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REGULAR ARTICLE

How do different motives for R&D cooperation affect firm performance? – An analysis based on Swiss micro data

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Abstract The starting point of our analysis is the empirical fact that firms pursue different goals when getting engaged in R&D collaborations, often more than one goal at the same time. Given that firms are driven by different motives for R&D cooperation, the aim of this article is to investigate the differences related to different motives with respect to the impact of R&D cooperation on firm innovativeness and firm productivity. Not only R&D cooperation in general but also cooperation driven by each of the seven motives considered in this paper correlate positively with the sales share of innovative products. With respect to innovativeness, the characterization of cooperation by the driving motive did not add much more than could be gained through the overall variable 'R&D cooperation yes/no'. Technology-motivated collaborative activities show a weaker tendency to positive direct effects on productivity than cost-motivated cooperation. In this case, the distinction of several cooperation motives yields some additional insights as compared to the overall cooperation variable. On the whole, distinguishing various cooperation motives appears to be fruitful because it allows more differentiated insights that would remain hidden behind the overall variable "R&D cooperation yes/no".

Keywords R&D cooperation · Innovation · Productivity

JEL Classification O31

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1 Introduction

This paper is mainly motivated by the observation of the necessity of the acquisition of new knowledge as a precondition for successful innovative activities of enterprises. New knowledge is not only generated inside the boundaries of a firm but also is acquired from the environment. Even the largest and most technologically self-sufficient enterprises require knowledge from beyond the firm boundaries. In addition to own research and development (internal R&D), enterprises typically are engaged in the trading of knowledge on the technology market (contract or external R&D) and/or co-operate actively—formally or informally—with other firms and research institutions. For applied industrial economics, it is an important task to understand how firms integrate internal knowledge and various types of externally acquired knowledge. In the last years, there has been an increasing interest in the economic literature to analyze the motives and determinants of alternative knowledge acquisition strategies (own R&D, R&D co-operation, contract-R&D, etc.; see, e.g., Cassiman and Veugelers 2006; Belderbos et al. 2006). An important motive for this research interest is the improvement of our understanding of the role of such strategies with respect to (a) the innovation performance and (b) the output performance of enterprises that engage in such strategies. Thus, there is also an increasing interest in assessing the impact of various knowledge acquisition strategies on the innovation and economic performance of a firm. Better insights into knowledge acquisition strategies and their impact on firm performance would allow the formulation of a knowledge-based technology policy.

In this paper, we concentrate on R&D cooperation. The starting point of our analysis is the empirical fact that firms pursue different goals when engaged in R&D collaborations, often more than one goal at the same time (see, e.g., Hagedoorn 1993; Hagedoorn et al. 2000). Given that firms are driven by different motives for R&D cooperation, the aim of this article is to investigate the differences related to different motives with respect to the impact of R&D cooperation on firm innovativeness and firm productivity.

To this end, we utilized data on seven different motives for R&D cooperation reported by Swiss firms in the years 1999, 2002 and 2005. Based on these data, we distributed cooperating firms into seven groups, according to the importance for them of each of the seven cooperation motives. Thus, we constructed a dichotomous variable for each of these cooperation motives. In a second step, we specified an innovation equation and a productivity equation, respectively, that included separately each of the seven cooperation motives as right-hand variables. These were estimated by random effect tobit and random effect OLS techniques, respectively, after testing for endogeneity for the seven motive variables. We also estimated the two impact equations for the overall cooperation variable (‘R&D cooperation yes/no) as reference.

New elements of this study are (a) the consideration of seven distinctive motives for R&D cooperation; (b) the investigation of the impact of these different motives on innovation and productivity; (c) the coverage of all sectors of the economy (manufacturing; services; construction); and (d) the consideration of more than one cross-section of firms, as is usually the case.

The plan of the study is as follows: in Section 2, we discuss the theoretical background of the study. Section 3 offers a summary of relevant empirical literature. In Section 4, we present the main hypotheses. Section 5 is committed to the presentation of the data used. Section 6 contains a short discussion of the seven different R&D cooperation motives investigated. The specification of the empirical models to be estimated is presented in Section 7. In Section 8, the results of the econometric estimations are discussed. Finally, Section 9 contains a summary of the most important results and some conclusions.

2 Conceptual background

Our conceptual approach builds on two different strands of literature on R&D cooperation. The first is the industrial organization (IO) literature, the second the management literature.

2.1 Industrial organization approach: what are the motives for R&D cooperation?

R&D cooperation, particularly in the form of research joint ventures, is an important single knowledge acquisition strategy that has been the subject of theoretical and empirical analysis for some years. Economic research in the field of R&D cooperation essentially aims at understanding why firms undertake R&D cooperation, how they do it, and with what result (see Kaiser 2002 and De Bondt 1996 for reviews of this literature). We concentrate here on why firms undertake R&D cooperation, and thus on the *motives* for R&D cooperation.

One of the most influential theoretical papers in this field is that of D'Aspremont and Jacquemin (1988). They derived a two-stage Cournot duopoly game, in which firms decide upon R&D investment and then compete in the product market. R&D expenditures are larger in research joint ventures than in the competition case if (exogenous) spillovers exceed a critical value. According to this approach, the main motive for R&D cooperation is the internalization and better utilization of knowledge that is easily leaking out to competitors in the framework of a cooperation contract.

An interesting generalization of the framework of D'Aspremont and Jacquemin (1988) was achieved by Kamien et al. (1992). Key findings of this paper are that (a) effective R&D investment is larger under research joint ventures than under competition if spillovers are sufficient large, (b) an increase in spillovers leads to a reduction of research efforts if goods are complements (substitutes) and spillovers are large (small) and also tends to reduce incentives to collaborate in R&D, (c) an increase in market demand leads to an increase of research efforts both under research joint venture and research competition (an increase of market demand has a positive effect on the likelihood of R&D cooperation), and (d) increased research productivity leads to increased incentives to invest in R&D and also to conduct joint-research. The main motive for R&D cooperation is in this model the same as in D'Aspremont and Jacquemin (1988), but the substitutive or complementary relation between the products of the collaborating firms is also an important determining factor. Moreover, this extended model framework offers more theoretical insights as to the conditions (high demand, high research productivity) under which R&D cooperation takes place, given the main motive of internalization of knowledge externalities.

