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Centre d'Etudes de Populations, de Pauvreté et de Politiques Socio-Economiques International Networks for Studies in Technology, Environment, Alternatives, Development

Working Paper

Département 'Entreprises'

N°2005-01

Research and Development Activities and Innovative Performance of Firms in Luxembourg

Presented at the 8th International Conference on Technology Policy and Innovation, July 06-08, 2005, Lodz

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Juillet 2005

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ID : 03-05-0179-I

RESEARCH AND DEVELOPMENT ACTIVITIES AND INNOVATIVE PERFOMANCE OF FIRMS IN LUXEMBOURG

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It is widely acknowledged that Research and Development (R&D) and innovation are important for economic success. This has guided the European Union Member States to decide, at the Barcelona European Council (2002), that public and private R&D inputs have to increase in order to reach 3% of GDP in 2010.

In addition, Research and Development and also innovation are highly important topics on the agenda of Luxembourg public authorities. We can illustrate this by the deep increase of the public support of R&D activities since 2000. At first, we can note that Government Budget Appropriations or Outlays on R&D (GBAORD) have tripled between 2000 and 2005 (+193%). Secondly, public research centres have been developed (R&D expenses of these centres increase by 70% between 2000 and 2003). Thirdly, the University of Luxembourg has been created in 2003.

Relating to this move, it seems quite interesting to study the effect of public and private R&D investments. In a more restrictive view, it seems also quite opportune to look at R&D impact on the firms' innovative performance. This second thematic is the subject of this analysis.

In order to study this, we will use the micro data from the Community Innovation Survey (CIS3) carried out in Luxembourg.[1] This survey has many advantages for the purpose of our study. At first, it provides micro data of R&D input, external knowledge adoption and co-operation agreement, including co-operation with the "science base" (i.e. scientific partners including public research centres). And secondly, it includes measurements of innovative results (i.e. percentage of turnover from innovative products).

Based on this data, the analysis will examine the following questions:

- What is the influence of firms R&D activities on their innovation output?
- May external knowledge increase firms' innovation output? More specifically, have firms, engaged in R&D activities above a critical level, greater abilities to take advantage of external knowledge (i.e. absorptive capacity hypothesis).
- Will co-operation with the science base (including Luxemburger public R&D centres) generate greater innovation outputs?

The first section introduces our theoretical background to study Research and Development influence. The second section focuses on our reference model. The third section introduces at the data (CIS3) and presents the variables. Finally, the last section is devoted to the empirical analysis.

1. Issues of Research and Development aspects

Firms are launching Research and Development activities in order to create new knowledge (first aspect of R&D). In this perspective, R&D with new knowledge that it contributes to provide, is an essential aspect of firm's innovation ability. In its turn, innovation results contribute to the improvement of firm performance.

This has been demonstrated empirically by Griliches (1986). This has also been confirmed recently by empirical studies based on the model carried out by Crepon, Duguet and Mairesse (1998 and 2000) that take into account the different steps of the innovation process in order to deepen the link between research and innovation.

Nevertheless, these last years have been characterized by the increasing interest of external knowledge for the innovation process (Arora and al., 2001). This gains recognition in the assertion that

[1] A large amount of complementary works has already been done with previous CIS data collection carried out in Luxembourg (some of them in addition to the European surveys). The main results and analysis of this process are included or quoted in Allegrezza (2001).

we are moving toward a « knowledge economy ». In this respect, Cohen and Levinthal (1989 and 1990) have shown that external knowledge is not easy to internalize and that firms have to invest resources in order to absorb them. Among these resources, they point out the importance of a previous R&D investment.

As a result, in addition to a direct contribution based on new knowledge creation, research can indirectly contribute to firms' innovative performance through absorptive capacity development (second aspect of R&D). These absorptive capacities are defined as "the ability to recognize the value of new information, to assimilate it, and apply it at commercial ends" (Cohen and Levinthal, 1990). In consequence, research may not only be assimilated to a process of new knowledge creation, but may have a mediating effect materialized by absorptive capacities of new external knowledge that research may generate.

Therefore, for the firm, R&D would have two faces: new knowledge creation, and absorptive capacities development. Nevertheless, Cohen and Levinthal (1989) have pointed out that these two faces are intrinsically linked, because with an R&D investment firms will also develop their absorptive capacities.

The role of these absorptive capacities has mainly been confirmed by macroeconomics analysis as the one achieved by Griffith, Redding and Van Reenen (2001) on a panel of manufacturing firms from 13 OECD countries. To our knowledge, Veugelers (1997) and also Becker and Peters (2000) have made some of the few empirical analysis of absorptive capacities with micro data.

Moreover, in order to deepen the analysis of the importance of external knowledge, it seems necessary to distinguish among those acquired by co-operation agreements, especially when these collaborations are engaged with scientific partners (third aspect of R&D that corresponds to co-operation with scientific partners). These scientific partners include universities, public research centres and firms specially dedicated to R&D activities.

