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Relevance of innovation cooperation for firms' innovation activity: the case of Slovenia

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The paper analyses the importance of innovation cooperation on the innovation activity of Slovenian firms, and puts it within the broader context of firm's innovation activity determinants. Probit estimations based on firm-level data confirm that, next to R&D spending, innovation cooperation is the most important factor in firms' probability to innovate. This paper is the first to explicitly analyse the effect of variety and different types of innovation cooperation. Within innovation cooperation, a significant and positive effect on innovation activity is confirmed for domestic as well as for international innovation cooperation, for public as well as private cooperation, especially with customers, suppliers and advisors, but not for cooperation with public institutions such as universities and R&D institutes. Innovation cooperation should, thus, be more intensively promoted, especially in countries that lag behind in own R&D spending.

Keywords: innovation cooperation; innovation activity; foreign direct investment; innovation partner; R&D

JEL classification: D2, L2, O3

1. Introduction

Innovation cooperation has become an increasingly prominent feature of firms' innovation activity. It varies from wholly-owned subsidiaries, across various types of equity and non-equity agreements, to transactions, where independent firms engage in arms-length transactions (Narula, 2003). Although R&D continues to be centralised and internalised, and tends to remain at home (Cantwell &Molero, 2003; Narula, 2003), innovation cooperation has proliferated in the last 40 years (Hagedoorn, 2001). The general increase of R&D partnerships has been accompanied by a strong increase in the share of non-equity R&D partnerships from about 20% at the beginning of 1970s to more than 90% in 1998 (Hagedoorn, 2001; Narula, 2003). According to the Community Innovation Survey 2008 (CIS2008), only 14.2% of EU27 firms innovation cooperations in 2006–2008 were cooperations with other firms within the firm group. A survey on innovation activity (CIS2008) shows the dominance of national and, to a lesser extent,

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European partners in innovation cooperation; as much as 56.5% of EU27 firms' innovation cooperations in 2006–2008 were within national boundaries of individual countries and another 26.0% were with partners from other European countries (Eurostat, 2011).

Growing innovation cooperation has been closely related to the process of globalisation, the convergence of consumer preferences, the pace and scope of technological change, the increasing similarity of technologies across countries and the cross-fertilisation of technology between sectors, leading to increasing costs and risks associated with innovation (Narula, 2003; Veugelers, 1997). Once a provisional or transitional step, innovation cooperation has become a core component of corporate innovation strategy. Our empirical study focuses on the heterogeneous effects of different types of innovation cooperation, which is innovative in the literature. The aim of the paper is to estimate the relevance of innovation cooperation for firms' innovation activity. More precisely, the paper attempts to answer the following questions: (i) what is the impact of innovation cooperation on innovation performance? (ii) What are the types of innovation cooperation? And (iii) which innovation partners have the most important impact on firms' innovation performance? Here, we distinguish between vertical cooperation with other firms (suppliers and customers) and horizontal cooperation with competitors, between cooperation with firms and with universities and public research institutions, between international and domestic cooperation, and between cooperation with European firms versus firms from more distant countries.

In our model, we put innovation cooperation in the context of the traditional determinants of a firm's innovation activity, such as own R&D, size and technological characteristics of industry. We expand determinants of innovation activity by examining the role of both inward and outward foreign direct investment (FDI), and by distinguishing between vertical and horizontal innovation cooperation, between domestic and international cooperation, and among different types of cooperating partners. We also study the impact of geographical proximity for innovation cooperation. The relevance of selected determinants of innovation activity and the change in probability to innovate due to innovation cooperation is estimated with probit models and by using firm-level data from Community Innovation Surveys for Slovenia in 1996–2008, firms' financial statements and data on FDI status.

The paper is structured as follows. This introduction is followed by a theoretical framework and empirical evidence about innovation cooperation as a determinant of a firm's innovation performance. Section 3 presents the data, the descriptive statistics and provides the model. Section 4 discusses the results and Section 5 concludes.

2. Theoretical Background, Existing Empirical Evidence And Hypotheses

2.1. *Theoretical concepts*

The underlying theories explaining innovation cooperation are, on the one hand, the transaction costs/internalisation perspective (lowering and/or sharing the costs of R&D activities, new space-shrinking technologies, harmonisation of regulations, liberalisation) and, on the other hand, the organisational capability and technology-based view of the firm (enhancing the value of the firm) (Hagedoorn, 2001; Narula, 2003; Veugelers, 1997). Conceptually, the innovation cooperation phenomenon is best explained within the industrial organisation framework. D'Aspremont and Jacquemin (1988) recognised that relations among firms are seldom of a wholly cooperative or non-cooperative type. They analyse the impact of cooperative and non-cooperative R&D in the framework of a duopoly with spillovers on social welfare. Contrary to expectations, which predict the

reduction of R&D expenditures (less wasteful duplication) and production (more monopoly power) in the case of cooperative R&D, the result is a welfare gain due to R&D spillovers from cooperating firms to the others. The issue of spillovers and cooperation versus non-cooperation in R&D has been further elaborated by Kamien, Muller, and Zang, (1992) and Lahiri (2003). In Kamien, Muller, and Zang (1992), research efforts that precede production are subject to spillovers and a research joint venture that cooperates in its R&D decisions yields the highest consumer plus producer surplus. According to Lahiri (2003), allocation of R&D expenditures on a cooperation component of R&D increases as the spillover rate on the competitive component increases. Thus, the higher the probability of spillovers the higher the motivation for R&D cooperation.