In a further paper, Kamien and Zang (2000) tried to integrate in their theoretical framework the idea of endogenous absorptive capacity, i.e. the idea that firms can determine through their own research effort the extent of absorption of external knowledge. The most important empirically result is that research joint ventures are more likely to occur the more "general" (in contrast to "specific") the R&D agenda. The less specific the R&D agenda, the greater is the possibility of spillovers, thus the greater the likelihood that R&D cooperation would be used as a mean of internalization of knowledge externalities. The R&D "specificity" argument is quite in accordance to the transaction costs approach (see, e.g., Williamson 1975).

2.2 Management literature approach to motives of R&D cooperation

The second strand of literature we take into consideration, namely the management literature, provides further helpful insights with respect to different motives of R&D cooperation. Following Calogirou et al. (2003), we distinguish three approaches within this literature. A first group of studies views R&D cooperation (more concretely, R&D joint ventures) as efforts of firms to shape the competitive environment in which they operate (see, e.g., Harrigan 1988; Porter 1990). Shaping competition and improving a firm's competitive position can be reached by sharing value chains with partners in a way that broadens the effective scope of a firm's own value chain. A second approach emphasizes resources and capabilities building on the resource-based view of the firm originally developed by Penrose (1959) and further elaborated by Teece (1982; dynamic capabilities approach) and Prahalad and Hamel (1990; core competences concept). In this view, technological alliances are effective organizational modes for gaining access to new and/or complex technologies as additional resources. Finally, a third approach focuses on the influence of uncertainty on the generation of new knowledge. Sharing of technological risks of the development of new technologies and learning processes referring to new specialized and complex technologies are important motives for building inter-firm technological alliances, according to this approach (see, e.g., Kogut 1988; Dodson 1991; Teece 1992).

Finally, Hagedoorn (1993) in a survey of the management literature on technology partnering, gives an overview of motives for technology alliances and develops a taxonomy of cooperation motives that was used together with the insights from the management literature to identify the most important cooperation motives. He distinguishes three main groups of motives for interfirm technology cooperation: (a) motives related to basic and applied research and some general characteristics, (b) motives related to concrete innovation processes or projects in a joint activity of two or more companies, and (c) motives related to market access and search for opportunities. The first group refers to reduction and sharing of costs, reduction and sharing of uncertainty in R&D, as well as to increased complexity of new technologies, monitoring of evolution of technologies, technology synergies or complementary technology. The second one is related to reducing of the period between invention and market introduction or shortening of product life cycle. The third category of cooperation motives is associated with aspects such as the expansion of product range, entry to markets of new products or entry to the foreign market. In sum, Hagedoorn emphasizes that concrete understanding of the motives of firms to engage in innovation cooperation provides additional insights to purely theoretical understanding of cooperation as an alternative organizational form of processing innovation to both markets and hierarchies.

2.3 Impact of R&D cooperation on economic performance

The theoretical literature in industrial organization (IO) has already addressed the important question about the relation of R&D cooperation and economic performance. This is also clear in the models discussed in Section 2.1. According to Link and Siegel (2003; Ch. 11), who wrote a survey on this literature, in general the answer to this question is that the propensity to R&D cooperation is positively related (a) to economic efficiency and (b) to the increase of consumer surplus through new or improved products or the faster introduction of such new or improved products.

The predominant static models with spillovers of the industrial organization (IO) approach predict mostly under-investment in R&D due to external costs caused by low appropriability of innovation gains. These models consistently find that research collaborations tend to alleviate the appropriability problem in the presence of high spillovers. Cooperating firms reduce duplicative research and are able to more fully appropriate innovation gains.[1]

The management literature treats R&D alliances as a specific type of organizing R&D activities that could lower transaction costs. Besides the avoidance of duplication of research results, synergies between cooperation partners could give rise to economies of scope and learning (through the transfer of experience among partners).

[1]See Link and Spiegel (2003; Ch. 11) for a more detailed discussion of other types of much less frequently used IO models that do not come to clear-cut results with respect to the impact of cooperation on firm performance.

In particular, Ahuja (2000, p. 429ff.), in a paper on collaboration networks, argues that collaboration in innovation can affect a firm's innovative output positively by providing three substantive benefits: knowledge sharing, knowledge complementarity and knowledge scale. As to knowledge sharing, the idea is that, when firms collaborate in R&D, the knowledge that is commonly generated is available to all partners. Thus, each single partner can potentially obtain a greater amount of knowledge than would be the case from a comparable research investment made individually. As to complementarity, the main argument is that the innovation process often demands the parallel use of different knowledge packages, the development and maintenance of which may prove to be difficult for many firms. Under such circumstances, cooperation can enable firms to exploit economies of specialization that otherwise would not be feasible without significantly larger investments. The third positive effect of cooperation on innovation performance results through the exploitation of economies in R&D that is made feasible through cooperation.

In a further relevant study, Sarkar et al. (2001) formulated (and tested empirically) two more specific hypotheses that may prove fruitful also for further research. The starting point is that the propensity to R&D cooperation ("alliance proactiveness") would be associated with higher levels of economic performance in terms of sale growth, market share and product development. The new elements in this analysis are the moderating roles of perceived technological uncertainty and of the size of the collaborating enterprise. The authors argue that the possibility of internalizing technological risks enhances innovation performance. Further, alliances between partners of unequal size mostly provide larger firms access to the tacit knowledge of small firms, which in turn benefit from the financial and marketing resources of the larger ones. Under such circumstances, the specific know-how of the small firms may increase their bargaining power vis-à-vis the large ones, thus enabling them to improve their economic performance. As a consequence, the higher the technological uncertainty and the smaller the cooperating firm, the stronger the (positive) relationship between the propensity of cooperation and performance.

A further group of studies investigates the influence of the position of a firm in a network of alliances, as well as the characteristics of networks on the performance of a collaborating firm. For example, Powell et al. (1996) developed the hypothesis that the growth of collaborating firms depends positively on (a) the degree of centrality of the firm in a network of cooperating firms and (b) the network experience in fields of activity other than R&D. Baum et al. (2000) formulated a series of hypotheses about the impact of several network characteristics such as the size and the efficiency of a network, the innovative capabilities of the network partners and the degree of external and internal competition, particularly on the performance of startups participating in a network.

On the whole, there is a tendency in the theoretical literature to expect a positive impact of R&D cooperation on innovativeness and economic efficiency.