Indeed, given that R&D activities of these scientific partners incorporate more basic research, a fruitful collaboration with them seems to require a certain degree of absorptive capacities (Cockburn and Henderson (1998)), and also "a sufficient expertise within these firms to use the results of externally performed research" (Mowery and Rosenberg (1989) quote by Veugelers and Cassiman (2003)). The success of the collaborations seems also to require the "connection" of scientific actors, especially those from universities, with the economy (Scott and al. (2001) for a literature review of transmission channels between universities and the economy).

This kind of distinction allows a priori to retain R&D co-operations, because it selects co-operations engaged with actors specifically dedicated to R&D. The insertion of those co-operations has a main advantage: it identifies the existence of complementarities between R&D of firms and R&D of public actors as those public actors include most of the firms' scientific partners.[2]

2. Analysis approach

The goal of this analysis is to identify the impact of different R&D aspects on innovation performance (percentage of turnover from products new for the firm). Indeed, these different R&D aspects are new knowledge creation, mediating effect of R&D and co-operation with scientific partners. It has to be stressed that these scientific partners are aimed at including R&D co-operation in this analysis.[3]

However, this identification cannot be made without any difficulties. Indeed these different aspects are intrinsically linked: the commitment in research activities ensures new knowledge creation and also absorptive capacity development, and this absorptive capacity induces the set up of co-operation with scientific partners.

This causes the set up of three distinctive models. Each one is aimed at the identification of one of the different R&D aspects on the innovation output. Even if it seems opportune to introduce in this

[2] While 34 firms from the sample notify co-operating with at least one scientific partner, among them 14 declare having such a co-operation with at least one commercial laboratory or one R&D firm, 27 with at least one university and 14 with at least one public or non-profit research centre.

[3] Nevertheless, R&D co-operation can also been realized with other partner types such as the suppliers, the customers or firms belonging to the same group.

analysis variables specifically linked with each of the different aspects of R&D, we will take into account an identical selection of control variables in the different models.

2.1 Knowledge creation and innovative performance

In order to take into account new knowledge creation impact, we will estimate resources devoted to R&D by its different measures: intensity, volume and the involvement above a critical level in R&D (=an R&D personnel of at least five persons). This leads to the presentation of three variants of the identification model of new knowledge creation effect.

Consequently, we will successively consider the benefits on innovation performance of R&D intensity, R&D volume and involvement above a critical level in R&D.

2.2 Mediating effect of R&D and innovative performance

Following Cohen and Levinthal (1989 and 1990), we assume that firms with absorptive capacities based on the involvement in R&D above a critical level benefit more from external knowledge than others. It amounts to estimate that R&D would have a mediating effect.

To our knowledge, there is no common practice in order to take into account absorptive capacity that shapes mediating effect of R&D. Becker and Peter (2000) consider successively a permanent R&D activity and an R&D department, Veugelers (1997) considers only an R&D laboratory.

As a proxy for an R&D department is lacking in our sample, we approximate absorptive capacities by the existence of an R&D personnel of at least five persons: in Luxembourg, this represents 31% of the innovative firms that have an R&D activity.

As the two faces of R&D are intrinsically linked, we will adopt the following strategy in order to test empirically our hypothesis about mediating effect of R&D. In a first step, we will distinguish between firms that have absorptive capacities and those that do not have. In a second step, we will estimate for each of them the effect of acquired external information on their innovation performance. In this second step we also simultaneously take into account the direct effect of R&D that takes the form of new knowledge creation (this is measured by the intensity of resources devoted to R&D). The introduction of this effect aims at circumscribe the mediating effect of R&D.

Consequently, controlling the direct effect of R&D, the identification of the mediating effect of R&D corresponds to test the following hypothesis: all together, is the effect of acquired external knowledge on innovative performance positive, significant and more important for firms with absorptive capacities?

2.3 Co-operation with scientific partners and innovation performance

Co-operations with scientific partners are partially linked with a given level of R&D engagement and also with firm's knowledge resources. Consequently, as it could be expected, co-operation practices are connected with firm's absorptive capacities. Indeed, we observe a strong relationship between co-operating with scientific partners and employing R&D personnel of five persons for the manufacturing firms on one hand (phi=0.503; $p<0.01$) and the proportion of higher educated people for the service sector on the other hand (Cramer's V=0.317; $p<0.01$).[4] In addition, these co-operations are concentrated in the manufacturing or services sectors with higher technological or knowledge intensities (Cramer's V=0.376; $p<0.01$).

The identification of the specific effect induced by co-operation with scientific partners on innovation output brings us to consider in a distinctive manner the other effects of R&D (i.e. knowledge creation and absorptive capacities). We have to mention that the sample size does not allow distinguishing national from foreign partners in our analysis.[5] This leads us to consider collaboration influence without any distinction between scientific partners from Luxembourg (mainly actors of the national public research) and those from outside Luxembourg. Consequently, it will not be possible to take effectively into account complementarities between national public R&D actors and firms.

