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Empirical Evidence on the Success of R&D Co-operation – Happy together?

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Non-technical summary

R&D co-operation has become an important organisational component in the innovation process. In recent years more and more firms have become involved in collaborative relationships with a variety of partners, from suppliers to customers and research institutes. The trend towards R&D co-operation has motivated researchers to empirically investigate the effects related to collaboration in firms. Most of them have dealt with input related motives for and effects surrounding R&D co-operation at the firm level, which include knowledge spillovers, access to complementary knowledge or cost- and risk-sharing in innovation projects. The output or rather the outcome of a co-operative agreement in terms of technological and economic success is at least equally important. In order to evaluate an R&D co-operation economically, its effect on the firm's economic success should be measured.

This paper contributes to the empirical work on the benefits of R&D co-operation by assessing how much firms profit from co-operative agreements with external partners. In so doing we distinguish between the specific contributions of four different co-operation partners: customers, suppliers, competitors and research institutions. We investigate the effect of past R&D co-operation on current success with innovations (sales of innovative products and cost reductions due to process innovations). Specific attention will be given to the effect of R&D co-operation on cost reductions brought about by innovations, a topic widely discussed in the theoretical literature but neglected until now in the empirical literature on the output of co-operation.

Our empirical analysis rests on firm level data from the annual German innovation survey, using two consecutive waves of the survey (Mannheim Innovation Panel of 2004 and 2005), which covers service and manufacturing industries. We apply a censored regression model to the data and find that R&D cooperation has a positive impact on the success of process innovations and sales of products new to the market, but no significant effect on sales of product imitations. By distinguishing between co-operations with different types of partners, we identify co-operation with competitors as being profitable in terms of cost reduction. If firms aim to develop products new to the market, co-operations with research institutes are helpful. However, we found no evidence of any positive effect of cooperation with competitors on the share of total sales a firm achieves with market novelties. R&D co-operations with suppliers and customers do not have a significant impact on any of the three measures of success.

Empirical Evidence on the Success of R&D Co-operation – Happy together?

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Abstract

In this paper we analyse the effect of R&D co-operation on firms' innovation performance. We investigate the effect of past co-operation on current sales of innovative products, distinguishing between products new to the firm and new to the market, and on cost reductions due to innovative processes. Particular attention is paid to the impact of different co-operation partners. The analysis rests on firm-level data from two consecutive waves of the annual German innovation survey. We find that innovative firms that cooperate have a higher share of turnover with market novelties and a higher share of cost reduction due to process innovations than non-cooperating firms. In particular, R&D co-operation with research institutes has a positive influence on a firm's economic success with market novelties, while R&D co-operation with competitors leads to an increase in the cost reduction attributable to innovative processes.

Keywords: R&D Co-operation, Innovation Success, Germany, Applied Econometrics

JEL-Codes: L25, O31, C24

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1 Introduction

Co-operation has become an important organisational component of the innovation process. In recent years more and more firms have become involved in collaborative relationships with a variety of partners, from suppliers to customers and research institutes. This surge in co-operative agreements pertaining to innovation activities has been documented by Hagedoorn (2002) among others. In addition, public support policies adopted by national authorities and the European Union since the end of the 1980s (e.g. BMBF 1988) have explicitly encouraged the formation of co-operations in R&D and innovation projects. The trend towards co-operation has motivated researchers to empirically investigate the causes and effects of collaboration in firms (e.g. Cassiman and Veugelers, 2002). Most of them have dealt with input related motives for and effects related to R&D co-operation at the firm level, which include knowledge spillovers, access to complementary knowledge or cost- and risk-sharing in innovation projects. As these inputs into the innovation process have become more important in recent years so has co-operation.

However, the motives for firms to cooperate in R&D are not restricted to the input side. The output or rather the outcome of a co-operative agreement in terms of technological and economic success is at least equally important. In order to evaluate economically an R&D co-operation, its effect on the firm's economic success should be measured. Firms benefit from a co-operation if the co-operation positively affects their economic success sufficiently that it can be assumed that the costs of a co-operation, e.g. transaction costs, are outweighed. Thus, it is important to analyse the effects of co-operation on outcome measures in addition to its effects on inputs.

In the theoretical literature considerable effort has been put into the identification of the effects and benefits of co-operation. D'Aspremont and Jacquemin's (1988; 1990) model has been the basis for many other researchers investigating the effect of co-operation and spillovers on R&D investment, output and profits. Empirical literature on the innovative and economic success of R&D co-operation is still relatively scarce but has been growing in recent years (see e.g. Lööf and Broström, 2004; Belderbos et al., 2004b).

This paper contributes to the empirical work on the benefits of co-operations on the outcome side by assessing the extent to which firms profit from forming co-operative agreements with external partners. In so doing we distinguish between the specific contributions of four different co-operation partners. In contrast to other studies, which are concerned with the effect of R&D co-operation on productivity and spillovers (e.g. Cincera et al., 2003; Belderbos et al., 2004b), our goal is to investigate the effect of past co-operation on current success with innovations (sales of innovative products and cost reduction due to process innovations). Specific attention will be given to the effect of co-operation on cost reduction due to innovations, a topic widely discussed in the theoretical literature but neglected until now in the empirical literature on the output of co-operation.

The following section provides a review of the literature on the input and output related effects of co-operation in innovation. Section 3 discusses the hypotheses to test and is followed by section 4 in which the data used is described and the empirical specification presented. In section 5 the empirical results are discussed before we draw conclusions in section 6.

2 Related Literature on the Benefits of Co-operation

Below we provide an overview of the theoretical and empirical studies of R&D co-operation. This section mainly focuses on the effects of R&D co-operation on the inputs of firms' innovation processes and the effect of R&D co-operation on the outcome in terms of technological and economic success. The effects of co-operation on social welfare are not included in this review, since our main focus is on the effects of R&D co-operation on individual firms.

Effect of R&D co-operation on inputs for the innovation process

A starting point for the analysis of possible effects of co-operation on firms' (innovation) performance is the input-related motives firms have for cooperating with external partners. They represent the firms' expectations regarding the benefits from cooperating on the input side of the innovation process. These motives have been analysed in many theoretical and empirical papers.

A central motive for firms to cooperate on R&D is the internalization of spillovers: Katsoulacos and Ulph (1998) build a theoretical model where spillovers are endogenous and state that it is essential for the understanding of the impact of research joint ventures on innovation performance to consider endogenous spillovers, i.e. spillovers that arise because firms co-operate. Steurs (1995) carries out numerical simulations of a theoretical model. He finds that for higher levels of intra- and inter-industry spillovers the expected output-related benefits of (inter-industry) R&D co-operation are higher. De Bondt (1996) conducts a review of theoretical studies that investigate the effect of spillovers on innovation activities of firms. He states, among other things, that firms can increase their profits if they manage to improve spillovers through co-operation. In this sense his study provides a link between the effects on inputs of R&D co-operation and those on outputs, which will be discussed below. Empirical studies have confirmed that generating knowledge inflows and prohibiting knowledge outflows are indeed important motives for - and consequently expected benefits of - co-operation (e.g. Cassiman and Veugelers, 2002; Belderbos et al., 2004a; Schmidt, 2005; Lopez, 2003).

