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Technological opportunities and the impact of internal and external innovation expenditures on innovation output

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Note to discussant:
This version is a working version. A more elaborated version will be presented at the ZEW inno-conference on 14 June, 2008.

May 2008

Abstract
This research investigates the impact of internal and external innovation expenditures on innovation output by using Spanish CIS3 data on 2282 innovative firms and applying several Knowledge Production Functions. Two main topics are dealt with. First, it is confirmed that different innovation activities lead to different types of innovation, but only when the specific technological opportunities that a firm experiences are taken into account. Second, firms make an allocation decision for spending on internal and external innovation activities. According to literature, these activities can be complementary in the way that external sources require internal knowledge for absorbing the benefits. This research shows that these complementarity effects indeed exists, but only in specific situations where the technological characteristics of the sector in which a firm operates and the objective of the innovation activities require so.

JEL classification:

Keywords: R&D, innovation, complementarity, Knowledge Production Function

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1 Introduction

The beneficial outcomes of innovation are widely studied and documented. The general consensus is that innovation has a positive impact on firm performance and economic development. For getting a better understanding of the innovation process and the decisions that are taken on firm level regarding this process, this research focuses on the relation between the innovation activities and innovation outcome. Specifically, I will look at how firms allocate their resources among the different innovation activities (internal to the firm or acquisition of external technology) and how this affects the innovative output. Hereby I will take sector perspective, due to the different technological characteristics and opportunities that exist among sectors.

Pavitt (1984) showed that different innovation strategies exist, depending on the technological opportunities and characteristics of the sector in which a firm operates. He defined four sector groups based on technological characteristics (sources of technology, production and use of innovations, means of appropriation and firm size): (i) supplier dominated firms, (ii) scale intensive firms, (iii) science based firms and (iv) specialized suppliers. A fifth group, information intensive firms, was added later (see e.g. Pavitt et al., 1989).

By using Spanish CIS3 data Spain and applying a Knowledge Production Function (Griliches, 1979) with innovation outcome as dependent variable and (internal and external) innovation inputs, and taking into account Pavitt´s sector groups, we would expect that firms from Science based sectors are large firms that rely mainly on R&D for generating a mix of product and process innovations. Furthermore, firms from Supplier dominated and Scale intensive sectors are expected to focus on cost-cutting process innovations, where the former are expected to be rather small innovative firms that rely on external sources of technology and the latter are expected to be large firms that combine R&D and acquisition of embedded technology. Specialized supplier firms are expected to be small firms that cooperate closely to with the users of their innovative products. Lastly, Information intensive are expected to be firms that focus on process innovation through the combination of internal knowledge with the acquisition of high-end machinery and equipment.

A secondary focus of this research is the interaction of the internal and external innovation activities and its impact on innovation outcome. Literature suggests that the successful absorption of external knowledge requires a certain level of internal knowledge (see e.g. Cohen and Levinthal, 1994). Again taking into account the technological characteristics of the firms, it is expected that the combination of internal and external innovation activities has a positive impact on innovation output. Taking into account the different technological opportunities that firms experience, we would expect that complementarity plays an important role in Supplier dominated and Scale intensive sectors.

Section 2 provides a literature overview and summarizes the empirical evidence on the relation between innovation input and output and complementarity effects. Section 3 discusses the available measures for innovation input and innovation output. It will also go deeper into the strengths and weaknesses of these measures. Section 4 discusses the data, while section 5 presents some descriptive statistics. Section 6 provides an explanation of the methods used and Section 7 shows the results. Finally, Section 8 will conclude.

2 Literature overview and empirical findings

For measuring the relation between internal and external innovation expenditures and innovation output, the econometric models developed by Griliches (1979) and Crépon *et al.* (1998) will be applied. Griliches (1979) divided the innovation-performance relation into three equations, where the second equation – the knowledge production function – relates innovation inputs to innovation output. Similarly, Crépon *et al.* (1998) developed a framework including three relationships: (i) the innovation input linked to its determinants, (ii) the knowledge production function relating innovation input to innovation output, and (iii) the productivity equation relating innovation output to productivity growth.

The available literature on the relation between innovation input and output mainly concentrates on the relation between R&D (as an input) and patents or innovation introduction (as an output), mainly due to data availability. The introduction of the CIS waves has initiated an increase in this field of research with an increasing variation in measures. Recent work comes from Griffith, Huergo, Mairesse and Peters (2006), Beneito (2006), Mairesse and Mohnen (2005), Conte and Vivarelli (2005), and Lööf and Heshmati (2002a).

