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WHICH FIRMS HAVE COOPERATIVE R&D AGREEMENTS WITH UNIVERSITIES?

SOME EMPIRICAL EVIDENCE FROM BELGIAN MANUFACTURING

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Abstract

This paper presents an econometric analysis of firm and industry characteristics conducive to cooperation with universities, using Community Innovation Survey (I) data for Belgium. We find that large firms are more likely to have cooperative agreements with universities. These agreements are formed whenever risk is not an important obstacle to innovation and typically serve to share costs. Consistent with the open science paradigm, we find no evidence for the importance of the capacity to appropriate the returns from innovation for explaining cooperative agreements with universities. We argue that cooperating with universities is complementary to other innovation activities such as performing own R&D, sourcing public information and cooperative agreements with suppliers and customers. Therefore, the decision to cooperate with universities cannot be analyzed in isolation from a firm's overall innovation strategy.

JEL classification: O32, O34, L13

Keywords: Industry-Science Links, Cooperation with Universities, Innovation Strategy

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1. Introduction

Theoretical and empirical work in innovation economics suggests that industry-science relations positively affect innovation performance through the use of scientific knowledge (see Kline and Rosenberg, 1986: Rosenberg & Nelson, 1994; Feller, 1990; Mowery, 1998; Mansfield, 1995). However, especially in Europe, there seems to be a gap between high scientific performance on the one hand and industrial competitiveness on the other hand. This gap, mainly attributed to low levels of Industry Science Links, is known as the “European paradox” (EC-DGECFIN, 2000). To tackle this “European Paradox” major benchmarking exercises are set up in the EU in search of best practices to improve the commercialisation of the EU science base by better linking Industry with Science (Polt, 2000).

The main incentive for enterprises to engage in these Industry Science Links (ISL) is the access to know-how. The evidence from the Community Innovation Survey in the EU (CIS-II) shows, however, that only a small fraction of innovative enterprises use science, i.e. universities and public research labs, as an important information source in their innovation projects: in 1996, only 4 percent of innovative enterprises used information from universities and 3%, from public (including non-profit) research organisations for designing their innovation projects (EC-DGECFIN, 2000). First, characteristics concerning these interactions explain the difficulty of organizing these ISLs. The highly uncertain and non-codifiable nature of scientific know-how results in high transaction costs and systemic failures in the market for this know-how. In addition, ISLs are hampered by diverging objectives of the partners while reward structures within academia are unfavourable to ISLs, (Siegel et al., 1999). Second, due to the highly specific nature of the know-how involved, only a select set of firms within specific industries will be interested in the scientific know-how offered by universities or other science institutes. Science is a more important source of information for innovation in science-based technology fields where new breakthrough innovations can be achieved and transferred to new products and processes (i.e. radical innovations)[1].

These relations between enterprises and public science institutions can take various forms. Among these, collaborative research has received a lot of attention, because effectively transferring scientific knowledge requires direct interaction of people. But, again,

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[1] For instance, using the same CIS-II survey data, 31% of “Novel Innovators” give science as an important source of information, compared to 4% on average (EC-DGECFIN 2000).

evidence from the Community Innovation Survey for the EU shows that only 10% of innovative firms have cooperative agreements with universities (EC-DGECFIN, 2000). Similarly, Hall, Link & Scott (2000) report that in the US the vast majority of research partnerships registered under the NCRA and NCRPA act do not include a university. Although the trend is rising, only a modest 15% of all research partnerships involve a university.

Because Industry Science collaboration seems to encounter such obstacles many countries have launched a variety of public promotion programmes supporting collaborative research between industry and public science institutions. Specific financial support for collaborative research receives the largest portion of public money for ISL promotion and is still gaining in importance in most countries. The EU framework programmes for research and technology development also follow this line of ISL promotion and represent major additional funding for collaborative research. Likewise, in the US, the Advanced Technology Program (ATP) provides direct funding for pre-competitive generic cooperative research.

A key factor affecting the quality and extent of collaborative research between science and industry is the demand side for scientific knowledge. Polt (2000) concludes, in line with the "European Paradox" doctrine, that within the EU lower levels of ISLs and relatively little cooperation between science and industry typically do not reflect a lack in supply of scientific knowledge. Low levels of ISLs in EU member states can be attributed mainly to a lack of demand on the enterprise side.

The aim of our paper is to study the demand side for ISL and, more particularly, for cooperative agreements between science and industry. Using EUROSTAT/CIS-I survey data for Belgium, we present an econometric analysis of the firm and industry characteristics most conducive to cooperation with universities. Such analysis may provide some insights into barriers from the industry side to engage in cooperative agreements with universities. Compared with existing studies, we extend the dimensions to be considered beyond size and industry affiliates to include the issues of appropriability and complementarity with other innovative strategies of firms. On the one hand, appropriation issues might affect the formation of cooperative agreements with universities. Firms might worry about actually appropriating any returns from these agreements with universities; or, conversely, low appropriability may stimulate the formation of these agreements because firms internalise the positive externality caused by these spillovers. On the other hand, cooperative agreements with universities do not stand on their own. Firms that are more open to public information sources are also more likely to interact with universities. Knowledge obtained through these interactions needs to be integrated within the firm's innovation process. And to successfully commercialise inventions made, firms engage in complementary innovation activities such as generating sufficient absorptive capacity to internalise this knowledge and organizing applied R&D projects with customers and suppliers to exploit it.

In line with existing studies, we find that large firms are more likely to have cooperative agreements with universities than small firms. These agreements are formed whenever risk is not an important obstacle to innovation and typically serve to share costs. Nevertheless, firms with foreign headquarters are less likely to be actively involved in industry-science links in Belgium. More interestingly, the data are consistent with a complementarity between R&D cooperation with universities and other innovation strategies of firms, such as performing own R&D, sourcing freely available public information and cooperative agreements with suppliers and customers. We do not find evidence of the importance of strong appropriation conditions for cooperative agreements with universities.

Section 2 describes the literature on R&D cooperation between industry and science, while Section 3 discusses our research approach. Section 4 presents the results regarding the firm and industry characteristics most conducive to cooperation in R&D with universities, and Section 5 concludes.

2. R&D Cooperation between Science & Industry

In the absence of a wide literature on the specific topic of R&D cooperation between industry and science, we start with the more abundant literature on R&D cooperation in general. Although this serves as useful benchmark, cooperation between industry & science poses some specific issues, which will be dealt with in more detail.

