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

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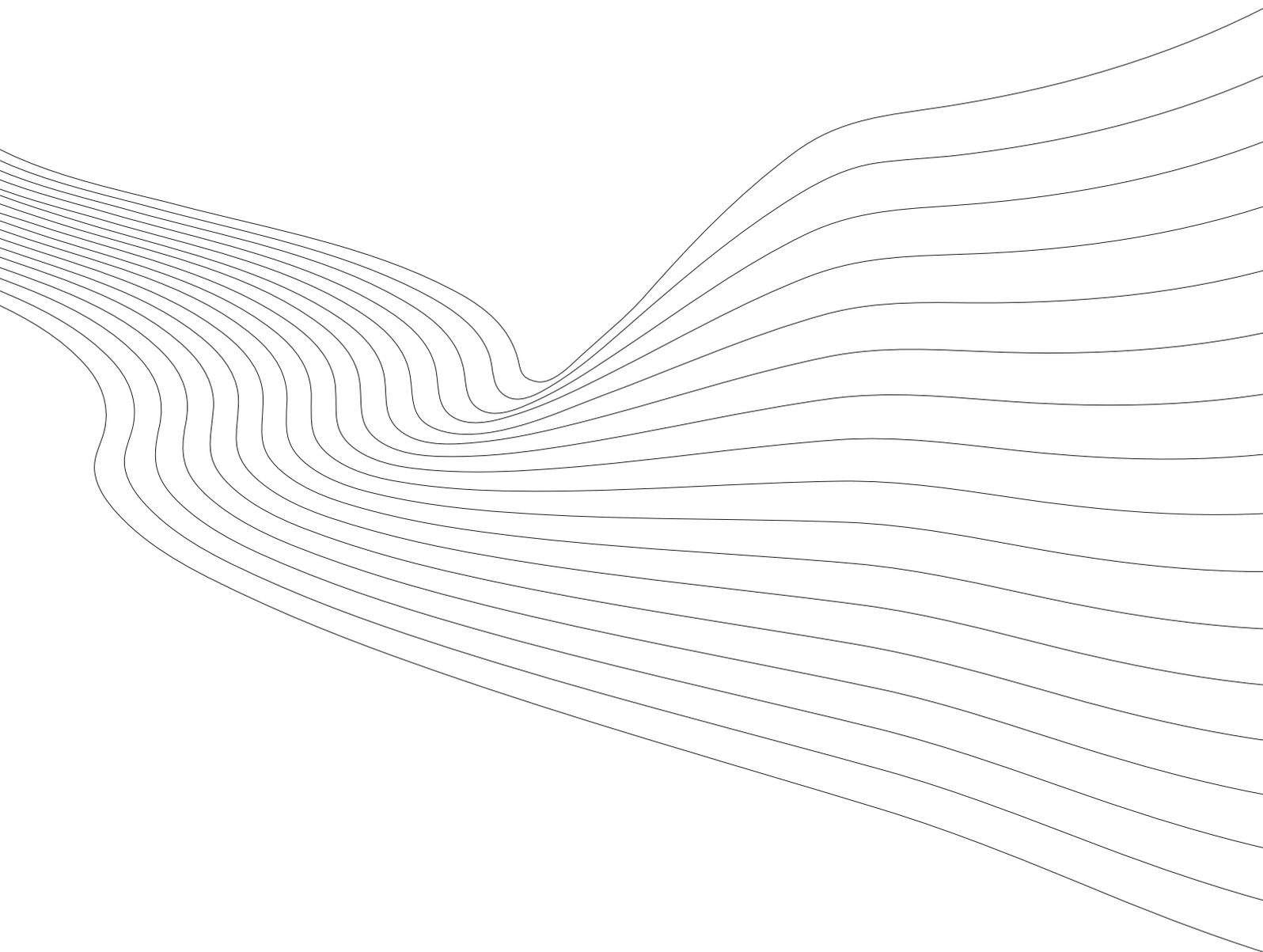
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# KOF Working Papers

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# **How Do Different Motives for R&D Cooperation Affect Firm Performance? – An Analysis Based on Swiss Micro Data\***

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## **Abstract**

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 (a) to the factors influencing the likelihood of R&D cooperation as postulated by theory; and (b) to the impact of R&D cooperation on firm innovativeness and firm productivity. On the whole, distinguishing various cooperation motives appears to be fruitful because it allows more differentiated insights with respect to the importance of factors determining cooperation that would remain hidden behind the overall variable “R&D cooperation yes/no”. 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 insights that it 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.

## 1. Introduction

This paper is mainly motivated by observation of the necessity of the acquisition of new knowledge as a precondition for successful innovative activities of enterprises. New knowledge is generated not only inside the boundaries of a firm but also 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 understanding how firms integrate internal knowledge and various types of externally acquired knowledge. In the last years there is an increasing interest in economic literature to analyze the motives and determinants of alternative knowledge acquisition strategies (own R&D, R&D co-operation, contract-R&D, etc.)<sup>1</sup>. 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. 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.<sup>2</sup> 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 (a) to the factors influencing the likelihood of R&D cooperation as postulated by theory; and (b) 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 in 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 based on theoretical literature a model of the determining factors of the propensity to cooperate in R&D comprising primarily variables measuring knowledge absorptive capacity, incoming spillovers and appropriability as well the intensity of competitive pressures. The seven motive dichotomous variables were the variables to be

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<sup>1</sup> See, e.g., Cassiman and Veugelers 2006; Belderbos et al. 2006.

<sup>2</sup> See, e.g., Hagedoorn (1993); Hagedoorn et al. (2000). Strictly, we cannot distinguish between firm 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.

explained by this model.<sup>3</sup> These seven cooperation equations were estimated by multivariate probit techniques in order to take into account the interdependence of the dependent variables due to the fact that firms are driven by more than one motive at the time. In a third 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 a cooperation equation and 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 it 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. Section 4 is committed to then presentation of the data used in the study. Section 5 contains a short discussion of the seven different R&D cooperation motives investigated in this study. The specification of the empirical model to be estimated is presented in section 6. In section 7 the results of the econometric estimations are discussed. Finally, section 8 contains a summary of the most important results and some conclusions.

## **2. Theoretical Background**

Our conceptual approach builds on two different strands of literature that offer theoretical explanations for R&D cooperation. The first one is industrial organization (IO) literature, the second one management literature (see Caloghirou et al. 2003 for a literature survey).