Another motive for and benefit of co-operation that is closely related to knowledge flows is access to external knowledge that is complementary to one's own (Hagedoorn, 1993). Hite and Hesterly (2001) argue that firms establish networks because they assume that they will benefit from the complementary assets and competencies their respective partners within the network can contribute. Scott, 1996 study indicates that co-operation leads to research in areas that would not have been on the firms "R&D horizon" without co-operation, providing evidence that the partner in the co-operation contributes complementary rather than similar knowledge.

Besides knowledge spillovers, resource constraints play an important role as a motive for co-operation. The most prominent example for this group of motives is the sharing of costs and risks among partners in the co-operative agreement (Sakakibara, 1997). The reduction of costs for the development of new processes and products through R&D co-operation can be interpreted as a benefit for the partners, because it reduces the inputs required to end up with the same output.

An overview of the empirical evidence on the link between expected and actual benefits of co-operation has been provided by Caloghirou et al. (2003). They cite their own empirical study (Caloghirou and Vonortas, 2000), which found that among European firms' expected benefits from co-operation were "acquisition/creation of new knowledge" and "acceleration of existing research" (Caloghirou et al., 2003: 559). The review of arguments for R&D partnerships by Hagedoorn et al. (2000) concludes that the expected results of research partnerships usually meet the initial incentives for forming the partnership. Furthermore, that co-operation can indeed lead to a reduction of costs of innovation activities has been shown by Beath et al. (1998). One of the results of their theoretical model is that "a Research Joint Venture (RJV) will economize on scarce R&D resources" (Beath et al., 1998: 47).

Effect of R&D co-operation on technological and economic success

The literature cited above mostly deals with the anticipated immediate effect of co-operation on the inputs for innovation activities, e.g. expecting higher spillovers or lower costs than other firms. These direct effects on inputs are not the only ones, however. It is reasonable to assume that R&D co-operation also affects the technological and economic success of firms.[1] Two ways of measuring technological success are the quality of products and improvements in the productivity of research. A usual measure of economic success is the

1 For a discussion of additional measures of innovative success see Janz (2003) and Caloghirou et al. (2003).

performance in terms of the share of sales from innovative products, cost reductions through innovations[2] or profits.

The quality of products as a dimension of the technological success of innovation activities and co-operation has not drawn a lot of attention from (empirical) researchers, mainly because the large innovation surveys (e.g. Community Innovation Survey) provide little if any information about the technological features of the innovations developed by firms. One technological feature that can be investigated using innovation surveys, however, is the novelty of innovations. Landry and Amara (2002) find that the novelty of innovations increases with the use of a larger variety of sources of information and collaborative agreements with external partners. Monjon and Waelbroeck (2003) include a wide range of collaboration variables and distinguish between domestic and foreign co-operation as explanatory variables for the novelty of innovations. They find a positive impact of co-operation with domestic equipment suppliers and foreign (EU) universities and a negative impact of co-operation with foreign (EU) equipment and software suppliers on the novelty of innovations. However, only 4 of the 24 dummies for co-operation included are significant at the 95% level in their model.

The effects of spillovers and co-operation on the productivity of research (another measure of technological success) have been analysed in many empirical studies. Griliches (1979; 1992) argues that R&D spillovers have a positive impact on productivity, as does Jaffe (1986). Nesta and Mangematin (2004) report that biotech firms that source knowledge through collaborative agreements perform better, in terms of patent applications, than those who do not. Love and Roper (2004) show that sourcing knowledge from external partners positively affects firms' innovation success in terms of sales of innovative products introduced in the previous three years.

As Klomp and van Leeuwen (2001) have shown, building on the model of Kline and Rosenberg (1986), there is a strong link between innovation performance and firm performance. Higher probabilities of success of innovation projects and more novel innovations usually lead to greater economic success for firms.

This brings us to the second group of success measures, the economic success of innovation activities. Kamien et al. (1992) analyse the effects of research joint ventures on welfare under Cournot and Bertrand competition and find that regardless of the type of competition assumed "an RJV [Research Joint Venture] cartel dominates […] as it yields the highest per-firm profit" (Kamien et al. 1992:

2 Note that the cost reduction is the result of an improved process (outcome of the innovation process) here and not the result of a reduction of costs for the development of an innovation (cost-sharing).

1303).[3] In the theoretical models building on D'Aspremont and Jacquemin (1988; 1990), where firms either cooperate in the pre-competitive stage and are rivals in the market or cooperate at both stages, R&D externalities occur and result in cost reductions or product improvements and higher firm profits if the level of spillovers is high enough (Kamien et al., 1992; Suzumura, 1992; Vonortas, 1994; De Bondt and Veugelers, 1991). This so called non-tournament literature argues that the benefits from co-operation for firms and society arise from cost-reductions that can spill over to other firms in the economy. Their argument is based on the assumption that more R&D always leads to lower costs. Most authors find that the aggregate R&D level is indeed higher with co-operation than without, if spillovers are significantly high. Consequently R&D co-operation is beneficial for firms.

The theoretical studies focus on the mechanisms by which co-operations affect (economic) success measures directly and indirectly, e.g. via spillovers.[4] Most of the empirical studies basically treat the mechanism as a black-box and directly analyse the difference in economic success between firms that cooperate and those that do not.

A recent contribution to this literature is made by Belderbos et al. (2004b) who analyse data on the innovation behavior of Dutch firms. They distinguish between four types of co-operation and find that R&D collaboration with competitors and universities increases the growth of sales attributable to market novelties, while co-operation with suppliers and competitors leads to a growth of value added per employee. Cincera et al.'s (2003) empirical study shows that international R&D co-operation positively affects a firm's productivity growth. Lööf and Broström (2004) find that collaboration between universities and firms not only increases the probability that firms will apply for a patent but also has a positive impact on innovative sales per employee. Gemünden and Ritter (1997) investigate the relationship between sales due to product innovations and cost reductions through process innovations using data from the Mannheim Innovation Panel (MIP). Based on descriptive analysis, they find that cooperating firms have higher sales attributable to product innovations than non-cooperating firms. Their study is the only one we are aware of that includes a direct measure for a firm's success with process innovations.[5] Two empirical studies based on the first waves of the MIP in the manufacturing sector also show that cooperating firms perform better in terms of innovative sales than other firms (König et al., 1994; Felder et al., 1994). While Felder et al. (1994) only provide descriptive

3 For additional theoretical models investigating the effect of co-operation and RJVs on profits see the review by De Bondt (1996).