Klomp and Van Leeuwen (1999) showed that firms that perform R&D on a permanent basis show a significant higher innovation output than firms not performing R&D on a continuous basis. Lööf and Heshmati (2002a) focused on the relation between expenditures on innovation input and its effect on innovation output, as part of the model for measuring the relation to performance. They found that a 10 percent increase in investment in innovative activities per employee increases innovation sales by nearly 3 percent. Besides, they found that the most important source of knowledge for innovation comes from within the firm, while competitors seem to be most important external sources of knowledge for innovation.

Mairesse and Mohnen (2005) found several positive relations between R&D (measured by employee or as a ratio of total sales) and innovation introduction (measured by probability to innovate and introducing products that are new to the market or to the firm). Looking at sector differences, they found that innovation output was generally more sensitive to R&D in low-tech sectors than in high-tech sectors. The findings of Griffith, Huergo, Mairesse and Peters (2006) are in line with these results. On studying the marginal effects of R&D intensity in four European countries (UK, France, Germany and Spain), they found that a greater R&D effort per employee leads to a higher probability of having a process innovation and a product innovation. However, no distinction was made between intramural and extramural R&D in both studies.

Concerning the acquisition of embedded knowledge and technology, Conte and Vivarelli (2005) investigated the impacts of total R&D investments and technology acquisition on innovation output. They found that R&D is strictly linked to product innovations, while technological acquisition is crucial for process innovations. With regard to sector differences, low-tech firms seem to rely more on technological acquisition, while high-tech sectors rely more on R&D input. This is in line with Ortega-Argilés, Potters and Vivarelli (2008) who found that firms in high-tech sectors rely heavily on R&D for labour productivity, while in low-tech sectors this relation is less strong. Firms in more traditional sectors with lower technological opportunities for generating new products concentrate mainly on other innovation inputs for improvements of their production processes, such as the acquisition of new machinery and equipment.

Beneito (2006) – analyzing Spanish survey data – made a distinction between intramural and extramural R&D and found that intramural R&D is the main source for more significant innovations (represented by patents), while extramural R&D is more productive in terms of incremental innovations (represented by utility models). Furthermore, "isolated" intramural R&D leads to both process and product innovations, while contracted R&D does not lead to significant innovations (measured by patents), unless they are combined with in-house capabilities (the ‘absorptive capacity’ hypothesis, see Von Tunzelmann and Acha (2005)). When looking at the combined effect of internal and external R&D and relating it respectively to significant and incremental innovations, each type of R&D input shows increasing elasticities in that kind of innovations where it is more productive in relative terms. Thus, internal R&D becomes more important for significant innovations, while external R&D becomes more important for incremental innovations.

The complementarity between internal and external innovation activities is confirmed in empirical research and case studies, depending on firm and environmental characteristics. Freeman (1991) provided an overview of early research on the importance of the use of external sources, combined with internal R&D, for successful innovation. The main conclusions were that the use of networks and the linkages with external sources of scientific and technical information and advice are decisive in determining the success of a single innovation.

The interest for this research goes to the interaction affects between internal and external innovation activities. Some empirical contributions on this topic come from Cohen and Levinthal (1989 and 1990). They find a strong relation between a firm's own R&D efforts and the use of external sources associated with more basic science. This relation depends on the industry’s technological characteristics, such as the importance of basic fields of science for innovation. In their 1990 paper, they found that the existence of the interaction between internal and external innovation input and the ability to valuate external knowledge appear to be part of a firm's decision in allocating resources for innovative activities.

Arora and Gambardella (1994) made the relation between firm and sector characteristics and the importance of external innovation activities. They argue that firms differ significantly in their ability to benefit from these collaborative relationships. This ability depends on the type of internal knowledge: scientific and technological know-how. The former is especially effective for screening projects and the latter for applying external knowledge.

Veugelers and Cassiman (1999) showed how firm and environmental characteristics affect the choice of internal know-how development and external acquisition. They found that small firms are more likely to focus either on exclusive internal or external innovation activities, while large firms are more likely to combine both. Also the appropriation regime affects: a strict regime is related to less external innovation activities.

Looking at the impact of different innovation expenditures, Piga and Vivarelli (2004) found that firms – operating in the specialized suppliers and science-based sectors – are more likely to conduct their R&D internally and that outsourcing relationships with suppliers are associated with a firm's propensity to engage in external R&D. Furthermore, it was found that performing R&D with other firms is more likely to be found in firms having objectives in the areas of both process and product innovation and that a firm with a concentrated ownership structure is more likely to seek other firms as partners.

