Cooperative research and firm performance

work in progress

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Abstract

The aim of this paper is to provide a microeconometric analysis of the impact of research joint venture participation on productivity, using a large panel of around 4000 firms. The findings of the theoretical literature on this topic are ambiguous and there are very few empirical papers analyzing this problem. I find weak evidence that participation in research consortia increases productivity in the USA and Japan while it does not have any effect in Europe.

Keywords: research joint ventures, firm performance, productivity

JEL classification: O320, L110, D240

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1 Introduction

With the opening of the world economy and increasing competition firms develop new strategies. One main element of the changing strategy is networking. Firms engage in cooperative agreements not only with their suppliers and customers but also with their direct competitors. This cooperation occurs in different fields including the distribution, production and research and development phases. The motives of cooperation are summarized by Mariti and Smiley (1983), Harrigan (1985), Porter and Fuller (1886), Contractor and Lorange (1988) and Haagedorn and Schakenraad (1991). The following list shows their findings[1]:

-sharing costs/risks;

-access to partners know-how/markets/products;

-efficiency enhancements (economies of scale in production/distribution/R&D, synergy effects from exchanging/sharing complementary know-how);

-competitive considerations (influence other alliance activities, monitor/control partner's technology/markets/products, influence competitive structure);

-government policy (subsidies for cooperation, local content, anti-trust).

This paper focuses on cooperation in research and development. The importance of research alliances is acknowledged by government policy in many countries. They grant exemption from anti-trust law to research joint ventures (RJVs) and encourage their formation by subsidies.

In the USA the National Cooperative Research Act (1984) and the National Cooperative Research and Production Act (1993) guarantee that every research alliance filed at the Federal Register is evaluated separately if they fail to fulfill antitrust laws. To encourage joint research the Clinton administration increased the budget of the Advanced Technology Program which funds collaborative research projects from the private sector (Branstetter and Sakakibara, 1998).

In Europe Article 81(3) (former 85(3)) of the EC treaty allows the EC Commission to exempt research alliances from Article 81(1) (which prohibits restrictive practices between firms which may affect the trade between the member states or the competition within the EC). In 1985 the Commission granted a 13-year block exemption to certain categories of R&D agreements. Moreover, it allows the joint exploitation of the results of that R&D. This exemption is for five years (if the participants are not direct competitors or if they are competitors but the sum of their market shares is less twenty percent). Regulation 151/93 also allows the joint marketing of the product wherever the common market share is less than 10%. There

[1]Source: Veugelers (1998).

are also several programs established and funded by the European Commission to promote cooperation in research. The European Strategic Program for Research in Information Technologies (ESPRIT) is by far the largest of these programs. Between 1983 and 1996 around 9000 organizations participated in over 1200 ESPRIT-financed projects (Lichtenberg, 1996).

In Japan industrial policy actively supported the formation of research consortia since 1959 (Sakakibara, 1997).

Many aspects of cooperative R&D were studied in the economic literature[2]. The theoretical literature analyzed extensively how spillovers affect R&D investment in a cooperative situation compared to competition, and how spillovers influence the profitability and welfare of R&D cooperation. Other issues the theoretical literature deals with are stability of research joint ventures, organizational design and asymmetries between research partners.

The very few empirical papers are centered around the motives for participation in research consortia. Only a handful of the studies evaluate the performance of participating firms. The performance measures used in these papers are research intensity (Roller et al, 1999), profitability (Siebert 1997) and stock market evaluation (Sleuwagen et al., 1995 and Scott, 1996). Surprisingly, only very little attention was paid to the impact of joint R&D on productivity[3]. The only exceptions I know of are the studies by Irwin and Klenow (1996) about the labor productivity of Semantech firms, and Branstetter and Sakakibara (1998) about the research productivity of Japanese research consortia. Productivity growth, as the engine of economic growth, is one of the main concern of industrial policy. Research joint ventures are exempt form antitrust laws because they are considered to promote (amongst others) efficiency. Also, as we saw before one of the reasons why firms form RJVs is to gain efficiency. This is why analyzing the effects of research joint venture participation on productivity is an interesting issue.