4 Pittaway et al. (2004) review the literature on the benefits of networks and provide an overview of mechanisms by which networking can positively influence the output of innovation activities.

5 The lack of empirical research on the cost-reducing effects of R&D co-operation as a topical issue in the theoretical literature can partially be explained by a lack of data. Up until now, only the German innovation survey has contained a question on cost-reducing process innovations.

statistics on the relationship between R&D co-operation and the share of turnover from product innovation, König et al. (1994) conduct a multivariate analysis, which is limited to manufacturing firms[6]. They do not include an indicator for each type of co-operation partner in their study, but rather the number of different types of partners.

In contrast to these findings, Siebert's (1996) analysis of 314 US research joint ventures reveals that cooperating firms have lower profit margins than non-cooperating firms. This result, which is largely based on descriptive statistics, is one of the few studies we are aware of that states that co-operation might have a negative effect on profits. Another one is by Berg et al. (1982). They find that firms participating in R&D joint ventures have a lower profitability than those who do not.

Some other studies have included variables for co-operation in their models explaining innovative sales.[7] The evidence from these studies is mixed. Klomp and van Leeuwen (2001) for example find a positive impact of a co-operation dummy on the innovation output of firms in a single equation model. In their simultaneous equation model, the effect is only marginally significant, however. Another study is by Janz et al. (2003). They analyse the determinants of innovation performance in Sweden and Germany and include variables for co-operation among firms in their equation for the determinants of innovation sales per employee. They find no significant impact of R&D co-operation with suppliers, customers, universities or research institutes on innovation performance in the same period. They find that R&D co-operation with competitors has a negative effect on innovative sales.

3 Analytical Framework and Hypotheses

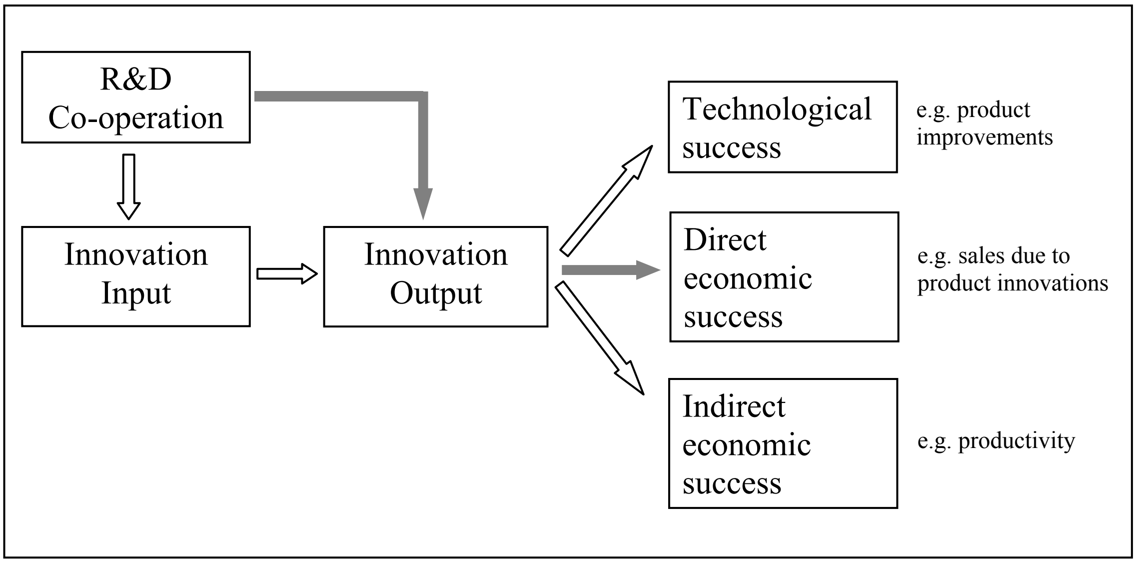
The literature review suggests that the benefits of R&D co-operation could be investigated either directly, i.e. by treating the mechanism through which co-operation influences performance as a "black box", or indirectly, by considering the impact of co-operation on inputs such as spillovers and research costs first and then looking into how it affects the benefits, as shown in figure 1. We will adopt the former approach in our study, i.e. we will analyse the effect of co-operation on direct economic success without looking at the intermediate mechanism by which R&D co-operation affects the innovation input.

6 A large scale survey on the innovation behaviour of firms in the service sector was first undertaken in 1996 in Germany.

7 Note that the co-operation dummy is one of the determinants of innovative success included in these studies, but no detailed analysis is carried out regarding this dummy since co-operation is not their main focus.

A similar approach has been followed by Belderbos et al. (2004b) and Cincera et al. (2003). They both use firm level data on R&D and innovation activities. Belderbos et al. (2004b) look at the effect of different types of cooperation on the growth of value added per employee and the growth of new-to-the-market sales per employee over a six year period. Cincera et al. (2003) investigate the direct effect of R&D co-operation on output growth. The success measures these authors use mostly focus on the effects of product innovation or innovation in a broader sense. Our study differs from Belderbos et al. (2004b) and Cincera et al. (2003) by including a direct measure of the success firms achieve thanks to process innovations, i.e. cost reductions due to process innovations.

Figure 1: Effects of co-operation on innovation input, output and success



The review of the literature shows that cooperation has a broad spectrum of impacts on the success of innovations and companies. In our paper we take this into account and investigate the link between R&D co-operation and success along three dimensions: sales of product innovations which are not new to the market, sales of market novelties, and cost reduction due to process innovations. In doing so, we restrict the analysis to the direct economic success of innovations and firms. We could also have included the technological success of innovation activities, measured with respect to the innovations' degree of novelty, in our model. We think, however, that some of this effect will be picked up by the sales attributable to product innovations and the cost reduction due to process innovations. We assume that the more novel a product or process innovation is the more turnover it contributes or the more cost reduction can be achieved, respectively. Taking our lead from the literature, we adopt an optimistic view of R&D co-operation and expect all three success measures to be positively influenced by R&D co-operations.

As far as different types of co-operation partners are concerned, we expect the following: Regarding cost reductions we suppose that R&D co-operations with competitors or suppliers in particular will have a positive impact. Since suppliers deliver inputs for the process of production in the form of knowledge and technology, co-operating with them might bring enhancements to this process, leading to cost reduction (cf. Belderbos et al., 2004b). Competitors might have similar processes and might work together in order to improve them. For example, in the automobile industry, cars from different manufacturers are sometimes built on the same platform which has been developed collectively. This contributes to reducing costs.

R&D co-operations with customers probably focus more on product innovations. Since customers are the recipients of the products or services, they know what they need or want and hence, co-operations with them are target-oriented towards improved products and reduce the risk associated with the acceptance or otherwise of the improved or new product. The latter reason is also mentioned by Tether (2002). Co-operations with research institutions might be targeted at more basic research and be long-term oriented. They would thus not have an immediate significant effect in the year after the co-operation. If they have an effect, they might be especially successful in the production of market novelties (cf. Tether, 2002).