The key issue in explaining innovation cooperation has to do with the explanatory mechanisms related to the firm's choices between internal R&D activities and external sources of R&D, innovation, and technology (Petit & Sanna-Randaccio, 2000; Sanna-Randaccio & Veugelers, 2003; Veugelers, 1997; Veugelers & Cassiman, 1999). The literature on internal, in-house R&D versus external R&D sourcing has too often been concentrated on the choice between the two, 'make' or 'buy', options while – as explicitly pointed by Veugelers (1997), Veugelers and Cassiman (1999) and also recognised by D'Aspremont and Jacquemin (1988) – it is, in fact, the complementarity of the two, and not substitution between the two, that is more in line with the actual situation. This points to the issues of the optimal integration of external knowledge and the adequate absorption capacity of firms using external R&D sourcing, i.e. own R&D activities are needed to efficiently use the external sources of knowledge (Chesbrough, 2006; Cohen & Levinthal, 1990; Kamien & Zang, 2000; Mowery & Rosenberg, 1989; Radnor, 1991; Veugelers & Cassiman, 1999).

2.2. *Empirical evidence*

Own R&D remains a crucial determinant of a firm's innovation capacity but also of its capacity to absorb external knowledge, of its ability to identify, assimilate, and exploit outside knowledge. Along these lines, empirical research on the impact of innovation cooperation on a firm's innovation capacity, as a rule, finds a strong positive relationship between innovation networking and innovation output. Powell and Grodal (2005, pp. 65–68) provide an extensive overview of studies claiming that innovation networking has a positive impact on a firm's innovation activity, yet a systematic study that would evaluate various types of external innovation cooperation simultaneously is lacking. Darby, Zucker, and Wang (2003) report on a positive impact of innovation cooperation on patenting of US firms; Kremp and Mairesse (2004) on a statistically significant and positive impact of French firms alliances for knowledge acquisition on their propensity to innovate; Adams and Mircea (2004) on the increase of innovation by US firms as a result of research joint ventures; Lokshin et al. (2008) that engagement of German firms in partnerships is beneficial for innovative performance and that firms with more diversified external activities (in terms of different types of partners) perform best; Belderbos, Carree, and Lokshin (2004) that cooperation of Dutch firms with competitors, and with universities and research institutes positively affects growth in innovative sales per employee; and Winters and Stam (2007) that innovation networks are positively related to product and process innovation of high technology SMEs. Arvanitis and Bolli (2009) compare the determinants and the effects of innovation cooperation on innovation performance at firm level in Belgium, Germany, Norway, Portugal and Switzerland and

find that international cooperation and cooperation with universities show a significantly positive effect on innovation performance in three out of five countries. Fitjar and Rodriguez-Pose (2011) examine the sources of firm product and process innovation in a large sample of Norwegian firms and find that engagement with external agents is closely related to firm innovation, and that collaboration with extra-regional agents is much more conducive to innovation than collaboration with local partners. Cotič Svetina and Prodan (2008) investigate the contribution of different knowledge sources to innovation performance of a sample of Slovenian firms and claim that firms need to supplement internal knowledge with external knowledge, primarily acquired from firms and institutions in the global environment.

Most of the empirical analyses demonstrate a positive relation, and a mutual reinforcing of internal R&D activities, while also indicating absorption capacity, and external sources of R&D. In other words, it is not only that innovation cooperation stimulates firm's innovation activity but also, vice versa, firm's innovation activity stimulates its innovation cooperation (Powell & Grodal, 2005). The issue has been tackled most comprehensively by Veugelers (1997) and Veugelers and Cassiman (1999) who, based on data for Flamish and Belgium firms, find that firms tend to combine internal and external sources of technology and that R&D cooperation has a significant positive effect on internal R&D only if the companies have sufficient absorptive capacity, i.e. internal R&D. Hou and Mohnen (2011) come to the same conclusion in the case of complementarity between in-house R&D and external technology acquisition in Chinese manufacturing firms. Becker and Dietz (2004) find that the intensity of in-house R&D of German firms stimulates the probability and the number of R&D cooperations with other firms and institutions, while Jiang and Li (2009) (also for German firms), claim that knowledge sharing, knowledge creation and their interaction significantly contribute to partner firms' innovative performance. Similarly, Frenz and Ietto-Gillies (2009) claim that interactions between the own-generation of knowledge by UK firms and external sources increase the innovation potential of enterprises.

Some studies also find no or little evidence for a positive impact of a firm's innovation cooperation on its innovation activity. On a large sample of Dutch SMEs, Kemp, Folkeringa, de Jong, and Wubben (2003) find no significant effect of innovation cooperation on innovation activity. The same goes for Janz, Lööf, and Peters (2003) in the case of the impact of innovation cooperation of German and Swedish innovative firms on their innovation output. On a large sample of Spanish manufacturing firms, Vega-Jurado, Gutierrez-Garcia, Fernandez-de-Lucio, and Manjarres-Henriquez (2008) suggest that the higher the firm's own technological competencies the less important are technological opportunities deriving from non-industry agents. Results of the analysis of UK enterprises by Frenz and Ietto-Gillies (2009) suggest that, while intra-company knowledge sources, own-generation, and bought-in R&D matter in innovation performance, the benefits of joint innovation efforts in the form of cooperation are less clear.

The impact of innovation cooperation on a firm's innovation performance depends on the firms' characteristics and may differ by the type of cooperation and partners. Distance and similarity among partners may also play a role. A systematic study on impact by types of cooperation and types of partners does not exist; however, the existing literature suggests that: (i) vertical cooperation with suppliers and customers may be more efficient than horizontal cooperation with competitors (Arranz & Fernandez de Arroyabe, 2008; Fitjar & Rodriguez-Pose, 2011; Janz, Lööf, & Peters, 2003; Miotti & Sachwald, 2003); (ii) cooperation with universities and public research institutions may be as useful, sometimes even more useful, than cooperation with firms (Arvanitis &

Bolli, 2009; Ayari, 2010; Belderbos, Carree, Diesderen, Lokshin, & Veugelers, 2004; Bercovitz & Feldman, 2007; Fabrizio, 2009; Fitjar & Rodriguez-Pose, 2011); (iii) the extent of innovation cooperation tends to rise as geographical distance falls (Cantwell & Molero, 2003), but evidence about cooperation with domestic versus international partners is mixed. Vinding (2002) claims that domestic partners tend to have greater positive impact on innovative performance than foreign partners, while Arvanitis and Bolli (2009), Miotti and Sachwald (2003), Lööf (2009), and Fitjar and Rodriguez-Pose (2011) claim the opposite. Finally, it seems that firms may profit from multiple ties in innovation cooperation.