### **2.1 Industrial Organization concepts related to knowledge acquisition**

An important strand of IO literature is concerned with endogenous *absorptive capacity* (Cohen and Levinthal 1989, 1990). On a theoretical ground we know that the absorptive capacity (Cohen and Levinthal (1989, 1990) of a firm is an important precondition to successfully capitalize on externally generated knowledge, i.e. generated by competitors,

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<sup>3</sup> To our knowledge the only other study that investigates motives of innovation R&D cooperation in a similar setting using motive variables as left-hand variables in a cooperation equation is the paper of Schmidt 2007 that is based on Canadian firm data. However, there are more studies using 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; Woerter 2007; Lopez 2008; Arvanitis and Bolli 2009).

suppliers, customers, and/or public research institutions and universities. Firms with well-educated staff and permanent research activities are supposed to have higher absorptive capacity than firms lacking such characteristics. The exploitation of externally acquired knowledge depends crucially on a firm's absorptive capacity.

The concept of *incoming spillovers* (see Cassiman and Veugelers 2002) is strongly related to the absorptive capacity of a firm. It indicates the "amount" of beneficial external knowledge flows for the firm. *Outgoing spillovers* measure the amount of a firm's knowledge that seeps out of the firm and can be utilized by other firms. While incoming spillovers may motivate a firm to seek R&D cooperation, outgoing spillovers exert the opposite influence, i.e. they hinder innovative activities because of the risk of internal knowledge leaking out to competitors. The negative effects of outgoing spillovers can be attenuated through several formal (e.g., patents) and informal (e.g., secrecy, lead time over competitors) *appropriability mechanisms*. In a strategic way firms seek to limit outgoing spillovers through secrecy measures or greater complexity of developed products or lead time over competitors. Furthermore firms try to internalise outgoing spillovers by ensuring property rights (e.g., patents). When the usual protection methods are not effective or not available, it is possible – this could be a further line of argumentation – that low appropriability of innovation returns may increase the incentives for R&D cooperation as a means of internalizing information flows among firms, under the condition that this cooperation is based on a contract that explicitly settles not only property rights but also all kinds of information exchange among partners.

There is an inherent relationship between these three concepts: absorptive capacity is necessary for a firm in order to be able to exploit available external knowledge, i.e. to ensure knowledge flows to the firm (incoming spillovers: either through "buy" or cooperation or other channels) but also is interested in protecting its own knowledge base from being exploited by other firms or institutions without paying for it, thus trying to keep outgoing spillovers under its control, for example, through various protection mechanisms.

Cassiman et al. (2002) developed a theoretical model that links knowledge flows to and from a firm's innovation process with the firm's investment decisions with respect to innovation. The model contains a technologically leading firm and a competitive fringe. The leading firm considers three types of investment: investments in applied research, investments in basic research and investments in intellectual property protection. By conducting basic research the leading firm can effectively access incoming knowledge flows (incoming spillovers). These incoming spillovers serve to increase the efficiency of own applied research. The leading firm can at the same time try to keep outgoing spillovers low by investing in protection, thus improving its appropriability of innovation returns. In the long run a leading firm will invest in basic research, which is a precondition for improving its absorptive capacity, when market opportunities are high, legal protection is important and the pool of accessible and relevant

external know-how is not limited, given a minimum size of the firm's budget for such investments.

## **2.2 Industrial Organization approach to 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 since some years. Economic research in the field of R&D cooperation essentially aims at understanding why firms are undertaking R&D cooperation, how they do it, and with what result (see Kaiser 2002 and De Bondt 1996 for reviews of this literature).

One of the most influential theoretical paper 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.

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.

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 of this paper is that research joint ventures are more likely to occur the more "general" (in contrast to "specific") the R&D agenda is.

## **2.3 Management literature approach to motives of R&D cooperation**

The second strand of literature we take into consideration, namely management literature, provides further helpful insights with respect to different motives of R&D cooperation. Following Caloghirou 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 is emphasizing resources and capabilities building on the resource-based view of the firm originally developed by Penrose (1959) and is 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 is focussing on the role of uncertainty for 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., Kohut 1988; Dodgson 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 to the insights from management literature for identifying the most important cooperation motives in the empirical part of this study.

## **2.4 Resulting hypotheses**

The above discussion of theoretical literature leads to the formulation of the following hypotheses for the empirical part of the study:

*Hypothesis 1:* The propensity to cooperate in R&D correlates *positively* with a firm's knowledge absorptive capacity;

*Hypothesis 2:* The propensity to cooperate in R&D correlates *positively* with the extent of incoming spillovers and *negatively* with the extent of outgoing spillovers.

## **2.5 Impact of R&D cooperation on economic performance**

The theoretical literature has already addressed the important question about the relation of R&D cooperation and economic performance. 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 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.<sup>4</sup>

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).

Based on the results of theoretical literature we formulate the following hypotheses for the empirical part of the study:

*Hypothesis 3:* Cooperative R&D enhances innovation performance (through new or improved products or faster introduction of such new or improved products);

*Hypothesis 4:* Cooperative R&D enhances firm productivity (through the reduction of innovation costs and/or the utilization of economies of scale, scope, or learning).

### **3. Review of selected relevant empirical literature**

#### **3.1 Determinants of R&D cooperation**

We restrain our literature survey to recent studies focusing primarily on the effects of incoming spillovers and appropriability mechanisms on the propensity to cooperate in R&D in studies based on CIS-similar data.

Cassiman and Veugelers (2002) investigate the effects of incoming spillovers and appropriability mechanisms on the probability to cooperate in R&D with suppliers/customers and public research institutions respectively. Based on an empirical analysis of 411 Belgium manufacturing firms it was found that it is very important to distinguish between incoming spillovers and appropriability as determinants for different types of R&D cooperations. Firms with higher incoming spillovers and better appropriation of knowledge have in general a higher probability of cooperating in R&D. Higher incoming spillovers positively affect the probability to cooperate with public research institutions, but have no effect on cooperation with customers or suppliers. Better appropriability of results of the innovation process, however, increases the probability of co-operating with customers or suppliers and is unrelated to cooperative agreements with research institutes. The results of this study demonstrate the relevance of distinguishing between incoming spillovers and appropriability.

Belderbos et al. (2004a) provide an interesting extension of the Cassiman and Veugelers (2002) results. Based on matched Dutch firm data for two cross sections (1996, 1998) the authors analyzed four different types of R&D cooperation (competitors, customers, suppliers, public research institutions) and found that there are considerable differences with respect to

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<sup>4</sup> 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.

the effects of various determinants on the various types of cooperation (heterogeneity of R&D cooperation strategies). Different types of co-operation seem to be viewed by the firms as complements rather than substitutes.

Bönte and Keilbach (2005) focused on vertical R&D cooperation (customers and suppliers). They distinguished between formal and informal cooperation. They found only weak empirical evidence for the relevance of incoming spillovers for formal as well for informal cooperation. In contrast, a firm's ability to limit outgoing spillovers has a positive effect on a firm's propensity to engage in both formal and informal cooperations at the same time. It does not affect, however, the probability of co-operating informally alone. The authors further emphasized the importance of absorptive capacity for informal cooperations.