Measuring the impacts of R&D co-operation on the economic success of firms is not without problems. Caloghirou et al. (2003) provide a discussion of the "thorny issues regarding both methodology and measurement of outcomes of collaboration" (Caloghirou et al., 2003: 557). They state that the measurement of outcomes is not specific to collaborations but is one of the problems surrounding the measurement of the performance of organisations in general. One of his concerns is that performance is affected by changes in firms' environments and not only by collaboration. We cannot fully control for this problem, since we do not have enough information on the environment the firms work in, e.g. with respect to the competition firms are facing, the regulatory framework, or what funding for R&D activities is available to firms. The only thing we know is their location in East or West Germany, which is a broad proxy for different business environments. The distinction between indicators and determinants is less problematic in our study, since all three of our success measures are clearly indicators of innovative success rather than determinants.

Another methodological issue is the time lag between co-operation and its impact on innovation success measures. Belderbos et al. (2004b) for example argue that the mixed results of the studies on the impact of co-operation on innovative sales are due to the difference in time lags used in these studies. We support this argument, as it is reasonable to assume that R&D co-operation (in particular pre-competitive co-operation) does not contribute to innovative performance right away, but rather in subsequent periods. Even if firms cooperate in the product market it might take some time for the positive effect of co-operation to set in, especially if firms cooperate in the introduction and marketing of innovative products, which are still at the beginning of their life cycle. The time lag between co-operation and its effects may also vary with the type of co-operation partner. To give an example, R&D co-operation with research institutes is usually more focused on basic research and technologies. The results of these research activities take longer to be implemented in innovative products and processes than the results of more applied research undertaken with competitors or customers.

The literature cited above does not give an indication of the duration of the time lag between co-operation and the impact on firms' success. We investigate the impact of co-operation in the year after the co-operation took place.

4 Data and Empirical Model

To test the hypotheses mentioned above, we use data from the Mannheim Innovation Panel (MIP). This annual survey on the innovation activities of firms with 5 or more employees is conducted by the Centre for European Economic Research (ZEW) on behalf of the German Federal Ministry of Education and Research (BMBF).[8]

For our analysis we use the 2004 survey, in which data was collected on the innovation behaviour of enterprises during the three-year period 2001-2003, and the innovation survey of 2005 (reference period 2002-2004). The MIP surveys use the European-wide harmonized methodology for the so called "Community Innovation Survey (CIS)" which is based on the Oslo Manual (OECD and Eurostat, 1997). The 2005 MIP survey was the German part of the fourth Community Innovation Survey. About 4,500 firms in manufacturing and services responded each year to the voluntary mail surveys, providing information on their innovation activities.

The dependent variables measuring innovation success can only be positive if the firm is an innovator, i.e. the firm has introduced at least one product or process innovation during the three-year period 2002 to 2004. We restrict our analysis to these innovating firms and look at their R&D co-operation behaviour in the years before 2002. Additionally, the firms had to provide all the information we needed to construct our other explanatory variables. Of the 1,900 firms that answered both surveys (2004 and 2005 survey), exactly 699 enterprises fit these criteria.

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8 For a more detailed description of the MIP survey see Janz et al. (2001) or Rammer et al. (2005).

Construction of the variables used[9]

As explained above, we use three variables to quantify the direct economic success of the firms: the reduction of the average costs for a company in 2004 due to new or significantly improved processes introduced between 2002 and 2004 (*REDP*), the share of sales in 2004 with significantly improved products or products new to the firm (but not new to the market) introduced between 2002 and 2004 (*IMIP*), and the corresponding share due to market novelties (*NOVP*). The latter two groups are mutually exclusive, depending on whether the product innovation is just new to the firm or new to the market.

Our main research question is whether cooperative R&D activities in the past have an impact on the firm's innovation success. First, we use an overall R&D co-operation dummy (*COOP*) which indicates whether a firm cooperated at all (with customers, suppliers, competitors or research institutes) during the three year period 2001-2003. Secondly, we divide the co-operations into different groups based on the partner and distinguish between co-operations with customers (*CO_CU*), with suppliers (*CO_SU*), with competitors or firms from the same sector (*CO_CO*) and with universities or institutional research firms (*CO_IN*). We expect differences in the impact of the various types of cooperative R&D on the specific success measures.

In order to explain the firm's innovation success with product and process innovations we also consider other variables in our empirical model which might have an impact[10]:

In line with previous studies, an important variable to explain the innovative success is the innovation expenditure intensity (*ININT*), measured as innovation expenditure (in thousand EURO) divided by the number of employees. The expected effect of this variable is positive, i.e. the higher the innovation expenditure, the higher the share of new and up-to-date products and the higher the success with innovations. The innovation intensity is included as lagged variable in order to mitigate simultaneity problems. In order to control for a non-linear relationship the squared intensity is also included in the regressions (*ININT2*).

A measure for the orientation of firms' R&D activities is included. We use the R&D staff, i.e. employees who are engaged in R&D activities, as a measure of the R&D orientation and argue that if a firm has R&D personnel its R&D orientation is longer-term than if it has not. Instead of including the number of

9 A detailed description of the construction of the variables included in our empirical model can be found in table 5 in the appendix.

10 A noteworthy share of R&D co-operations with research institutes might be publicly funded. Since we are not interested in the effect of public funding and other motives on firms' decisions to engage in R&D co-operation, but rather the impact of established co-operations on the success of firms, we do not include a variable for public funding in our analysis.

R&D employees, which would be a measure similar to the innovation intensity, we capture the long-term orientation of R&D with a dummy variable (*RDEMPD),* which equals one if the company has any R&D employees.

The innovation expenditure intensity and the R&D orientation of a firm also control partially for the absorptive capacity of firms. However, as Cohen and Levinthal (1990) have argued, a firm's absorptive capacity is also dependent on its employees' absorptive capacity. In order to take this aspect into account, the share of highly qualified employees, i.e. employees with a university degree, is included in our empirical model (*HQUAL*). The higher the share, the higher the ability to absorb and exploit external knowledge. This ability is seen as a critical factor in the innovation processes of firms (see e.g. Fagerberg, 2005) and is necessary to develop high-quality product or process innovations. We therefore expect a positive impact on the economic success measures.

We also control for the export intensity (*EXINT*) since firms that are active on the international market face tougher competition abroad than at home. This might bring pressure to cut costs in the manufacture of products or provision of services in order to stay competitive. By going abroad they also might learn from their foreign competitors how to improve their production processes and cut costs. In both cases the effect of the export intensity on cost reduction through process innovations would be indirect rather than direct. In addition, the foreign market might also increase demand for the products or services. In order to control for endogeneity, we use a lagged variable.