2.3. Research hypotheses

Based on the literature review above, the hypotheses to be tested in our empirical model are the following.

- Innovation cooperation has a positive impact on innovation performance of Slovenian firms.
- Vertical cooperation with other firms (suppliers and customers) has a stronger impact on innovation performance than horizontal cooperation with competitors.
- Innovation cooperation with firms has a more positive impact on innovation performance than cooperation with universities and public research institutions.
- International cooperation has a more positive impact than domestic cooperation.
- Innovation cooperation with European firms has stronger effects than cooperation with firms from more distant countries.

Innovation cooperation explored by varieties of partners as a determinant of Slovenian firms' innovation performance will be tested in the model, which contains all the standard determinants of firm's innovation activity. We will include own R&D, as a crucial determinant of firm's innovation activity/capacity and of its capacity to absorb external knowledge (Cohen & Levinthal, 1989) but also other standard explanatory variables of a firm's innovation activity, such as a firm's size, internationalisation and market position (export intensity, inward and outward FDI) and industry characteristics.[1]

3. Data, descriptives and model specification

This paper empirically tests the importance of innovation cooperation for Slovenian firms' innovation activity and examines whether the type of cooperation and partner matter. The model takes into account all standard innovation activity determinants, expands them to examine the role of inward and outward FDI, and pays special attention to innovation cooperation and its varieties. Existing empirical evidence of Slovenian firms' innovation activity confirms the importance of the main standard explanatory determinants, i.e. innovative firms are likely to be larger and to invest much more in R&D, and they are more inclined to export and are more likely to be foreign-owned. The innovation activity of firms is also persistent over time (Damijan, Jaklič, & Rojec, 2006).

Our empirical analysis combines three firm-level data sources: Community Innovation Surveys (CIS) conducted by the Slovenian Statistical Office (SORS) from 1996 to 2008, financial statements collected by Agency of the Republic of Slovenia for Public Legal Records and Related Services (AJPES), and information on FDI status (parent company or foreign affiliate) provided by the Bank of Slovenia.[2] With above EU

average level of innovation cooperation and below EU average level of innovation activity, the case of Slovenia is particularly appropriate for examination. According to CIS 2008, 39.5% of Slovenian firms make some kind of technological innovation (later referred to as 'innovative firms'), which is at par with the EU27 average of 40.4%, while 53.4% of Slovenian innovative firms are involved in external innovation cooperation, as compared with 30.1% EU27 average (Table 1).

Data on innovation cooperation of Slovenian firms are available from seven CIS surveys from 1996, 1998, 2000, 2002, 2004, 2006 and 2008. In 2000–2008, the fraction of innovative firms engaged in any type of external innovation cooperation increased from 43.4% to 53.4%. The density of innovation cooperation exhibits a much stronger upward trend; i.e. the number of various types of cooperation per cooperating firm increased from 1.68 in 1996 to as much as 3.79 in 2008, compared with the 2.77 EU27 average in 2008.

We classify innovation cooperation partners along three different dimensions: (i) cooperation with public and private entities, where the frequency of the latter clearly dominates; (ii) cooperation with domestic, international or both types of partners, where domestic cooperation is more frequent than international, but the difference is not very high; and (iii) cooperation with specific types of innovation partners. Here, the most

Table 1. Innovation activity and innovation cooperation by type of partners of Slovenian firms in 1996–2008 and EU27 firms in 2008.

	Slovenia							EU27
	1996	1998	2000	2002	2004	2006	2008	2008
Number of firms in the CIS	1398	1708	2438	2535	2103	2185	2277	
Innovative firms* as % of all surveyed firms	22.2	23.1	20.8	20.5	29.2	39.2	39.5	40.4
% of innovative firms engaged in innovation cooperation	44.7	45.7	43.4	44.0	52.1	52.3	53.4	30.1
% of innovative firms engaged in innovation cooperation with**:								
1a) Public entities	24.4	n.a.	28.8	26.9	26.9	28.7	29.6	n.a.
1b) Private entities	35.4	n.a.	60.2	44.4	49.3	55.8	52.8	n.a.
2a) Domestic entities	42.1	n.a.	56.6	42.7	45.9	51.1	49.8	n.a.
2c) International entities	16.7	n.a.	39.6	31.0	37.6	46.0	44.0	n.a.
3a) Suppliers of equipment, materials, components,software	15.4	n.a.	30.6	23.5	41.0	48.2	46.1	18.4
3b) Clients or customers	6.8	n.a.	35.5	26.5	34.4	42.3	41.0	17.2
3c) Competitors or other firms of the same sector	0.6	n.a.	9.7	6.9	22.1	27.8	28.1	8.6
3d) Other firms	19.6	n.a.	10.8	20.8	19.2	23.0	24.8	11.9
3e) Consultants, commercial labs, or private R&D institutes	10.3	n.a.	28.0	21.7	22.8	26.5	28.8	10.4
3f) Universities or other higher education institutions	12.5	n.a.	23.7	21.0	24.0	27.7	28.1	10.6
3 g) Government or public research institutes	16.4	n.a.	15.8	14.4	14.7	17.9	20.6	6.4
Innovation cooperation density***	1.68	n.a.	2.35	2.85	3.51	3.68	3.79	2.77

Notes:
*Firms with any kind of technological innovation.
**Innovation cooperation partners are classified along three dimensions.
***Average number of types of cooperation partners per cooperating firm.
Source: SORS, Eurostat, http://epp.eurostat.ec.europa.eu/portal/page/portal/science_technology_innovation/data/database.

frequent cooperation is cooperation with suppliers and clients, followed far behind by competitors, consultants, commercial labs and universities, and other firms. Finally there are government or public research institutes (see Table 1). From CIS 2000 onwards, cooperation partners are further distinguished by geographical location. On average in 2000–2008, 31.8% of innovative firms claim to have innovation cooperation with domestic partners, 12.0% with European partners, 5.3% with US partners and 5.9% with partners from other countries. As expected, the frequency of innovation cooperation falls with distance.