Dachs et al. (2004) found in a comparative study for Finland and Austria that incoming spillovers are in general an important determinant of cooperation propensity in both countries. While sector affiliation and innovation intensity are further important driving factors in Austria, appropriability and public funding activities are the main factors that promote R&D co-operations in Finland.

Schmidt (2005) using CIS3 data for Germany focused on the role of spillovers in explaining R&D cooperation of various types: co-operations with suppliers and customers as well with research institutions. He found in accordance with results for other countries a positive effect of knowledge flows reflecting incoming spillovers on the likelihood of R&D cooperation. In addition, he could show that firms with high internal R&D budgets are more likely to cooperate with universities than with suppliers and customers.

Although not assessing the relative importance of spillovers and appropriability, Tether (2002) provides us with an interesting analysis of R&D cooperation in relation with different types of innovation activities. Based on UK data the author found that R&D cooperations are more common among firms that introduce innovations new to the market and that the existence of R&D activities as well as the intensity of such activities tend to increase the likelihood that a firm has R&D cooperations with external partners.

Abramovsky et al. (2005) studied cooperative R&D activity in a comparative study for four European countries by using data from the CIS3 for France, Germany, Spain and the UK in a similar setting as this in Cassiman and Veugelers (2002). They found a positive relationship between the likelihood of cooperating in R&D and incoming spillovers as well as appropriability.

In a recent study based on Spanish firm data Lopez (2008) found that besides information flows from external sources cost-risk sharing is an important determinant of R&D cooperation.

Finally, as an exception of the rule of taking into account primarily firms using CIS-similar data we mention here the study of Röller et al., which is based on USA data for RJVs, a

specific form of R&D cooperation. The empirical results support the hypotheses that firms of different sizes have disincentives to form RJVs and that sharing of R&D costs is an important incentive for RJV participation.

### **3.2 R&D cooperation and firm performance**

We concentrate in our literature review on the impact of cooperation on innovativeness and economic performance because these topics are also on the focus of this paper. Table 1 contains a listing of the important impact studies published after 2000 (see Link and Siegel 2003, Ch. 11 for a survey of literature on this topic before 2000). This list is not exhaustive but certainly representative of the state of empirical research in this field. It contains studies for six European countries (Belgium, Finland, France, Germany, the Netherlands and Sweden) and Japan.

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). Other studies find 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) show that in France innovation performance is not affected by cooperation agreements with national partners but increased by cooperation with foreign partners. Lööf and Heshmati (2002) find positive effects of cooperation for both national and international partners.

Most of the studies that distinguish various types of cooperation partners find out 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 in our list in Table 1 the findings are differing from study to study due to the fact that the studies often use different firm cross-sections, different model specifications and different econometric methodologies. In sum, there is relative 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 to be able to make a general assessment of such effects.

## **4. 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.).<sup>5</sup> 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 and within each industry three industry-specific firm size classes with full coverage of the upper class of large firms). We used in this study only data for firms conducting R&D activities in the relevant period.<sup>6</sup> The final data set includes 2922 enterprises from all fields of activity and size classes (see table A.1 in the appendix for the structure of the used data set by industry, firm size class and year respectively).

## 5. 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 2). 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 are referring 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).

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 2 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

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<sup>5</sup> Versions of the questionnaire in German, French and Italian are available at [www.kof.ethz.ch](http://www.kof.ethz.ch).

<sup>6</sup> 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.

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.

## **6. Model specification and construction of variables**

### **6.1 Cooperation equations**

#### **6.1.1 Dependent variables**

We constructed a dichotomous variable taking the value 1 for cooperating firms and the value 0 for non-cooperating firms. We also constructed a dichotomous variable for every single motive of R&D cooperation. The value 1 of each of these variables was taken by cooperating firms that reported the value 4 or 5 on a five-point Likert scale assessing the importance of a certain cooperation motive. The value 0 was given to all other cooperating firms as well as non-cooperating firms (see section 7.1 for the justification of this construction).

#### **6.1.2 Independent variables**

We used the same vector of independent variables for all seven cooperation motive equations and the overall cooperation variable (see Table 3, column 1; Table 4).<sup>7</sup> Absorptive capacity was approximated (a) by the variable HQUAL (share of employees with tertiary-level education) and (b) by the variable TPOT (anticipated technological potential). According to hypothesis 1 we expect positive effects of these two variables. With respect to cooperation motives we further specify hypothesis 1 as follows: Technology-oriented motives of R&D cooperation (e.g., access to new specialized technology or exploitation of technological complementarities) are expected to be found more often than financial and cost-oriented motives (e.g., sharing of R&D costs or reduction of product development time) in firms with high knowledge absorptive capacity. Thus, hypothesis 1a is as follows:

*Hypothesis 1a:* Firms with primarily technology-oriented motives show a higher absorptive capacity than firms pursuing primarily financial and cost-oriented motives.

The extent of incoming spillovers was measured by variables reflecting the importance of the following external knowledge sources: users and customers (variable KCUST); suppliers (KSUP); and science-based knowledge from universities and patent disclosures (KPATSCIENCE). Also for these variables we expect positive effects according to the first part of hypothesis 2. The variable COPY (easiness of copying a firm's innovations as relevant innovation obstacle) is a proxy for the extent of outgoing spillovers. When a firm reports high hindrance of innovation activities due to the easiness of copying a firm's innovations, such a firm obviously cannot protect its innovations effectively, outgoing spillovers are strong,

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<sup>7</sup> The exact definition of all independent variables is found in the notes to Tables 3 and 4.

appropriability of innovation revenue is low. According to the second part of hypothesis 2 a negative effect is expected for this variable.

The variables IPC (intensity of price competition) and INPC (intensity of non-price competition) measure the effect of a firm's competitive environment on R&D cooperation. The effect of competitive pressures on R&D cooperation was analyzed in Katsoulacos and Ulph (1998). The theoretical expectation is that the propensity to cooperate is increasing with increasing concentration because coordination costs of partnering are decreasing. Our variables are measuring directly competitive pressure and not indirectly as in the case of market structure variables. We expect that both variables show a positive sign. Thus, we postulate hypothesis 5 as follows:

*Hypothesis 5: Competitive pressures correlate positively with cooperation propensity, particularly when the underlying cooperation motives are primarily oriented towards the acquisition of new knowledge.*

A further independent variable is the natural logarithm of the number of employees (LEMPL). We expect a positive effect of the firm size variable in accordance to standard theoretical expectations, also to empirical studies on the effect of firm size on R&D investment. Each cooperation equation includes industry dummies and time industries.