3 Review of selected relevant empirical literature

We concentrate here on the impact of cooperation on innovativeness and economic performance because these topics are also the focus of this paper.[2] We consider only studies that were published after 2000. (See Link and Siegel 2003, Ch. 11 for a survey of literature on this topic before 2000.) Existing studies refer primarily to European countries (Belgium, Finland, France, Germany, the Netherlands and Sweden) and Japan and two of them refer to the USA. The research setting consists mostly of an innovation equation, which contains, among other innovation-relevant variables, measures for innovation cooperation, often differentiated by partner category (suppliers, customers, universities, etc.). A few papers investigated also the impact of cooperation on economic performance (e.g., sales growth, value added per employee).

A number of empirical studies have found a positive impact of engaging in R&D cooperation on innovation performance usually measured by the sales share of innovative products. (See, e.g., Lööf and Heshmati 2002; and Belderbos et al. 2004b.) Moreover, Belderbos et al. (2004b) assumed (and found confirmed by their empirical analysis) that labour productivity may be positively affected by collaborative R&D aimed at cost reductions, while sales increase through innovative products is more likely to be related to collaboration that is more oriented to basic R&D efforts. Further studies with positive effects of (overall) innovation cooperation on innovation performance measured by different indicators can be found in Czarnitzki et al. (2007) for German and Finnish firms and Simonen and McCann (2008) for Finnish firms.

Other studies have found little or no evidence for a significant correlation between cooperation and innovation performance as measured by output indicators. (See, e.g., Kemp et al. 2003; Okamuro 2007; Aschhoff and Schmidt 2008). There is a tendency for cooperation propensity to correlate positively with input but not with output innovation indicators. (See, e.g., Klomp and van Leeuwen 2001). Distinguishing between cooperation with national and international partners, Miotti and Sachwald (2003) showed that, in France, innovation performance was not affected by cooperation agreements with national partners but increased by cooperation with foreign partners. Lööf and Heshmati (2002) found positive effects of cooperation for both national and international partners.

Adams and Marcu (2004), in a study based on USA firm data covering the years 1991 and 1996, found the participation in R&D joint ventures to be positively correlated with an indicator for new products but not with an indicator for patents. The authors concluded that joint research aims at commercialization but not invention.

[2] Some studies used explicitly motive variables as right-hand variables in cooperation equations in addition to the factors postulated by theory. (See, e.g., Sakakibara 1997; Bayona et al. 2001; Lopez 2008; Arvanitis and Bolli 2012; Woerter 2011). We could find only one study that investigated motives of innovation R&D cooperation in a setting using motive variables as left-hand variables in a cooperation equation (Schmidt 2007).

Darby et al. (2004), in a further study based on USA firm data, found that participation in R&D joint ventures organized by the Commerce Department's Advanced Technology Program (ATP) increased significantly innovation as measured by patenting.

Most of the studies that distinguished various types of cooperation partners found that the impact of cooperation on innovativeness depends heavily on the type of partner, but no general pattern is discernible. For countries with more than one study, the findings sometimes differ from study to study, due to the fact that they often use different firm cross-sections, different model specifications and different econometric methodologies. In sum, there is a relatively large heterogeneity of results, but nevertheless a general tendency for positive effects of cooperation on innovation performance is also discernible. We could find only too few studies on the impact of cooperation on productivity (Cincera et al. 2003; Belderbos et al. 2004b) to be able to make a general assessment of such effects.

4 Resulting hypotheses

Based on the above discussion of the theoretical and empirical literature, we formulate the following hypotheses for the empirical part of the study:

Hypothesis 1: Cooperative R&D enhances innovation performance (through new or improved products or faster introduction of such new or improved products);
Hypothesis 1a: We would expect that particularly the effects of motives that are more oriented towards the acquisition of new knowledge would be significantly larger than the effects of more cost- and fund-oriented motives.
Hypothesis 2: Cooperative R&D enhances firm productivity (through the reduction of innovation costs and/or the utilization of economies of scale, scope, or learning).
Hypothesis 2a: In addition, we would expect positive effects, particularly for more cost- and fund-oriented cooperation motives.
Hypothesis 2b: We would further expect that this effect is stronger when the reduction of technological risks is an important cooperation motive;

5 Data

The data used in this study were collected in the course of three surveys among Swiss enterprises in the years 1999, 2002 and 2005, using a questionnaire that included, besides questions on some basic firm characteristics (sales, exports, employment, investment and employees' vocational education), several innovation indicators quite similar to those in the Innovation Surveys of the European Community (CIS), as well as information on R&D cooperation projects (type of partners, motives, etc.).[3] The survey was based on a (with respect to firm size) disproportionately stratified random sample of firms with at least 5 employees covering all relevant industries of the manufacturing sector, the construction sector and selected service industries, as well as firm size classes. On the whole, 28 industries were studied, and within each industry, three industry-specific firm size classes with full coverage of the upper class of large firms. The response rate was, in the first wave, (1999) 33.8%, in the second wave (2002), 39.6%, and in third wave, 38.7%, respectively. The response rates did not vary much across industries and size classes with a few exceptions (overrepresentation of machinery, underrepresentation of clothing/leather, wood processing and hotels/catering).

We used in this study only data for firms conducting R&D activities in the relevant period.[4] The final data set includes 2922 enterprises from all fields of activity and size classes. (See Table 6 in the appendix for the structure of the used data set by industry, firm size class and year, respectively.) Our questionnaire provides information on different motives firms pursued in a certain period, but a firm could conduct more than one R&D cooperation project in this period. Thus, we cannot distinguish between firms that pursue more than a motive at the time for a certain cooperative project and firms that have more than one cooperative project in the reference period but with different motives.

6 Descriptive analysis: motives of R&D cooperation

Under "R&D cooperation" we understand cooperative activities in R&D that could take the form of R&D agreements, agreements for technological exchange, joint ventures in R&D, etc. Contract R&D is explicitly not included in the definition we use in our survey. According to the above definition, 997 firms, i.e. 34.1% of firms with R&D activities in our sample, reported R&D cooperation (see Table 1). The share of cooperating firms varied between 27.4% (2002) and 38.7% (1999). Based on management literature we identified six single motives for R&D cooperation. Three of them refer to *financial or cost requirements*: reduction of technological costs (MOT1), saving R&D costs (MOT2), and reduction of product development time (MOT3). A fourth one is also a financial motive and is related to the utilization of public promotion grants for which a cooperative project is a precondition (MOT7). Three further motives reflect primarily *knowledge requirements*: access to specialized new technology (MOT4), utilization of technological synergies (MOT5), and access to complex new technology (MOT6).