A first approach to better understand why firms choose to **cooperate in R&D** is offered by *Transaction Cost Economics*. Pisano (1990) describes alliances as a hybrid form of organisation between hierarchical transactions within the firm and arms-length transactions in the market place. Arm's length technology transactions can have high (transaction) costs. Own development within the firm limits these transaction costs, but prevents access to specialist know-how in other firms. Collaboration allows access to this specialised know-how, while at the same time allowing for a transfer of technology at lower transaction costs as compared to arm's length. It not only allows for a better control and monitoring of technology transfers, but also the inherent reciprocity relationship and "hostage" exchange between complementary partners minimizes opportunism. However, information asymmetries and the uncertain and tacit nature of R&D may also in this case endanger the exploitation of cooperative benefits. But rather than turn to contracts to minimize the incentives for opportunism in cooperation, firms view alliances as a learning experience and only gradually build up commitment (Mody, 1993) or enter into larger networks of alliances, selecting partners where reputation matters more and where complementarity is maximized (Gulati, 1995). Also, the property rights approach in an incomplete contract framework predicts under which conditions common ownership of R&D projects will prevail.[2]

The *Industrial Organisation* literature on R&D cooperation focuses on the effect of imperfect appropriability of results from the innovation process on the incentives to innovate, when firms cooperate in R&D (e.g. Katz, 1986; Spence, 1984; d'Aspremont & Jacquemin, 1988; Kamien, Muller & Zang, 1992). On the one hand, imperfect appropriability increases the benefits from cooperative R&D agreements. R&D spillovers will lead to own cost or demand effects, increasing the incentives for R&D cooperation through the internalisation of the positive externality. Information sharing further increases the profitability of R&D cooperation. When spillovers are high enough, i.e. above a critical level, cooperating firms will spend more on R&D and will be increasingly more profitable compared to non-cooperating firms (d'Aspremont and Jacquemin, 1988; Kamien et al., 1992; De Bondt, 1997). On the other hand, imperfect appropriability increases the incentive of firms to free ride on each other's R&D investments (e.g. Shapiro and Willig, 1990; Kesteloot and Veugelers, 1995) and encourages free-riding on the R&D efforts of the research joint venture by

[2] Aghion & Tirole (1994), for instance, discuss the organisation of R&D activities, i.e. the choice of integration versus non-integration between a firm and its R&D contractor. These RJVs are to be distinguished from "horizontal" RJVs, which raise "a host of other fascinating issues concerning free riding, allocation of ownership rights as well as control rights over the research process and antitrust policy" (p 1206).

outsiders to the cooperative agreement (Greenlee and Cassiman, 1999). Recent extensions of these models take into account that firms may manage these spillover levels actively to maximally capitalize on the benefits from R&D cooperation. Firms attempt to increase incoming spillovers not only directly through information sharing, but also indirectly by investing in own R&D. The notion of "absorptive capacity" introduced by Cohen & Levinthal (1989) and further explored in Kamien & Zang (2000) stresses the importance of a stock of prior knowledge to effectively absorb spillovers, while cooperating.

To what extent can the results from the literature on cooperation in R&D, which focuses mainly on collaboration among firms, be extended to **collaboration between firms and universities**? Will the specific nature of the know-how being transacted generate a different profile of firms engaging in these types of cooperation? The specific contribution of science to industrial innovation is easy to explain when looking at the type of knowledge typically offered by science and the demand for such knowledge in the innovation cycle. Science institutions offer new technical and methodical knowledge which is mainly needed in innovation activities oriented towards developing new technologies, new materials, new devices and for products very new to the market. These activities take place in the early stages of the innovation process, characterised by high technological uncertainty and still low demand for the outcomes of innovation activities.

Given the specific characteristics of scientific knowledge, R&D cooperation between universities and industry is characterised by high uncertainty, high information asymmetries between partners, high transaction costs for knowledge exchange requiring the presence of absorptive capacity on each side of the market transfer, high spillovers to other market actors (i.e. a low level of appropriation of benefits out of the knowledge acquired), and restrictions for financing knowledge production and exchange activities due to risk-averse and short-term oriented financial markets. In addition, minimizing opportunistic partner behavior in cooperative contracts will be more difficult when the technology is characterized by a large amount of uncertainty. Nevertheless, the more generic nature of research projects with universities and research institutes involves fewer appropriation issues, as compared to the more commercially sensitive content when cooperating in later development stages, with customers/suppliers and *a fortiori* with competitors (Cassiman and Veugelers, 2002). Also Hall, Link & Scott (2001) note that when research results are uncertain, neither party can define meaningful boundaries for any resulting Intellectual Property, and hence appropriation is less likely to be an insurmountable issue.

Econometric studies of R&D cooperation between firms and science indicate the importance of firm size and own R&D as drivers for cooperation. This is reminiscent of the absorptive capacity idea, which stresses the need to have in-house (technological) power to optimally benefit from R&D cooperation. Leiponen (2001) obtains a positive size effect and also a positive research competence effect of R&D collaborations with universities from Finnish innovation survey data. Adams, Chiang & Jensen (2000) also report a larger size and larger R&D effect for firms that are linked to federal labs via cooperative R&D. The importance of size and R&D intensity is very much in line with the results from the studies on R&D cooperation in general. They also find strong evidence that the size and R&D orientation of firms is beneficial to R&D cooperation (o.a. Röller et al., 1997; Kleinknecht & van Reijnen, 1992; Colombo & Gerrone, 1996; Hagedoorn, Link & Vonortas, 2000 for an overview). Nevertheless, Mohnen & Hoareau (2002) do not find R&D intensity to be significantly related to cooperation with universities. They do find that size, government support, patenting and scientific industry status contribute positively towards explaining R&D collaborations with universities relative to other types of cooperation. Capron &

Cincera (2002) also confirm the importance of firm size and government support as significant drivers for R&D cooperation with universities.

None of these papers, when assessing causes and effects, properly accounts for the simultaneity between own R&D and R&D cooperation arising from complementarity. Colombo & Gerrone (1996), testing the Granger causality between a firm's R&D intensity and its technology co-operative agreements, conclude that a simultaneous treatment of in-house R&D intensity and technological co-operation is the appropriate framework. Veugelers (1997), taking into account this simultaneous relationship, finds that firms which spend more on internal R&D have a significantly higher probability of co-operation in R&D and that once correction has been made for this, size (which typically positively influences internal R&D) is no longer relevant for explaining R&D co-operation. Kaiser (2002), using a simultaneous equations framework, finds a positive but only weakly significant effect of cooperation on own R&D expenditures. Cassiman and Veugelers (2002) provide evidence of a strong positive effect of own R&D activities on cooperation in R&D, but after controlling for endogeneity this effect is less significant.

