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INSTITUTO DE ECONOMIA

Inter-Firm Technological Cooperation: Effects of Absorptive Capacity, Firm-Size and Specialization

nº 425

Frederico Rocha

Textos para Discussão

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Abstract

This paper aims to add evidence on the role played by firms' technological competencies in the determination of their intensity of cooperation with other firms. Using a database composed by patents jointly filed by two or more firms in the European Patent Office, the paper confronts the hypotheses of complementary or substitutive character of technological cooperation in relation to intra-mural R&D. The results suggest that more technologically and productive specialized firms are more likely to cooperate and find no support for the hypothesis that greater level of R&D expenditure will induce greater reliance on technological cooperation. It is also suggested that firms cooperate with partners that hold complementary competencies.

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Introduction

Recent empirical and historical studies have demonstrated that new developments in technology, such as cross-fertilization of technological fields, increase in the costs of development of technology and the reduction of the product cycle, have produced a restructuring of the organization of technological activities (Mowery & Rosenberg, 1989). One of the main consequences of this restructuring seems to be the growth in the number of inter-firm technological agreements (Chesnais, 1988).

The increase in inter-firm cooperation has been accompanied by an intense debate about the role of technological competencies in the establishment of alliances, where two streams have different interpretations about the phenomenon. On the one hand, there are those scholars from the resource-based theory of the firm that view technological cooperation as a complementary effort to the firms' in-house technological activities. In this respect, Cohen and Levinthal (1989) have argued that the acquisition of externally produced knowledge should be accompanied by an increase in the firm's R&D due to the importance of R&D in the determination of a firm's absorptive capacity. This hypothesis has been tested in a number of different studies with mixed results (Colombo & Garrone 1996, Arora & Gambardella 1990, Kleinknecht & Reijnen 1992). On the other hand, there are those authors that believe that technological cooperation is substitutive to firms'

R&D. One important exemplar of this approach is Richardson (1972) who has emphasized the role of asset dissimilarity in the shaping of organization of industry when complementary assets are involved. He has argued that dissimilar assets are unlikely to be internalized and therefore should be acquired through alliances. The decision to collaborate in technology should then be understood as a strategic choice to avoid high sunk costs. More specialized firms should be more likely to engage in inter-firm agreements while more technologically and productively diversified firms – that hold a wider range of competencies – should be more prone to integrate such activities.

This paper attempts to contribute to the debate using a database built from patents jointly filed by two or more firms in the European Patent Office. It aims to address issues associated with the substitutive or complementary character of the technological agreements and to the role played by firms' technological competencies and capabilities. The first section is dedicated to the display of the theoretical ideas and the empirical evidence that illuminate the paper. The second section presents the data that is going to be used and tries to cover its main limitations. The third section presents the main results of the paper and links them to the main propositions made by the literature on the subject.

1. Theoretical and Empirical Background

Mowery & Rosenberg (1989) and Chesnais (1988) have argued that the re-organization of technological activities during the 1980's was mainly related to recent developments in technology, such as: (i) the continued

growth in development costs; (ii) technological convergence or cross-fertilization of technologies; (iii) shorter product cycles; and (iv) faster rates of technical change. The growth in R&D costs implies that the minimum efficient scale of R&D projects has increased. This is particularly important if the time to profit from the innovation – the product cycle – has been reduced, because the fixed costs of innovation will have to be covered in a shorter period. Technological convergence has demanded firm's competencies to be spread over a greater number of technological fields, that is, the number of technologies that a firm has to deal with has increased. It should be stressed however that none of the listed events implies the total externalization of R&D laboratories, but solely the level of commitment in sunk costs related to knowledge specific assets.

The Importance of Absorptive Capacity

According to this picture, the choice to follow cooperative strategies could be a consequence of the substitution of technological cooperation for intramural R&D, that is, technological inter-firm collaboration can be used to reduce innovation costs through the decline in the need for internalized competencies. Yet, as pointed out by Mowery & Rosenberg (1989), one of the most important drawbacks of cooperation is the under-investment in competencies that may take firms to weaken competitive positions in the long run. This should be important because technological environments are complex and involve a great deal of uncertainty associated with its outcomes and costs. As a consequence, rationality should be bounded and knowledge should be processed for deliberation to take place. Furthermore, as technical knowledge involves tacit characteristics and is cumulative, firms should need to absorb knowledge in order to take decisions about recent developments and to determine what types of knowledge they should contract. Granstrand et al. (1997) and Patel & Pavitt (1994a,b) add some empirical evidence to these observations. They show that big firms' competencies are spread across technical fields outside those where they hold distinctive competencies. Moreover, firms have become increasingly more technologically diversified in recent years. They argue that this should be a consequence of the need to develop knowledge on those technical fields where firms do not act directly, but need to *interact* with other firms. For the specific case of collaborative agreements, this can be confirmed by case studies that show that in order to absorb knowledge produced outside their boundaries, firms have to develop competencies in the technical fields where cooperation is being used (Granstrand et al. 1992). According to this approach, the new wave of technological cooperation has a complementary rather than a substitutive character to intramural R&D, in that the increase in the level of cooperation should involve an increase in in-house R&D expenditures.