A formal expression of the cooperation equations is as follows:

$$R\&D\_COOP_{it} = \alpha_0 + \alpha_1 HQUAL_{it} + \alpha_2 COPY_{it} + \alpha_3 TPOT_{it} + \alpha_4 KCUST_{it} + \alpha_5 LSUP_{it} + \alpha_6 KPATSCIENCE_{it} + \alpha_7 IPC_{it} + \alpha_8 INPC_{it} + \alpha_9 LEMPL_{it} + \text{industry and time controls} + e_{it} \quad (1)$$

$$MOT_{ijt} = \beta_{0j} + \beta_{1j} HQUA_{ijt} + \beta_{2j} COPY_{ijt} + \beta_{3j} TPOT_{ijt} + \beta_{4j} KCUST_{ijt} + \beta_{5j} LSUP_{ijt} + \beta_{6j} KPATSCIENCE_{ijt} + \beta_{7j} IPC_{ijt} + \beta_{8j} INPC_{ijt} + \beta_{9j} LEMPL_{ijt} + \text{industry and time controls} + e_{ijt} \quad (2)$$

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

## 6.2 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) und human capital input (natural logarithm of the share of employees with tertiary-level education; LHQUAL). The effect of R&D cooperation on innovation performance was

taken into consideration by inserting separately the dichotomous variables for cooperation motives.<sup>8</sup> Further, the innovation equation included the two competition measures (IPC; INPC) and controls for foreign forms, firm size, industry affiliation and survey year.

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

According to hypothesis 3, we would expect that in general all motives would contribute to high innovation performance but not to the same extent. Further, 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 3a*).<sup>9</sup>

A formal expression of the innovation equations is as follows:

$$LINNS_{it} = \delta_0 + \delta_1 LRDS_{it} + \delta_2 LHQUAL_{it} + \delta_3 IPC_{it} + \delta_4 INPC_{it} + \delta_5 R\&D\_COOP_{it} + \delta_6 LEMPL_{it} + \delta_7 FOREIGN_{it} + \text{industry and time controls} + e_{it} \quad (3)$$

$$LINNS_{ijt} = \varepsilon_{0i} + \varepsilon_{1j} LRDS_{ijt} + \varepsilon_{2j} LHQUAL_{ijt} + \varepsilon_{3j} IPC_{ijt} + \varepsilon_{4j} INPC_{ijt} + \varepsilon_{5j} MOT_{ijt} + \varepsilon_{6j} LEMPL_{ijt} + \varepsilon_{7j} FOREIGN_{ijt} + \text{industry and time controls} + e_{ijt} \quad (4)$$

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

### 6.3 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. The effect of R&D cooperation on innovation performance was taken into consideration by inserting separately the dichotomous variables for cooperation motives.<sup>10</sup>

We expected positive effects for the variables for physical capital, human capital and R&D expenditure per employee (see also Arvanitis 2008). According to hypothesis 4 we would

<sup>8</sup> Due to strong multicollinearity it was not possible to have all seven variables for cooperation motives in the same innovation equation (see Table A.3 in the Appendix).

<sup>9</sup> For a similar hypothesis see also Belderbos et al. (2004b), p. 1480.

<sup>10</sup> 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.

expect throughout positive effects for all cooperation motives, particularly for more cost- and fund-oriented (MOT1, MOT2 MOT3, and MOT 7) (*hypothesis 4a*) (see also Belderbos et al. 2004b, p. 1480 for a similar hypothesis).

A formal expression of the innovation equations is as follows:

$$LQL_{it} = \zeta_0 + \zeta_1 LRDL_{it} + \zeta_2 LHQUAL_{it} + \zeta_3 LCL_{it} + \zeta_4 IPC_{it} + \zeta_5 INPC_{it} + \zeta_6 R\&D\_COOP_{it} + \zeta_7 FOREIGN_{it} + \zeta_8 FLEMP_{it} + \text{industry and time controls} + e_{it} \quad (5)$$

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

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

## 7. Empirical results

### 7.1 Methodological remarks

#### 7.1.1 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 of the cooperation motive equations that cannot be econometrically solved in a panel data setting as easily as it 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 3) that renders more difficult a Heckman-type solution as it 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.<sup>11</sup> 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 results in Table 3 and Table 4 referring to the dichotomous variable R&D\_COOP show that this not the case.

<sup>11</sup> 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).

### 7.1.2 Interdependence of the dependent variables

In a second step, we took into consideration the interdependence among the cooperation motive variables. To this end, we estimated a multivariate probit model, i.e. a simultaneous system of seven cooperation equations for the seven different motives, instead of seven separate probits. We applied the procedure implemented in STATA, which is based on the so-called GHK-simulator for multivariate distributions.<sup>12</sup>

### 7.1.3 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 the 10% test level for all seven motive variables as well as for the overall cooperation variable (see Table A.4 in the Appendix; the instruments used are also listed in column 2). Therefore, there is significant evidence for endogeneity in the innovation equation. As a consequence, Table 3 and Table 5 show only the estimates of the innovation equation based on the predicted instrumented variables for the overall cooperation 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 A.4 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 and Table 6 contain the OLS random effect estimates for the original cooperation motive variables.<sup>13</sup>

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<sup>12</sup> The STATA procedure 'mprobit' estimates M-equation probit models by the method of simulated maximum likelihood. The Geweke-Hajivassiliou-Keane (GHK)-simulator is applied to evaluate the M-dimensional Normal integrals in the likelihood function (for a description of the GHK-simulator see Greene 2003).

<sup>13</sup> 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).

## **7.2 Cooperation equations**

### **7.2.1 R&D Cooperation yes/no**

For the overall cooperation variable R&D\_COOP we obtain as expected a positive effect for the proxy for absorptive capacity (HQUAL) (Table 3, column 1; random effect probit estimates). The extent of incoming spillovers is also positively correlated to the overall cooperation proximity when these spillovers are related to science-based knowledge (universities and patent disclosures; KPATSCIEN). This is not the case when spillovers are coming from suppliers (insignificant coefficient of KSUP) or customers (negative coefficient of KCUST). Further, if a firm anticipates a large technological potential for its field of activities, a fact that implies a high probability of incoming spillovers given a certain degree of appropriability, it also shows a high cooperation propensity (statistically positive coefficient of the variable TPOT). Outgoing spillovers do not appear to have any effect on the cooperation propensity. We also could not find any discernible effect of competitive pressures. Finally, as in similar empirical studies there is a non-linear positive relationship between firm size (measured by the number of employees) and the cooperation propensity (variable LEMPL).