Since our data come from a panel of firms in several time periods, the dependent variable is equal to 1 if a firm has made any innovation of products (services) or production processes in period t, and 0 otherwise. Explanatory variables include firms' characteristics discussed in previous chapters and some control variables, which are:

- a dummy for previous innovation activity (using innovation information from preceding CISs),
- capital intensity (capital per employee),
- skill intensity or human capital (wages per employee)
- relative productivity (firm's value added per employee relative to average productivity of the particular sector (three-digit level), 'rval'),
- share of R&D expenditures in total sales (R&D intensity),
- size of R&D department (R&D staff),
- export propensity (export revenues in total revenues),
- dummy for foreign ownership (foreign affiliate, inward FDI),
- dummy for direct investment abroad (parent enterprise, outward FDI),
- dummy variable for innovation cooperation, baseline being no innovation cooperation,
- dummy variables that disaggregate innovation cooperation on:
  ○ public, private, or both; baseline being no innovation cooperation,
  ○ domestic, international, or both, baseline being no innovation cooperation,
- dummy variables for technological and knowledge intensity of sectors in which firms operate. The OECD (2005) classification (NACE Rev. 1.1.) of technology and knowledge intensive sector is used: high, medium-high, medium-low, and low technology for manufacturing and knowledge-intensive and less-knowledge-intensive for services[3] (baseline for all categories are utilities and construction industries, which account for almost 5% of the sample). For completeness, a dummy for natural resources industries (Agriculture, hunting and forestry; Fishing; Mining and quarrying) is also included,
- dummy variables for specific geographic location of the partner: domestic, European, USA, other countries (various baselines),
- dummy variables for specific type of partner: suppliers, customers, competitors, advisors universities, government, and other partners (various baselines).

Since the innovation cooperation questions always span the period of two previous years, averages of all variables are taken over these years for each CIS variable that is not year specific.[4]

In modelling a binary response, one can use a linear or a nonlinear model. In the first case, we are dealing with a linear probability model (LPM) and in the second, with either a logit or probit model. There are several disadvantages to using a LPM, namely that errors are heteroscedastic by construction, that it can predict probabilities out of the

[0,1] interval and that probability is linearly related to continuous variables for all values. Probit and logit solve these issues, which is why we concentrate on a non-linear model, and only use the linear one in case of robustness cheques and fixed effects.

We can set up a non-linear latent variable model as in equation (1), where the latent variable y^* captures a binary occurrence whether a firm innovates or not, either in terms of one of its products, services or processes, dependent on some explanatory variables. The choice rule for innovation is $y = 1$ when $y^* > 0$ ($e > -x'\beta$) and $y = 0$ when $y^* \leq 0$ ($e \leq -x'\beta$).

$$Y^* = \beta_0 + \beta_1 x_1 + \cdots + \beta_n x_n + e = x'\beta + e \tag{1}$$

We then make an assumption that the error term e has a normal distribution resulting in probit. We can write the probability of a firm innovating as in equation (2), where we exploit the symmetry of the cumulative distribution function $\Phi(e)$, which is the integral of the probability density function $\phi(e)$

$$\Pr(y = 1|x) = \Pr(y^* > 0|x) = \Pr(e > x'\beta) = 1 - \Phi(-x\beta) = \Phi(x'\beta) \tag{2}$$

The marginal effect of a change in an explanatory variable x_j on the probability to innovate can then be written as in equation (3), where we evaluate the probability density function $\phi(x'\beta)$ at the averages of all explanatory variables.

$$\frac{\partial \Pr(y = 1|x)}{\partial x_j} = \frac{\partial \Phi(x'\beta)}{\partial x_j} = \phi(x'\beta)\beta_j \tag{3}$$

However, equation (3) for the marginal effect does not hold for non-linear terms, where β_j would then have to be replaced with $\beta_j + 2\beta_j x_j$ for the case of a quadratic term x_j^2, and equivalently for higher orders. More importantly, it cannot be used to interpret nor test the marginal effects of interaction terms, which is very frequently overlooked in the literature. Norton, Wang, and Ai (2004) show with simple derivations how the marginal effect on the interaction term in non-linear models is not simply the reported coefficient, which can easily be of a different sign and/or even insignificant (or zero), compared with the true marginal effect. The problem can persist even when using the odds ratio or incidence-rate ratios, although Buis (2010) claims that the interaction can be used in this case, with the caveat that the multiplicative effect is different from the marginal effect, that is, the multiplicative effect controls for the difference between the groups in the baseline odds, while the marginal effect does not. We are careful with the estimation of the innovation cooperation dummy interaction terms (public and private, domestic and international) and use the Norton, Wang, and Ai (2004) method for calculating the average interaction effect, but in robustness cheques also include the odds ratio method for comparison.

Although most innovation surveys (including other CIS surveys across Europe) in the literature suffer from sample selection bias, as only firms with innovation activity are surveyed, this does not represent an obstacle with our data. The data we are using cover a sample of both innovative and non-innovative firms, in fact only around 30% of the firms in our total sample innovate. Thus, the data offer a unique opportunity to evaluate the heterogeneity of innovation cooperation and its impact on innovation performance and, as opposed to other innovation surveys, we do not need to employ sample selection procedures such as the Heckman method, since we have firms that innovate and firms that do not innovate in our sample.