Finally, Cassiman and Veugelers (2006) study complementarity among firm's innovation activities. Hereby, they also look at the environmental characteristics. Earlier results were confirmed (internal R&D and external knowledge acquisition are complementary innovation activities), but that the degree of complementarity depends on the firm's context, such as sector's technological opportunities.

3 Measures for innovation input and output

3.1 Innovation inputs

In order to get a better understanding of the innovation strategies (i.e. the use of innovation inputs) of sectors with different technological opportunities, the focus of this research will be on the impact of internal innovation inputs and external innovation inputs on the innovation output. This section will discuss the innovation inputs of interest for this research.

3.1.1 R&D intensity

Probably the most widely studied input to innovation is research and development (R&D) expenditures. The Frascati Manual (2002) defines R&D as "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications". The term R&D, in this sense, covers three activities, namely (i) basic research (experimental or theoretical work undertaken primarily to acquire new knowledge, without any particular application or use in view), (ii) applied research (original investigation undertaken in order to acquire new knowledge towards a specific practical aim or objective), and (iii) experimental development (systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new or improved materials, products, services or processes).

R&D is often used as a proxy for innovation. Although the advantages of R&D as an indicator are clear (widely available over long time periods on firm, sector and national level), it is only one of many inputs to innovation. There have been several estimations of the relative importance of R&D as part of the total innovation inputs, ranging from 20 to 40 per cent (see e.g. Brouwer and Kleinknecht (1997)).

Other disadvantages of using R&D as only proxy of innovation are related to measurement issues. Firms tend to underreport informal and small scale R&D activities. These R&D activities do not show up in financial reporting but do show up in innovation surveys that include somehow simplified questions about R&D (Kleinknecht 1987). Furthermore, different interpretations of the definition of R&D in surveys, secrecy, and regional splitting may lead to biased data on R&D investment. This may lead to disturbing comparisons across sectors, regions and countries (Brouwer et al, 2000).

In the CIS3, a distinction is made between intramural and extramural R&D. It refers to the same type of activities, but performed by other firms, organisations, such as public and private research organisations (see Frascati Manual, 2002). For this research, this distinction is important, since it gives insight in a firm's choices for performing own R&D or outsourcing it. Both will be measured as ratios of the turnover (intensity), but the latter forms part of external innovation expenditures.

3.1.2 Other external innovation inputs

It is obvious that the inclusion of questions on expenditures on the acquisition of R&D, knowledge and machinery and equipment is much richer than the classical R&D expenditures data. However, since many firms do not have precise information on all these innovation inputs, the response rate will decrease and answers might be rough estimates in stead of precise amounts.

External innovation activities (besides extramural R&D) that are captured by the CIS questionnaire and of interest for this research are:

- Acquisition of other external knowledge: patented and non-patented inventions, trademarks, know-how, software and other types of knowledge for use in a firm's innovations.
- Acquisition of machinery and equipment: advanced machinery, computer hardware and computer hardware specifically purchased to implement new or significant improved products and processes.

These inputs will be summed up (together with extramural R&D) and normalized as a ratio of turnover, as is the case with intramural R&D expenditures.

3.2 Innovation outputs

Because of the diversity and complexity of possible innovation output, no single measure can be expected to proxy a firm's innovation completely. The selection of the indicator is very much related to the objectives of the research. The focus in this research is to be able to point out differences in the impact of the various innovation activities. Therefore, a two-step model will be applied where both the introduction of product and process innovations and the contribution of the sales of innovative products in the total turnover, as provided by the CIS, will be investigated.

Unless the lack of information on the importance and quality of the introduced innovations, the first two indicators show a firm's propensity to innovate, while the share of turnover due to innovative products is commonly used to indicate the intensity of innovation (see e.g. Lööf and Heshmati, 2002; Mairesse and Mohnen, 2002). It is a direct measure of successful *product* innovation, measuring innovations that were introduced into the market and that resulted in a positive cash-flow (Kleinknecht, Van Montfort and Brouwer, 2000). Due to questionnaires design, no impact measure of process innovations is taken into account.

4 Data and descriptive statistics

This paper uses (Spanish) firm-level data, drawn from the CIS 3, on 8,024 firms on the years 1998-2000.

A number of firms (603) that were recently established or showed turnover increases or decreases of more than 10% due to mergers, acquisitions and vending of parts of the firm were excluded. Also firms with missing values for the introduction of either a product or process innovation (3) were taken out.