Beyond the simultaneous relationship between own R&D and cooperation in R&D, there are few studies which consider complementarity with other innovation activities for cooperating firms. Liebeskind et al. (1996) uncovered that, in the biotech sector, companies that were engaged in joint research and publishing with academic institutions were more effective at externally sourcing new scientific knowledge. Arora and Gambardella (1990) examine the complementarity among external sourcing strategies of large firms in the biotechnology industry. They study four types of external sourcing strategies for large chemical and pharmaceutical companies in biotechnology (agreements with other firms, with universities, investments in and acquisitions of new biotechnology firms). They find evidence of complementarity between all types of external sourcing strategies, even after correcting for a set of firm characteristics. Furthermore, the correction for firm characteristics suggests that large firms with higher internal knowledge, measured by number of patents, are more actively involved in pursuing a combination of strategies of external linkages.

Also with respect to the appropriability issue, there is little explicit empirical evidence. Hall, Link & Scott (2001), using survey evidence from a small subset of ATP funded projects, demonstrate that Intellectual Property Rights issues between firms and universities do exist and in some cases those issues represent an insurmountable barrier, preventing R&D cooperative agreements from being formed in the first place. Such situations are more likely to occur when the expected duration of the research is relatively short term and thus more certain in terms of the characteristics of the research findings.

Cassiman and Veugelers (2002) find that better appropriability of results of the innovation process increases the probability of cooperating with customers or suppliers, but is unrelated to cooperative agreements with research institutes. Commercially sensitive information, which is the result of these more applied research projects, often leaks out to competitors through common suppliers or customers. Hence, only firms that can sufficiently protect their proprietary information are willing to engage in this type of cooperative agreements, an issue which does not seem to be present in cooperative agreements with research institutes.

3. The Research Design: Appropriability and Complementarity between R&D cooperation with science and other innovation activities of the firm

We present an econometric analysis of the firm characteristics most conducive to cooperation with universities, using EUROSTAT/CIS-I survey data for Belgium. The decision to cooperate or not is analyzed with a probit model. In line with the existing literature, we include the standard explanatory variables like firm size, innovative profile or industry affiliation. But in addition, we add appropriability conditions and take into account the presence of complementary innovation activities.

A standard hypothesis of the literature is that the *size of enterprises* may affect their behaviour concerning cooperation with universities. Empirical evidence suggests that large enterprises have the necessary in-house capabilities to effectively interact with science (e.g. separate R&D departments, university-trained employees, available time and financial resources for establishing and maintaining science links). Nevertheless, small firms may be better placed to interact with science, for instance, because they have sprung off from university research. The level of engagement in ISLs by SMEs strongly depends on their absorptive capacities and their involvement in innovation activities.

A high share of foreign-owned enterprises in the economy may be a restricting factor to ISLs, as the national affiliates of multinational enterprises may not carry out that type of research, which strongly relies on new scientific knowledge, i.e. strategic research and research on completely new products, materials and technologies. However, empirical studies have shown that foreign-owned affiliates behave very similarly to domestic-owned enterprises in the same sector and size class (see, among others, Gerybadze & Reger, 1999). Furthermore, foreign-owned enterprises may have R&D funds available from their parent company.

As work by Mariti & Smiley (1983), among others, has indicated, reasons of cost and risk sharing are important drivers for cooperation in general. When costs are an important obstacle to innovation, we expect to observe more cooperative agreements set up for the purpose of cost sharing. More specifically in industry-science collaboration, given the early-stage characteristic of the know-how involved, financial barriers to innovation may be strong given the imperfections of the financial markets for these early-stage ventures. This is often a reason why governments provide additional funding for industry-science collaboration. In the case of university-industry collaboration, the innovation process is still characterised by high technological uncertainty. Although higher risk invokes higher transaction costs, at the same time it induces risk-sharing benefits from cooperation, resulting in an ambiguous effect on the probability of cooperating with science.

A first specific focus of our analysis is the impact of the appropriation regime. Following the suggestions from the literature, the more generic nature of research projects with universities and research institutes should involve fewer *appropriation issues*, as compared to the more commercially sensitive cooperation with customers/suppliers or competitors. We test whether the appropriation regime is a significant characteristic for firms cooperating with universities. We distinguish between two types of protection: *legal* protection of products and processes through patents, brand names or copyright; and *strategic* protection of products and processes through secrecy, complexity or lead time. We test strategic protection at the firm level and the effectiveness of legal protection as an industry variable.

A second specific focus of our analysis is the consideration of *other complementary innovation activities*. ISL and cooperative agreements with science institutions, in particular, develop a firm's basic R&D capacity. This basic R&D capacity increases the efficiency of the applied research conducted within the firm.[3] Hence, since R&D cooperation with research institutes increases the firm's basic research capability, which in turn increases the efficiency of applied research, one should find a complementary relationship between own R&D and cooperative agreements with science institutes, especially for larger firms. For this, we include the own R&D capacity in our analysis. This is in line with prior studies providing strong evidence that own R&D activities of firms positively affect R&D cooperation, reminiscent of the absorptive capacity idea. We also include cooperative strategies of the firm with customers and suppliers. These types of vertical cooperative agreements typically involve development activities. With applied R&D capacities complementary to basic R&D capacities that are developed in cooperative agreements with universities, we expect both types of cooperation to be mutually reinforcing.

However, this basic R&D capacity may also stimulate the firm into other innovation activities beyond (own) (applied) R&D. Rosenberg (1990) stresses the importance attached to performing *basic research* by companies that see it "as a ticket of admission to an information network". Viewed in its capacity to absorb external information efficiently into in-house innovation activities, basic research will act as an important driver for complementarity with other external sourcing strategies. One such external sourcing strategy is the use of publicly available information. Knowledge disseminated through publications, conferences and patents is a stock of knowledge that can be used by the industry as a public good input into commercial research. The effective transfer of this know-how typically requires a basic research capability by the receiving party, which can be built through cooperative agreements with science institutions. Following the literature, we expect that higher free spillovers will increase the scope for learning within cooperative R&D agreements. Because of improved technological competence of the partners, the marginal benefit of forming a research joint venture will be higher, implying a higher probability of cooperation.

In order to address the possible endogeneity problems with complementary strategies, we will use a two-step estimation procedure. The two-step estimation procedure consists of first regressing the complementary strategies on a set of specific *assumed* exogenous variables in the first step. In the second step, we use the predicted values of the complementary strategy variables as independent variables in the probit for cooperation with universities.[4,5] The next section details the data, the variables and the econometric methodology used, before presenting the results.