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[4] The proportion of higher educated people is distinguished by the following categories : 'less than 1%' 'from 1% to less than 10%', 'from 10% to less than 20%', 'from 20% to less than 50%', 'from 50% to less than 80%', 'at least 80%'.

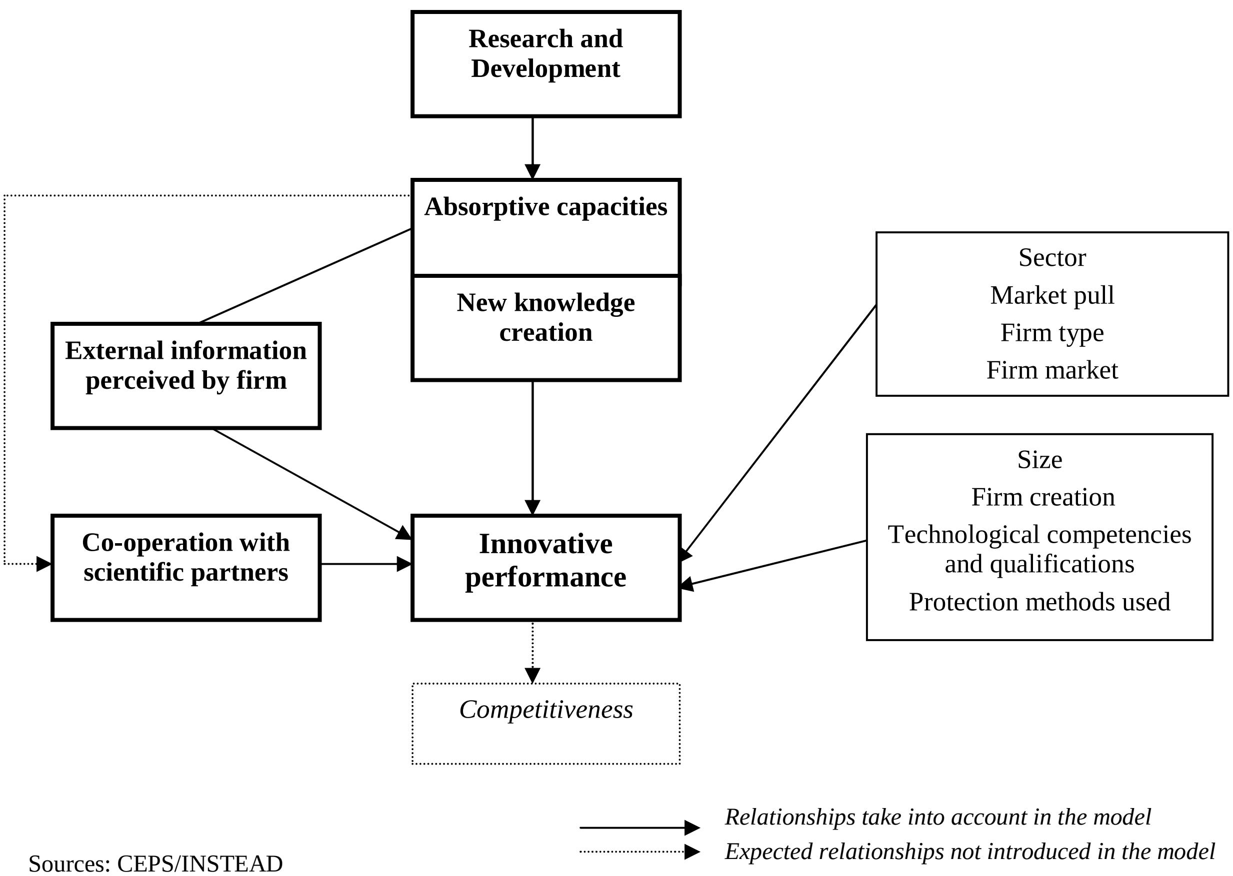
[5] Only 34 firms from our sample have pointed out to co-operate with at least one scientific actor, national or from abroad, and among these firms 22 notify taking part in a co-operation with at least one national partner.

2.4 Other aspects influencing innovating performance

In each model, we introduce the following identical selection of control variables: firm size, firm sector, and firm type (subsidiary of a group or not and origin of the group), firm creation in the 1998-2000 period and main origin of the firm market (i.e. national or international market). We also include in these models market pull, usage of protection methods for innovation and also the lack of technological competencies or skilled employees.

We expect a positive and significant effect of market pull, external knowledge importance and the use of protection methods on innovative performance. On the contrary, a negative and significant effect of the lack of technological competencies or skilled employees is expected.