The sample is divided into five sector groups: the four groups of Pavitt's taxonomy (Science based, Supplier dominated, Scale intensive and Specialized suppliers) and a fifth (Information intensive) that was later added to this group (see Pavitt *et al.*, 1990). Since not all sectors are covered by this sector classification, 1,594 out of the 7,418 firms were not assigned to this classification (see Vossen (1998) for a translation of Pavitt's sector groups to NACE) and thus not taken into consideration. The final dataset consist of 5,950 firms, of which 2,779 firms declared to have introduced an innovation (either product or process). The next section will show the results of some descriptive analyses.

Variable	*Explanation*
INPDT	Introduction of product innovation (1=yes)
INPCS	Introduction of product innovation (1=yes)
INNO	Introduction of product/process innovation (1=yes)
INPDTINPCS	Introduction of product & process innovation (1=yes)
RRDIN	Internal innovation expenditures (1=yes)
RRDINX	Expenditures on internal innovation by turnover
INNEX	External innovation expenditures (1=yes)
INNEXX	Expenditures on external innovation by turnover

4.1 Characteristics in total population

Table 1 presents (weighted) characteristics of the whole population (5,950 firms). Looking at share of innovators, great differences can be distinguished among the sector groups. Firms from the sector groups Specialized suppliers and Science based show the highest share of innovators in any type of innovator, except for *Only process innovators*. Here they show the smallest share. Firms from the Supplier dominated sector group have the smallest share of innovators in any type of innovator, except for only process innovators, where it has an above average share.

Table 1: Characteristics of the whole population (5950 firms)

Share of:	*Information intensive*	*Supplier dominated*	*Scale intensive*	*Specialized suppliers*	*Science based*	*Total*
Innovators	0.396	0.322	0.355	0.477	0.568	0.381
Product innovators	0.248	0.198	0.236	0.386	0.491	0.265
Only product innovators	0.098	0.082	0.103	0.177	0.225	0.115
Process innovators	0.299	0.240	0.252	0.300	0.343	0.266
Only process innovators	0.149	0.123	0.118	0.091	0.077	0.116
Product and process innovators	0.150	0.117	0.133	0.209	0.266	0.150

The same exercise as in Table 1 has been repeated, but for innovating firms only (see Table 2).

Table 2: Types of innovators among the innovators (2779)

Share of:	*Information intensive*	*Supplier dominated*	*Scale intensive*	*Specialized suppliers*	*Science based*	*Total*
Innovators	1	1	1	1	1	1
Product innovators	0.625	0.617	0.666	0.809	0.865	0.695
Only product innovators	0.246	0.253	0.291	0.371	0.396	0.302
Process innovators	0.754	0.747	0.709	0.629	0.604	0.698
Only process innovators	0.375	0.383	0.334	0.191	0.135	0.305
Product and process innovators	0.378877	0.363239	0.375018	0.437419	0.469376	0.393253

4.2 Characteristics of innovators

In this paragraph the focus is on describing the 2,779 innovating firms. See Annex I for detailed descriptive statistics for innovation output and allocation of resources over innovation activities, per type of innovator (All, Only product, Only process, Product and Process).

As expressed in the introduction, it is expected that firms from Science based rely heavily on internal R&D. In fact, this is shown in both the share of performers of internal R&D and the allocation of budget to internal R&D. Besides, the Science based sector group has the highest expenditures (as share of turnover). The group of Science based sectors is the only group where internal innovation activities are not smaller than the external innovation activities.

One of the objectives of this research is to reveal the impact of the innovation activities on the innovation output. Looking at the different allocation strategies for Only product innovators and Only process innovators, it becomes obvious that Only Process innovators spend a greater share of their turnover on external innovation expenditures. The average innovation expenditures/turnover is the highest for Product and Process innovators.

The percentages of type of innovator per sector group are given in Table 3.

Table 3: Innovator characteristics

	Information intensive	*Supplier dominated*	*Scale intensive*	*Specialized suppliers*	*Science based*	*Total*
Product innovators (%)	0.246024	0.253397	0.291199	0.371214	0.395577	0.301794
Process innovators (%)	0.3751	0.383364	0.333784	0.191367	0.135048	0.304952
Product & process innovators (%)	0.378877	0.363239	0.375018	0.437419	0.469376	0.393253
Most important innovation activity*	Acq. of machinery & other equipment	Acq. of machinery & other equipment	Acq. of machinery & other equipment	Acq. of machinery & other equipment	Internal R&D	Acq. of machinery & other equipment
… performers as share of all firms	0.693609	0.654307	0.64082	0.612312	0.671033	0.630496
… expenditures as share of turnover	0.049866	0.053253	0.058412	0.018675	0.070212	0.048762

*Table 1 gives an overview of the innovative activities

Further proof of different innovation behaviour is shown in the correlation matrix (Table 4).