In this paper I study this effect using a large panel of companies. I find evidence that joint R&D increases productivity.

In the next section I describe the theoretical and empirical background. Section 3 presents the empirical model, the data and the results. Section 4 concludes.

[2]See Veugelers (1998) for a detailed survey.

[3]The general lack of time-series dimension in the data makes it difficult for researchers to carry out productivity studies, because they cannot really control for fixed effects and possible endogeneity.

2 Background

Theoretical background

Evaluating the overall benefits of cooperative research is very difficult because the cooperation can have an impact both on R&D spending and the competitive structure of the industry.

Geroski (1992) summarizes the theoretical findings on this topic. He organizes his discussion around three externalities concerning cooperative R&D: technological spillovers, pecuniary externalities and environmental externalities. Pecuniary externalities occur when the actions of a firm directly affect the competitive position or profits of one of its rivals. This can be either positive (risk sharing) or negative (rivals returns on their R&D are constrained by pre-emptive R&D). Environmental externalities arise when the actions of a firm influence the attitudes of another firm towards itself. An example of environmental externalities is when a firm, being in a cooperative R&D venture is more willing to cooperate with its partner in other activities. He concludes that R&D ventures are desirable whenever technological spillovers and positive pecuniary externalities exist. Also, a non-exclusive consortia which operates between firms with complementary skills and products that undertakes pro-competitive research is preferable to a cooperative research agreement between firms on the same output market.

When evaluating the impact of cooperative R&D we have to separate its direct effect on productivity and its indirect effect through research intensity and competition. How does cooperation in R&D affect productivity? R&D output is considered to have a positive effect on productivity (many times this output is a new process which allows lower unit costs in production). In case of joint research, the research productivity is affected. So, the same amount of R&D investment results in more (or less) innovation. Then, if the competitive structure and firms' R&D investments are unaffected, cooperation in innovative activities increases (decreases) productivity compared to the competitive R&D case.

This direct effect of joint research and development is studied by Kamien et al. (1992), Beath et al. (1998) and Baumol (1999). The common feature of their analysis is that they model process innovation (cost reduction).

Kamien et al. (1992) present an oligopoly model with spillovers where firms compete either a la Cournot or a la Bertrand in the product market. They examine R&D performance and welfare in four different research scenarios. They find that a research joint venture that cooperates in its R&D decisions yields the lowest unit cost with lower research intensities under Cournot competition, and, in most cases, under

Bertrand competition. In their model diminishing returns in the R&D production function are crucial.

Beath et al. (1998) present a non-tournament model of process innovation with spillovers in the R&D process and with a Cournot duopolium in the output market. They explicitly model the innovation as a two stage process where in the first stage the knowledge is produced and in the second stage this knowledge is employed to reduce unit cost. They distinguish between simple and complementary research paths. The research process, like in Kamien et al. (1992) exhibits diminishing returns (either in the first or in the second stage). They show that in the case of a simple research path the RJV only operates one research lab and gets the same cost reduction cheaper than in the competitive case. In case of complementary research paths the RJV either operates one or two research labs, depending where diminishing returns occur in the innovation process, and the level of cost reduction is at least as high as in the competitive case with spending less in the RJV than the sum of the two firms spending separately.

Baumol (1999), on the other hand finds in an Cournot oligopolistic setting where research outputs are complementary that when the number of cooperating firms increases, each firms' unit cost decreases but with an increase in R&D investment. Thus, the implications of cooperation for productivity are ambiguous.

In the following part I describe the empirical literature on this topic.

Empirical background

There are very few papers where the impact of joint R&D on productivity (research or factor) is analyzed empirically. In both studies summarized below the authors estimate the effect of participation in *government sponsored* R&D consortia.

Irwin and Klenow (1996) evaluated the SEMATECH program in the US. SEMATECH was set up to conduct research and development for manufacturing semiconductor products. The consortium was set up in 1987 and enjoyed government subsidies between 1987-1996. Irwin and Klenow used a panel of firm level variables for the period 1970-1993. They found that the SEMATECH firms spent less on research and had higher sales growth than non-participating firms. On the other hand, they did not find significant difference between non-member and member firms in terms of labor productivity growth, physical investment and returns on assets. A weak point of their analysis was the control group they used. The fixed effects model they used controlled for permanent differences in firm performance but it did not correct for the possible endogeneity in the response for SEMATECH participation: that the distribution of the parameter of the participation dummy may differ systematically for participating and non-participating firms.