In a seminal work, Cohen & Levinthal (1989) show that R&D has indeed two different functions – it is undertaken to generate innovations and/or to increase the firm's absorptive capacity – and therefore it should be considered complementary to external sources of knowledge. They find evidence that greater levels of R&D are undertaken in those sectors where there is higher degree of systemic and intra-industry spillovers. Colombo & Garrone (1996) test Cohen & Levinthal's (1989) hypothesis for the specific case of cooperation in information technology sectors and find high correlation between the two variables. Arora & Gambardella (1990) analyze four different modes of acquisition of technology for the biotechnology case: inter-firm technological agreements, University-firm collaboration, minority share participation in small high-tech firms, acquisition (more

than 50%) of small high-tech firms. They find that the number of participations of a firm amongst these variables are positively correlated which shows a great level of complementarity between these strategies. Furthermore, using the number of patents in biotechnology as a measure for in-house technological efforts in that area of knowledge, they show that patents are positively correlated – and statistically significant – to the number of inter-firm agreements, University-firm links and minority participation, and negatively, though not statistically significant, correlated to acquisitions. Though important, these studies have limited samples, associated with a limited number of sectors. Veugelers (1997), analyzing a sample of Flemish firms in a probit model, where cooperative ventures is the bivariate dependent variable, finds that R&D expenditures influence firms in the option to undertake technological alliances, though, in another equation, with R&D expenditures as the dependent variable, the R&D cooperation dummy shows no significance and even a negative sign. This finding suggests that though R&D expenditures may influence the probability to undertake cooperative agreements, there is not a straight forward relationship between the amount of R&D expenditures and the intensity of cooperative linkages. In contrast, Kleinknecht & Reijnen (1992) find no evidence for the confirmation of Cohen & Levinthal's (1989) hypothesis. Using a probit model, they show that the probability of a firm to engage in R&D cooperation has no relationship with the R&D intensity of the firm.

The Importance of Asset Specificity, Comple-mentarity and Dissimilarity

Richardson (1972) has focused on the importance of asset complementarity in the organization of industry. According to his arguments, coordination problems may arise when assets are transacted in small numbers, that is, when the demand for a certain asset is associated with specific characteristics[1]. A number of problems may arise when specific assets are transacted. First, activities performed by different firms are sometimes not easily synchronized, for instance, the timing of performance may be difficult to coordinate or information flows may be too slow to follow the demand for assets and there is no market to overcome the deficiencies of the specialized supplier; the specification of the assets to be transacted may be hard to transmit through blueprints, that is, information flows are costly. Second, the asset being transacted may have innovative attributes, that is, the outcome of the activities may be difficult to forecast, so that one cannot know *ex ante* the costs and/or the value of the assets to be transacted. Third, the production of assets may require investment in sunk costs and parties may be wary with respect to opportunistic behavior.

All of the three shortcomings of market transactions pointed out above are present in the case of technical progress. First, the need to grow specific competencies in technology development activities may bring about problems associated with synchronization. Firms in the market may fail to provide the adequate competencies to acquire the required technology, they may have trouble understanding the needs of the user firm, that is, many problems in technology may not be transmitted through blueprints. The tacit characteristic of technology demands costly pre-contractual interaction between the R&D laboratory and downstream activities, such as production and marketing, so that technological features and needs can be defined and agreed. Furthermore, the uncertainty embedded in these activities may pose some obstacles to the *ex ante* calculation of costs and rewards of the innovative process and thus *ex ante* agreements on price may face problems. The complexity of the transaction

may even obstruct the calculation of the necessary sunk costs investments what may hinder solutions such as the provision of hostages (Teece, 1988).

Therefore, two types of problems may arise in innovative activities due to the specificity of assets. First, the market system may be unable to overcome problems of coordination due to the existence of design and innovative attributes (Milgrom & Roberts 1993, Coase 1937). In this case, the solution may be the introduction of some authoritative relationship, such as the internalization of the activity. Second, the agreement on rules to govern *ex post* pricing may also encounter limitations (Williamson, 1975). Cost plus contracts may encourage the practice of high costs by the hired party demanding monitoring from the contracting party. Yet, monitoring costs may reach very high values. In addition, the exchange of knowledge between the R&D lab and the manufacturing firms may open room for opportunistic behavior by the supplier that can transfer part of the acquired proprietary knowledge to rival firms. Finally, the tacit and cumulative elements of knowledge produce a lock-in situation leaving the contracted party in a better position to undertake following research activity or creating circumstances where the supplier may behave opportunistically like in the correcting of some errors or mistakes that may have arisen from the R&D activity itself (Teece, 1988).