[3] Versions of the questionnaire in German, French and Italian are available at www.kof.ethz.ch.

[4] Since we did not correct for a possible sample selection bias for firms that did not conduct R&D, the results can be interpreted as applicable only to firms investing in R&D.

Table 1 Motives for R&D cooperation

Motives	1999		2002		2005		Total	
	N	%	N	%	N	%	N	%
MOT1 Reduction of technological risks	62	7.1	60	5.6	57	5.9	179	6.1
MOT2 Saving of R&D costs	90	10.2	83	7.8	98	10.1	271	9.3
MOT3 Shortening of development time	166	18.9	126	11.8	147	15.1	439	15.0
MOT4 Acess to specialized technology	204	23.2	182	17.0	192	19.7	578	19.8
MOT5 Utilization of technological synergies	206	23.4	202	18.9	200	20.6	608	20.8
MOT6 Knowledge of complex technologies	138	15.7	134	12.5	126	13.0	398	13.6
MOT7 Utilization of public promotion grants	43	4.9	33	3.1	25	2.6	101	3.5
R&D_COOP R&D cooperation	340	38.7	293	27.4	364	37.4	997	34.1

Percentage of firms reporting the values 4 and 5 on a five-point Likert scale (1: 'not important'; 5: 'very important'). Basis: firms with R&D activities

Starting point of our analysis is the fact that firms mostly pursue more than one motive at a time in R&D cooperation. This is demonstrated by the figures in Table 1 that show the frequency of reporting of the seven different motives taken into account in this study. The most frequent motives for all three periods are (a) the utilization of technological synergies (MOT5) and (b) the access to specialized technology (MOT4). Shortening of development time (MOT3) and acquisition of knowledge of complex technologies (MOT6) seem to be somewhat less important than MOT3 and MOT5. Reduction of technological risks (MOT1), saving R&D costs (MOT2) and utilization of public promotion grants for which a cooperative project is a precondition (MOT7) are pursued in most cases by less than 10% of cooperating firms. The proportions between the motives remained relatively stable over time, pointing to a rather stable pattern of motives of R&D cooperation.

Given that most literature on cooperation focuses on the partners engaged in such agreements (suppliers, competitors, customers, universities, etc.), it would be interesting to throw a glance on the relationship between cooperation motives and cooperation partners. We found that pursuing a certain category of motives is not related with any specific type of cooperation partner. For example, 61.0% of firms with cost-oriented motives were engaged in cooperative projects with vertical partners (suppliers, clients, etc.), 61.5% with horizontal partners (competitors) and 66.3% with universities and research institutions. The respective figures for firms pursuing knowledge-oriented motives were 79.2%, 77.9% and 84.3%. Thus, the realization of a certain cooperation motive appears to be independent of the partner category involved in a cooperation agreement. For example, a cost reduction goal can be realized with a supplier, a customer or even a university depending, among other things, on the nature of the technology involved.

7 Model specification and construction of variables

7.1 Innovation equations

As dependent variable we used the natural logarithm of the sales shares of innovative products (new products and considerably modified products; variable LINNS). The specification of the innovation variable followed the resource-based approach of innovation, thus containing variables for R&D (natural logarithm of R&D expenditure divided by sales; LRDS) and human capital input (natural logarithm of the share of employees with tertiary-level education; LHC). The effect of R&D cooperation on innovation performance was taken into consideration by inserting separately the dichotomous variables for cooperation motives.[5] Further, the innovation equation included the two competition measures (IPC; INPC) and controls for foreign forms, firm size, industry affiliation and survey year. (See Table 2 for the definition of the model variables.)

Based on standard empirical evidence from earlier studies, we expected positive effects of the human capital variable (LHC), the R&D intensity (LRDS), the intensity of non-price competition (INPC) and—to a lesser extent—the intensity of price competition (IPC), and firm size (see Arvanitis 2008). The effect of the variable FOREIGN was not a priori clear.

The original five-level ordinate variables (1: not important"; 5: 'very important") were transformed to binary variables (value 1: levels 4 and 5 of the original five-level variable; value 0 for the levels 1, 2 and 3 of the original variable).[6] According to hypothesis 1, we would expect that, in general, all motives would contribute to high innovation performance but not to the same extent. Moreover, we would expect that, particularly, the effects of motives that are more oriented towards the acquisition of new knowledge (MOT4, MOT5, and MOT6) would be significantly larger than the effects of more cost- and fund-oriented motives (MOT1, MOT2, MOT3 and MOT7) (hypothesis 1a).

A formal expression of the innovation equations is as follows:

$$\begin{aligned} LINNS_{it} &= \alpha_0 + a_1 LRDS_{it} + \alpha_2 LHC_{it} + \alpha_3 IPC_{it} + \alpha_4 INPC_{it} \\ &\quad + \alpha_5 R\&D\_COOP_{it} + \alpha_6 LEMPL_{it} + \alpha_7 FOREIGN_{it} \\ &\quad + industry\ and\ time\ controls + e_{it} \end{aligned} \tag{1}$$

[5]Due to strong multicollinearity, it was not possible to have all seven variables for cooperation motives in the same innovation equation (see Table 8 in the Appendix).

[6]As a referee suggested, the construction of binary variables may entail the possibility of information loss or ambiguity of results, depending on the choice of threshold for the construction of the variable, for example 3 or even 2 instead of 4. We estimated the productivity models (a) adding the variable R&D_COOP in order to control for cooperation activities in general and (b) using the five-level ordinal variables instead of the binary variables. In case (a), the variable R&D_COOP was statistically insignificant and the results for the motive variables were quite similar to those in Table 5. In case (b), the ordinal variables showed qualitatively the same effects as in Table 5. We conclude that the use of binary variables did not cause any discernible distortions.