Branstetter and Sakakibara (1998) conducted a microeconometric analysis of Japanese research consortia. They found that government sponsored R&D consortia participation increased R&D spending. Also, they found that participating firms had higher research productivity than other firms. They measured research output by the number of patents. They controlled for the possible endogeneity in the response for participation in a RJV. Following the logic outlined in the previous section, increased research productivity means a positive direct effect of joint research on productivity.

3 Empirical investigation

In the empirical analysis I investigate the effect of research joint venture participation on productivity using a large panel of European, Japanese and US firms. I use the estimation technique developed by Arellano and Bond (1991).

The model

Consider the following log-linear Cobb-Douglas production function:

$$\begin{aligned} y_{it} &= \lambda y_{i,t-1} + (1-\lambda)\beta_n n_{it} + (1-\lambda)\beta_k k_{it} + \alpha r_{it} + \gamma_t + \eta_i + \epsilon 1_{it} + m_{it} \\ & \epsilon 1_{it} \sim MA(0) \end{aligned} \tag{1}$$

Where y_{it} is the log output of firm i in year t, n_{it} is log employment and k_{it} is log capital stock. The term r_{it} stands for the log R&D output of the firm i . The term γ_t is a year specific intercept, η_i is an unobservable firm specific effect, $\epsilon 1_{it}$ is a productivity shock and m_{it} is measurement error. In case of constant returns to scale $\beta_n + \beta_k = 1$, but this is not necessarily imposed. The inclusion of the lagged output is the simplest way of describing the fact that it takes some time for the output to reach its new long run level whenever he inputs change. The inclusion of this lag also supports the assumption on the serially uncorrelated productivity shocks (Nickell (1996) considers the same production function).

To analyze the role of research joint venture participation I assume that the R&D production function is the following:

$$\begin{aligned} R_{it} &= RD^{\mu}_{i,t-1} e^{\nu RJV_{i,t-1}} e^{\epsilon 2_{it}} \\ & \epsilon 2_{it} \sim MA(0), \end{aligned} \tag{2}$$

where R_{it} is the output (result) of research and development, $RD_{i,t-1}$ is the R&D stock of the company and $RJV_{i,t-1}$ is the number of research joint ventures the firm participates in. Thus, the output of innovative activity depends on the R&D spending and on an R&D productivity term. This research productivity term depends on the number of cooperative research agreements.[4] The lagged levels of R&D stock and RJV participation refer to the fact that their effect on research output is not immediate. I estimate the equation also with earlier lags of the RJV participation.

Taking the logarithm of equation (2) results in a simple log-linear form:

$$r_{it} = \mu rd_{i,t-1} + \nu RJV_{i,t-1} + \epsilon 2_{it}. \tag{3}$$

Introducing (3) into (1) and rearranging the resulting equation we get:

$$y_{it} = \pi_1 y_{i,t-1} + \pi_2 n_{it} + \pi_3 k_{it} + \pi_4 RJV_{i,t-1} + \pi_5 rd_{i,t-1} + \gamma_t + \eta_i + \omega_{it} \tag{4}$$

Notice that the error term ($\omega_{it} = \epsilon 1_{it} + \alpha\epsilon 2_{it} + m_{it}$) follows an MA(0) process if there is no measurement error. In the presence of measurement error this process can be different from MA(0), depending on the marginal process of m_{it}.

Estimation

To eliminate the firm specific effect I take first differences of the equation in (4). To avoid problems with the logarithm of 0 I set the log R&D stock of non-R&D firms to 0 and introduce a non-R&D dummy which equals to 1 if the firm does not spend on research and development. Industry dummies interacted with time dummies correct for the change in the competitive structure in different industries.