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3 Cassiman, Perez-Castrillo and Veugelers (2002) develop a model on the complementarity between basic and applied research. They find that once leading firms start accessing external know-how by spending on basic research as a way to create effective know-how, the ratio of basic to applied research will increase, the more they spend on R&D. They thus provide an explanation for why larger firms with larger applied R&D budgets will be more inclined to be engaged in basic R&D. Also Aghion & Howitt (1996) provide a model on the choice between basic and applied research, favoring larger firms for basic research.

4 In addition to being computationally less demanding, using our two-step estimation procedure provides more robust estimates compared to simultaneously estimating the system. Simultaneous estimation, requiring a full specification of all structural equations, might be plagued by biases arising from omitted variables in any of the individual equations, leading to inconsistent estimates for the whole system (see Vella and Verbeek, 1999).

5 In order to avoid inconsistent estimates for the second step estimation in the case of a dichotomous endogenous variable in a probit equation, which is the case for CPvert, we estimate the CPvert first step equation as a linear probability model and use the predicted value of this variable in the second step of the estimation (Heckman and Macurdy, 1985).

4. Cooperation in R&D between industry and science: empirical evidence from Belgian Manufacturing

4.1. The data

The data used for this research are innovation data on Belgian manufacturing industry that were collected as part of the Community Innovation Survey conducted by Eurostat in the different member countries in 1993 (CIS-I). The survey was intended to develop insights into the problems of technological innovation in manufacturing industry and was the first of its sort organized in many of the participating countries. It contained questions characterizing the R&D strategies of firms: whether they innovate or not, make and/or buy technology, and cooperate or not.[6] In addition, the data allow to identify motives of and obstacles to innovation, sources of technological information, mechanisms used to absorb know-how, as well as mechanisms used to protect the results from innovation. The later versions of the CIS survey (CIS-II and CIS-III) are unfortunately less rich in terms of other variables included; most notably, the appropriation of the results from innovation was not retained in later surveys. This is why we concentrate on CIS-I. A representative sample of 1335 Belgian manufacturing firms was selected and a 13-page questionnaire sent out to them. The response rate was higher than 50% (748). A limited non-response analysis was conducted, where no systematic bias could be detected with respect to size and industry affiliation.

The sample used in this study is restricted to the firms that innovate. These firms are distinguished from those that do not innovate based on their answer to the question of whether they were actively engaged in innovation in the previous two years (by introducing new or improved products or processes) and returned a positive amount spent on innovation: 60% (439) of the firms in the sample claim to innovate, while only 40% do not. The non-innovating firms did not provide information about several variables used in the analysis. In our regression analysis we correct for sample selection using the two-step Heckman correction.[7]

4.2. The variables

Our dependent variable, whether firms cooperate or not, *CPuniv*, is constructed from the questionnaire where firms responded whether or not they cooperate with universities.[8] Due to missing values, we are left with 374 firms that innovate, of which 106 have a cooperative agreement with universities.[9]

As independent variables we include the classical factors shown in previous literature to affect the decision to cooperate. We include *SIZE*, measured by the logarithm of firm employment. Taking logarithms allows to account for a non-linear size effect. A dummy variable *FOR* is included which takes the value of 1 if the firm has foreign headquarters. In addition, the survey information analyses the importance of cost & risk-sharing motives for cooperation with science in particular. The firms rated the importance of different obstacles

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6 An analysis of the R&D strategies chosen by the sample firms is reported in Veugelers & Cassiman (1999).

7 Sample selection with respect to innovating firms is rejected and does not significantly affect our results (see below).

8 The questionnaire only contains information on whether firms cooperate or not. No information on extent and nature of the cooperative agreement was available.

9 Table A1 in the Appendix provides a detailed description of all the variables used in the analysis.

to innovation on a scale of 1 (unimportant) to 5 (crucial). We construct an aggregate measure of the responses to questions such as lack of suitable financing, high costs of innovation, long pay-back period or difficult to control cost of innovation: *COST*. Similarly, *RISK* is the response to the importance of high risks as a barrier to innovation. To correct for "science-based industries", we include *industry dummies,* as well as an industry level variable for scientific cooperation[10].

The survey data allow us to focus our analysis of cooperation with universities on the extent to which Intellectual Property Rights and the capacity of firms to protect the rents from their innovative efforts shape their cooperative activities. In CIS-I, firms had to rate the effectiveness of five different methods for protecting products and processes, respectively (10 different questions overall), on a scale from 1 (unimportant) to 5 (crucial). We distinguish between two types of protection: *legal* protection of products and processes through patents, brand names or copyright; and *strategic* protection of products and processes through secrecy, complexity or lead time. We construct a variable with the mean score for these questions to generate a measure of legal and strategic protection. However, we will only use strategic protection as a firm-level variable on appropriability (*PROTstrat*). Legal protection is an industry variable, rather than a firm-specific characteristic. The industry average captures the technology and market characteristics that determine the legal appropriability regime of the industry (*IndPROTleg*).

A second specific focus of our analysis is the consideration of other complementary innovation activities. First, we include own R&D capacity. The CIS-I survey for Belgium does not provide reliable data on R&D budgets. In the absence of this, we have to resort to other proxies. In the questionnaire, firms rated the importance of internally available information for their innovation process on a 5-point scale from unimportant (1) to crucial (5). The importance of internal information to innovation is included to proxy for internal know-how capabilities, which should increase the effectiveness of absorbing externally acquired information *(INTSourcing*). The problem with the measure for econometric purposes is its low variance, since almost all firms in our sample indicate internal sources to be important.[11]

Second, we examine the complementarity between cooperation with universities and other external sourcing strategies.[12] A first external sourcing strategy is the use of publicly available information. In the questionnaire, firms rated the importance of publicly available information for their innovation process from three sources on a 5-point scale from unimportant (1) to crucial (5). The information sources were: patent information; specialist conferences, meetings and publications; trade shows; and seminars. To generate a firm-specific measure of incoming spillovers, we construct the mean of the answers on these questions (*PUBSourcing*). Finally, we also include other cooperative strategies of the firm, more particularly with clients and suppliers (*CPvert*).

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[10] The industry is defined at the NACE 2 digit sector level and the industry average is the average score from the firms responding in the sample in the same NACE 2 sector.

[11] An alternative question, namely whether firms were engaged in own R&D activities, allowed to construct a dummy variable. But since all firms that cooperated with universities scored positively on this dummy, we could not use this information. Similarly, the question on the presence of permanent R&D activities only yielded 5 non-positive observations.