4. Results

The results of probit estimations based on firm-level data for Slovenian manufacturing and non-manufacturing firms in the period 1996–2008 are given in Table 2, where all the coefficients are already reported as marginal effects, and all regressions include time fixed effects. Regressions (1) and (2) do not yet disaggregate innovation cooperation on different types, while regressions (3) and (4) use the domestic versus international disaggregation, and regressions (5) and (6) public versus private disaggregation. In all three sets of regressions we run the regression on the maximum available number of observations that still include innovation cooperation, and then on a subsample where three additional variables can be included: innovation in the previous period, R&D as a share of sales, and R&D employees. When these three variables are included, both past innovation and the number of people working in the R&D unit affect the probability to innovate positively and are significant, as expected, whereas R&D as a share of sales is mostly significant or bordering on significance. The number of available observations decreases from more than 6000 to 2000 when these variables are included, therefore our interpretation concentrates more on the estimations based on the larger sample.

In practically all estimations, capital per employee, wage and relative VA per employee are not confirmed as significant predictors of innovation activity. On the other hand, all three variables of firm internationalisation are significant, as export intensity and outgoing FDI affects innovation activity positively, while incoming FDI negatively. Outward FDI with own subsidiaries abroad brings the proximity of foreign customers and competitors, which may stimulate innovation. On the other hand, being a foreign subsidiary, i.e. a part of a multinational enterprise (MNE) per se does not predict higher innovation activity, in fact quite the opposite. This points to the type of foreign subsidiaries prevailing in Slovenia, which are rarely competence centres or innovation units (see Majcen, Rojec, Jaklič, & Radošević, 2005). In terms of sectoral technological intensity, firms from high- and medium-high tech manufacturing sectors are the most likely to innovate, while the natural resources sector and sectors of services that are less knowledge intensive are least likely to innovate.

Our variables of interest are those on innovation cooperation, the first one being in regression (1). Judging on the full sample, the firms that cooperate in innovation, have a whopping and statistically significantly higher probability to innovate, namely, those firms are almost 80% more likely to innovate than the firms that do not cooperate. Since both innovative and non-innovative firms fill in all the parts of the survey, although it must be noted that, intuitively, firms that do cooperate on innovation would be more likely to innovate, this should not be taken for granted and should be empirically corroborated, as our results imply that this positive relationship is still far from linear, implying there is variation left to be explained. We continue with our empirical focus on the heterogeneous effects of different types of innovation cooperation, which is more interesting as well as innovative in the literature.

It is also important to note that it is not completely straightforward to disaggregate innovation cooperation on different types, as the baseline category has to be the constant. This implies that in the disaggregation on domestic and international (or public and private), another category has to be added, which is domestic interacting with international (or public interacting with private), with the baseline being no cooperation, which can be seen in regressions (3) and (4). This requests the introduction of a special code to estimate the interaction, and there can be only one interaction per regression. The new estimate is thus an average of estimates for all observations and has no single

Table 2. Estimation of innovation cooperation, total and disaggregated.

Dep. var: innovation	(1) baseline	(2) baseline plus	(3) domestic and international	(4) domestic and international	(5) public and private	(6) public and private
Innovation in previous period		0.149* (0.080)		0.136* (0.080)		0.152* (0.082)
R&D as a share of sales		14.034* (8.203)		12.615 (7.951)		14.449* (8.473)
R&D employees		0.017*** (0.003)		0.015*** (0.002)		0.017*** (0.003)
Capital per employee	−0.000 (0.000)	−0.000 (0.000)	0.000 (0.000)	−0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Wage	0.000 (0.000)	0.000 (0.000)	−0.000 (0.000)	0.000 (0.000)	−0.000 (0.000)	0.000 (0.000)
Relative VA per employee	0.004 (0.005)	0.002 (0.011)	0.005 (0.003)	0.001 (0.009)	0.006* (0.004)	−0.000 (0.009)
Exports as a share of sales	0.148*** (0.033)	0.074 (0.057)	0.074*** (0.024)	0.058 (0.052)	0.084*** (0.026)	0.077 (0.059)
Incoming FDI	−0.061** (0.030)	−0.026 (0.041)	−0.046** (0.023)	−0.029 (0.039)	−0.048* (0.024)	−0.022 (0.039)
Outgoing FDI	0.194*** (0.023)	0.024 (0.033)	0.095*** (0.015)	0.018 (0.030)	0.100*** (0.016)	0.030 (0.033)
Innovation cooperation	0.790*** (0.012)	0.369** (0.178)				
OECDhightech	0.236*** (0.047)	0.003 (0.101)	0.116*** (0.023)	−0.004 (0.094)	0.121*** (0.026)	−0.013 (0.108)
OECDmedhightech	0.253*** (0.037)	0.094 (0.077)	0.122*** (0.024)	0.081 (0.071)	0.127*** (0.027)	0.088 (0.076)
OECDmedlowtech	0.127*** (0.039)	0.087 (0.071)	0.065** (0.029)	0.076 (0.065)	0.065** (0.032)	0.082 (0.070)
OECDlowtech	0.127*** (0.038)	0.082 (0.075)	0.060** (0.029)	0.073 (0.068)	0.062* (0.032)	0.077 (0.074)
OECDkonwledgeintensive	0.119*** (0.037)	0.030 (0.072)	0.071*** (0.027)	0.024 (0.064)	0.072** (0.031)	0.020 (0.073)

OECDkonwledgelessintensive	−0.086**	−0.001	−0.048	−0.002	−0.056	−0.014
	(0.038)	(0.075)	(0.037)	(0.066)	(0.040)	(0.075)
OECDnaturalresources	0.194	0.171	0.058	0.145	0.060	0.176
	(0.122)	(0.107)	(0.080)	(0.099)	(0.088)	(0.110)
Domestic/private			0.388***	0.281*	0.404***	0.377**
			(0.024)	(0.160)	(0.021)	(0.185)
International/public			0.334***	0.481**	0.313***	0.214
			(0.031)	(0.191)	(0.031)	(0.138)
Domestic_intern/ private_public			−0.422	−0.596	−0.435	−0.370
Observations	6,239	2,081	5,474	2,081	5,275	2,058
Time FE	YES	YES	YES	YES	YES	YES
R^2 Pseudo	0.538	0.644	0.592	0.647	0.588	0.642

Notes: Robust standard errors in parentheses.
***$p<0.01$; **$p<0.05$; *$p<0.1$; Product, service and process innovations are treated equally.
Source: Own calculations based on SORS.

standard error, as its significance varies from observation to observation. Nevertheless, even if we take the average interaction effect, which reduces the combined effect of both types of innovation cooperation disaggregation, the total effect is still positive. In terms of which type of cooperation is more important, domestic cooperation is more salient than international cooperation, and private cooperation is much more important than public cooperation.