Table 4: Correlation matrix

	INPDT	*INPCS*	*INPDTINPCS*
RRDINX	0.01	-0.06	0.05
INNEXX	-0.01	0.09	0.01

5 Methodology

5.1 Basic KPF

The basic knowledge production function, as defined by Griliches (1979) is as follows:

$$IO_i = \alpha_i + \beta IEE_i + \beta EIE_i + \sum_h \beta PAVITT_h + \beta coop_i + \beta size_i + \varepsilon$$

IO represents the innovation output. This is measured in three ways:

1. Propensity of introducing a new product: INPDT
2. Propensity of introducing a new process: INPCS
3. Percentage of sales due to new products: TURNIN

The different innovation inputs are represented by IEE (internal innovation expenditures) and EIE (external innovation expenditures). The dummy variables are represented by firm size, Pavitt's technological sector groups and cooperation agreements.

5.2 Two-step model

Conte and Vivarelli (2005) proposed a two-step model consisting of a bivariate probit model and a truncated model for measuring the impact of innovation input on output, due to the different character of the dependent variables. First, the introduction of product and/or process innovation is modelled by a biprobit model (see subsection 5.3.1.). Second, the impact on the percentage of innovative sales is modelled by a truncated model (see subsection 5.3.2).

5.2.1 Bivariate probit model for INPDT and INPCS

When the dependent variable is a dummy variable indicating whether a firm introduced a product or process innovation, the probit model is used. The goal is to measure the effect of a change in the internal and external innovation expenditures on the probability of introducing such an innovation.

The standard probit model is defined as:

$$P(y_i = 1) = \Phi(X_i \beta_i) \tag{2}$$

where $y_i = 1$ indicates the introduction of a product or process innovation, X_i is a vector of the regressors from the Knowledge Production Function (1) and Φ is the standard normal cumulative distribution function.

In this research, there are two different innovative outcomes taken into account: product and process innovations. This simultaneous consideration requires a bivariate probit model with the following specification (see Conte and Vivarelli (2005) for a likelihood ratio test that favors the bivariate probit model above two separate probit models):

$$\begin{cases} Y_{1i}^* = \alpha_{1i} + X_{1i}\beta_1 + \varepsilon_{1i} & Y_{1i} = 1 \quad \text{if} \quad Y_{1i}^* > 0,\ Y_{1i} = 0 \text{ otherwise} \\ Y_{2i}^* = \alpha_{2i} + X_{2i}\beta_2 + \varepsilon_{2i} & Y_{2i} = 1 \quad \text{if} \quad Y_{2i}^* > 0,\ Y_{2i} = 0 \text{ otherwise} \end{cases} \tag{3}$$

and:

$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix} \Bigg| X \sim \Phi\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1\ \rho \\ \rho\ 1 \end{pmatrix} \right) \tag{4}$$

The bivariate probit model estimates the values of β_1 and β_2 and ρ by maximum likelihood (MLE). The likelihood function is:

$$\ln L = \sum w_j \ln \Phi_2 (q_{1j}(X_i\beta)^{\beta}, q_{2i}(z_i\gamma)^{\gamma}, \rho_i^* \tag{5}$$

$$\begin{cases} q_{1i} = 1 \quad \text{if} \quad Y_{1i} \neq 0\,, \quad -1 \text{ otherwise} \\ q_{2i} = 1 \quad \text{if} \quad Y_{2i} \neq 0\,, \quad -1 \text{ otherwise} \end{cases}$$

, where w_i are optional weights and Φ_2 is the bivariate normal cdf for estimating bivariate probit models.

5.2.2 Truncated regression model

Due to the questionnaire's design, the sales-weighted measure of a firm's innovativeness (TURNIN) assumes a positive value *only* for firms that have introduced a *product* innovation (INPDT=1) and not for firms that only introduced a *process* innovation. This means that the density of the possibility of introducing a product/process innovation is conditional on being a non-limit (positive) observation, and follows a truncated normal distribution in X_{i2} with a variance and truncation at zero.

The percentage of sales due to innovative products is a limited dependent variable, due to the selection process of the survey. It assumes a value greater than 0 (and smaller or equal to 1) only for firms that have introduced product innovation and a value of 0 for firms that have not introduced a product innovation.

The purpose of the estimation is to look at the impact on TURNIN for all innovators and not only for product innovators. In this case, OLS could be seriously misleading. Therefore a truncated regression model is applied.