[12] In order to correctly test the complementarity between different innovation activities, we need to estimate the incremental effect of combining these activities on performance. See Cassiman and Veugelers (2002b) for a careful identification of complementarity between innovation activities.

4.3. The model specification

Our basic equation to be estimated is as follows:

$CPuniv = \alpha_1 + \alpha_2 SIZE + \alpha_3 FOR + \alpha_4 COST + \alpha_5 RISK + \alpha_6 PROTstrat +$

$\alpha_7 IndPROTleg + \alpha_8 IndCPuniv + industry\ dummies + v_1$ *(1)*

To check the impact of complementary innovation activities we extend the basic specification (1) with internal R&D, through the variable *INTSourcing* and the two external sourcing strategies: sourcing of publicly available information (*PUBSourcing*) and cooperation with vertically related companies (*CPvert*).

$CPuniv = \alpha_1 + \alpha_2 SIZE + \alpha_3 FOR + \alpha_4 COST + \alpha_5 RISK + \alpha_6 PROTstrat +$

$\alpha_7 IndPROTleg + industry\ dummies +$

$\alpha_8\ INTSourcing + \alpha_9\ PUBSourcing + \alpha_{10}\ CPvert + v_2$ *(2)*

When *INTSourcing, PUBSourcing* and *CPvert* are complementary innovation strategies with *CPuniv*, this will imply that these variables, when included in the regression for *CPuniv,* will be correlated with the error term v_2, whenever we have not been able to include all drivers of complementarity in the set of independent variables for *CPuniv* or only because of common measurement error or common omitted variable bias. To tackle this problem we will use a two-step estimation procedure, where we first regress the complementary strategies on a set of specific *assumed* exogenous variables in the first step. In the second step, we use the predicted values of the complementary strategy variables as independent variables in the probit for cooperation with universities :

$INTSourcing = b_1 + b_2 SIZE + b_3\ OBSTEXTERNAL + b_4 OBSTRESOURCE + b_5\ IndINTsourcing + industry\ dummies + e_1$ *(3)*

$PUBSourcing = c_1 + c_2 SIZE + c_3\ BASICRD + c_4\ IndPUBsourcing + industry\ dummies + e_2$ (4)

$CPvert = d_1 + d_2 SIZE + d_3 FOR + d_4 TECH + d_5 PROTstrat + d_6 IndPROTleg + d_7 IndCPvert + industry\ dummies + e_3$ *(5)*

Included as instruments for the complementary strategies are the industry averages for each of the endogenous innovation activities. We assume that each of these industry mean variables picks up the effects of unobserved industry-specific attributes that contribute to that endogenous firm-specific variable.[13] In addition, we include as instrument for *INTSourcing* our measure of firm size as well as obstacles to innovation such as lack of internal and external resources that are effectively preventing firms from innovating.

[13] For a full specification of the model and the instruments, see also Table A2 in the Appendix. For a detailed description of the variables included, see Tables A1 and A2 in the Appendix.

For *PUBSourcing* the literature seems to suggest that absorptive capacity through internal technological capabilities is important to optimally benefit from external information flows. As an explanatory variable we thus include our assumed exogenous measure for absorptive capacity: firm size. It is often argued that generic research diffuses more easily (Vonortas, 1994; Kamien and Zang, 1998). Hence, firms that find sources of basic R&D more important for their innovation process, relative to information sources of applied R&D, are more likely to benefit from free public information and hence are expected to have a higher score on *PUBSourcing*. The variable *BasicRD* measures the importance for the innovation process of information from research institutes and universities *relative to* the importance of suppliers and customers as an information source. We use this variable to proxy for the "basicness" of R&D performed by the firm (see also Mohnen & Hoareau, 2002).[14,15]

As instruments for vertical cooperation, *CPvert*, we include, in line with cooperation with universities, size, foreign links and industry dummies. In contrast to cooperation with research institutes, the search for synergies and appropriation is a key issue when dealing with more commercially sensitive information in vertical cooperative agreements (see Cassiman & Veugelers, 2002). Hence we include our measures for appropriation on the firm and industry level. We also include a measure for the lack of technological information as an obstacle to innovation, *TECH*, which measures the absence of potential for synergies in cooperative agreements and hence should work negatively on the likelihood to cooperate.

When a firm is using a complementary innovation activity, this should stimulate the use of cooperation with universities. Hence to capture the effect from using complementary strategies, we expect a positive effect when including these (instrumented) strategies in the probit for *CPuniv*.

A final issue we need to deal with is a possible sample selection. As we only have information for those firms that are innovation-active, the coefficients in the *CPuniv* regression might be inconsistently estimated because of sample selection. The regression is corrected for sample selection following a two-stage Heckman correction procedure appropriate in the case of a probit regression. In the first stage the innovation equation is estimated. We regress in a probit model whether the firm innovates on the following independent variables: size, export intensity, a number of variables measuring obstacles to innovation (cost, lack of external resources, lack of technological opportunities, lack of demand) and industry dummies (see Veugelers and Cassiman, 1999 for a development of this result).

4.4. The results

Table 1 first presents some descriptive statistics about the variables used. The mean values of all variables are significantly higher for firms cooperating with universities than for firms without similar cooperative R&D agreements. Larger firms, firms with foreign ownership and those being cost constrained have a higher frequency of cooperating with

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14 The questionnaire grouped all the questions on the importance of different information sources for the innovation process in the same subsection. Scores of the same firms should be readily comparable. Note that by using this ratio of two scores, the potential problems of the subjectivity of these measures is reduced.

15 This is one of the variables that is likely to be endogeneous, but since the purpose of this paper is to study the decision to cooperate and the drivers of external knowledge flows, we will assume that the research approach chosen by the firm, i.e. the relative mix between basic and applied research, is exogenous.

science. This holds also for firms that are better able to appropriate the returns from innovation, but not for firms facing a higher risk. It seems that if risk is perceived as a barrier to innovation, firms are less likely to cooperate with universities. This difference is not significant however.