### **7.2.2 MOT1 to MOT7**

Table 4 shows the multivariate probit estimates for the seven cooperation motives (i.e. groups of firms that pursued a certain cooperation motive). We found significant positive correlations between any pair of motive equations. Thus, there is considerable empirical justification for estimating a multivariate probit model. There are large similarities but also discernible differences among the estimates based on different cooperation motives as to the factors determining the propensity of cooperation. For all seven equations positive effects were found for the variable reflecting absorptive capacity (HQUAL), for the variable for technological potential (TPOT), for the variable KPATSCIENCE and for firm size (LEMPL). These effects were found also for the overall cooperation propensity and appear to be basic characteristics of any type of cooperation motive. The fact that absorptive capacity (variable HQUAL) appears to be, broadly speaking, equally important for all seven motives is in contradiction to hypothesis 1a in section 6. Firms stronger oriented towards technological motives do not appear to have a higher absorptive capacity than other firms. A possible reason for this effect could be that most firms pursued more than one motive at the time, so that our estimates do not reflect “pure” motive effects.

The differences refer to the effects of the variable for the outgoing spillovers (COPY), to the variables that characterize the competitive environment (IPC; INPC) and to the variables KCUST and KSUP. For MOT3, MOT5, MOT6 and MOT7 we found no significant effect for the variable COPY. This variable shows a significantly positive coefficient only in the

estimates for MOT1, MOT2 and MOT5. This finding is contradictory to the second part of hypothesis 2. As already mentioned in section 2 a possible argumentation for such an effect would go like this: Reporting the easiness of copying as a severe innovation obstacle means that a firm is confronted with conditions of low appropriability of its potential innovation gains. Under these circumstances it is probable that a firm would pursue cooperation with other firms in order to reduce or eliminate such spillovers through specific cooperation contracts that regulate property rights better than in the case of non-cooperation. It is also reasonable to assume that firms that consider the saving of R&D costs (MOT2) or the reduction of technological risks (MOT1) as important cooperation motives would be firms that are confronted with high external costs caused by low appropriability.

A further interesting finding is that firms pursuing MOT1 (saving of R&D costs) utilize external information from customers more intensively than other firms, while firms with MOT3 (shortening of development time) and MOT4 (access to specialized technology) use more information than other firms that comes from suppliers.

Finally, firms that are stronger oriented towards technological motives (MOT4 and MOT5) show positive effects of competitive pressures, especially non-price competition (INPC), on cooperation propensity.

### **7.3 Innovation equations**

The estimates for the variables LRDS, LHQUAL, IPC and INPC (dependent variable: LINNS) in the innovation equations in Table 3, columns 2 and 3 and Table 5 show similar effects as in earlier studies (see, e.g., Arvanitis 2008). We obtained positive coefficients for the tree types of factor endowment LRDS, LHQUAL 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 3 in section 2) as well as the positive expectations of most policy makers, e.g. in the European Union, favouring R&D cooperation based on the argument that cooperation enhances innovation performance. The results in Table 5 seem to confirm the finding for the overall cooperation propensity. We obtained significantly positive effects for all seven motive categories; MOT2 (saving of R&D costs), a primarily financial motive, appears to have the largest impact on innovation performance. On the whole, no tendency for technological motives to be more effective with respect to innovation performance is discernible, contrary to hypothesis 3a with respect to different cooperation motives postulated in section 6.2).

## 7.4 Productivity equations

The productivity estimates in Table 2, columns 4 and 5 and Table 6 show the expected signs for the factor endowment variables LRDL, LHQUAL and LCL (see Arvanitis 2008). Also 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). On the whole, hypothesis 4 seems to be confirmed by these findings. Two of the three motives with significant positive effects are primarily cost-oriented, so that hypothesis 4a as formulated in section 6.3 is partly confirmed.

## 8. Summary and conclusions

With respect to the factors determining the propensity to cooperate in R&D the main results of the study are as follows: *Hypothesis 1* referring to the positive influence of knowledge absorptive capacity on the propensity to R&D cooperation is throughout confirmed, at least for the proxy for absorptive capacity used in this study (share of employees with tertiary-level education; HQUAL).

The *first* part of *hypothesis 2* concerning possible positive effects of incoming spillovers is also at a large extent confirmed, particularly for the variables for technological potential (TPOT) and for science-based external knowledge (KPATSCIENCE).

The findings with respect to the *second* part of *hypothesis 2* about the expected negative effects of outgoing spillovers, here measured by the variable COPY, are not clear-cut. We found no effect for the overall cooperation variable as well as for four out of seven cooperation motives, but positive effects for three cooperation motives (namely risk-sharing, cost-sharing and utilization of technological synergies) that are contrary to theoretical expectations. As already mentioned in section 2, an ex-post explanation for this effect could be as follows: in these cases low appropriability of innovation returns may even increase the incentives for R&D cooperation as a means of internalizing information flows among firms, under the condition that this cooperation is based on a contract that explicitly settles not only property rights but also all kinds of information exchange among partners, a condition for which unfortunately no evidence is available in this study.

Further, *hypothesis 5* with respect to the influence of competitive pressures on cooperation appears to be valid, primarily with respect to non-price competition, only for three motives (also for the overall cooperation variable), namely such motives that are more technology-oriented.

On the whole, distinguishing various cooperation motives appears to be fruitful because it allows more differentiated insights with respect to the importance of factors determining

cooperation that would remain hidden behind the overall variable “R&D cooperation yes/no”, as the comparison of the results in Table 2 and 3 shows.

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 3*). *Hypothesis 3a* (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.<sup>14</sup> With respect to innovativeness the characterization of cooperation by the driving motive did not add much more insights that it 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 ones, but not for the other four motives that have been considered in this study (*hypothesis 4*). *Hypothesis 4a* (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.

A first implication for technology policy would be that policy goals that are stronger oriented towards innovation performance could be reached independent of the type of motivation of cooperating firms. On the contrary, if policy goals are stronger 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 cooperation 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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<sup>14</sup> However, one has to take into account that the motive variables correlate strongly with each other reflecting also the fact that firms pursue more than one motive at the same time.