Figure 1: Synthetic presentation of the overall model



Sources: CEPS/INSTEAD

3. Data used and measurement of variables

3.1 Data used

The Micro data used in this paper comes from the third Community Innovation Survey (CIS3) carried out in Luxembourg. For this survey, 603 firms have been surveyed in order to form a representative sample of the 1393 firms operating, with at least ten employees, in the manufacturing sector or in a selection of the service sectors.[6] Among these 603 firms, 440 observations are available for the empirical analysis.[7]

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[6] The sector surveyed are the following: the 'manufacturing sector', 'electricity, gas and water supply', 'wholesale trade', 'transport, storage and communication', 'financial intermediation', 'computer and related activities', 'research and development', 'architectural and engineering activities', 'technical testing and analysis'.

[7] The response rate was higher than 70% and no systematic bias could have been found by size or sector.

The data collected in this survey include two types of crucial measures for our analysis. At first they describe resources devoted to R&D (i.e. R&D employees and R&D expenditure) by R&D active firms, and also acquired external knowledge and types of co-operation engaged. Secondly, they include innovative performance measurement of firms that innovate in products (i.e. percentage of turnover generate by innovative products).

Indeed we do not have any measurement of process innovation output. However, for any sectors (i.e. the manufacturing sector or the service one), we note a strong link between product and process innovations: 40% of the innovators associate product and process innovation, and only 21% are only innovative in process.[8] In addition, restricting our analysis to product innovators does not exclude the main R&D performers: firms only process innovators count for less than 1% of total R&D expenditure.

In other ways, information collected by this survey comes mainly from innovative firms (45% of the firms). For these firms are described effects of innovation, innovation co-operation, protection methods for innovation and hampering factors of innovation. As a result, restricting our measurements on innovative firms could introduce a selection bias in the estimates. In order to correct this potential selection bias, we introduce the Heckman procedure (1979). As no difference has been observed in the sign and significance of our estimates, we will not make use this procedure in this analysis and our results will be produced without it.

3.2 Measurement of variables

In order to collect data on innovation output, firms were asked to specify, from total turnover in 2000, the percentage of turnover from new or improved product for the firms introduced between the 1998-2000 period. This percentage constitutes our dependent variable. As this is restricted between 0 and 1, we have applied a logit transformation $[\ln(Y_i/(1 - Y_i))]$ so that the estimate will be efficient. Nevertheless, in order not to have extreme values, values below 0.01 and upper 0.99 (before the transformation) have been replaced, following Mairesse and Mohnen (2004), by 0.01 and 0.99.

According to the different R&D aspects considered in this paper, separate variables have been introduced to take into account importance of R&D activities.

In one hand, we consider traditional R&D measures such as volume of resources devoted to R&D represented by the amount of the R&D personnel (logarithm of the number of R&D employees) or intensity of these resources quantified by the R&D expenditure divided by turnover. Additionally, we take into account a sustained engagement in R&D represented with R&D personnel of at least five employees (yes=1; no=0).

In other hand, we insert variables that take place in R&D aspects as defined above. To do so, we consider, at first, external information that have contributed to innovation projects. These external information sources are divided between the following main types: institutional sources (universities, government of private non-profit research institutes), market sources (suppliers, clients or customers, competitors or other firms from the same industry) and other sources (professional conference or meetings or journals, fairs or exhibitions). Firms were asked to assess on a 4-point scale (from ‘not used’ (0), to ‘very important’ (3)) the importance of these sources for innovation success. In order to build an index of the importance of theses sources we aggregate, following Cassiman and Veugelers (2002a), each item score and we rescale the sum between 0 and 1.

At second, we consider cooperation agreements. Innovative firms notify to have made or not co-operations for their innovation activities. These co-operations (38% of the innovative firms) have taken place with the following partners: the suppliers, the clients or customers, the competitors or other firms from the same industry, the consultants, the commercial laboratories or R&D firms, the universities or higher education institutes and the government or private non-profit research centres. In order to take into account these co-operations, we first set a co-operation variable equal to 1 when firms declare that they had at least one co-operative agreement with any type of partners, and 0 otherwise. Second, we set the co-operation with scientific partner variable to 1, 0 otherwise, if the firms have collaborated with the following partners: commercial laboratories or R&D enterprises, universities or higher education institutes, government or private non-profit research institutes. This distinction is aimed at targeting co-

[8] We have the following result for the manufacturing sector (Phi=0.451; $p<0.01$) and the service sector (Phi=0.392; $p<0.01$).

operations with institutes specifically dedicated to R&D. We expect that such a co-operation require some knowledge resources in order to assimilate their fruits, and to apply them to commercial ends. Moreover, this distinction permits to proxy collaborations between public research and firms. Indeed, as previously point out, firms have declared to co-operate most of the time with the universities and the government or non-profit research centres.

To conclude, we introduce other control variables. At first, we consider the usage of protection method for innovation. Firms have to report the usage of formal methods (patent applications, registration of design patterns, trademarks and copyright) or strategic methods (secrecy, complexity of design, lead-time advantage on competitors) to protect their innovation. Unfortunately, firms do not have to rate the importance of these methods. As a consequence, we cannot create an index of protection degree as set up by Cassiman and Veugelers (2002a). In other ways, the usage of formal methods does not seem to match the service sector practice. Therefore, we keep for the analysis the two following strategic usages: secrecy practice (yes=1; no=0) and lead-time advantage on competitors (yes=1; no=0).