The truncated normal regression model that satisfies that assumptions of a classical linear model is:

$$Y = \beta_0 + X_i\beta_i + \varepsilon,\ \varepsilon|X_i \sim \text{Normal}(0,\sigma^2) \qquad (6)$$

However, the assumption of random sample from the population is violated. For estimating β_i and σ^2, we need the distribution of y_i, given that $y_i \le c_i$ (the truncated threshold, 0 in this case) and X_i. This is written as:

$$g(y|X_i, c_i) = \frac{f(y|X_i\beta_i, \sigma^2)}{F(c_i|X_i\beta_i, \sigma^2)},\ y \le c_i \qquad (7)$$

Here, $f(y|X_i\beta_i, \sigma^2)$ denotes the normal density with mean $\beta_0 + X_i\,\beta_0$ and variance σ^2, and $F(c_i|X_i\beta_i, \sigma^2)$ is the normal cdf with the same mean and variance, evaluated at c_i. This is the population density for y, given X_i, divided by the probability that y_i is less than or equal to c_i (given X_i), $P(y_i \le c_i,\ X_i)$. The density is renormalized by dividing by the area under $f(\cdot|X_i\beta_i, \sigma^2)$ that is to the left of c_i. The maximum likelihood estimators are obtained by taking the log of (7), sum across all I and maximize the result with respect to β_i and c_i.

6 Results

6.1 Biprobit

A bivariate probit model estimates the impact of the innovation expenditures on both the likelihood to introduce a process innovation and a product innovation. See Table 5 for the results.

Applying the biprobit model as described in the former section, the results for all firms are not significant (except for a negative coefficient for small firms and increasing positive and significant coefficients for medium and large firms). An explanation for this could be diversity of firms that are under analysis, which neutralizes the specific effects that can be seen when looking at sector group level. A look at the different sector groups is therefore justified. Size is an important determinant of the propensity to introduce a product innovation: for largest firms this is the stronger and gets smaller with decreasing size. Also the belonging to a group has a positive impact.

The Science based sector does not show significant results for either internal or external innovation expenditures, except for the negative relation between external innovation expenditures and the probability of introducing a product innovation. This confirms the substitutability of innovation activities and should be seen as a statistical artifact, as also found in Conte and Vivarelli (2005). Cooperation has a positive effect.

For the other sectors, the internal and external innovation expenditures behave more or less as expected. Specialized suppliers concentrate mainly on providing large production intensive firms with improved processes. Here, external knowledge plays an important role and is positively and significantly related. For Scale intensive firms, logically, the scale matters, but internal and external innovation activities do not have a significant impact. There is an increasing positive and significant effect going from small to large firms. For information intensive firms, the best way to increase performance is the improvement of processes. Internal and external innovation activities therefore have both a strong positive and significant effect.

6.2 Truncated regression

For the impact of innovation on the share of innovative sales, the truncated model, as explained in the Section 5, has been applied and are shown in Table 5. Here, the positive effect of internal innovation expenditures is confirmed for all firms. However, the size effect shows a contrary pattern: smaller firms have a higher share of turnover due to innovative sales. This can be explained through logic: smaller firms have a smaller range of products and thus a new product has a higher impact on the firm's sales than firms with a wide product range.

Internal innovation activities show as expected positive and significant results, except for firms from Supplier Dominated and Information Intensive sector groups: these are the sectors that focus mainly on process innovations (which is not taken into account in TURNIN).

From Pavitt's reasoning, the strong positive and significant impact of RRDINX on TURNIN for firms from the Scale intensive sector group is surprising, since we would expect cost-cutting process innovations through combining R&D and acquisition of embedded technology. However, in the descriptive statistics we saw earlier that the Scale intensive sector group has the second highest innovation expenditures over turnover ratio (after Science based). It seems that firms from these sectors focus both on product and process innovations.