Although types of partners cannot be simply included in the regressions and estimated, due to technical limitations, as with for instance three types of partners (1,2,3), there are already eight unique categories ({1},{2},{3},{1,2},{2,3},{1,3},{1,2,3},{Ø}) or four interaction dummies to be estimated, which becomes technically increasingly nuanced, difficult to compare and interpret. Thus, for the inclusion of specific types of cooperation partners and specific geographical location of partners, we simply include the dummies and not the interactions, so we can only get a general idea of the importance of each factor, as the baseline then varies from dummy to dummy, and the coefficients are not directly comparable amongst each other, or, when they are compared, the comparisons are only indicative.

Table 3 shows only the variables of interest in the regressions where specific types of partners are included. There are two types of more specific disaggregation shown, both on the entire sample as well as on the reduced sample, when additional controls

Table 3.   Innovation cooperation partners.

	(1) Large sample	(2) Small sample	(3) Large sample	(4) Small sample
Suppliers	0.089***	0.220***		
	(0.020)	(0.032)		
Customers	0.187***	0.234***		
	(0.021)	(0.033)		
Competitors	−0.262***	−0.101*		
	(0.025)	(0.054)		
Advisors	0.137***	0.176***		
	(0.023)	(0.034)		
Universities	0.025	0.041		
	(0.023)	(0.036)		
Government	0.019	0.047		
	(0.026)	(0.040)		
Other partners	0.051**	0.184***		
	(0.020)	(0.032)		
Domestic			0.291***	0.425***
			(0.019)	(0.112)
European			0.189***	0.394***
			(0.020)	(0.113)
USA			−0.137	
			(0.170)	
Other countries			−0.143	
			(0.190)	
Observations	5,058	2,036	5,173	2,025
Time FE	YES	YES	YES	YES
R^2 Pseudo	0.525	0.499	0.594	0.625

Notes: Robust standard errors in parentheses.
*** $p<0.01$; ** $p<0.05$; * $p<0.1$.
Source: Own calculations based on SORS.

Table 4. Robustness cheques.

	(1) Baseline	(2) Domestic and international	(3) Public and private	(4) Baseline	(5) Domestic and international	(6) Public and private
Innovation cooperation	199.918*** (49.281)			0.514*** (0.021)		
Domestic/private		65.800*** (18.617)	77.562*** (22.992)		0.349*** (0.022)	0.388*** (0.013)
International/public		58.657*** (28.758)	47.740*** (33.211)		0.277*** (0.031)	0.493*** (0.037)
Domestic_intern/ private_public		0.019*** (0.012)	0.019*** (0.015)		−0.432*** (0.038)	−0.598*** (0.040)
Observations	6,239	5,474	5,275	6,239	5,474	5,275
Time FE	YES	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	YES	YES	YES
R^2 Pseudo	0.540	0.607	0.603	0.377	0.377	0.377
Number of id				3,845	3,108	3,061

Notes: Robust standard errors in parentheses.
***$p<0.01$; **$p<0.05$; *$p<0.1$.
Source: Own calculations based on SORS.

are included. The first type is based on the nature of the partner, and the second one based on the location of the partner. In terms of partners, the partners that increase the probability of a firm to innovate the most are customers. In addition, cooperating with suppliers and advisors has a positive and significant effect on innovation, but we do not detect a significant effect of cooperation of either with universities or with government. Also, cooperation with competitors seems to impede innovation activity. The second type of disaggregation based on location confirms previous results, which are that domestic cooperation is more important than international, and that cooperating with European partners has a significant and positive effect on the probability to innovate, while cooperation with the US or other countries does not affect innovation significantly.

Finally, endogeneity issues and robustness cheques must be taken into account. We explicitly address two possible sources of a bias on our coefficients for external cooperation. There might be a contemporaneous feedback effect from innovation activity to innovation cooperation, as more innovation might lead to a company being open to more innovation cooperation. This is tested using the lags of the right-hand variables which, at the very least, circumvent the contemporaneous endogeneity. The results do not deviate much from the baseline results and are not reported in the interest of space. Continuing the technical debate in the paper on how to correctly estimate interactions in a probit, Table 4 offers some robustness checks for our main results, as well as estimations with firm fixed effects, additionally controlling for all endogeneity sources arising from firm specificities constant in time. Again, in the interest of space, we only report the coefficients of interest. We use the odds ratio specification in regressions (1)–(3), and the within-estimation in regressions (4)–(6). With the odds estimation, a value of above one corresponds to a positive marginal effect of that factor, while a value of below one corresponds to a negative effect of that factor. Firstly, innovation cooperation is a very salient factor in innovation activity. Moreover, the Buis (2010) method corroborates our previous results, as domestic innovation cooperation has a higher impact than international, and private a higher impact than public. In both cases, the interactions, as before, reduce the combined effect. In the following three regressions we also control for firm specific effects, and thus use a linear probability model, which is more suitable for the inclusion of fixed effects. The partial coefficients confirm our previous results in terms of the importance of innovation cooperation, and confirm our previous results in terms of domestic cooperation being more important than international. However, there is a change in public versus private cooperation disaggregation; as with firm fixed effects, public cooperation seems to have a larger effect than private cooperation. Whether this is a statistical artefact or in fact a consequence of the inclusion of firm fixed effects should be further examined.