Considering other control variables, some of them concern the environment of the firm and some others the firm itself. Referring to the environment of the firm, we consider the firm sector (9 different sectors), operating, or not, mainly in an international market (yes=1; no=0) and belonging or not to a national group (yes=1; no=0), an European group (yes=1; no=0) or an extra-European one (yes=1; no=0).[9] In addition, we take into account the market pull. Firms have to report the importance of the effects of innovation that they have met on a 4-point scale (from 'not relevant' to 'high'). Among these effects, we select the three following: increased range of goods or services, increased market or market share and improved quality in goods or services. We consider that a firm have met a market pull if it reports that at least one of these three effects has been very important for its innovations introduced in the 1998-2000 period. Based on this criterion, innovative firms were 63% to meet a market pull. Referring to the firm, we retain the size of the firm (=logarithm of the number of employees), to have been created during the 1998-2000 period (yes=1; no=0) and the degree of hampering factors for innovation coming from the lack of technological competencies and the lack of qualified personnel (=sum of the score of these two hampering factor measured on a 4-point scale (from not relevant(0) to high(3), rescaled between 0 and 1).[10]

4. Empirical results

In order to consider the effect of R&D activities on innovative performance we have used multivariate analysis. Those permit to take into account the influence on innovation performance of variables that are not the aim of our analysis, such as the size and sector of firms. Moreover, these methods allow taking the relationship between the different aspects of the analyzed phenomenon into consideration. This constitutes a major advantage for our analysis, because as indicated previously the different aspects of R&D are intrinsically linked together: engagement in R&D activities ensure new knowledge creation, but also absorptive capacities development, and those capacities in their turn support the development of co-operations with scientific partners.

To do so, we introduce three different regression models based on the share of turnover due to products new for the firm.[11]

4.1 New knowledge creation

The first regression (1.1) measures the importance of R&D activities taking into account the intensity of resources devoted to R&D quantified by R&D expenditures divided by turnover (table 1). This regression does not include other R&D measures such as R&D volume included in regression (1.2) or a sustained engagement in R&D shape with R&D personnel of at least five persons.

As expected, a positive and significant effect of the intensity of resources devoted to R&D (regression 1.1), of the volume of R&D resources (regression 1.2 and 1.3) and of a sustained R&D activity

[9] These sectors are considered by the following distinction: high and medium high-tech manufacturing industry, medium low tech manufacturing industry, low tech manufacturing industry, whole sale and commission trade, transport and communication, financial intermediation, computer activities, R&D – engineering activities and consultancy – technical testing and analysis.

[10] We observe a liaison between these two variables relating to a lack of internal competencies (Spearman rho=0.68; p<0.01).

[11] The examination of errors term verified that regression assumptions were met, and that were no severe multi-colinearity.

(regression 1.3) is found. It has to be pointed out that the last effect is no longer significant when we simultaneously introduced the intensity of resources devoted to R&D and the importance of external information. Nevertheless, the effect of the volume of R&D resources (p=0.158) quantified by the amount of the R&D personnel tends to be lower that the threshold of significance considered in this article (15% level). This result could come from the absence of one of the main R&D actors in the sample.

The main positive effect on the proportion of the turnover due to product new for the firm is the size of the firm: small firms seem to be more efficient in innovation than bigger ones. The main negative effect arises from the lack of qualified employees or technological competencies.

We also observe in each regression the positive and significant effect of market pull, external knowledge importance, or of the creation of the firm in the 1998-2000 period. We also note that in comparison with « independent firms » not belonging to a group, the positive and significant effect of subsidiaries of extra-European groups (72% of these firms belong to an US group), but also of Luxemburger groups.