Finally, some firm characteristics that potentially influence a firm's success with product and process innovations are included in our model. We control for the firm size by using the logarithm of the number of employees (*LNEMP*). We test the effect of being part of group by means of the dummy variable *GROUP*. The firm's age (*LNAGE*) is included to take into account the possibility that the share of new products might be especially high for young firms. This is because they are not yet as well-established and have just developed their first products, which are new to the firm or even new to the market. In addition, we control for firms located in Eastern Germany (*EAST*). It has been shown that the innovation activities of East German firms still differ from West German ones (see e.g. Aschhoff et al., 2006). We include dummies for twelve industries (*IND1–IND12*) in the regressions in order to capture industry-specific effects. *IND1* serves as the base category.

Descriptive statistics

Descriptive statistics of the variables used in the regressions are presented in table 1, divided in cooperating and non-cooperating firms.[11] On average, the non-cooperating firms reduced costs by two per cent in 2004, while the reduction for cooperating firms was one per cent higher on average.[12] A two-sided t-test on mean equality in both groups while allowing for unequal variances between the two groups indicates that the mean difference is statistically significant at the 5 per cent level. However, the share of firms with no cost reduction, i.e. the censored observations, is rather high. About 70 per cent of the firms sampled reported no cost reductions at all. Looking at the other two success measures *IMIP and NOVP*, the t-test shows that the two variables are significantly higher (at the 1% significance level) for cooperating firms than for non-cooperating ones. The share of sales from new or significantly improved products equals 12 per cent for the non-cooperating firms while the share is almost twice as large for the cooperating firms. The relative difference between the two groups is even higher for the share of sales due to market novelties: 3.4 versus 11.6 per cent. Overall, the proportions of firms with zero turnover from new products or market novelties are 41 and 66 per cent, respectively.

Let us now turn to co-operation behavior. 32 per cent of the sampled companies cooperated during the period 2001 to 2003.[13] Co-operations with universities or research institutes were predominant. 84 per cent of the cooperating firms collaborated with these partners. The shares of firms with cooperative agreements with customers and suppliers are just under half the size and amount to 42 and 45 per cent, respectively. Almost a quarter of cooperating firms are engaged in co-operations with their competitors.

Looking at the other explanatory variables, we can see that the firms spent on average seven thousand Euros per employee on innovation in 2003. A little more than half of the firms had R&D employees and almost a quarter of the workforce has a university degree. Both shares are higher for cooperating firms which indicates that these firms have higher absorptive capacities that might be used for their internal innovation processes. The average size of a firm in the sample is 60 employees. For the average firm, about 18 per cent of the sales were exports in 2003 and the average firm age was 15 years. Almost 60 per cent of the firms sampled are part of a group and 36 per cent are located in Eastern Germany. About two thirds of the firms are active in the manufacturing sector.

11 The descriptive statistics of the whole sample can be seen in table 6 (appendix).

12 Five observations were dropped due to their extremely high cost reduction, up to 80 per cent, in order to ensure that the results are not driven by these outliers.

13 The share of co-operating firms is slightly higher compared to the projected numbers for Germany for 2003. This is mainly due to the different bases of the percentage. For the projections all innovators of 2003 are considered. In this sample the firms had to be an innovator in 2004.

Table 1: Descriptive Statistics

	Non-cooperating firms		Cooperating firms	
Variable [b]	Mean	Std. dev.	Mean	Std. dev.
REDP	2.142	4.754	3.248	6.001
IMIP	12.385	20.573	19.884	20.412
NOVP	3.361	9.477	11.563	20.347
COOP [a]	0	0	1	0
CO_CU [a]	0	0	0.425	0.495
CO_SU [a]	0	0	0.456	0.499
CO_CO [a]	0	0	0.230	0.422
CO_IN [a]	0	0	0.836	0.371
ININT [a]	4.167	7.642	13.868	15.470
ININT2 [a]	75.630	314.486	430.592	951.215
RDEMPD [a]	0.359	0.475	0.897	0.297
HQUAL [a]	0.187	0.236	0.342	0.277
LNEMP	3.951	1.593	4.411	1.687
EXINT [a]	0.142	0.221	0.264	0.274
LNAGE	2.754	0.732	2.639	0.710
GROUP	0.537	0.499	0.690	0.463
EAST	0.323	0.468	0.425	0.495
IND1	0.057	0.232	0.044	0.206
IND2	0.049	0.215	0.031	0.174
IND3	0.093	0.291	0.040	0.196
IND4	0.091	0.288	0.115	0.320
IND5	0.195	0.396	0.257	0.438
IND6	0.068	0.251	0.088	0.285
IND7	0.030	0.170	0.133	0.340
IND8	0.068	0.251	0.009	0.094
IND9	0.068	0.251	0.009	0.094
IND10	0.059	0.236	0.013	0.115
IND11	0.148	0.355	0.243	0.430
IND12	0.076	0.265	0.018	0.132
# of obs.	473		226	

[a] Lagged values
[b] A detailed description of the variables can be found in table 5 (appendix)

Empirical Model

Because all our dependent variables are censored, i.e. restricted to the interval between 0% and 100%, we use a censored regression or tobit estimation procedure to estimate our model. Since the proportion of observations with 100% is rather small, i.e. between zero and one per cent contingent on the depended variable, we only consider the lower bound in our estimations.[14] The tobit is

14 We also estimated the tobit models integrating the upper bound. But the results stay the same since the number of upper bound censored observations is fairly small.

similar to a probit model in the sense that a latent variable is estimated. The formal tobit model in our case is given by:[15]

$$y_i^* = \beta' x_i + \varepsilon_i, \quad i = 1,...,N \tag{1}$$

$$y_i = 0 \quad if \quad y_i^* \le 0 \tag{2}$$

$$y_i = y_i^* \quad if \quad y_i^* > 0 \tag{3}$$

The coefficient estimations of tobit models are inconsistent in the presence of heteroscedasticity and also lead to biased standard errors. Therefore we conduct a Lagrange-Multiplier test on multiplicative heteroscedasticity proposed by Greene (2003) after the estimations of the homoscedastic tobit models. The Null-Hypothesis is that homoscedasticity is present. If heteroscedasticity is detected, the tobit model is re-estimated using the exponential function of the variables that cause heteroscedasticity as the variance. Finally, a Likelihood-Ratio-Test on the joint significance of the variables in the heteroscedasticity term is carried out in order to check whether the heteroscedastic tobit model leads to more precise results.