Table 1. Descriptive Statistics[a]

	Mean	Mean if *CPuniv* = 0	Mean if *CPuniv* = 1
*SIZE****	5.12 (1.63)	4.76 (1.51)	6.16 (1.52)
*FOR****	0.37 (0.48)	0.33 (0.47)	0.48 (0.50)
*COST***	0.49 (0.20)	0.47 (0.20)	0.52 (0.18)
RISK	0.48 (0.27)	0.49 (0.28)	0.47 (0.25)
*PROTstrat****	3.30 (0.96)	3.2 (1.03)	3.58 (0.65)
*IndPROTleg****	1.91 (0.36)	1.86 (0.31)	2.07 (0.46)
*INTsourcing****	3.88 (0.96)	3.79 (1.02)	4.13 (0.71)
*PUBsourcing****	2.85 (0.73)	2.75 (0.73)	3.12 (0.66)
*CPvert****	0.30 (0.46)	0.19 (0.39)	0.60 (0.49)

*** Difference in means between cooperating and non-cooperating firms significant at 1 percent
** Significant at 5 percent
* Significant at 10 percent
[a] Standard deviations in parentheses

As suggested by our hypothesis of complementarity with other innovation activities, the mean importance of *INTsourcing*, *PUBsourcing* and *CPvert* is significantly higher for firms cooperating with universities compared to firms without these cooperative agreements. Further evidence consistent with complementarity among innovation activities is offered by examining the correlation between these different innovation activities. Table 2 reveals that all these innovation activities are significantly positively correlated.

Table 2. Pairwise Correlations between Innovation Activities

	Cpuniv	*CPvert*	*INTsourcing*	*PUBsourcing*
CPuniv	1			
CPvert	0.399	1		
INTsourcing	0.158	0.150	1	
PUBsourcing	0.236	0.238	0.215	1
All correlations are significant at 1%				

Table 3 presents the results from the probit regressions. Regression (1) shows our base regression without accounting for any complementary innovation activities. As expected and in line with previous studies, *SIZE* positively affects the likelihood of cooperating with universities. Foreign ownership, *FOR*, once corrected for other characteristics, has a negative effect on cooperation with universities. Foreign subsidiaries are, therefore, less likely to be involved in ISL in Belgium, all else equal. Although these foreign subsidiaries form part of the multinationals' innovation system, they are typically involved in the more applied R&D activities while the central R&D department at headquarters remains more involved in basic R&D and associated ISLs. When costs are an important obstacle to innovation, innovating firms have a strongly significant higher probability of engaging in cooperative agreements with universities (*COST*). While cost-sharing seems to be an important driver of cooperation, risk-sharing is not. Firms for which risk is an important barrier to innovate are actually less likely to cooperate with universities (*RISK*). Viewed from a transaction cost perspective this result is not so surprising. Therefore, it seems important to distinguish between costs and risks when analyzing the cooperation decision. Substituting *COST* and *RISK* with an independent variable that combines cost and risk factors, as is frequently done in the literature, results in an insignificant parameter estimate. Finally, neither strategic nor legal protection affects the likelihood of engaging in cooperation with universities (*PROTstrat*, *IndPROTleg*). These results indicate that appropriation does not seem to preoccupy firms when cooperating with universities.

Table 3. Probit Regressions *CPuniv*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SIZE	0.397*** (0.067)	0.385*** (0.069)	0.439*** (0.775)	—	0.374*** (0.0685)	0.327*** (0.0725)	0.146* (0.091)	0.211* (0.121)
FOR	-0.33* (0.19)	-0.30 (0.192)	-0.354* (0.193)	0.036 (0.169)	-0.307* (0.191)	-0.34* (0.203)	-0.336* (0.20)	-0.376* (0.224)
COST	1.443*** (0.544)	1.448*** (0.551)	1.415*** (0.551)	1.149** (0.514)	1.40*** (0.55)	1.325** (0.574)	1.175** (0.571)	0.906 (0.617)
RISK	-1.156*** (0.389)	-1.232*** (0.398)	-1.292*** (0.404)	0.983*** -(0.373)	-1.298*** (0.397)	-1.257*** (0.416)	-0.982** (0.411)	-1.069** (0.441)
PROTstrat	0.142 (0.107)	0.119 (0.111)	0.111 (0.11)	0.147 (0.102)	0.0833 (0.111)	0.058 (0.116)	0.109 (0.114)	0.10 (0.125)
IndPROTleg	-0.096 (0.695)	-0.099 (0.694)	-0.082 (0.719)	-0.0093 (0.647)	-0.232 (0.706)	-0.606 (0.624)	-1.584** (0.694)	-1.638** (0.738)
IndCPuniv	3.995*** (1.296)	4.187*** (1.313)	3.973*** (1.331)	4.492*** (1.314)	4.148*** (1.322)	4.968*** (1.408)	4.81*** (1.331)	5.215*** (1.46)
INTsourcing	—	0.171* (0.10)	-0.105 (0.471)	0.955*** (0.409)	—	—	—	—
PUBsourcing	—	—	—	—	0.314** (0.135)	0.256* (0.141)	2.738*** (0.619)	2.479*** (0.663)
CPvert	—	—	—	—	—	0.894*** (0.185)	0.275 (0.261)	0.40 (0.284)
Constant	-4.013*** (1.154)	-4.552*** (1.191)	-3.656** (1.893)	-7.07*** (1.892)	-4.26*** (1.172)	-3.523*** (1.103)	-7.546*** (1.504)	-7.041*** (1.646)
Industry Dummies	included	included	included	included	included	included	included	included
	$\chi^2(22)$=130.65*** LL=-158.3 N=376	$\chi^2(23)$=133.83*** LL=-154.78 N=373	$\chi^2(23)$=135.67*** LL=-154.52 N=375	$\chi^2(22)$=99.10*** LL=-172.65 N=375	$\chi^2(23)$=136.11*** LL=-154.91 N=374	$\chi^2(24)$=160.32*** LL=-142.80 N=374	$\chi^2(24)$=153.74*** LL=-146.09 N=374	$\chi^2(23)$=74.22*** N=343

***significant at 1 percent, **significant at 5 percent, *significant at 10 percent.

In the following regressions we include different complementary innovation activities sequentially[16]. We start with own R&D. In regression (2) we include internal information sources as a proxy for own R&D capacity (*INTsourcing*). Own R&D capacity positively affects the decision to cooperate with universities, although this is only significant at 10%. As the existing literature indicates, there is a strong presumption of endogeneity of this variable. Correcting for potential endogeneity, we find that there is no effect of own R&D capacity (regression (3)), confirming previous studies.[17] However, we suspect that this effect is driven by collinearity between *SIZE* and *INTsourcing* due to our correction procedure, rather than because own R&D capacity has no effect on cooperation with universities. Regression (4) shows that when dropping *SIZE*, our corrected measure of own R&D capacity is highly significant. We therefore conclude that *SIZE* seems to be a good proxy for the form's own R&D and absorptive capacity and decide to drop *INTsourcing* from our subsequent regressions. Note that this by no means indicates that own R&D capacity is inconsequential for university cooperation. On the contrary, the difficulty of finding an alternative measure for own R&D capacity which did not perfectly predict cooperation with universities indicates a strong complementarity between cooperation and own R&D (see footnote 11), actually too strong to be able to assess econometrically.