Table 2 Definition of model variables

Variables	Definition
Dependent variables	
LQL	Natural logarithm of value added per employee
LINNS	Natural logarithm of the sales share of innovative products (sum of the sales shares of new products and considerably modified products)
Independent variables	
LCL	Natural logarithm of capital income per employee (capital income = value added minus labour costs)
LRDS	Natural logarithm of R&D expenditure divided by sales
LRDL	Natural logarithm of R&D expenditures per employee
LHC	Natural logarithm of employment share of employees with tertiary-level education in per cent;
IPC	Intensity of price competition(1)
INPC	Intensity of non-price competition(1)
FOREIGN	Foreign firm yes/no (dummy variable)
LEMPL	Natural logarithm of the number of employees (in full-time equivalents)
R&D_COOP	R&D cooperation yes/no (dummy variable)
Motives of cooperation(1)	
MOT1	Reduction of technological risks
MOT2	Saving of R&D costs
MOT3	Shortening of the duration of the development stage
MOT4	Access to specialized technology
MOT5	Utilization of technological synergies
MOT6	Acquisition of knowledge for especially complex technologies
MOT7	Utilization of public promotion grants
Instruments(1)	
OBS_R&D	Obstacle of innovation: lack of R&D personnel
OBS_ENV	Obstacle of innovation: environmental regulation
OBS_ACCEPT	Obstacle of innovation: lack of technology acceptance
OBS_PROM	Obstacle of innovation: lack of public promotion of innovation
KPATSCIENCE	Patent disclosures and universities as an external source of information
KSUP	Suppliers as an external source of information
KCUST	Users and clients as an external source of information
COPY	Easiness to copy innovations

(1): Transformations of originally five-level ordinate variables (1: ‘not important’; 5: ‘very important’) to a binary variable (value 1: levels 4 and 5 of the original five-level variable; value 0 for the levels 1, 2 and 3 of the original variable

$$\begin{aligned} LINNS_{ijt} &= \beta_{0i} + \beta_{1j} LRDS_{ijt} + \beta_{2j} LHC_{ijt} + \beta_{3j} IPC_{ijt} + \beta_{4j} INPC_{ijt} \\ &\quad + \beta_{5j} MOT_{ijt} + \beta_{6j} LEMPL_{ijt} + \beta_{7j} FOREIGN_{ijt} \\ &\quad + industry\ and\ time\ controls + e_{ijt} \end{aligned} \tag{2}$$

[firm i; j: 1,…,7 (cooperation motives); t: 1999; 2002; 2005].

7.2 Productivity equations

As independent variable, we used the natural logarithm of value added per employee (variable LQL). The productivity equation contained measures for physical capital (natural logarithm of capital income per employee; LCL), human capital (LHQUAL) and R&D (natural logarithm of R&D expenditures per employee; LRDL), as well as controls for foreign firms, firm size, industry affiliation and survey year. (See Table 2 for the definition of the model variables.) The effect of R&D cooperation on innovation performance was taken into consideration by inserting separately the dichotomous variables for cooperation motives.[7]

We expected positive values for the variables for physical capital, human capital and R&D expenditure per employee (see also Arvanitis 2008). According to hypothesis 2, we would expect throughout positive effects for all cooperation motives, particularly for more cost- and fund-oriented motives (MOT1, MOT2 MOT3, and MOT 7) (hypothesis 2a). We would further expect that the effect on productivity is stronger when the reduction of technological risks is an important cooperation motive (hypothesis 2b in accordance to Sarkar et al. 2001).

A formal expression of the innovation equations is as follows:

$$\begin{aligned} LQL_{it} = \gamma_0 + \gamma_1 LRDL_{it} + \gamma_2 LHC_{it} + \gamma_3 LCL_{it} + \gamma_4 IPC_{it} \\ + \gamma_5 INPC_{it} + \gamma_6 R\&D\_COOP_{it} + \gamma_7 FOREIGN_{it} + \gamma_8 LEMPL_{it} \\ + \textit{industry and time controls} + e_{it} \end{aligned} \quad (3)$$

$$\begin{aligned} LQL_{ijt} = \delta_{0j} + \eta_{1j} LRDL_{ijt} + \delta_{2j} LHC_{ijt} + \delta_{3j} LCL_{ijt} + \delta_{4j} IPC_{ijt} \\ + \delta_{5j} INPC_{ijt} + \delta_{6j} MOT_{ijt} + \delta_{7j} FOREIGN_{ijt} + \delta_{8j} LEMPL_{ijt} \\ + \textit{industry and time controls} + e_{ijt} \end{aligned} \quad (4)$$

[firm i; j: 1,. . . ,7 (cooperation motives); t: 1999; 2002; 2005].

8 Empirical results

8.1 Methodological remarks

8.1.1 Sample selection bias

The variables for the cooperation motives are measured only for the cooperating firms. This might give rise to a sample selection problem for the estimation

[7] Belderbos et al. (2004b) recommended controlling for external knowledge sources and R&D expenditures in the productivity equation. We refrained here from taking the external source variables into consideration because of strong multicollinearity between some of these variables and the motive variables.

of the cooperation motive equations that cannot be econometrically solved in a panel data setting as easily as is usually done in a cross-section setting by applying the methodology proposed by Heckman (1979). Moreover, there is a problem of interdependence of the motive variables due to the fact that most of the firms reported more than one option on the questions of motives (see also Section 6) that renders more difficult a Heckman-type solution as is implemented in most statistical packages. As an alternative, in a first step, we set all non-cooperating firms to zero for all motive variables.[8] Thus, the zero value of the motive variables refers not only to cooperating firms but also to non-cooperating firms. This has to be taken into account when the results are interpreted. A possible objection to the chosen approach could be that the differences among cooperating firms with different motives – the specific topic of this study – would be dominated by the differences between cooperating and non-cooperating firms. The comparison of the results in Table 3 for the dichotomous variable R&D_COOP and Tables 4 and 5 for the single motives show that this not the case.

8.1.2 Endogeneity of the cooperation motive variables

A further econometric issue refers to the possibility of endogeneity of the motive variables when used as right-hand variables in the innovation and the productivity equation respectively.

We tested endogeneity by applying the procedure by Rivers and Vuong (1988) separately for each cooperation motive variable. The coefficients of the residuals (predicted instrumented variables minus original variable) in the innovation equations were statistically significant at the10% test level for all seven motive variables as well as for the overall cooperation variable. (See Table 9 in the Appendix; the instruments used are also listed in column 2; the definition of the instruments is found in the lower part of Table 2.) Therefore, there is significant evidence for endogeneity in the innovation equation. As a consequence, Table 3, column 1 and Table 4 show only the estimates of the innovation equation based on the predicted instrumented variables for the overall cooperation variable and the seven cooperation motives, respectively. For the estimation of the innovation equations, we applied a Tobit random effect estimator. Bootstrapping was used in order to estimate the standard errors of the estimated parameters.