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Table 1: Summary of empirical literature: impact of cooperation on firm performance

Study	Innovation indicator	Productivity indicator	Innovation cooperation indicator
Netherlands: Klomp and Van Leeuwen (2001) Cross-section	innovation expenditures/ sales sales share of innovative innovative products	nc	overall cooperation: +  overall cooperation: ns
Kemp et al. (2003) Cross-section; SMEs	share of total time spent in innovation activities  sales share of new products	nc	firms: + research institutions: + universities: ns all types of partners: ns
Duysters and Loxsin (2007) Cross-section	sales shares of new products	nc	'alliance portfolio: + complexity'
Sweden: Löf and Heshmati (2002) Cross-section	innovation expenditures per employee  sales of innovative products per employee	nc	<i>domestic:</i> suppliers: + competitors: -  <i>foreign:</i> research institutions: + universities: + customers: + consultancy: +  <i>domestic:</i> competitors: + customers: + universities: ns  <i>foreign:</i> suppliers: +

Lööf and Brostöm (2005) Cross-section	research expenditures/ sales sales of innovative products patent applications yes/no	nc	within group: + universities: + universities: + universities: +
Belgium: Michele et al. (2003) Cross-section; R&D coop.		sales growth	overall cooperation: ns
Belderbos et al. (2004) Cross-section; R&D coop.	sales of innovative products (‘new to the market’) per employee (level; growth)	value added per employee (level; growth)	<i>innovative sales prod.:</i> competitors: ns customers: ns suppliers: ns universities: + overall cooperation: + <i>labour productivity:</i> competitors: + customers: ns suppliers: + universities: ns overall cooperation: +
Peeters and van Pottelsberghe de la Potterie (2006) Cross-section; R&D coop.	patents yes/no  number of patents	nc	scientific institutions: + competitors: + vertical partners: + scientific institutions: + competitors: + vertical partners: +
Germany: Becker and Dietz (2004) Cross-section	R&D expenditures/sales  product innovations yes/no	nc	overall cooperation: + number of partners: + overall cooperation: + number of partners: ns
Czarnitzki al. (2007)			

Cross-section	R&D expenditures/sales patents yes/no number of patents per employee	nc	overall cooperation: + overall cooperation: + overall cooperation: +
Aschhoff and Schmidt (2008) Cross-section	sales share of products 'new to market'	nc	overall cooperation: ns suppliers: ns customers: ns competitors: ns universities: ns
	sales share of products 'new to firm'		overall cooperation: ns suppliers: ns customers: ns competitors: ns universities: +
	cost reduction due to processs innovation		overall cooperation: + suppliers: ns customers: ns competitors: + universities: ns
Finland: Cross-section	R&D expenditures/sales patents yes/no number of patents per employee	nc	overall cooperation: + overall cooperation: + overall cooperation: +
France: Miotti and Sachwald (2003) Cross-section; R&D coop.	patents yes/no	nc	overall cooperation: + public institutions: + Competitors: + vertical partners: +
	sales share of innovative products		overall cooperation: + public institutions: ns Competitors: + vertical partners: ns
Monjon and Waelbroeck (2003) Cross-section	degree of product novelty	nc	<i>domestic:</i> within group: ns competitors: ns

customers: ns  
suppliers: +  
universities: -  
research institutions: ns  
*foreign EU:*  
within group: ns  
competitors: ns  
customers: ns  
suppliers: -  
universities: +  
research institutions: +  
*foreign USA:*  
within group: ns  
competitors: -  
customers: ns  
suppliers: +  
universities: ns  
research institutions: -

Japan:  
Okamuro (2007)  
Cross-section; R&D coop.

technological success  
indicator

commercial success  
indicator

number of partners: ns

number pf partners: +

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*Note:* overall cooperation: dummy variable innovation (R&D) cooperation ys/no + / -: statistically significant at the 10% test level; ns: statistically not significant (at the 10% test level); nc: not considered.

Table 2: 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 Access 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

*Note:* 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.

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

Explanatory variables	R&D_COOP <sup>(1)</sup>	LINNS <sup>(2)</sup>	LINNS <sup>(2)</sup>	LQL <sup>(3)</sup>	LQL <sup>(3)</sup>
	RE PROBIT	RE TOBIT	RE TOBIT	RE OLS	RE OLS
HQUAL <sup>(4)</sup>	0.010*** (0.002)				
COPY <sup>(5)</sup>	0.104 (0.078)				
TPOT <sup>(6)</sup>	0.278*** (0.068)				
KCUST <sup>(7)</sup>	-0.132** (0.067)				
KSUPP <sup>(8)</sup>	-0.051 (0.088)				
KPATSCIENCE <sup>(9)</sup>	0.243*** (0.072)				
IPC <sup>(10)</sup>	0.056 (0.074)	-0.041 (0.051)	-0.058 (0.062)	0.015 (0.009)	0.008 (0.013)
INPC <sup>(11)</sup>	0.069 (0.066)	0.198*** (0.045)	0.179*** (0.055)	0.001 (0.008)	-0.002 (0.010)
LRDS <sup>(12)</sup>		0.061*** (0.012)	0.062*** (0.019)		
LRDL <sup>(13)</sup>				0.006*** (0.002)	0.005 (0.003)
LHC <sup>(14)</sup>		0.139*** (0.026)	0.103*** (0.040)	0.026*** (0.005)	0.017** (0.008)
LCL <sup>(15)</sup>				0.378*** (0.005)	0.375*** (0.014)
FOREIGN <sup>(16)</sup>		-0.001 (0.064)	-0.005 (0.073)	0.043*** (0.012)	0.035*** (0.013)
R&D_COOP <sup>(1)</sup>		0.022 (0.048)		0.018** (0.009)	
R&D_COOP_HAT <sup>(1)</sup>			0.200* (0.117)		0.068** (0.028)
LEMPL <sup>(17)</sup>	0.154*** (0.026)	0.001 (0.017)	-0.028 (0.024)	0.017*** (0.003)	0.005 (0.006)
Const.	-1.844*** (0.206)	1.863*** (0.156)	2.258*** (0.295)	7.532*** (0.061)	7.721*** (0.178)
Left-censored	2760	2738	2738	2686	2686
Wald Chi2	173.7***	475.4***	583.8***	7880.1***	5348.1***
R-sq. within				0.660	0.664
R-sq. between				0.776	0.776
R-sq. overall				0.766	0.766
Rho	0.372	0.231***	0.242***	0.442	0.452
Chi2 test for rho=0	47.7***				

Note: (1): R&D\_COOP: R&D cooperation yes/no (dummy variable; R&D\_COOP\_HAT: instrumented R&D\_COOP (see table A.4 for the endogeneity tests and the instruments used); (2): LINNS: natural logarithm of the sales share of innovative products (sum of the sales shares of new products and considerably modified products); (3) natural logarithm of value added per employee; (4): HQUAL: employment share of employees with tertiary-level education in per cent; (5) COPY: easiness to copy innovations; (6): TPOT: technological potential, i.e., scientific and technological knowledge relevant to the firm's innovative activity; (7): KCUST:

users and clients as an external source of information; (8): KSUP: suppliers as an external source of information; (9): PATSCIENCE: patent disclosures and universities as an external source of information; (10): IPC: intensity of price competition; (11): INPC: intensity of non-price competition; (12) LRDS: natural logarithm of R&D expenditure divided by sales; (13): LRDL: R&D expenditures per employee; (14) LHC: natural logarithm of employment share of employees with tertiary-level education in per cent; (15): LCL: natural logarithm of capital income per employee (capital income = value added minus labour costs); (16): FOREIGN: foreign firm yes/no (dummy variable); (17): LEMPL: natural logarithm of the number of employees (in full-time equivalents); all above qualitative variables are 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. 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.