4.   Conclusions

Innovation cooperation has become an increasingly prominent feature of firms' innovation activity. The aim of the paper is to estimate the relevance of various types of innovation cooperation of Slovenian firms on their innovation activity. Using firm-level data on innovation activity, combined with financial data and data on foreign versus domestic ownership for a large sample of Slovenian firms in 1996–2008, we arrive at several interesting findings.

First, probit estimates reveal that overall innovation cooperation is, next to R&D spending, the most important predictor of firms' innovation activity. Second, other

significant determinants with a positive impact on firms' innovation activity are R&D personnel, innovation activity in the past and both outward FDI and export intensity. Inward FDI, i.e. being a foreign subsidiary per se does not predict higher innovation activity, but even reduces it. This points to the type of foreign subsidiaries prevailing in Slovenia, which are rarely competence centres or innovation units. Third, within innovation cooperation, a significant and positive impact on innovation activity is confirmed for domestic as well as for international innovation cooperation, especially with EU partners. Cooperation with domestic partners is however more salient than with foreign partners. Fourth, cooperation with partners from the private sector, especially with customers, suppliers and advisors, is more important than cooperation with partners from the public sector (such as universities and R&D institutes).

The positive impact of innovation cooperation on innovation activity suggests that the potential of innovation cooperation should be better exploited, especially in countries that lag behind in R&D spending and have less developed national innovation systems There are many challenges of how to improve the effects of innovation cooperation, for national innovation systems, public universities and institutes and enterprises themselves, because domestic partners are of vital importance for innovation performance. Strengthening the number and varieties of partners as well as capacities of firms to cooperate are important and may be enhanced through education. The results show that universities and public research institutions may improve as partners in innovation cooperation, and that innovation performance increases with the variety of innovation partners. Established cooperation in home countries leads to better international cooperation and performance. Innovation cooperation thus needs strategic and learning processes. This puts forward a request for further research that would explore the determinants and impact of international innovation cooperation in greater detail. Knowing firm level determinants, obstacles and the effects of innovation cooperation would help recognise the most frequent risks and so build more efficient innovation strategies. The external (outside firm) determinants of innovation cooperation are also worth exploring to adjust policy measures.

Funding

Notes

1. See Veugelers and Cassiman (1999) for a detailed discussion on explanatory variables of firm's innovation activity. For the impact of multinationality (multinational versus other enterprises) and foreign versus domestic ownership see also Sanna-Randaccio and Veugelers (2003) and Cantwell and Molero (2003).
2. Data availability varies from one source to another. In merging the three databases 1290 observations out of 15,934 were dropped (8%) due to a failure to match.
3. Two digit NACE is used for aggregation.
4. Due to space limitations summary statistics of firm level data are not included in the text. It is available at upon request.

References

Adams, J. D., & Mircea, M. (2004). *R&D sourcing, joint ventures and innovation: A multiple indicators approach* (Working Paper 10474). Cambridge, MA: National Bureau of Economic Research.

Arranz, N., & Fernandez de Arroyabe, J. C. (2008). The choice of partners in R&D cooperation: An empirical analysis of Spanish firms. *Technovation, 28*, 88–100.

Arvanitis, S., & Bolli, T. (2009). *A Comparison of firm-level innovation cooperation in five European countries* (Working Papers No. 232). ETH Zürich: KOF.

Ayari, N. (2010). *Internal capabilities, R&D cooperation with universities and firms' innovativeness level: Evidence from Spain*. (Working Paper No. 07/2010). Pamplona: Universidad de Navarra.

Becker, W., & Dietz, J. (2004). R&D cooperation and innovation activities of firms – Evidence for the German manufacturing industry. *Research Policy, 33*, 209–223.

Belderbos, R., Carree, M., Diesderen, B., Lokshin, B., & Veugelers, R. (2004). Heterogeneity in R&D cooperation strategies. *International Journal of Industrial Organization, 22*, 1237–1263.

Belderbos, R., Carree, M., & Lokshin, B. (2004). Co-operative R&D and firm performance. *Research Policy, 33*, 1477–1492.

Bercovitz, J., & Feldman, M. (2007). Fishing upstream: Firm innovation strategy and university research alliances. *Research Policy, 36*, 930–948.

Buis, M. L. (2010). Stata tip 87: Interpretation of interactions in nonlinear models. *Stata Journal, 10*, 305–308.

Cantwell, J., & Molero, J. (2003). Introduction. In J. Cantwell & J. Molero (Eds.), *Multinational enterprises innovative strategies and systems of innovation* (pp. 1–14). Cheltenham: Edward Elgar.

Chesbrough, H. (2006). Open innovation: A new paradigm for understanding industrial innovation. In H. Chesbrough, W. Vanhaverbeke, & J. West (Eds.), *Open innovation: Researching a new paradigm* (pp. 1–12). Oxford: Oxford University Press.

Cohen, W., & Levinthal, D. (1989). Innovation and learning: The two faces of R&D. *Economic Journal, 99*, 569–596.

Cohen, W., & Levinthal, D. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly, 35*, 128–152.

Cotič Svetina, A., & Prodan, I. (2008). How internal and external sources of knowledge contribute to firms' innovation performance. *Managing Global Transitions, 6*, 277–299.

Damijan, J. P., Jaklič, A., & Rojec, M. (2006). Do external knowledge spillovers induce firms' innovations? Evidence from Slovenia. In A. T. Tavares & A. Teixeira (Eds.), *Multinationals, clusters and innovation: Does public policy matter?* (pp. 27–47). Basingstoke: Palgrave MacMillan.