A similar procedure was used to test endogeneity in the productivity equations. Table 9 in the Appendix shows the used instruments as well as the results of the respective tests. In this case, we could not find any evidence for endogeneity, with the exception of the overall cooperation variable. Thus, Table 3, column 2 shows the estimates based on the predicted instrumented

[8]See Belderbos et al. (2004a), Capron and Cincera (2004) and Schmidt (2007) for a similar approach. See also the discussion on this issue in Mohnen and Hoareau (2003) and Schmidt (2007).

Table 3 R&D cooperation: relationship to innovation and productivity

Explanatory variables	LINNS	LQL
	RE TOBIT	RE OLS
LRDS	0.062***	
	(0.019)	
LRDL		0.005
		(0.003)
LHC	0.103***	0.017**
	(0.040)	(0.008)
LCL		0.375***
		(0.014)
IPC	−0.058	0.008
	(0.062)	(0.013)
INPC	0.179***	−0.002
	(0.055)	(0.010)
FOREIGN	−0.005	0.035***
	(0.073)	(0.013)
R&D_COOP	0.200*	0.068**
	(0.117)	(0.028)
LEMPL	−0.028	0.005
	(0.024)	(0.006)
Const.	2.258***	7.721***
	(0.295)	(0.178)
N	2738	2686
Left-censored	204	
Wald Chi2	583.8***	5348.1***
R-sq. within		0.664
R-sq. between		0.776
R-sq. overall		0.766
Rho	0.242***	0.452

Controls: 27 2-digit industry dummies (reference industry: food, beverage, tobacco) and 2 year dummies. ***, **, * denote statistical significance at the 1%, 5% and 10% test level, respectively

variable for R&D_COOP, while Table 5 contains the OLS random effect estimates for the 7 original cooperation motive variables.[9]

8.2 Innovation equations

The estimates for the variables LRDS, LHC, IPC and INPC (dependent variable: LINNS) in the innovation equations in Table 3, column 1 and Table 4 show similar effects as in earlier studies (see, e.g., Arvanitis 2008). We obtained positive coefficients for the tree types of factor endowment LRDS, LHQC and LCL as well as for the intensity of non-price competition (INPC).

We focus here on the findings referring to the overall cooperation variable and the seven cooperation motives. After taking into account the endogeneity of the variable R&D_COOP, we found a positive effect of the overall cooperation propensity on the share of innovative products (column 2 in Table 3). This is a first important result that appears to justify the theoretical expectations (see hypothesis 1 in Section 2) as well as the positive expectations of most

[9]We refrain here from estimating first-difference equations for innovation and productivity as well as using lags for right-hand variables because our panel is strongly unbalanced. For the same reason, we do not investigate persistence of cooperation as in Belderbos et al. (2004b).

Table 4 Innovation and cooperation motives; random effects Tobit estimates with instrument variables for the cooperation motive variables

Explanatory variables	LINNS	LINNS	LINNS	LINNS	LINNS	LINNS	LINNS
LRDS	0.061***	0.061**	0.061***	0.061***	0.061***	0.061**	0.061***
	(0.018)	(0.017)	(0.016)	(0.016)	(0.016)	(0.017)	(0.017)
LHC	0.101***	0.103***	0.107***	0.108***	0.096***	0.109***	0.089**
	(0.034)	(0.033)	(0.042)	(0.037)	(0.034)	(0.039)	(0.041)
IPC	−0.080	−0.146**	−0.055	−0.035	−0.056	−0.046	−0.048
	(0.077)	(0.071)	(0.060)	(0.070)	(0.064)	(0.069)	(0.065)
INPC	0.173***	0.196***	0.155***	0.161***	0.152***	0.165***	0.165***
	(0.045)	(0.056)	(0.047)	(0.055)	(0.051)	(0.050)	(0.053)
FOREIGN	−0.017	−0.020	−0.019	−0.016	−0.018	−0.016	0.001
	(0.068)	(0.084)	(0.077)	(0.069)	(0.068)	(0.073)	(0.078)
MOT1	0.262***						
	(0.090)						
MOT2		0.318***					
		(0.104)					
MOT3			0.240***				
			(0.092)				
MOT4				0.216**			
				(0.092)			
MOT5					0.264***		
					(0.094)		
MOT6						0.233**	
						(0.104)	
MOT7							0.229***
							(0.107)

Table 4 (continued)

Explanatory variables	LINNS	LINNS	LINNS	LINNS	LINNS	LINNS	LINNS
LEMPL	−0.035	−0.021	−0.041	−0.031	−0.026	−0.021	−0.017
	(0.020)	(0.018)	(0.025)	(0.019)	(0.016)	(0.022)	(0.017)
Const.	2.771***	2.683***	2.521***	2.352***	2.469***	2.416***	2.657***
	(0.388)	(0.352)	(0.350)	(0.286)	(0.270)	(0.340)	(0.403)
N	2738	2738	2738	2738	2738	2738	2738
Left-censored	204	204	204	204	204	204	204
Wald Chi2	724.8***	572.9***	691.0***	735.2***	684.0***	799.0***	920.8***
Rho	0.242***	0.241***	0.240***	0.241***	0.241***	0.241***	0.241***

See Table 9 for the endogeneity tests and the instruments used. Controls: 27 industry dummies (reference industry: food, beverage, tobacco) and 2 year dummies. ***, **, * denote statistical significance at the 1%, 5% and 10% test level, respectively. Rho: share of variance that can be traced back to heterogeneity. Standard errors were estimated by bootstrapping

Table 5 Labour productivity and cooperation motives; random effects OLS estimates

Explanatory variables	LQL	LQL	LQL	LQL	LQL	LQL	LQL
LRDL	0.007**	0.006**	0.006**	0.006**	0.006**	0.007**	0.007**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
LHC	0.026***	0.026***	0.026***	0.025***	0.026***	0.026***	0.027***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
LCL	0.378***	0.378***	0.378***	0.378***	0.378***	0.378***	0.378***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
IPC	0.015	0.014	0.015	0.016*	0.015	0.015	0.015
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
INPC	0.001	0.001	−0.000	0.000	0.000	0.001	0.001
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
FOREIGN	0.043***	0.043***	0.042***	0.043***	0.043***	0.043***	0.043***
	(0.013)	(0.012)	(0.012)	(0.012)	(0.013)	(0.013)	(0.013)
MOT1	0.016						
	(0.016)						
MOT2		0.026*					
		(0.014)					
MOT3			0.037***				
			(0.011)				
MOT4				0.034***			
				(0.010)			
MOT5					0.014		
					(0.010)		
MOT6						0.008	
						(0.012)	
MOT7							0.012
							(0.022)