Table 1: New knowledge creation and innovative performance

	Regression 1.1			**Regression 1.2**			**Regression 1.3**		
	Est		T-test	Est		T-test	Est		T-test
Intensity of R&D input	**3.30**	*******	2.33	-		-	**2.48**	******	1.81
Volume of R&D resources	-		-	**0.28**		1.42	-		-
At least five R&D employees	-		-	-		-	**0.81**	*******	2.01
External knowledge	**1.69**	********	2.82	1.66	****	2.76	1.70	****	2.87
Market pull	**0.63**	*******	2.14	0.64	***	2.15	0.62	***	2.13
Firm creation	**1.26**	*******	2.17	1.42	***	2.36	1.19	***	2.1
Lack of technological competencies et qualifications	**-1.54**	********	-3.09	-1.60	****	-3.26	-1.61	****	-3.27
No R&D activity	0.04		0.14	0.18		0.44	0.23		0.67
co-operation in innovation activity	0.08		0.29	0.04		0.13	0.00		0.01
Lead-time advantage on competitors	0.10		0.33	0.13		0.44	0.14		0.49
Secrecy	-0.17		-0.57	-0.07		-0.22	-0.17		-0.57
Firm size	**-0.40**	********	-4.33	-0.47	****	-4.33	-0.48	****	-4.61
Subsidiaries of Luxemburger groups	**0.89**	*******	2.33	0.85	***	2.15	0.85	***	2.22
Subsidiaries of European groups	0.31		0.85	0.27		0.74	0.34		0.95
Subsidiaries of extra-European groups	**0.98**	*******	2.2	0.89	***	2.06	0.90	***	2.1
Market manly international	0.11		0.35	0.08		0.26	0.07		0.23
High and medium high-tech manufacturing industry	-0.27		-0.31	-0.40		-0.47	-0.16		-0.19
Medium low tech manufacturing industry	-0.50		-0.98	-0.62		-1.22	-0.46		-0.9
Low tech manufacturing industry	**-1.23**	********	-2.7	-1.26	****	-2.71	**-1.16**	*******	-2.58
Transport and communication	**-0.84**	*****	-1.65	-0.85	**	-1.65	**-0.74**	*****	-1.46
Financial intermediation	-0.72		-1.39	**-0.81**	*****	-1.54	-0.69		-1.33
Computer activities	-0.33		-0.71	-0.28		-0.56	-0.26		-0.56
R&D – Engineering activities and consultancy – Technical testing and analysis	0.85		1.44	0.89		1.44	**0.92**	*****	1.52
Constant	-0.79		-1.23	-0.60		-0.91	-0.68		-1.07
Number of observations	180			180			180		
Adjusted R^2	0.26			0.27			0.28		

Sources: CIS3 survey – CEPS/INSTEAD, STATEC, Ministry of Culture, Higher Education and Research (MCESR); calculations : CEPS/INSTEAD.
Notes: references = firms not subsidiary of a group; whole sale and commission trade sector.

* significant at the 15% level; ** significant at the 10% level; *** significant at the 5% level ; **** significant at the 1% level.

On the contrary, belonging to the 'low tech manufacturing industry' and to a lesser extent to the financial intermediation or the transport and communication sector have a negative impact on innovation performance. It has to be pointed out that we have previously unexpectedly found that the 'low tech manufacturing industry' tends to be less innovative than the 'medium low tech manufacturing industry'.[12] Then, if the first seems to be more innovative that the second one, a part of the innovations introduced by the first one seem to be of a lower importance, at least for product innovations.

We have also observed that, for the financial sector, taking into account innovation as product and process innovation is not appropriate.[13] In order to improve innovation valuation, it appeared necessary to include other important changes introduced by firms especially those of organizational type. The result present in this analysis, that show a lower output for product innovation in this sector (significant at the 15% level in the regression 1.2), seems to confirm the inadequate nature of "traditional" innovation measure for the financial sector.

Finally, we have also previously found that the transport and communication sector was small innovative: the percentage of innovation firms in this sector (34%) is two times lower than in the computer activities sector (75%). Consequently, except the low rate of innovation in this sector, those accomplished appear of a low importance.[14]

The co-operation insertion, without any distinction of the partners' types, does not have any significant effect on product innovator performance. This absence of effect seems to be linked to the various nature of co-operation which, following Schmidt (2004), can be presented as: cost-sharing or risk-sharing, knowledge development and motives related to firm characteristics. The knowledge development that should positively impact innovation performance is only one among others of the co-operation motives.

In the same way, we do not observe any significant effect of the following protection methods used: lead time advantage and secrecy practice. Nevertheless, we should not conclude with this result that protection innovation modes do not have any effect on innovation output. Indeed, we do not have full information on protection method usage. No information are available on their degree of importance for the innovation process.

4.2 Mediating effect of R&D

Our main point is to consider empirically if a certain degree of R&D involvement provides absorptive capacities to the firm. These are defined as the ability to recognize the value of new information, to assimilate it, and apply it to commercial ends. In this way, R&D will have a mediating effect materialized with absorptive capacities that new knowledge will generate.

In order to approximate an involvement degree that should confer absorptive capacities, an R&D personnel of at least five persons is considered. Our hypothesis test comes to the following consideration: taking into account direct effect of R&D (to do so we will consider R&D intensity), do firms with absorptive capacities better profit (innovation output) of external information sources that firms without absorptive capacities.

In a first regression, not including R&D activities importance (2.1), we observe a positive and significant effect of external information for firms with or without absorptive capacities (table 2). In addition, this effect is more important for firms with absorptive capacities than without.

In a second regression (2.2) including R&D activities intensity, we note that external information importance has again a positive and significant effect on innovation performance. We notice this for firms with or without absorptive capacities, but the external information effect is obviously bigger for firms with absorptive capacities. This seems to corroborate absorptive capacities function that ensures a better practice of external knowledge in commercial terms.

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[12] Vincent Dautel (2004b), "Quelles entreprises ont innové au Grand-Duché de Luxembourg entre 1998 et 2000?", CEPS/INSTEAD, Document de Recherche n°03-04-00- 99- I, 21 p, to be published in the 'Cahier Economique' of Statec.