Thus, the benchmark equation I estimate is the following:

$$\begin{aligned}\Delta y_{it} &= \pi_1 \Delta y_{i,t-1} + \pi_2 \Delta n_{it} + \pi_3 \Delta k_{it} + \pi_4 \Delta RJV_{i,t-1} + \pi_5 \Delta rd_{i,t-1} + \\ &\quad + \pi_6 nonRD_{i,t-1} + \pi_7 IND_{it} + \pi_8 year + \omega_{it}\end{aligned} \tag{5}$$

Notice that with this specification the coefficient of the RJV term measures the direct effect of cooperative research on productivity. On the other hand, omitting

[4] This way of modeling the innovation process is very similar to the one used by Branstetter and Sakakibara (1998).

the rd variable and the $nonRD$ and time-specific industry dummies, π_4 measures the total effect of RJV participation on productivity.

The values of employment, capital stock, research joint venture participation, R&D stock and lagged sales are possibly correlated with the error term and the firm specific effect. However, assuming the usual initial conditions ($E(x_{i1}\omega_{it}) = 0$ for $t = 2, 3, ..., T$ where x_{i1} represents the endogenous regressors) to hold, in the absence of measurement error all the lagged levels of these regressors beyond $t - 1$ can be used as instruments after first differencing to eliminate the firm specific effect. With an MA(1) measurement error all the lagged levels beyond $t - 2$ can be used as instruments. The crucial assumption is the absence of serial correlation. This will be tested.

However, there is a possible problem: if the marginal processes for the endogenous variables are highly persistent the lagged levels can be weakly correlated with the subsequent first differences. In this case the GMM estimator has been found to have poor finite sample properties (Blundell and Bond, 1998). In this case the use of Herwy w

The variables used in the estimations are the following:

Output, as a proxy I use net real sales. Other possibility would be to construct a measure of value added using the wage bill, pre-tax profits, interest payments and depreciation. However, the reported profits can be different from the true ones, so this measure is not reliable (see Nickell, 1996).

Employment, the variable measures the full-time, part-time and seasonal employment.

Capital, I proxy capital stock with real total assets. In the future I intend to substitute this measure with another constructed from capital investment

R&D stock, this variable is constructed using the R&D expenditures of firms and a 0.15 depreciation rate. I assume that before the sample period the growth rate of R&D investment was the same as the average growth rate in the sample period. This variable is missing in many observations, mainly in Europe. This is why I show results with and without this variable.

RJV participation, the variable contains the number of research joint ventures the firm has joined since 1985. Since there is no information about researchcapital[0-10TD0Tcn20m9rct

Total RJV effect

In table 1 all regressors are treated as endogenous. The instruments are dated $t-3$ and $t-4$ (where the length of the time series allows) for all regressors in the first two columns. In the third and fourth columns only instruments dated $t-3$ are used. Instruments dated $t-2$ were not accepted by the Sargan-test of overidentifying restrictions. This is consistent with the existence of an MA(1) measurement error. Notice that in the first and last columns the Sargan-test shows weak instruments, thus these results may be questionable and improved. Negative first order serial correlation is accepted (although only on the 3% level for the case of Japan). Second order serial correlation is rejected. This is in accordance with the assumptions and taking first differences.

In all four columns there is a positive sign associated with the coefficient of the *RJV* variable. However, there is no evidence in the mixed sample that RJV participation significantly improves productivity. In the US sample the magnitude of the total RJV effect is quite large (one additional cooperative research agreement increases output by around 10%) but not significant. In the case of Japan he magnitude is similar and the effect is significant on the 5% level. In Europe one additional RJV participation increases output by 0.7% but this effect is not significant. This results can be explained in different (and slightly contradictory) ways. In Japan cooperative research has an important tradition. In the US firms form RJVs extensively, as well. Thus, in these two countries firms already had learned how to benefit the most from cooperative research while in Europe it is not the case. Another explanation can that in Europe firms are used to extensive networking and coordination even without signing cooperative agreements (think about German tools which can be used together even if they come from different factories which seemingly do not have any connections). Thus, in Europe there is no significant difference between the behaviour of firms which participate and the one of those who don't in research joint ventures.