Table 5 (continued)

Explanatory variables	LQL	LQL	LQL	LQL	LQL	LQL	LQL
LEMPL	0.018***	0.017***	0.017***	0.016***	0.017***	0.018**	0.018***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Const.	7.530***	7.531***	7.542***	7.542***	7.532***	7.530***	7.529***
	(0.061)	(0.061)	(0.061)	(0.061)	(0.061)	(0.061)	(0.061)
N	2686	2686	2686	2686	2686	2686	2686
Wald Chi2	7861.2***	7873.0***	7892.9***	7895.5***	7864.0***	7859.2**	7858.6***
R-sq. within	0.659	0.659	0.662	0.662	0.660	0.659	0.659
R-sq. between	0.776	0.777	0.776	0.777	0.776	0.776	0.776
R-sq. overall	0.766	0.766	0.766	0.766	0.766	0.766	0.766
Rho	0.443	0.442	0.445	0.445	0.443	0.443	0.443

Control variables: 27 industry dummies (reference industry: food, beverage, tobacco) and 2 year dummies. ***, **, * denote statistical significance at the 1%, 5% and 10% test level, respectively. Rho: share of variance that can be traced back to heterogeneity policy makers, e.g., in the European Union, favouring R&D cooperation based on the argument that cooperation enhances innovation performance. Also the results in Table 4 for MOT7 (utilization of public promotion grants) seem at first glance to confirm policy expectations with respect to the effectiveness of the promotion of cooperation in R&D. But a second look shows that it is not clear what improves innovation performance: the public grant or the cooperation (which is a condition for the grant). At any rate, policy measures that make cooperation easier (for example, information platforms aiming at bringing together potential partners) could enhance innovativeness, even if they were not associated with R&D subsidies.

We obtained significantly positive effects for all seven motive categories. But there are differences as to the relative magnitude of these positive effects.[10] MOT2 (saving of R&D costs), a primarily financial motive, appears to have the strongest impact on innovation performance. Reduction of technological risks (MOT1) and the utilization of technological complementarities (MOT5) seems also to enhance also innovation performance, less than MOT2 but more than the other four remaining motives. On the whole, no tendency for technological motives to be more effective than cost-oriented motives with respect to innovation performance is discernible, contrary to hypothesis 1a.

The relatively stronger innovation effects of the three motives MOT1, MOT2 and MOT5 are in (partial) accordance with Ahuja (2000). This author's theoretical expectation has been that knowledge sharing, knowledge complementarity and knowledge scaling would be the cooperation motives positively correlated with a high innovation performance of the cooperating firm (see Section 2.1.3). MOT1 and MOT2 could be considered as proxies for knowledge scaling, MOT5 as proxy for knowledge complementarity. MOT4 and MOT6 could be seen in this approach as proxies for knowledge sharing. Thus, the relevance for innovation of knowledge sharing as a third important driver of cooperation does not seem to be supported by our results. Nevertheless, the theoretical expectations for the first two motives have been—broadly speaking—confirmed by our results.

In sum, a second important result is that saving of R&D costs, reduction of technological risks as well as utilization of technological complementarities appear to be the motives that drive most strongly innovation performance. Saving costs is a standard economic motive, reduction of technological risks and utilization of complementarities are standard internalization motives in the sense of the transaction cost approach. Under the sensible assumption that the risk motive implies risks due to insufficient protection of proprietary knowledge that leaks out to competitors, this variable would cover also the main motive identified by the IO approach.[11]

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[10] All motive variables are binary variables, i.e. they are identically scaled, so that, for the discussion of *relative* magnitude, it does not make a difference if we consider coefficients or marginal effects.

[11] Unfortunately, our data do not provide us with some additional information in this direction.

8.3 Productivity equations

The productivity estimates in Table 3, column 2 and Table 5 show the expected signs for the factor endowment variables LRDL, LHC and LCL (see Arvanitis 2008). Here we focus on the results for the cooperation motive variables.

We found a significantly positive effect for the overall cooperation variable as well as for three different motives: MOT2 (sharing of R&D costs); MOT2 (shortening of product development time); and MOT4 (access to specialized technology). Hypothesis 2 is confirmed: only three out of seven motives show positive and statistically significant coefficients.

Hypothesis 2a receives only partly confirmation: we obtain positive significant coefficients for only two out of four cost-oriented motives (MOT2 and MOT3) but just for one out of three knowledge-oriented motives (MOT4). No evidence could be found in favour of hypothesis 2b (in accordance to Sarkar et al. 2001): the coefficient of the variable MOT1 (reduction of technological risks) is positive but statistically insignificant.

The *direct* effects on productivity come from cost saving and the shortening of the time needed to develop new products, essentially a further cost-saving motive, and the utilization of technological complementarities. We know already that the four other motives do not show a direct productivity effect, but have a positive impact on innovation performance. As a consequence, we can assume that there are also *indirect* effects of these four motives on productivity that are channelled through innovation that itself enhances productivity (positive effect of the variable for R&D expenditure per employee (LRDL) in Table 5).

9 Summary and conclusions

Concerning the impact of R&D cooperation (a) on innovativeness and (b) labour productivity, the most important results are as follows. Not only R&D cooperation in general but also cooperation driven by each of the seven motives considered in this paper correlate positively with the sales share of innovative products (*hypothesis 1*). *Hypothesis 1a* (R&D cooperation driven by primarily technology-oriented motives would be more innovative than those that are more cost-oriented) is not confirmed. Obviously differences as to the pursued motives do not affect significantly innovativeness.[12] With respect to innovativeness, the characterization of cooperation by the driving motive did not add much more insight that could be gained through the overall variable ‘R&D cooperation yes/no’.

Finally, we found a positive impact of cooperation in general as well as for collaborations pursuing three motives, two of them financial, but not for the

[12] However, one has to take into account that the variables for the motives correlate strongly with each other reflecting the fact that firms pursue more than one motive at the same time.

other four motives (partial confirmation of *hypothesis 2*). *Hypothesis 2a* (R&D cooperation driven by cost-oriented motives would be productive than those that are rather technology-oriented) is only partially confirmed. Technology-motivated collaborative activities show a weaker tendency to positive direct effects on productivity than cost-motivated cooperation. In this case, the distinction of several cooperation motives yields some additional insights as compared to the overall cooperation variable. Also *hypothesis 2b* (strong effect of the motive “reduction of technological risks”) is not confirmed.