Table 4: Determinants of R&D cooperation based on seven different motives; multivariate probit estimates

Explanatory variables	MOT1 <sup>(1)</sup>	MOT2 <sup>(2)</sup>	MOT3 <sup>(3)</sup>	MOT4 <sup>(4)</sup>	MOT5 <sup>(5)</sup>	MOT6 <sup>(6)</sup>	MOT7 <sup>(7)</sup>
HQUAL <sup>(8)</sup>	0.007*** (0.002)	0.005** (0.002)	0.006*** (0.002)	0.007*** (0.002)	0.007** (0.002)	0.007** (0.002)	0.011*** (0.002)
COPY <sup>(9)</sup>	0.266*** (0.087)	0.135* (0.079)	0.076 (0.074)	0.025 (0.070)	0.129* (0.068)	0.118 (0.074)	-0.017 (0.115)
TPOT <sup>(10)</sup>	0.336*** (0.078)	0.314*** (0.071)	0.373*** (0.064)	0.370*** (0.061)	0.305*** (0.060)	0.278*** (0.064)	0.400*** (0.093)
KCUST <sup>(11)</sup>	0.186** (0.079)	0.079 (0.070)	0.079 (0.063)	-0.045 (0.060)	0.090 (0.059)	0.011 (0.065)	0.020 (0.095)
KSUP <sup>(12)</sup>	-0.018 (0.104)	0.012 (0.092)	0.172** (0.080)	0.138* (0.078)	0.062 (0.077)	0.129 (0.084)	0.027 (0.128)
KPATSCIENCE <sup>(13)</sup>	0.300*** (0.079)	0.223** (0.074)	0.310*** (0.066)	0.326*** (0.062)	0.247*** (0.061)	0.317*** (0.066)	0.165* (0.096)
IPC <sup>(14)</sup>	0.130 (0.092)	0.246*** (0.082)	0.041 (0.071)	-0.017 (0.066)	0.033 (0.066)	0.026 (0.071)	0.017 (0.103)
INPC <sup>(15)</sup>	0.042 (0.078)	-0.006 (0.069)	0.119* (0.062)	0.110* (0.060)	0.121** (0.059)	0.076 (0.063)	0.086 (0.092)
LEMP <sup>(16)</sup>	0.121*** (0.026)	0.039* (0.023)	0.112*** (0.022)	0.094*** (0.020)	0.068*** (0.021)	0.060*** (0.022)	0.055* (0.031)
Const.	-3.209 (0.209)	-2.123*** (0.181)	-2.160*** (0.161)	-1.740*** (0.148)	-1.767*** (0.155)	-1.937*** (0.162)	-2.640*** (0.223)
N				2760			
Wald $\chi^2$				606.1***			
Rho21				0.552***			
Rho31				0.551***			
Rho41				0.508***			
Rho51				0.453***			
Rho61				0.482***			
Rho71				0.388***			
Rho32				0.584***			
Rho42				0.500***			
Rho52				0.552***			
Rho62				0.507***			
Rho72				0.572***			
Rho43				0.761***			
Rho53				0.717***			
Rho63				0.682***			
Rho73				0.456***			
Rho54				0.827***			
Rho64				0.779***			
Rho74				0.577***			
Rho65				0.776***			
Rho75				0.607***			
Rho76				0.637***			
LR test of rho21 = ..... =				3111.3***			

rho76 = 0							
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*Note:* (1): MOT1: reduction of technological risks; (2): MOT2: saving of R&D costs; (3): MOT3: shortening of the duration of the development stage; (4): MOT4: access to specialized technology; (5) MOT5: utilization of technological synergies; (6): MOT6: acquisition of knowledge for especially complex technologies; (7): MOT7: utilization of public promotion grants; (8): HQUAL: employment share of employees with tertiary-level education in per cent; (9) COPY: easiness to copy innovations; (10): TPOT: technological potential, i.e., scientific and technological knowledge relevant to the firm's innovative activity; (11): KCUST: users and clients as an external source of information; (12): KSUP: suppliers as an external source of information; (13): PATSCIENCE: patent disclosures and universities as an external source of information; (14): IPC: intensity of price competition; (15): INPC: intensity of non-price competition; (16): LEMPL: natural logarithm of the number of employees (in full-time equivalents); all above variables (with the exception of HQUAL and LEMPL) are 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. Controls: 24 industry dummies (reference industry: food, beverage, tobacco) and 2 year dummies. \*\*\*, \*\*, \* denote statistical significance at the 1%, 5% and 10% test level, respectively; heteroscedasticity-robust standard errors (White-procedure).

Table 5: Innovation and cooperation motives; random effects tobit estimates with instrument variables for the cooperation motive variables

Explanatory variables	LINNS <sup>(1)</sup>						
LRDS <sup>(2)</sup>	0.061*** (0.018)	0.061** (0.017)	0.061*** (0.016)	0.061*** (0.016)	0.061*** (0.016)	0.061** (0.017)	0.061*** (0.017)
LHQUAL <sup>(3)</sup>	0.101*** (0.034)	0.103*** (0.033)	0.107*** (0.042)	0.108*** (0.037)	0.096*** (0.034)	0.109*** (0.039)	0.089** (0.041)
IPC <sup>(4)</sup>	-0.080 (0.077)	-0.146** (0.071)	-0.055 (0.060)	-0.035 (0.070)	-0.056 (0.064)	-0.046 (0.069)	-0.048 (0.065)
INPC <sup>(5)</sup>	0.173*** (0.045)	0.196*** (0.056)	0.155*** (0.047)	0.161*** (0.055)	0.152*** (0.051)	0.165*** (0.050)	0.165*** (0.053)
FOREIGN <sup>(6)</sup>	-0.017 (0.068)	-0.020 (0.084)	-0.019 (0.077)	-0.016 (0.069)	-0.018 (0.068)	-0.016 (0.073)	0.001 (0.078)
MOT1 <sup>(7)</sup>	0.262*** (0.090)						
MOT2 <sup>(8)</sup>		0.318*** (0.104)					
MOT3 <sup>(9)</sup>			0.240*** (0.092)				
MOT4 <sup>(10)</sup>				0.216** (0.092)			
MOT5 <sup>(11)</sup>					0.264*** (0.094)		
MOT6 <sup>(12)</sup>						0.233** (0.104)	
MOT7 <sup>(13)</sup>							0.229*** (0.107)
LEMPL <sup>(14)</sup>	-0.035 (0.020)	-0.021 (0.018)	-0.041 (0.025)	-0.031 (0.019)	-0.026 (0.016)	-0.021 (0.022)	-0.017 (0.017)
Const.	2.771*** (0.388)	2.683*** (0.352)	2.521*** (0.350)	2.352*** (0.286)	2.469*** (0.270)	2.416*** (0.340)	2.657*** (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***