Table 5: Biprobit with INPDT and INPCS as dependent variables

BIPROBIT	*All firms*		*Science based*		*Supplier dominated*		*Specialized suppliers*		*Scale intensive*		*Information intensive*	
	Product	Process	Product	Process	Product	Process	Product	Process	Product	Process	Product	Process
RRDINX	1.066	0.229	0.521	-0.085	14.882**	8.598	21.754*	-0.973	0.124	1.732	19.554	21.426**
	(1.016)	(0.230)	(0.564)	(0.382)	(6.972)	(6.017)	(12.212)	(2.057)	(1.331)	(1.483)	(13.471)	(10.533)
INNEXX	-0.030	0.025	-0.182*	0.472	0.034	3.162	-4.175*	7.493**	0.025	-0.149	-1.791*	2.760**
	(0.048)	(0.062)	(0.096)	(0.558)	(0.033)	(1.554)	(2.273)	(3.459)	(0.105)	(0.110)	(1.100)	(1.230)
Small	0.187*	-0.278***	0.030	-0.361	0.766**	0.107	-0.357	-0.016	0.743***	-0.447**	-0.068	0.014
	(0.108)	(0.105)	(0.173)	(0.150)	(0.342)	(0.454)	(0.453)	(0.355)	(0.206)	(0.211)	(0.254)	(0.262)
Medium	0.265**	-0.120	0.241	-0.645	0.756**	0.199	-0.027	-0.065	0.774***	-0.134	0.018	0.312
	(0.135)	(0.119)	(0.233)	(0.199)	(0.359)	(0.459)	(0.445)	(0.356)	(0.205)	(0.208)	(0.373)	(0.381)
Large	0.504***	0.089	-0.019	0.138	1.434***	0.601	0.042	0.336	0.966***	-0.126	0.030	0.454
	(0.124)	(0.122)	(0.277)	(0.234)	(0.410)	(0.488)	(0.556)	(0.390)	(0.204)	(0.207)	(0.321)	(0.338)
Co	0.087	-0.106	0.444***	-0.197	-0.314	0.384	-0.675*	-0.375	0.334**	0.044	0.260	-0.702***
	(0.164)	(0.112)	(0.172)	(0.158)	(0.519)	(0.345)	(0.403)	(0.297)	(0.171)	(0.181)	(0.404)	(0.400)
Gp	0.342***	-0.070	0.008	-0.151	0.433**	-0.235	0.218	0.246	0.381**	-0.097	0.393	0.137
	(0.096)	(0.091)	(0.176)	(.150)	(0.196)	(0.187)	(0.308)	(0.275)	(0.146)	(0.161)	(0.245)	(0.235)
Science based	0.673***	-0.403***										
	(0.142)	(0.139)										
Supplier dominated	0.041	0.042										
	(0.137)	(0.149)										
Specialized suppliers	0.432***	-0.367**										
	(0.155)	(0.158)										
Scale intensive	0.090	-0.084										
	(0.124)	(0.134)										
Information intensive												
Constant	0.004**	0.861***	0.886	0.622	-0.587***	0.358	0.957**	0.165	-0.460**	0.894***	0.247	0.382
	(0.136)	(0.144)	(0.163)	(0.130)	(0.334)	(0.445)	(0.457)	(0.358)	(0.201)	(0.207)	(0.266)	(0.273)
Wald Pavitt's sector group dummies joint significant test (p-value)												
Wald firm size dummies joint significant test (p-value)												
Observations	2282		367		582		218		947		168	

Robust standard errors in brackets

*significant at 10%, **significant at 5%, ***significant at 1%

Table 6: Truncated regression with TURNIN as dependent variable

TRUNCATED	*All firms*	*Science Based*	*Supplier dominated*	*Specialized suppliers*	*Scale intensive*	*Information intensive*
	Turnin	Turnin	Turnin	Turnin	Turnin	Turnin
RRDINX	0.559*** (0.190)	0.765*** (0.247)	0.129 (4.975)	2.122** (1.056)	4.106*** (1.572)	18.687 (19.360)
INNEXX	-0.207 (0.129)	-0.747*** (0.287)	-0.318 (0.261)	3.506 (3.322)	-0.179 (0.157)	7.058 (4.825)
Small	0.519*** (0.191)	0.487*** (0.128)	7.985*** (2.051)	-0.081 (0.339)	0.603 (0.712)	0.718 (0.967)
Medium	0.481** (0.219)	0.554*** (0.160)	7.726*** (1.951)	-0.066 (0.360)	0.777 (0.741)	0.705 (1.343)
Large	0.347 (0.216)	0.359** (0.174)	7.276*** (1.939)	-0.480 (0.375)	1.039 (0.767)	0.804 (1.254)
Co	-0.066 (0.163)	0.077 (0.116)	-1.266* (0.679)	-0.015 (0.370)	0.013 (0.302)	-0.556 (1.036)
Gp	-0.115 (0.136)	-0.052 (0.122)	0.469** (0.210)	0.317 (0.353)	-0.915 (0.384)	0.347 (0.816)
Science based	0.253 (0.224)					
Supplier dominated	0.189 (0.238)					
Specialized suppliers	-0.104 (0.215)					
Scale intensive	0.051 (0.284)					
Information intensive						
constant	-1.376*** (0.426)	-0.532** (0.217)	-8.214*** (0.080)	-0.569*** (0.573)	-2.051 (1.173)	-3.269 (3.055)
Wald Pavitt's sector group dummies joint significant test (p-value)						
Wald firm size dummies joint significant test (p-value)						
Observations	1806	491	346	175	649	145

Robust standard errors in brackets
*significant at 10%, **significant at 5%, ***significant at 1%

7 Concluding remarks

This researched focused on the effects of allocation decision of innovation expenditures on the innovation output. Three measures are used for innovation output: propensity of introducing a product or process innovation and the share of innovative sales. An important factor in this research has been the differences in these relationships for firms with different technological opportunities and characteristics.