Darby, M. R., Zucker, L. G., & Wang, A. (2003). *Universities, joint ventures and success in the advanced technology program* (Working Paper 9463). Cambridge, MA: National Bureau of Economic Research.

D'Aspremont, C., & Jacquemin, A. (1988). Cooperative and noncooperative R&D on duopoly with spillovers. *American Economic Review, 78*, 1133–1137.

Eurostat. (2011). *Science, technology and innovation in Europe*, 2011 edition. Luxembourg: Publications Office of the European Union.

Fabrizio, K. R. (2009). Absorptive capacity and the search for innovation. *Research Policy, 38*, 255–267.

Fitjar, R. D., & Rodriguez-Pose, A. (2011). *Firm collaboration and modes of innovation in Norway* (Discussion Paper No. DP8484). London: Centre for Economic Policy Research.

Frenz, M., & Ietto-Gillies, G. (2009). The impact on innovation performance of different sources of knowledge: Evidence from the UK Community Innovation Survey. *Research Policy, 38*, 1125–1135.

Hagedoorn, J. (2001, August). *Inter-firm R&D partnership – An overview of major trends and patterns since 1960*. Strategic research partnerships: Proceedings from a National Science Foundation Workshop, Arlington, VA. http://www.nsf.gov./statistics/nsf01336/p1s3.htm

Hou, J., & Mohnen, P. (2011). *Complementarity between in-house R&D and technology purchasing: Evidence from Chinese manufacturing firms* (Working Paper Series 2011-048). Maastricht: UNU-MERIT.

Janz, N., Lööf, H., & Peters, B. (2003). *Firm level innovation and productivity – Is there a common story across countries?* (Working Paper 03-26). Mannheim: ZEW.

Jiang, X., & Li, Y. (2009). An empirical investigation of knowledge management and innovative performance: The case of alliances. *Research Policy, 38*, 358–368.

Kamien, M. I., Muller, E., & Zang, I. (1992). Research joint ventures and R&D cartels. *American Economic Review, 82*, 1293–1306.

Kamien, M. I., & Zang, I. (2000). Meet me halfway: Research joint ventures and absorptive capacity. *International Journal of Industrial Organization, 18*, 995–1012.

Kemp, R. M. G., Folkeringa, M., de Jong, J. P. J., & Wubben, E. F. M. (2003). *Innovation and firm performance* (Research Report H2000207). Zoetermeer: SCALES.

Kremp, E., & Mairesse, J. (2004). *Knowledge management, innovation and productivity* (Working Paper 10237). Cambridge, MA: National Bureau of Economic Research.

Lahiri, R. (2003). *Cooperation v/s non-cooperation in R&D competition with Spillovers* (Discussion Papers and Working Papers Series 166). School of Economics and Finance, Queensland University of Technology.

Lokshin, B., Belderbos, R., & Carree, M. (2008). The productivity effects of internal and external R&D: Evidence from a dynamic panel data model. *Oxford Bulletin of Economics and Statistics, 70*, 399–413.

Lööf, H. (2009). Multinational enterprises and innovation: Firm level evidence on spillover via R&D collaboration. *Journal of Evolutionary Economics, 19*, 41–71.

Majcen, B., Rojec, M., Jaklič, A., & Radošević, S. (2005). Productivity growth and functional upgrading in foreign subsidiaries in the Slovenian manufacturing sector. *East-West Series in Economic and Business Environment, 8*, 73–100.

Miotti, L., & Sachwald, F. (2003). Cooperative R&D: Why and with whom? An integrated framework of analysis. *Research Policy, 32*, 1481–1499.

Mowery, D., & Rosenberg, N. (1989). *Technology and the pursuit of economic growth*. Cambridge: Cambridge University Press.

Narula, R. (2003). Understanding the growth of international R&D alliances. In J. Cantwell & J. Molero (Eds.), *Multinational enterprises, innovative strategies and systems of innovation* (pp. 129–152). Cheltenham: Edward Elgar.

Norton, E. C., Wang, H., & Ai, C. (2004). Computing interaction effects and standard errors in logit and probit models. *Stata Journal, 4*, 154–167.

Organisation for Economic Co-Operation and Development. (2005). *OECD science, technology and industry scoreboard 2005*. Paris: Author.

Petit, M. L., & Sanna-Randaccio, F. (2000). Endogenous R&D and foreign direct investment in international oligopolies. *International Journal of Industrial Organization, 18*, 339–367.

Powell, W. W., & Grodal, S. (2005). Networks of innovators. In J. Fegerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The oxford handbook of innovation* (pp. 56–85). Oxford: Oxford University Press.

Radnor, M. (1991). Technology acquisition strategies and processes: A reconsideration of the make versus buy decision. *International Journal of Technology Management, 7*, 113–135.

Sanna-Randaccio, F., & Veugelers, R. (2003). Global innovation strategies of MNEs: Implications for host economies. In J. Cantwell & J. Molero (Eds.), *Multinational enterprises, innovative strategies and systems of innovation* (pp. 14–46). Cheltenham: Edward Elgar.

Vega-Jurado, J., Gutierrez-Garcia, A., Fernandez-de-Lucio, I., & Manjarres-Henriquez, L. (2008). The effect of external and internal factors on firms' product innovation. *Research Policy, 37*, 616–632.

Veugelers, R. (1997). Internal R&D expenditures and external technology sourcing. *Research Policy, 26*, 303–315.

Veugelers, R., & Cassiman, B. (1999). Make and buy in innovation strategies: Evidence from Belgian manufacturing firms. *Research Policy, 28*, 63–80.

Vinding, A. L. (2002). *Interorganizational diffusion and transformation of knowledge in the process of product innovation* (PhD thesis). Aalborg: Department of Business Studies, Aalborg University.

Winters, R., & Stam, E. (2007). *Innovation networks of high tech SMEs: Creation of knowledge but no creation of value* (Economic Research papers 2007–042). Jena: Friedrich Schiller University and Max Planck Institute of Economics.