Note: (1): LINNS: natural logarithm of sales share of innovative products (sum of the sales shares of new products and considerably modified products); (2) LRDS: natural logarithm of R&D expenditure divided by sales; (3) LHQUAL: natural logarithm of the employment share of employees with tertiary-level education; (4): IPC: intensity of price competition; (5): INPC: intensity of non-price competition; IPC and INPC are 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). (6): FOREIGN: foreign firm (dummy variable); (7): MOT1: reduction of technological risks; (8): MOT2: saving of R&D costs; (9): MOT3: shortening of the duration of the development stage; (10): MOT4: access to specialized technology; (11) MOT5: utilization of technological synergies; (12): MOT6: acquisition of knowledge for especially complex technologies; (13) MOT7: utilization of public promotion grants; these seven motive variables are instrumented; see table A.4 for the endogeneity tests and the instruments used; (14): LEMPL: natural logarithm of the number of employees (in full-time equivalents). 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.

Table 6: Labour productivity and cooperation motives; random effects OLS estimates

Explanatory variables	LQL <sup>(1)</sup>						
LRDL <sup>(2)</sup>	0.007** (0.002)	0.006** (0.002)	0.006** (0.002)	0.006** (0.002)	0.006** (0.002)	0.007** (0.002)	0.007** (0.002)
LHQUAL <sup>(3)</sup>	0.026*** (0.005)	0.026*** (0.005)	0.026*** (0.005)	0.025*** (0.005)	0.026*** (0.005)	0.026*** (0.005)	0.027*** (0.005)
LCL <sup>(4)</sup>	0.378*** (0.005)						
IPC <sup>(5)</sup>	0.015 (0.009)	0.014 (0.009)	0.015 (0.009)	0.016* (0.009)	0.015 (0.009)	0.015 (0.009)	0.015 (0.009)
INPC <sup>(6)</sup>	0.001 (0.008)	0.001 (0.008)	-0.000 (0.008)	0.000 (0.008)	0.000 (0.008)	0.001 (0.008)	0.001 (0.008)
FOREIGN <sup>(7)</sup>	0.043*** (0.013)	0.043*** (0.012)	0.042*** (0.012)	0.043*** (0.012)	0.043*** (0.013)	0.043*** (0.013)	0.043*** (0.013)
MOT1 <sup>(8)</sup>	0.016 (0.016)						
MOT2 <sup>(9)</sup>		0.026* (0.014)					
MOT3 <sup>(10)</sup>			0.037*** (0.011)				
MOT4 <sup>(11)</sup>				0.034*** (0.010)			
MOT5 <sup>(12)</sup>					0.014 (0.010)		
MOT6 <sup>(13)</sup>						0.008 (0.012)	
MOT7 <sup>(14)</sup>							0.012 (0.022)
LEMPL <sup>(15)</sup>	0.018*** (0.003)	0.017*** (0.003)	0.017*** (0.003)	0.016*** (0.003)	0.017*** (0.003)	0.018** (0.003)	0.018*** (0.003)
Const.	7.530*** (0.061)	7.531*** (0.061)	7.542*** (0.061)	7.542*** (0.061)	7.532*** (0.061)	7.530*** (0.061)	7.529*** (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

Note: (1): LQL: natural logarithm of value added per employee; (2) LRDL: natural logarithm of R&D expenditures per employee; (3) LHQUAL: natural logarithm of employment share of employees with tertiary-level education; (4): LCL: natural logarithm of capital income per employee (capital income = value added minus labour costs); (5): IPC: intensity of price competition; (6): INPC: intensity of non-price competition; IPC and INPC are 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. (7): FOREIGN: foreign firm (dummy variable); (8): MOT1: reduction of technological risks; (9): MOT2: saving of R&D costs; (10): MOT3: shortening of the duration of the development stage; (11): MOT4: access to specialized technology; (12) MOT5: utilization of technological synergies; (13): MOT6: acquisition of knowledge for especially complex technologies; (14): MOT7: utilization of public promotion grants; all seven motive variables are originally measured on a five-point Likert scale (1: 'not important'; 5:

'very important'); for our model we constructed dummy variables: value 1 for firms reporting 4 or 5 on the original five-point scale; value 0 for firms reporting 1, 2 or 3 on the original scale; (15): LEMPL: natural logarithm of the number of employees (in full-time equivalents). 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.

## APPENDIX:

Table A.1: Composition of sample by industry; firm size class; year

	Number of firms with R&D activities	Firms with R&D cooperation (%)
<i>Industry:</i>		
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
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
<i>Firm size:</i>		
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
<i>Year:</i>		
1999	879	38.7
2002	1070	27.4
2005	974	37.4
Total	2922	34.1

Table A.2: 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
HQUAL	2940	22.373	20.245
COPY	2769	0.228	0.420
TPOT	2940	0.387	0.487
KCUST	2940	0.524	0.499
KSUP	2940	0.169	0.375
KPATSCIENCE	2940	0.320	0.467
IPC	2940	0.729	0.444
INPC	2940	0.437	0.496
FOREIGN	2907	0.166	0.372
LEMPLE	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



IPC	0.029	0.038	0.053	0.033	0.052	1.000							
INPC	0.130	0.000	0.059	0.083	0.053	-0.051	1.000						
FOREIGN	0.060	-0.006	-0.023	0.045	0.300	0.020	0.065	1.000					
LEMP	0.102	-0.116	0.047	0.060	0.239	0.115	0.077	0.099	1.000				
LRDS	0.162	-0.033	-0.024	0.082	0.077	-0.024	0.068	0.048	-0.046	1.000			
LRDL	0.166	-0.039	-0.029	0.093	0.121	-0.002	0.079	0.092	0.015	0.963	1.000		
LHC	0.179	-0.030	-0.110	0.080	0.114	-0.023	0.050	0.129	0.038	0.218	0.243	1.000	
LCL	0.077	-0.005	-0.038	0.032	0.117	-0.033	0.046	0.118	0.062	-0.055	0.067	0.078	1.000

Table A.4: 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; KPATSCIENCE	insignif.	OBS_R&D; OBS_ENV ; OBS_ACCEPT OBS_PROM
MOT5	signif.	COPY; KPATSCIENCE	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

*Note:* ‘Coeff.’: coefficients of the residuals (predicted (instrumented) variables minus original variables) in the innovation equation and the productivity equation resp; ‘Instrument’: instruments used; signif./insignif.: test level 10%.