[13] Vincent Dautel (2004a),"La mise en œuvre d'innovations selon les caractéristiques intrinsèques des PME et PMI luxembourgeoises", CEPS/INSTEAD, Document de Recherche n° 03-04-00- 98- I, 31 p, to be published in the 'Cahier Economique' of Statec.

[14] Given the small number of observations a grouping of the transport sector (90% of these firms) and the communication one (10%) has been made.

After studying the situation, a double importance of an involvement in R&D upper a threshold becomes apparent: this gives to the firm new knowledge and absorptive capacities, each of them positively influencing innovative performance.

Table 2: Mediating effect of R&D and innovative performance

	Regression 2.1			**Regression 2.2**		
	Est		T-test	Est		T-test
Intensity of R&D input	-		-	**2,89**	***	1,93
External knowledge with absorptive capacity	**2.88**	****	3.15	**2,28**	***	2,54
External knowledge without absorptive capacity	**1.51**	***	2.47	**1,6**	****	2,61
Market pull	0.60	***	2.03	0,62	***	2,09
Firm creation	1.46	***	2.47	1,25	***	2,16
Lack of technological competencies et qualifications	-1.59	****	-3.24	-1,54	****	-3,09
No R&D activity	0.04		0.12	0,1		0,31
Co-operation in innovation activities	0.03		0.12	0,05		0,18
Lead-time advantage on competitors	0.17		0.57	0,11		0,38
Secrecy	-0.11		-0.35	-0,17		-0,57
Firm size	-0.46	****	-4.4	-0,43	****	-4,27
Subsidiaries of Luxemburger groups	0.83	***	2.12	0,86	***	2,23
Subsidiaries of European groups	0.24		0.67	0,3		0,83
Subsidiaries of extra-European groups	0.84	**	1.91	0,92	***	2,05
Market manly international	0.11		0.36	0,1		0,33
High and medium high-tech manufacturing industry	-0.41		-0.48	-0,26		-0,3
Medium low tech manufacturing industry	-0.66		-1.29	-0,5		-0,98
Low tech manufacturing industry	-1.33	****	-2.85	-1,22	****	-2,71
Transport and communication	-0.89	**	-1.74	-0,81		-1,6
Financial intermediation	-0.83	*	-1.58	-0,71		-1,37
Computer activities	-0.28		-0.58	-0,3		-0,65
R&D – Engineering activities and consultancy – Technical testing and analysis	0.89	*	1.46	0,87	*	1,47
Constant	-0.41		-0.62	-0,68		-1,04
Number of observations	180			180		
Adjusted R^2	0.25			0.26		

Sources: CIS3 survey – CEPS/INSTEAD, STATEC, MCESR; calculations: CEPS/INSTEAD.
Notes: references = firms not subsidiary of a group; whole sale and commission trade sector.

* significant at the 15% level; ** significant at the 10% level; *** significant at the 5% level ; **** significant at the 1% level.

4.3 Co-operation with scientific partners

We have found above, that co-operation without any distinction of the partner type, do not have any significant positive effect on product innovative performance. This can be attributed to the various motives of the co-operations. Then, it seems appropriate to make a distinction between these co-operations in order to consider those that take place with scientific partners. It can be expected that the knowledge development motive initiate this kind of co-operation that specifically include R&D and consequently that these co-operations will favour an increase of the innovation output. Nevertheless, it has to be pointed out that the survey does not include any question on reasons of recourse to co-operation.

In order to consider co-operation with scientific partner, we take into account those that take place with universities, commercial laboratories, R&D enterprises and government or private non-profit research institutes. As seen above, these scientific partners are mainly public R&D actors coming from Luxembourg or abroad. In addition, a link between co-operation with a national partner and a foreign one is observed: innovative firms cooperating with a national/foreign scientific partner are often simultaneously engaged in at least one co-operation with a foreign/national scientific partner.[15]