A first implication for technology policy would be that policy goals that are more oriented towards innovation performance could be reached independent of the type of motivation of cooperating firms. On the contrary, if policy goals are more strongly oriented towards direct effects on economic performance, then policy effectiveness depends strongly on firms being driven rather by cost-sharing than technology-acquiring motives. One of the motives considered in this study referred to the utilization of public grants for the promotion of R&D cooperation. Due to the fact that Swiss technology policy is based primarily on the promotion of R&D co-operation between private enterprises and universities, we can conclude that this specific type of promotion of cooperation should have been more effective in terms of innovativeness than in terms of economic performance as measured by labour productivity.

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Appendix

Table 6, 7, 8 and 9.

Table 6 Composition of sample by industry; firm size class; year

	Number of firms with R&D activities	Firms with R&D cooperation (%)
Industry:		
Food, beverage, tobacco	181	26.0
Textiles	71	42.3
Clothing, leather	20	40.0
Wood processing	60	33.3
Paper	47	19.2
Printing	70	28.6
Chemicals	195	48.7
Plastics, rubber	99	27.3
Glass, stone, clay	65	30.8
Metal	38	36.8
Metal working	218	28.9
Machinery	448	36.8
Electrical machinery	124	38.7
Electronics, instruments	276	43.1

Table 6 (continued)

	Number of firms with R&D activities	Firms with R&D cooperation (%)
Industry:		
Vehicles	33	39.4
Watches	78	25.6
Other manufacturing	78	24.4
Energy, water	26	46.2
Construction	114	26.3
Wholesale trade	123	26.8
Retail trade	52	17.3
Hotels, catering	43	14.0
Transport, telecommunication	80	27.5
Banks, insurance	128	43.8
Real estate, leasing	6	16.7
Computer services	83	34.9
Business services	159	39.0
Personal services	8	0.0
Firm size:		
5–19 employees	473	31.1
20–49 employees	584	24.3
50–99 employees	535	27.9
100–199 employees	551	37.4
200–499 employees	491	41.8
500–999 employees	159	47.2
1000 employees and more	130	56.2
Year:		
1999	879	38.7
2002	1070	27.4
2005	974	37.4
Total	2922	34.1

Table 7 Descriptive statistics

Variable	N	Mean	Std. dev.
MOT1	2922	0.061	0.240
MOT2	2922	0.093	0.290
MOT3	2922	0.150	0.357
MOT4	2922	0.198	0.398
MOT5	2922	0.208	0.406
MOT6	2922	0.136	0.343
MOT7	2922	0.035	0.183
R&D_COOP	2922	0.341	0.474
LINNS	2940	3.030	1.192
LQL	2901	11.898	0.449
IPC	2940	0.729	0.444
INPC	2940	0.437	0.496
FOREIGN	2907	0.166	0.372
LEMPL	2940	4.417	1.469
LRDS	2940	6.761	2.175
LRDL	2940	7.694	2.333
LHC	2940	2.689	1.012
LCL	2735	10.941	0.900

Table 8 Correlations

	MOT1	MOT2	MOT3	MOT4	MOT5	MOT6	MOT7	R&D_ COOP	LINNS	LQL	IPC	INPC	FORE IGN	LEMPL L	LRDS	LRDL	LHC
MOT1	1.000																
MOT2	0.370	1.000															
MOT3	0.399	0.387	1.000														
MOT4	0.345	0.301	0.604	1.000													
MOT5	0.285	0.394	0.535	0.678	1.000												
MOT6	0.324	0.297	0.462	0.586	0.545	1.000											
MOT7	0.194	0.280	0.167	0.276	0.268	0.304	1.000										
R&D_COOP	0.361	0.443	0.594	0.703	0.721	0.558	0.266	1.000									
LINNS	0.068	0.017	0.065	0.049	0.064	0.057	0.051	0.056	1.000								
LQL	0.045	0.075	0.108	0.107	0.083	0.068	0.020	0.102	−0.032	1.000							
IPC	0.039	0.061	0.029	0.003	0.022	0.012	0.000	0.097	−0.027	−0.011	1.000						
INPC	0.033	0.012	0.077	0.061	0.066	0.047	0.037	0.049	0.125	0.054	−0.051	1.000					
FOREIGN	0.034	0.022	0.057	0.037	0.030	0.042	0.007	0.037	0.062	0.156	0.020	0.065	1000				
LEMPL	0.110	0.079	0.158	0.150	0.119	0.118	0.059	0.157	−0.020	0.123	0.115	0.077	0.099	1000			
LRDS	0.086	0.051	0.124	0.127	0.115	0.099	0.069	0.115	0.246	−0.032	−0.024	0.068	0.048	−0.046	1000		
LRDL	0.097	0.066	0.152	0.150	0.131	0.117	0.074	0,137	0.224	0.120	−0.002	0.079	0.092	0.015	0.963	1000	
LHC	0.114	0.086	0.133	0.163	0.145	0.127	0.100	0.177	0.141	0.201	−0.023	0.050	0.129	0.038	0.218	0.243	1000
LCL	0.016	0.038	0.065	0.063	0.051	0.044	−0.002	0.055	−0.018	0.844	−0.033	0.046	0.118	0.062	−0.055	0.067	0.078

Table 9 Results of endogeneity tests (Rivers and Vuong 1988)

Predicted variable	LINNS		LQL	
	Coeff.	Instrument(s)	Coeff.	Instrument(s)
MOT1	signif.	COPY; KPATSCIENCE	insignif.	COPY; KCUST
MOT2	signif.	COPY; IPC; KPATSCIENCE	insignif.	COPY; IPC
MOT3	signif.	KSUP; KPATSCIENCE	insignif.	OBS_R&D; OBS_ENV
MOT4	signif.	KSUP; PATSCIENCE	insignif.	OBS_R&D; OBS_ENV; OBS_ACCEPT; OBS_PROM
MOT5	signif.	COPY; PATSCIENCE	insignif.	OBS_ACCEPT; OBS_PROM
MOT6	signif.	KPATSCIENCE	insignif.	OBS_R&D; OBS_ENV
MOT7	signif.	KPATSCIENCE	insignif.	OBS_R&D; OBS_PROM
R&D_COOP	signif.	KPATSCIENCE	signif.	KCUST

'Coeff.': coefficients of the residuals [predicted (instrumented) variables minus original variables] in the innovation equation and the productivity equation resp; 'Instrument': instruments used; signif./nn insignif.: test level 10%

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