In regressions (5) and (6) we add two other external sourcing strategies, *PUBsourcing* and *CPvert*, to our base regression. Both the importance of publicly available information for the innovation process and cooperative agreements with customers and suppliers are positively related with cooperation with universities. This result suggests complementarity between different innovation activities. Obviously, these variables are plagued by endogeneity.[18] Correcting for endogeneity (regression (7)), the importance of *PUBsourcing* increases spectacularly, both in significance and in quantitative effect on the decision to cooperate. The positive effect of vertical cooperation, however, is lost after the correction. Either vertical cooperation, properly accounted for, is not complementary to cooperation with universities, or our correction badly predicts vertical cooperation and the predicted value is therefore a bad instrument. In order to discriminate between these two alternative explanations of our results we resort to an alternative empirical strategy. We jointly estimate *CPuniv* and *CPvert* as a bivariate probit. If these activities are truly complementary the joint estimation would correct for this joint determination. Table 4 presents these results. Regressions (1) and (2) are the uncorrected bivariate probit regressions for *CPuniv* and *CPvert*. In regressions (3) and (4) we correct *PUBsourcing* for endogeneity as we did in the previous case. First, it is interesting to note that the results of regressions (1) and (3) on *CPuniv* confirm our results in Table 3 (regressions (5) and (7)) on the drivers of cooperation with universities. Furthermore, the correlation between *CPuniv* and *CPvert* is positive and highly significant, confirming the complementarity between these innovation activities. Our independent variables, however, are unable to explain this correlation, as the remaining error terms are still highly correlated. Therefore, constructing from these results a predicted *CPvert* variable is unlikely to pick up the elements driving the observed complementarity between cooperation with universities and cooperation with suppliers and customers. In the absence of a good explanatory model, the predicted *CPvert* in Table 3 (regression (7)) is therefore expected to show up insignificant.

16 The results on the "base" variables remain robust across the various specifications.
17 See Table A2 in the Appendix for the instruments used. Alternative specifications gave very similar results.
18 See Table A2 in the Appendix for the IV-regression.

Table 4. Bivariate Probit CPuniv and Cpvert

	(1) *CPuniv*	(2) *CPvert*	(3) *CPuniv*	(4) *CPvert*
SIZE	0.375*** (0.0687)	0.24*** (0.582)	0.184** (0.0812)	0.262*** (0.0704)
FOR	-0.344* (0.193)	-0.144 (0.175)	-0.366* (0.20)	-0.159 (0.175)
COST	1.199** (0.53)	—	1.003* (0.535)	—
RISK	-1.172*** (0.383)	—	-0.884** (0.389)	—
TECH	—	-0.422 (0.335)	—	-0.370 (0.331)
PROTstrat	0.095 (0.11)	0.190** (0.096)	0.133 (0.111)	0.229** (0.094)
IndPROTleg	-0.302 (0.731)	-0.562 (1.428)	-1.657** (0.737)	-0.738 (1.547)
IndCPuniv	4.487*** (1.322)	—	5.382*** (1.318)	—
IndCPvert	—	4.163** (2.09)	—	4.655** (2.187)
PUBsourcing	0.305** (0.134)	0.20* (0.117)	2.854*** (0.603)	-0.0687 (0.494)
Constant	-4.164*** (1.204)	-2.943 (1.985)	-7.972*** (1.482)	-2.262 (2.266)
Industry Dummies	Included	Included	Included	Included
	Rho = 0.514*** c2(45)=135.41*** LL=-328.45 N=372		Rho = 0.589*** c2(45)=140.90*** LL=-318.71 N=372	
*** Significant at 1 percent, ** Significant at 5 percent, * Significant at 10 percent				

An interesting result, nevertheless, is the significant positive effect of strategic protection for vertical cooperation in regressions (2) and (4) in Table 4.[19] While appropriation does not seem to affect the decision to cooperate with universities, the regressions for *CPvert* indicate that the more applied R&D agreements with customers and suppliers do take into consideration the potential loss of appropriability before engaging in such an agreement. This different result accentuates the open information environment in which cooperative agreements with universities take place, in contrast with other cooperative agreements.

19 This effect can also be noted in the correction use for *CPvert* in Table A2 in the Appendix. See also Cassiman and Veugelers (2002).

Finally, we check our results for possible sample selection. Regression (8) in Table 3 applies a Heckman procedure for probit regressions. We estimate a selection equation for whether the firms innovate or not, and adjust the original probit regression of *CPuniv* for this outcome.[20] Both *SIZE* and *COST* have smaller point estimates and are less significant after correcting for sample selection. Both these variables strongly account for the decision to innovate. But, as can be observed, our remaining estimates are affected little by this selection and sample selection is actually rejected by the data.

5. Conclusions

In line with the "European Paradox" doctrine which attributes low levels of Industry Science Links in Europe to a lack of demand from the enterprise sector, this paper studies the demand side for ISLs and more particularly for cooperative agreements in R&D between firms and universities. We present an econometric analysis on the firm and industry characteristics most conducive to cooperation with universities, using EUROSTAT/CIS I data from Belgian manufacturing firms.

In line with previous studies we find large firms to be more likely to have cooperative agreements with universities. In the econometric analysis, it turns out that firm size seems to be the better measure for own absorptive R&D capacity of the firm, at least in the absence of a better measure for own R&D with sufficient variance among innovative firms. Furthermore, firms with foreign headquarters are less likely to be actively involved in industry science links in Belgium, which is consistent with MNEs keeping basic R&D, which is more prone to ISL, centralized at the headquarter level. Firms impeded by costs to innovate are more likely to cooperate with universities, attracted by the cost-sharing option from cooperation. However, risk sharing was not found to be associated with cooperation with universities. This could be related to the higher transaction costs for cooperative agreements in highly uncertain R&D projects.

In line with the Industrial Organisation models on R&D cooperation, we also examine the impact of appropriation of know-how on the incentives to engage in R&D cooperation with universities. We find that the capacity to effectively protect the returns from innovations is not a significant factor for cooperation with universities. This confirms the importance of a perspective of open, non-exclusive exchange when cooperating with scientists in basic exploratory cooperative research. This is in contrast with cooperative agreements with suppliers and customers, where the effectiveness of strategic protection mechanims is a highly significant factor, since commercially sensitive information, which is the result of these more applied research projects, may leak out to competitors through common suppliers or customers.