Table 3: Co-operation with scientific partners and innovative performance

	Regression 3.1			Regression 3.2		
	Est		T-test	Est		T-test
Intensity of R&D input	**3.33**	***	2.33	**3,01**	***	2
External knowledge	**1.41**	***	2.26	-		-
External knowledge with absorptive capacity	-		-	**1,88**	***	2,11
External knowledge without absorptive capacity	-		-	**1,35**	***	2,12
Co-operation with scientific partners	**0.67**	***	2.05	**0,63**	**	1,9
Co-operation with other partners	-0.11		-0.36	-0,13		-0,41
Market pull	0.61	***	2.05	0,60	***	2,01
Firm creation	1.25	***	2.15	1,24	***	2,14
Lack of technological competencies et qualifications	-1.50	****	-3.02	-1,50	****	-3,03
No R&D activity	0.04		0.13	0,09		0,27
Lead-time advantage on competitors	0.05		0.17	0,06		0,22
Secrecy	-0.19		-0.63	-0,19		-0,63
Firm size	-0.41	****	-4.45	-0,44	****	-4,35
Subsidiaries of Luxemburger groups	0.82	***	2.15	0,80	***	2,08
Subsidiaries of European groups	0.26		0.71	0,25		0,7
Subsidiaries of extra-European groups	0.92	***	2.1	0,88	**	1,96
Market manly international	0.07		0.24	0,07		0,23
High and medium high-tech manufacturing industry	-0.30		-0.35	-0,3		-0,35
Medium low tech manufacturing industry	-0.59		-1.16	-0,58		-1,14
Low tech manufacturing industry	-1.33	****	-2.83	-1,32	****	-2,83
Transport and communication	-0.87	**	-1.71	-0,84	**	-1,66
Financial intermediation	-0.69		-1.35	-0,68		-1,33
Computer activities	-0.47		-0.98	-0,44		-0,92
R&D – Engineering activities and consultancy – Technical testing and analysis	0.56		0.93	0,59		0,98
Constant	-0.49		-0.72	-0,42		-0,61
Number of observations	180			180		
Adjusted R^2	0.28			0.27		

Sources: CIS3 survey – CEPS/INSTEAD, STATEC, MCESR; calculations: CEPS/INSTEAD.
Notes: references = firms not subsidiary of a group; whole sale and commission trade sector.

* significant at the 15% level; ** significant at the 10% level; *** significant at the 5% level ; **** significant at the 1% level.

In order to estimate the influence of co-operation with scientific partners, we will consider two variants of the model. These variations differ with the insertion of R&D activities and external knowledge.

In a first regression (3.1), we take into account the intensity of R&D resources devoted to R&D and external knowledge importance (table 3). Nevertheless, in order to take into account the absorptive capacities influence, a second regression (3.2) includes a distinction between external knowledge with or without absorptive capacities.

[15] Phi=0.463; p<0. 01.

In these regressions a positive and significant effect of co-operation with scientific partner on innovative performance is found. In addition, with the insertion of the co-operation, the positive and significant effect of external knowledge remains stable, with or without absorptive capacities. Consequently, even scientific knowledge acquired with co-operation is important, other types of co-operation have also a great interest for innovation performance, with or without R&D engagement upper a threshold.

This result speaks in favour in one hand of firms to conclude co-operation agreements with scientific partners and on the other hand of the development of public research actors. Indeed, these have the skills to develop the national stock of scientific knowledge and the ability to offer opportunities of R&D co-operation.

However, this conclusion has to be considered cautiously because a distinction between national or foreign scientific partner cannot be done.

Conclusion

Based on the data from the third Community Innovation Survey carried out in Luxembourg, it has been demonstrated that Research and Development has an influence on innovation performance. This influence has been shown for the three following aspects of R&D: knowledge creation, absorptive capacities development and R&D co-operation (=collaboration with scientific partners). Therefore, a triple impact of R&D aspects is found.

Indeed, first repercussion of R&D, new knowledge resulting from R&D activity that we measure by intensity or volume of R&D resources or R&D involvement upper a threshold (at least five R&D employees) increase product innovators output. As a result, firms actively engaged in R&D tend, comparatively to others innovative firms, to derive a more important proportion of their turnover from their new products.

In other ways, firms' external knowledge importance for innovation outcome has been put to the fore. This external knowledge appeared, second repercussion of R&D, all the more fruitful that firm was engaged upper a threshold in R&D. Consequently, this result tends to validate absorptive capacities hypothesis that consider that firms with absorptive capacities (approximated here with an R&D personnel of at least five employees) have, in commercial terms, a fruitful usage, than others, of external knowledge.

Finally, it has been shown, third repercussion of R&D, the importance of the co-operation with scientific partners (including actors from public research) that appears as R&D co-operation. These co-operations with scientific partners stimulate, so are they, product innovation output.

In order to profit from each of the beneficial R&D effects, it becomes apparent a double importance for firms in the service sector and a triple for those belonging to the manufacturing one, of an R&D investment upper a threshold. Indeed, this R&D engagement permits added knowledge creation (in comparison with a lower investment in R&D) and absorptive capacities development. Moreover, it generates for the manufacturing firms opportunities of co-operations with scientific partners (in the service sector it is rather the share of educated people that generates these co-operations).

These results that highlight the primacy of R&D investment above a critical level plead in favour of stimulating firms' R&D activities. In this respect, public R&D activities have a role to play: the development of public R&D activities should lead firms, especially in the high-tech sectors and the knowledge based services, to increase their R&D investment in order to benefit from these knew knowledge creation. This conclusion is based on the following assertion of Cohen and Levinthal (1990): *"We predict that an increase in technological opportunity--the amount of available relevant external technical knowledge--will elicit more R&D in more difficult learning environments. Greater technological opportunity signifies greater amounts of external information, which increase the firm's incentive to build absorptive capacity, and a more challenging learning environment increases the level of R&D necessary to build absorptive capacity."*

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