Results show that the size effect is important. Larger firms are more prone to introduce a product innovation, but the share of turnover due to these products is greater for smaller firms. The belonging to a group of firms also has a positive impact. Looking at the allocation of resources, it becomes obvious that internal innovation expenditures have the greatest impact on product innovation (both propensity and share of turnover). The technological opportunities are clearly shown: firms with high technological opportunities, such as Science based (for share of turnover) and Specialized suppliers show positive results. More surprisingly, also firms from the sector groups Supplier dominated (for propensity) and Scale intensive (share of turnover) show positive and significant values. Looking at the sector composition for Scale intensive firms, the presence of car producers might have a great impact on this.

The non-significant impact of internal and external innovation expenditures on product innovation for Science based firms is surprising. Here further research on the interaction between internal and external research is necessary. This will be done for the final version that will be presented at the ZEW conference. Also the missing Wald tests for the biprobit analyses will be presented then.

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Annex I: Descriptive statistics

All innovators

Table 7: Share of performers of internal and external innovation for all innovators

Performer of	*Information intensive*	*Supplier dominated*	*Scale intensive*	*Specialized suppliers*	*Science based*	*Total*
Internal innovation	0.242	0.283	0.386	0.599	0.700	0.416
External innovation	0.802	0.788	0.752	0.727	0.691	0.754

Table 8: Allocation of innovation expenditures for innovators

Expenditures as a ratio of total turnover	*Information intensive*	*Supplier dominated*	*Scale intensive*	*Specialized suppliers*	*Science based*	*Total*
Internal innovation	0.004	0.006	0.012	0.018	0.070	0.019
External innovation	0.053	0.061	0.064	0.021	0.070	0.058
Total	0.057	0.067	0.076	0.039	0.140	0.077

Only Product innovators

Table 9: Share of performers of internal and external innovation for Only product innovators

Performer of	*Information intensive*	*Supplier dominated*	*Scale intensive*	*Specialized suppliers*	*Science based*	*Total*
Internal innovation	0.202	0.244	0.413	0.692	0.773	0.471
External innovation	0.725	0.617	0.569	0.614	0.614	0.606

Table 10: Allocation of innovation expenditures for Only product innovators

Expenditures as a ratio of total turnover	*Information intensive*	*Supplier dominated*	*Scale intensive*	*Specialized suppliers*	*Science based*	*Total*
Internal innovation	0.002	0.004	0.010	0.021	0.065	0.020
External innovation	0.036	0.019	0.090	0.010	0.019	0.047
Total	0.038	0.023	0.100	0.031	0.084	0.067

Only Process innovators

Table 11: Share of performers of internal and external innovation for Only process innovators

Performer of	*Information intensive*	*Supplier dominated*	*Scale intensive*	*Specialized suppliers*	*Science based*	*Total*
Internal innovation	0.099	0.109	0.182	0.131	0.299	0.155
External innovation	0.810	0.844	0.851	0.807	0.604	0.826

Table 12: Allocation of innovation expenditures for Only process innovators

Expenditures as a ratio of total turnover	*Information intensive*	*Supplier dominated*	*Scale intensive*	*Specialized suppliers*	*Science based*	*Total*
Internal innovation	0.002	0.003	0.012	0.004	0.027	0.008
External innovation	0.076	0.047	0.057	0.038	0.216	0.065
Total	0.078	0.050	0.069	0.042	0.243	0.073

Product and process innovators

Table 13: Share of innovation activities for Product and process innovators

Performer of	*Information intensive*	*Supplier dominated*	*Scale intensive*	*Specialized suppliers*	*Science based*	*Total*
Internal innovation	0.397	0.485	0.556	0.719	0.748	0.579
External innovation	0.842	0.837	0.801	0.782	0.776	0.806

Table 14: Allocation of innovation expenditures for Product and process innovators

Expenditures as a ratio of total turnover	*Information intensive*	*Supplier dominated*	*Scale intensive*	*Specialized suppliers*	*Science based*	*Total*
Internal innovation	0.008	0.010	0.014	0.021	0.087	0.026
External innovation	0.041	0.106	0.051	0.023	0.071	0.062
Total	0.049	0.116	0.065	0.044	0.158	0.088