Of course, one should keep in mind that these results show only the total effect. So, it can be the case that in Europe the changes in R&D spending and in the competition offset a significant direct RJV effect. Similarly, the significant total RJV effect in Japan does not necessarily mean a significant direct effect on research productivity and thus on productivity.

Direct RJV effect

To investigate the relation between the direct and indirect effects of research joint venture participation I constructed a subsample where the firm's R&D spending can

be controlled for. I also introduced industry dummies (2-digit SIC level) interacted with time dummies. The results are shown in table 2.

The first column shows the total effect of joint research on output. In the second column industry-time dummies are introduced. Thus, the coefficient of the RJV variable shows the total effect net the indirect effect through competition. In the third column the coefficient of the RJV variable shows the total effect net the indirect effect through R&D spending. In the last column both R&D stock and industry-time dummies are introduced. Thus, the direct RJV effect is measured. In all four estimations we accept first order and reject second order serial correlation and the instruments are valid. All lagged levels of the variables beyond $t-2$ are used as instruments.

The results show that in the case of the United States the indirect effect of RJV participation through competition on productivity has the opposite sign that the direct effect. This is in accordance with the theoretical background: RJV participation increases productivity through its effect on research productivity. On the other hand, the competition is less stiff in an industry with RJVs, which decreases productivity.

The indirect effect through R&D spending has the same sign as the direct effect. The indirect effect is slightly smaller in magnitude through competition than through R&D spending.

Different lags of the RJV participation

Using the first lag of the RJV participation variable is questionable. We do not have any information about the time-span of the impact of cooperative research on productivity. In vertical relationships with a supplier it is possible to get significant impact very soon (for example the research aims to find the correct shape of the product of one firm that can be used in the machine of the other). On the other hand, cooperative research between firms and universities often involve basic research, which will has its returns only on the long run.

The length of the panel does not allow for using early lags. This is why I decided to investigate the effects of introducing only the second lag of RJV participation in addition. The results show that participation in an additional research joint venture altogether increases productivity (the sum of the coefficients of the first and second lags, which are jointly significant). Also, the effect in a year is more important than in two years.

4 Conclusion and further work

Using a sample of around 4000 firms I estimated the effect of research joint venture participation on productivity. I found weak evidence that joint research improves productivity. This result supports the industrial policy of governments which encourages the formation of research consortia.

This paper contains only the first results of my investigation. In the near future I want to estimate the production function imposing constant returns to scale. Also, I would like to distinguish between vertical (suppliers and universities) and horizontal RJVs. This would allow me to elaborate the analysis of the indirect effect through R&D spending. Also, this would enable me to investigate further the "RJV-lag problem".

Another direction of further research is including an "R&D subsidy" variable. In case of the United States there is information in the data about government funds (not the sum, only the fact that the published R&D expenditure of a firm includes government subsidy). The inclusion of this variable may give us further information about the effectiveness of industrial policy.

Table 1: Impact of RJV participation on productivity (1985-1994)

Independent variables	Pooled sample	United States	Japan	Europe
$y_{i,t-1}$	.363	.325	.399	.103
	(4.98)	(4.47)	(3.81)	(1.25)
n_{it}	.470	.651	.051	.531
	(3.57)	(3.91)	(0.68)	(3.73)
k_{it}	.102	.034	.076	.278
	(1.21)	(0.29)	(0.54)	(3.09)
$RJV_{i,t-1}$	.029	.101	.104	.007
	(.90)	(1.43)	(1.96)	(0.66)
$euro$	-.156			
	(-.16)			
$japan$	.009			
	(2.38)			
1^{st} serial corr	-5.6	-4.3	-2.1	-2.3
(p-value)	(.00)	(.00)	(.03)	(.02)
2^{nd} serial corr	-.2	.2	-1.1	1.4
(p-value)	(.83)	(.86)	(.28)	(.30)
Sargan-test	140.91	52.83	33.55	25.57
degrees of freedom	48	48	24	12
(p-value)	(.00)	(.29)	(.09)	(.01)
Number of obs.	20479	15018	5159	2078
Number of firms	3960	2575	964	643

The equations were estimated using the DPD98 package written by Arellano and Bond. All four estimations include jointly significant time dummies. The table reports consistent one-step estimators that are robust to heteroskedasticy of general form. The two step (fully efficient) estimators are not reported, because Arellano and Bond (1991) indicate that standard errors are overstatedly low in this case (t-values are in parentheses).