5 Results

We estimate tobit models including first the overall co-operation dummy (COOP) and then the dummies for the four different types of co-operation. The results of a Lagrange-Multiplier-Test on group-wise multiplicative heteroscedasticity of the industries, size classes and the location “Eastern Germany”[16] in the models are shown in table 2. The test reveals heteroscedasticity of the size class dummies in all specifications. The industry and East dummies are only heteroscedastic in specific models. As consequence, we estimate the tobit again, thereby controlling for the detected heteroscedasticity.[17]

15 See Greene (2003) for a more detailed description of censored regression models.

16 These are the variables usually assumed to be heteroscedastic in this setting (see e.g. Czarnitzki and Kraft, 2004)

17 The results of the homoscedastic tobit models can be found in table 8 (appendix).

Table 2: LM-test-statistics on heteroscedasticity for all tobit models

Tested Variable	Critical value	LM-value					
		REDP		IMIP		NOVP	
	χ^2(df,α)[a)]	(1)	(2)	(3)	(4)	(5)	(6)
Industry dummies	χ^2(11, 1%)=24.72	48.08***	47.25***	11.31	12.11	30.93***	30.00***
Size class dummies	χ^2(4, 1%)=13.28	25.16***	27.10***	17.73***	17.87***	33.97***	34.45***
East	χ^2(1, 1%)=6.63	3.30*	5.59**	1.15	0.70	0.17	0.07

Note: *** (*) indicate significance level of 1% (10%).
a) df: degrees of freedom, α: significance level
Columns (1), (3) and (5) refer to the tobit model with the aggregated co-operation variable *COOP*, columns (2), (4) and (6) to the models with the four different "co-operations" dummies.

The results of the heteroscedastic tobit regressions are shown in tables 3 and 4. Our main concern is whether the co-operation dummies have an impact on economic success. The estimations show different results for the general engagement in R&D co-operation on the three success measures. The aggregated R&D co-operation dummy reveals a significant increase in the cost reductions due to process innovations and in the share of sales due to market novelties. These are products not only new to the firm but also to the market the firm operates in. R&D co-operation was found to have no significant impact on the share of sales from product imitations. These products are improved or new to the firm but do not include innovations new to the market. They are products which already existed in a firms' market.

Taking a more detailed look at R&D co-operation, it becomes apparent that different co-operation partners have different effects on the specific success measures. The structure for the relationship between R&D co-operation and the output of process innovations is different to that between co-operation and the output of product innovations.

Regarding the effects of the different co-operation partners on cost reduction we find that R&D co-operation with competitors or firms from the same sector has a highly significant positive effect, while the overall co-operation dummy had only a weakly significant positive impact. On the other hand, co-operations with suppliers do not have an impact on success with process innovations. External expertise acquired through co-operation with competitors can help firms to improve their production processes significantly. Our results provide empirical evidence for the arguments put forward by the non-tournament literature that the level of cost-reduction achieved is higher if competitors cooperate than if they compete in their R&D activities.

Table 3: Heteroscedatic tobit regressions with the general co-operation dummy

	(1)	(2)	(3)	(4)	(5)	(6)
	REDP		**IMIP**		**NOVP**	
	Coeff. (Std. err.)	Marginal effect	Coeff. (Std. err.)	Marginal effect	Coeff. (Std. err.)	Marginal effect
COOP [a)]	2.361*	0.553	1.982	1.142	5.069**	1.432
	(1.356)		(2.746)		(2.551)	
ININT [a)]	0.375**	0.084	0.569**	0.325	0.468*	0.126
	(0.169)		(0.289)		(0.258)	
ININT2 [a)]	-0.007**	-0.002	-0.010*	-0.006	-0.002	-0.001
	(0.004)		(0.005)		(0.005)	
RDEMPD [a)]	1.779	0.398	14.468***	8.159	11.517***	3.071
	(1.476)		(3.046)		(3.146)	
HQUAL [a)]	-5.583	-1.254	8.793	5.023	14.889**	4.019
	(4.027)		(6.993)		(7.130)	
LNEMP	1.387***	0.311	1.664*	0.950	0.039	0.011
	(0.538)		(0.881)		(0.938)	
EXINT [a)]	-2.452	-0.551	0.908	0.518	8.920*	2.408
	(2.735)		(5.366)		(4.824)	
LNAGE	0.003	0.001	-3.470**	-1.982	-0.572	-0.154
	(0.797)		(1.634)		(1.553)	
GROUP	-0.686	-0.155	-1.333	-0.763	0.670	0.180
	(1.350)		(2.655)		(2.550)	
EAST	-3.373	-0.724	3.899	2.257	-4.105	-1.076
	(2.069)		(2.800)		(2.633)	
CONSTANT	2.038***		-8.199		-16.173*	
	(0.277)		(7.880)		(8.327)	
Wald-Test on joint significance of industry dummies	$W(\chi^2(11))=$ 24.04**		$W(\chi2(11))=$ 8.62		$W(\chi^2(11))=$ 21.22**	
# of obs.	699		699		699	
Log-Likelihood	-974.518		-2,163.969		-1,274.068	
LR-Test on heteroscedasticity	$LR(\chi^2(16))=$ 38.730***		$LR(\chi^2(4))=$ 27.283***		$LR(\chi^2(15))=$ 46.805***	

Note: *** (**, *) indicate significance level of 1% (5%, 10%).
a) Lagged values
11 industry dummies are included in regressions but not shown.

The result that the overall co-operation dummy does not have a significant effect on the share of sales from product imitations stays the same when looking at the different types of co-operation. No type of co-operation has a significant impact on this success measure. It seems not to be beneficial to cooperate on R&D in order to improve products or to imitate already existing products. One explanation might be that the knowledge required for this type of innovation can be obtained through other channels.

Table 4: Heteroscedatic tobit regressions with four co-operation dummies

	(1)	(2)	(3)	(4)	(5)	(6)
	REDP		**IMIP**		**NOVP**	
	Coeff. (Std. err.)	Marginal effect	Coeff. (Std. err.)	Marginal effect	Coeff. (Std. err.)	Marginal effect
CO_CU a)	2.290	0.548	4.506	2.681	4.249	1.251
	(1.915)		(3.726)		(3.085)	
CO_SU a)	-2.626	-0.528	4.628	2.753	-1.307	-0.348
	(1.950)		(3.494)		(3.126)	
CO_CO a)	6.437**	1.846	2.911	1.716	-5.346	-1.295
	(2.545)		(4.333)		(3.725)	
CO_IN a)	2.086	0.482	-5.025	-2.795	7.305**	2.168
	(1.690)		(3.267)		(3.031)	
ININT a)	0.374**	0.082	0.553*	0.317	0.465*	0.127
	(0.166)		(0.287)		(0.258)	
ININT2 a)	-0.007**	-0.002	-0.010**	-0.006	-0.003	-0.001
	(0.004)		(0.005)		(0.005)	
RDEMPD a)	1.721	0.377	15.154***	8.556	10.716***	2.884
	(1.436)		(3.025)		(3.091)	
HQUAL a)	-7.576*	-1.668	9.541	5.462	14.617**	3.981
	(4.220)		(6.944)		(6.906)	
LNEMP	1.113**	0.245	1.570*	0.899	-0.193	-0.052
	(0.520)		(0.879)		(0.924)	
EXINT a)	-1.930	-0.425	1.132	0.648	8.503*	2.316
	(2.760)		(5.367)		(4.774)	
LNAGE	0.147	0.032	-3.348**	-1.916	-0.124	-0.034
	(0.778)		(1.631)		(1.548)	
GROUP	-0.565	-0.125	-1.363	-0.782	0.433	0.118
	(1.318)		(2.644)		(2.530)	
EAST	-3.438	-0.723	4.172	2.423	-3.680	-0.976
	(2.105)		(2.785)		(2.600)	
CONSTANT	-8.261**		-7.487		-15.533*	
	(3.937)		(7.832)		(8.077)	
Wald-Test on joint significance of industry dummies	$W(\chi^2(11))=$ 26.91***		$W(\chi^2(11))=$ 8.28		$W(\chi^2(11))=$ 22.14**	
# of obs.	699		699		699	
Log-Likelihood	-970.114		-2,161.288		-1,270.186	
LR-Test on heteroscedasticity	$LR(\chi^2(16))=$ 39.716***		$LR(\chi^2(4))=$ 27.138***		$LR(\chi^2(15))=$ 46.174***	