Cooperative agreements with universities are typically embedded in a wider innovative strategy of the firm. We find consistent evidence of a complementary relationship, for firms cooperating with universities, with other innovation activities such as using public information as an important information source for innovation. Also, the complementarity with other cooperative agreements, notably with suppliers and customers, is confirmed in the data.

[20] See Table A2 in the Appendix for the result of the innovation selection equation.

Overall the results seem to suggest that the low frequency of cooperative agreements with universities in Belgian manufacturing may be related to an industry structure that is characterized by a high share of small and medium-sized firms whose R&D activities are concentrated more on development projects, rather than the more basic research projects where the link with science is more apparent. The fact that a lot of large firms in the Belgian manufacturing sector are typically subsidiaries of foreign firms also contributes to lower levels of ISLs. Furthermore, a too narrow portfolio of innovative activities of Belgian firms implies a lack of complementary innovation activities, which would stimulate cooperation with universities.

Before these results are molded into firm policy conclusions, more work is needed both empirically and theoretically. Empirical work, replicating the results across countries and across time, is needed. More importantly, the analysis should be extended, beyond whether cooperation occurs or not, towards assessing the efficiency of such cooperation and its impact on innovative performance and growth. We also need new insights from theory to be better able to assess which capacities firms need to master in-house in order to engage effectively in cooperation with science. This would allow to derive better proxies for internal R&D capabilities and find better drivers for complementarity among innovation activities.

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Appendix

Table A1. The Variables

Dependent Variables	
CPuniv	*CPuniv* = 1, if firms cooperate with Universities.
CPvert	*CPvert* = 1, if firms cooperate with (1) Suppliers, or (2) Customers.
INTsourcing	Importance of Internal Information Sources of the firm for Innovation (number between 1 (unimportant) and 5 (crucial)).
PUBsourcing	Mean score of importance of following information sources for innovation process (number between 1 (unimportant) and 5 (crucial)): (1) Patent information, (2) Specialized conferences, meetings and publications, (3) Trade shows and seminars.
Independent Variables	
SIZE	Natural Logarithm of Number of Employees in 1992 in 10,000
FOR	*FOR* =1, if the firm has foreign headquarters.
COST	Sum of scores of importance of following obstacles to innovation process (number between 1 (unimportant) and 5 (crucial)): (1) No suitable financing available, (2) High costs of innovation, (3) Pay-back period too long, (4) Innovation cost hard to control (rescaled between 0 and 1).
RISK	Importance of high risks as an obstacle to innovation (number between 1 (unimportant) and 5 (crucial), rescaled between 0 and 1).
PROTstrat	Average measure of effectiveness of secrecy, complexity and/or lead time as a protection measure of innovation (on scale 1 (unimportant) to 5 (crucial)).
IndProtleg	Average measure of effectiveness of patents or registration of brands as a protection measure of innovation (on scale 1 (unimportant) to 5 (crucial)).
IndCPuniv	Mean of *CPuniv* at industry level. Industry level is defined at 2-digit NACE.
Industry Dummies	Industry dummies are included where the industry is defined as groupings of NACE 2-digit level industries.

Appendix (continued)

Table A1. The Variables (continuation)

Instrumental Variables INTsourcing	
OBSTEXTERNAL	Mean of score of scores on Importance of lack of external technical services, lack of cooperation opportunities with other companies, and lack of technological opportunities.
OBSTRESOURCE	Mean of score of scores on Importance of lack of innovation personnel, lack of technical personnel, lack of information about technologies, and lack of market information as barrier to innovation (on scale 1 (unimportant) to 5 (crucial)).
IndINTsourcing	Mean of *INTsourcing* at industry level. Industry level is defined at 2-digit NACE.
Instrumental Variables PUBsourcing	
BASICRD	Measure of importance for the innovation process of information from research institutes and universities relative to the importance of suppliers and customers as an information source.
IndPUBsourcing	Mean of *PUBsourcing* at industry level. Industry level is defined at 2-digit NACE.
Instrumental Variables CPvert	
TECH	Importance of lack of technological information as an obstacle to innovation, (number between 1 (unimportant) and 5 (crucial), rescaled between 0 and 1)).
IndCPvert	Mean of *CPvert* at industry level. Industry level is defined at 2-digit NACE.
Selection Equation Innovation	
INNOV	*INNOV*=1 if firm developed or introduced new or improved products or processes in the last 2 years AND reported a positive budget for innovation expenditures.
OBSTTECHNOLOGY	Importance of lack of technological opportunities as barrier to innovation (on scale 1 (unimportant) to 5 (crucial)).
EXPINT	Export Intensity in 1992 (Exports/Sales x 0.1).
OBSTINTEREST	Importance of lack of interest by customers for new products as an obstacle to innovation (number between 1 (unimportant) and 5 (crucial)).

Appendix (continued)

Table A2. Correction for Endogeneity and Selection

	(1) *INTsourcing* (OLS)	(2) *PUBsourcing* (OLS)	(3) *CPvert* (OLS)	(4) *INNOV* (Probit)
SIZE	0.089*** (0.028)	0.0711*** (0.026)	0.0745*** (0.016)	0.322*** (0.059)
OBSTTECHNOLOGY	—	—	—	-0.306*** (0.076)
OBSTEXTERNAL	0.175*** (0.069)	—	—	0.285*** (0.10)
OBSTRESOURCE	-0.134* (0.073)	—	—	—
BASICRD	—	0.503*** (0.118)	—	—
FOR	—	—	-0.0482 (0.053)	0.0984 (0.194)
TECH	—	—	-0.092 (0.094)	—
PROTstrat	—	—	0.0458* (0.025)	—
IndPROTleg	—	—	-0.0779 (0.131)	—
EXPINT	—	—	—	0.728*** (0.223)
COST	—	—	—	0.871*** (0.194)
OBSTINTEREST	—	—	—	-0.162** (0.669)
IndINTsourcing	0.941*** (0.18)	—	—	—
IndPUBsourcing	—	0.862*** (0.138)	—	—
IndCPvert	—	—	0.961*** (0.248)	—
IndInnov	—	—	—	1.476** (0.666)
Constant	-0.355 (0.718)	-0.306 (0.387)	-0.261 (0.249)	-1.835*** (0.587)
Industry Dummies	—	—	Included	Included
	F(4,395)=11.39*** Adj R^2 =0.094 N=400	F(3,422)=30.37*** Adj R^2 =0.172 N=426	F(21,366)=4.5*** Adj R^2 =0.159 N=388	Rho = 0.0657 $\chi^2(24)$=74.22*** N=504

*** Significant at 1 percent, ** Significant at 5 percent, * Significant at 10 percent