Table 2: Direct impact of RJV participation on productivity (1987-1993), USA

Independent variables	I	II	III	IV
$y_{i,t-1}$	.216	.191	.216	.210
	(2.05)	(1.86)	(2.15)	(2.29)
n_{it}	.757	.862	.703	.845
	(4.64)	(4.97)	(3.86)	(4.86)
k_{it}	-.084	-.148	-.059	-.088
	(-.53)	(-.98)	(-.41)	(-.61)
$RJV_{i,t-1}$	.075	.082	.036	.059
	(1.94)	(1.86)	(1.07)	(1.64)
$rd_{i,t-1}$	.009		-.002	-.071
	(2.38)		(-.02)	(-1.07)
$nonRD$			-.017	-.036
			(-0.95)	(-2.19)
IND_{it}	no	yes	no	yes
1^{st} serial corr	-3.4	-3.3	-3.4	-3.4
(p-value)	(.00)	(.00)	(.00)	(.00)
2^{nd} serial corr	1.5	1.5	1.5	1.4
(p-value)	(.14)	(.14)	(.15)	(.15)
Sargan-test	74.55	67.85	90.77	88.26
degrees of freedom	80	80	100	100
(p-value)	(.65)	(.83)	(.74)	(.79)
Number of obs.	4473	4473	4473	4473
Number of firms	678	678	678	678

The equations were estimated using the DPD98 package written by Arellano and Bond. All four estimations include jointly significant time dummies. The table reports consistent one-step estimators that are robust to heteroskedasticy of general form (t-values are in parentheses).

Table 3: Total impact of RJV participation on productivity (1985-1994)

Independent variables	I	II	III
$y_{i,t-1}$	.363	.429	.428
	(4.98)	(6.99)	(6.40)
n_{it}	.470	.239	.250
	(3.57)	(2.64)	(2.76)
k_{it}	.102	.274	.295
	(1.21)	(3.09)	(3.35)
$RJV_{i,t-1}$	.029		.102
	(.90)		(1.67)
$RJV_{i,t-2}$		.016	-.077
		(.67)	(-1.32)
euro	-.156	-.014	-.015
	(-.16)	(-2.40)	(-2.63)
japan	.009	.001	.001
	(2.38)	(.50)	(0.26)
1^{st} serial corr	-5.6	-4.3	-4.3
(p-value)	(.00)	(.00)	(.00)
2^{nd} serial corr	-.2	-.4	-.4
(p-value)	(.83)	(.68)	(.69)
Sargan-test	140.91	131.94	118.27
degrees of freedom	48	48	47
(p-value)	(.00)	(.00)	(.00)
Number of obs.	20479	16505	16505
Number of firms	3960	3960	3960

The equations were estimated using the DPD98 package written by Arellano and Bond. All three estimations include jointly significant time dummies. The table reports consistent one-step estimators that are robust to heteroskedasticy of general form (t-values are in parentheses).

Appendix

The mixed sample contains information of 4862 firms in an unbalanced panel with the length peaking around 8 periods. There are 288 eight firms participating in at least one research joint venture.

In the US sample there is information about 2885 firms. There are 175 firms participating at least in one research joint venture. The maximum number of research joint ventures a firm participates in after 1985 is 10.

In Europe there is information about 895 firms. There are 27 firms participating at least in one research joint venture. The maximum number of research joint ventures a firm participates in after 1985 is 16.

In Japan there is information about 1082 firms. There are 86 firms participating at least in one research joint venture. The maximum number of research joint ventures a firm participates in after 1985 is 18.

Descriptive statistics - means

Variable	Mixed	USA	Europe	Japan
net sales (million USD)	1810	1361	2669	2607
employment	10491	9427	16759	10040
total assets (million USD)	1643	1272	2317	2320
Number of obs.	32687	21098	4120	7469
Number of firms	4862	2885	895	1082

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