Note: *** (**, *) indicate significance level of 1% (5%, 10%).
a) Lagged values
11 industry dummies are included in regressions but not shown.

The firms that cooperate with universities or research institutions in their R&D and innovation activities have a higher share of turnover from market novelties than firms that do not co-operation or those cooperating with customers, suppliers or competitors. To achieve success with market novelties by co-operation, it seems to be particularly important to bring together the expertise and knowledge of research institutes and universities with one's own. The acquisition of or conflation with complementary knowledge from basic research is needed for fundamental innovations.

The control variables provide some interesting insight as well. For the innovation intensity we find an inverted U-shaped influence on the cost reduction and the share of sales from product imitations. The turning point for the inverse U can be calculated from the coefficients obtained. It lies at around 25 and 29 thousand €/employee, respectively. The share from product imitations decreases after an innovation intensity of about 29 thousand €/employee. The reason for this finding might be that there is a "substitution effect" at work. After the threshold has been reached, development activities might get more ambitious and lead to some real new products. As a result the firm will have a lower turnover share from product imitations and a higher share from market novelties. This can be confirmed by the finding regarding the share of turnover from market novelties: we find a positive and linear relationship. Hence, with higher innovation intensity, success with totally new product innovations always increases. However, no economies of scale in developing new technologies are found.

The employment of R&D staff, which implies a long-term R&D orientation, has a highly positive impact on both the share of sales with product imitations and the share with market novelties. However, the dummy for R&D employees does not have a significant effect on cost reductions via process innovations, which might indicate that R&D activities deal mainly with product innovations. In order to achieve cost reductions, the acquisition of new technology and its adaptation to the specific environment within the firm might be the key. R&D is not needed for this. The share of highly qualified employees has a positive impact on the share of sales attributable to market novelties, underscoring the importance of absorptive capacity for the development of genuinely new products.

Larger firms can realize larger cost reductions. They might have a greater potential to save costs than small firms, which provides an incentive for them to invest money and resources in process innovations. The size variable has a positive effect on the share of sales from product imitations. It is insignificant in the regression on the dependent variable for market novelties. These findings point to the existence of economies of scale in process innovations and the non-existence of economies of scale in the development of new technologies.

The export intensity is only positive and significant for market novelties. The explanation for this finding is straightforward: Firms which are exposed to international competition are forced to develop higher-quality and more novel products. This argument is especially valid for a high wage country like

Germany. To give an example, the German textile industry almost exclusively relies on the development of market novelties, while the production takes place in low cost countries (Beise et al., 2002). At the same time the market for real innovative products is larger for firms that export their products than for firms that do not export.

Regarding a firm's age, we can state that the younger the firm the larger the share of sales due to product imitations. Since a young firm has not yet been active in the market for a long time and might still be at the stage of introducing their first products, it is logical that the share of new or significantly improved products is higher for these firms. But as the estimates also show, young firms do not necessarily introduce market novelties. Being a member of a group has no impact on the direct economic success measures. The three measures of success also show no significant differences between the Eastern and Western parts of Germany. The results of these variables are fairly robust and stay similar to the estimates when dummies for the four different types of co-operation are included.

6 Conclusion

Our analysis focused on the effects of R&D co-operation on the direct success of innovations, as measured by three variables: cost reductions due to process innovations, share of sales from product imitations, and share of sales from market novelties. The R&D co-operations were distinguished by type of partner: customer, supplier, competitors, and research institutions. The study reveals that R&D co-operation has a positive effect on the success of process innovations and sales of market novelties, but no significant effect on sales of product imitations.

By distinguishing between co-operations with different types of partners, we identify co-operation with competitors to be profitable in terms of cost reduction. If firms aim to develop products new to the market, co-operations with research institutes are helpful. Our analysis partly confirms the findings of Belderbos et al. (2004b) who find a significant positive effect of university co-operation on the growth of new-to–the-market sales within a two year period after co-operation. However, we found no evidence of any positive effect of competitor cooperation on the share of sales from market novelties. R&D co-operations with suppliers and customers do not have a significant impact on the three success measures. The results show that it is important to look at the specific types of R&D co-operations because they have different impacts on the direct economic success firms achieve with their innovations.

A question that our results suggest is: why do not all innovative firms cooperate on R&D activities with external partners, if it is as beneficial as we have estimated? On the one hand the firm itself might not have the capacity and capability to search for a co-operation partner and manage the co-operation; on the other hand, there might be no partner available to cooperate with.

A limitation of this study is that we could not control for the duration of the co-operation. We observe whether firms are involved in R&D co-operation or not, but not when the co-operation started. The chosen lag structure between R&D co-operation and its effects, based on a one-year delay, is another constraint of our study. It is certainly worth looking at the impact of R&D co-operation over a longer period of time. This would provide a better basis for the researchers to asses the success of different forms of R&D co-operation than just looking at the (extremely) short-term effects.

The type of partners could also be split up by country of origin. Foreign co-operation partners might differ in the knowledge and experience they possess and could thus have a greater influence on innovative success than domestic ones. Whether this is really the case should be addressed in future studies.

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Appendix

Table 5: List of constructed variables

Variable	Description	
REDP	Reduction of average costs (in %) in 2004 due to new processes introduced during 2002 to 2004 (in %)	
IMIP	Share of turnover in 2004 from imitated products, i.e. new or significantly improved products excluding turnover from market novelties, introduced during 2002 to 2004 (in %)	
NOVP	Share of turnover in 2004 with market novelties introduced during 2002 to 2004 (in %)	
COOP	Co-operative R&D projects in 2001-2003	
CO_CU	Co-operative R&D projects with customers in 2001-2003	
CO_SU	Co-operative R&D projects with suppliers in 2001-2003	
CO_CO	Co-operative R&D projects with competitors in 2001-2003	
CO_IN	Co-operative R&D projects with research institutes or universities in 2001-2003	
ININT	Innovation intensity (innovation expenditures in thousand EURO/number of employees) in 2003	
ININT2	Innovation intensity squared	
RDEMPD	Firm has R&D employees in 2003 (Dummy)	
HQUAL	Share of employees with a higher education degree in 2003 (in %)	
LNEMP	Number of employees (in logarithm) in 2004	
EXINT	Export intensity (exports/turnover) in 2003	
LNAGE	Firm's age (in logarithm) in 2004	
GROUP	Member of a group in 2004	
EAST	Located in Eastern Germany (the former GDR) in 2004	
	NACE:	
IND1	10, 14, 26, 40, 41, 45	Mining, non-metallic mineral products, electricity, gas, water supply, collection, purification and distribution of water, construction
IND2	15, 17-19	Food, beverages, tobacco; textile, clothes and leather goods
IND3	20-22, 36, 37	Wood, paper, publishing, printing, furniture, jewellery, musical and sport instruments, toys, recycling
IND4	23-25	Fuels and chemicals, rubber and plastic products
IND5	27-29, 34, 35	Basic metals, fabricated metal, machinery and equipment, motor vehicles and components, other transport
IND6	30-32	Office machinery and computers, electrical machinery, radio, television and communication equipment
IND7	33	Medical, precision, optical instruments, watches
IND8	50-52	Retail and wholesale trade
IND9	60-63, 641	Land, water, air transport, supporting transport activities, post activities
IND10	65-67	Financial intermediation, activities auxiliary to financial intermediation
IND11	642, 72, 73, 741-744	Telecommunication, computer activities, research and development, tax and business consultancy, market research, architectural and engineering activities and related technical consultancy, technical testing and analysis, advertising
IND12	70, 71, 745-748, 90, 921	Real estate activities, renting of machinery without operator and of personal and household goods, labor recruitment, investigation and security activities, industrial cleaning, miscellaneous business activities n.e.c., refuse disposal, sanitation activities, motion picture

Table 6: Descriptive Statistics (699 observations)

Variable	Mean	Std. dev.	Min	Max
REDP	2.500	5.211	0	40
IMIP	14.809	20.805	0	100
NOVP	6.013	14.455	0	100
COOP [a)]	0.323	0.468	0	1
CO_CU [a)]	0.137	0.344	0	1
CO_SU [a)]	0.147	0.355	0	1
CO_CO [a)]	0.074	0.263	0	1
CO_IN [a)]	0.270	0.444	0	1
ININT [a)]	7.303	11.716	0	80.537
ININT2 [a)]	190.396	621.410	0	6,486.194
RDEMPD [a)]	0.533	0.494	0	1
HQUAL [a)]	0.237	0.260	0	1
LNEMP	4.099	1.637	0	9.116
EXINT [a)]	0.181	0.246	0	1
LNAGE	2.717	0.726	0	5.493
GROUP	0.587	0.493	0	1
EAST	0.356	0.479	0	1
IND1	0.053	0.224	0	1
IND2	0.043	0.203	0	1
IND3	0.076	0.265	0	1
IND4	0.099	0.298	0	1
IND5	0.215	0.411	0	1
IND6	0.074	0.263	0	1
IND7	0.063	0.243	0	1
IND8	0.049	0.215	0	1
IND9	0.049	0.215	0	1
IND10	0.044	0.206	0	1
IND11	0.179	0.383	0	1
IND12	0.057	0.232	0	1

[a)]Lagged values

Table 7: Homoscedastic tobit regressions

	(1)	(2)	(3)	(4)	(5)	(6)
	REDP		IMIP		NOVP	
	Coeff. (Std. err.)	Coeff. (Std. err.)	Coeff. (Std. err.)	Coeff. (Std. err.)	Coeff. (Std. err.)	Coeff. (Std. err.)
COOP a)	1.696	-	1.773	-	7.839***	-
	(1.621)	-	(3.020)	-	(3.058)	-
CO_CU a)	-	2.350	-	5.213	-	4.915
	-	(2.129)	-	(3.968)	-	(3.775)
CO_SU a)	-	-0.255	-	5.421	-	1.228
	-	(2.038)	-	(3.753)	-	(3.650)
CO_CO a)	-	6.038**	-	2.764	-	-4.769
	-	(2.491)	-	(4.762)	-	(4.551)
CO_IN a)	-	-0.433	-	-5.439	-	9.604***
	-	(1.937)	-	(3.566)	-	(3.563)
ININT a)	0.406**	0.398**	0.608**	0.595**	0.680**	0.663**
	(0.179)	(0.180)	(0.293)	(0.292)	(0.287)	(0.285)
ININT2 a)	-0.008**	-0.009**	-0.010**	-0.011**	-0.006	-0.006
	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
RDEMPD a)	0.638	0.626	15.376***	15.965***	11.381***	10.451***
	(1.741)	(1.717)	(3.229)	(3.197)	(3.527)	(3.479)
HQUAL a)	-3.634	-4.266	7.877	8.552	18.328***	18.138***
	(3.907)	(3.902)	(6.703)	(6.680)	(6.857)	(6.811)
LNEMP	1.112**	0.974**	0.851	0.797	-0.911	-1.038
	(0.498)	(0.495)	(0.919)	(0.920)	(0.941)	(0.937)
EXINT a)	-0.110	0.224	-1.673	-2.004	8.082	6.829
	(3.165)	(3.144)	(6.057)	(6.047)	(5.884)	(5.850)
LNAGE	0.422	0.458	-4.360**	-4.361**	-1.948	-1.675
	(0.969)	(0.961)	(1.793)	(1.788)	(1.875)	(1.859)
GROUP	0.230	0.288	-1.102	-1.288	1.839	1.642
	(1.427)	(1.414)	(2.613)	(2.603)	(2.782)	(2.761)
EAST	-0.399	-0.097	3.198	3.330	-6.548**	-6.336**
	(1.563)	(1.550)	(2.832)	(2.813)	(3.017)	(2.986)
CONSTANT	-16.286***	-15.243***	-2.045	-1.541	-11.955	-12.113
	(4.504)	(4.453)	(8.058)	(8.042)	(8.454)	(8.409)
Wald-Test on joint significance of industry dummies	$W(\chi^2(11))=$ 15.25	$W(\chi^2(11))=$ 14.90	$W(\chi^2(11))=$ 7.71	$W(\chi^2(11))=$ 7.76	$W(\chi^2(11))=$ 26.93***	$W(\chi^2(11))=$ 26.90***
# of obs.	699	699	699	699	699	699
Log-Likelihood	-993.883	-989.972	-2,177.610	-2,174.857	-1,297.471	-1,293.273

Note: *** (**, *) indicate significance level of 1% (5%, 10%).
a) Lagged values
11 industry dummies are included in regressions but not shown