Both problems call for the intra-mural development of technology. Mowery (1983) and Teece (1988) have emphasized the importance of the role played by in-house R&D labs and have shown the small growth of contractual R&D. However, the point explored by Richardson (1972) calls attention for the role of firm coherence in the determination organization of industry. When complementary and specific assets are dissimilar the configuration of the industry may be affected. When assets are closely complementary and involve complex or specific transactions, there is need for close coordination. As a consequence, they cannot be freely traded through market transactions. The presence of dissimilarity poses some important shortcomings for the internalization of the development of the asset. In the case of technology some of the limitations are: (i) the tacit and cumulative character of technology imply the need for in-house development of the competencies that induce high costs[2] with high level of irreversibility; and (ii) rapid changing technological environments may ask for fast answers while the building of technological competencies may be quite slow.

Firms may deal with dissimilarity in distinct ways. They may buy it outside, acquire it through cooperation or simply internalize it. The propensity to internalize dissimilar assets should be a function of two different features: (i) the level of risk aversion of the firm to invest in sunk costs; and (ii) the diversity of its productive and technological base. In the first case, apart from individual and managerial characteristics, there may be some role played by wealth effects associated with firm size. In the latter case, a firm's level of specialization is the main determinant.

Empirical findings confirm the relevance of complementarity. Hagedoorn & Schakenraad (1990) have found that technological complementarity is the most important motive for the undertaking of joint R&D in the three fast changing technology fields they investigate, followed by the reduction of innovation span[3], that is, the access to dissimilar knowledge and the answer to a fast moving environment. In addition, Hagedoorn & Schakenraad (1990) show that most cooperative agreements are related to strategic objectives rather than cost economizing ones. Mariti & Smiley (1983) have identified technological complementarity as the most important motive for firms' engagement in cooperative arrangements (including non-

technological). Rocha (1995) has shown, using a joint patent database, that technological cooperation has mainly occurred between partners that mainly belong to different productive sectors and therefore that hold dissimilar competencies.

Nationality

Most work on inter-firm technological cooperation stresses differences in the intensity of cooperation across different nationalities of firms (Hagedoorn 1996, Chesnais 1988, Aoki 1988). The literature mainly calls attention for the greater propensity to cooperate of Japanese firms (Chesnais, 1988). Some justifications for this tendency are associated with: (i) the importance of the *keiretsu* structure in the coordination of the efforts of firms belonging to the same group (Chesnais, 1988); (ii) the labor market rigidities in Japanese companies, where the hiring of mid-career scientists may be difficult, turning the building of new dissimilar competencies very difficult, and therefore increasing the reliance of Japanese firms on external competencies (Aoki, 1988); and (iii) government intervention in the formation of horizontal R&D consortia of firms (Chesnais, 1988).

2. Methodology

2.1 The Variables

The dependent variable

Two types of data are normally used in the study of technological cooperation. Information is either obtained from surveys and questionnaires applied to firms (Mariti & Smiley, 1983, and Kleinknecht & Reijnen

1992) or from news on agreements publicized in the specialized press (Ricotta & Mariotti, 1986, and Hagedoorn & Schakenraad, 1990). All these data sources present important shortcomings and are biased in different ways[4]. This paper attempts to add knowledge on technological alliances by using an alternative indicator composed by patents jointly filed by the firm with one or more business partners (in the European Patent Office) divided by the total number of patents filed by the firm as a measure of the propensity to cooperate.

The use of patents to measure technological activity has some important drawbacks: (i) smaller firms have greater propensity to patent; (ii) sector and technologies differ in their propensity to patent; (iii) the presence of a firm in a market covered by a specific patent office affects its propensity to patent. The greater the presence of a firm is, the greater its propensity to patent should be; and (iv) the value of patents have greater variability. One can also pose some further problems in the use of patents as an indicator of cooperation: (i) it does not capture non-innovative technological cooperation. Therefore, efforts such as technology transfer and cross-licensing will remain out of the analysis; (ii) it does not perform uniformly across different modes of cooperation. Joint ventures' contributions should be largely underestimated by the indicator, due to the fact that they may be filed in the name of the joint venture. In this case, they were not captured by the patent search; (iii) it is mainly a measure of output, so it can underestimate cooperative inputs that are not turned into patents; and (iv) it may capture some effects that do not result from cooperative relationships, such as the use of joint patents as hostage for the establishment of long term cooperation in productive activities.

Unlike most of the literature on technological cooperation that uses the number of agreements as a measure of intensity of cooperation and test it against the R&D intensity (Colombo & Garrone 1996), this paper uses a relative variable – joint patents divided by total patents – as a measure of the propensity to cooperate. Some problems may arise when an absolute variable is tested against a relative variable. Firms with greater levels of R&D expenditure may cooperate more though in lower proportion than less R&D intensive firms. Bigger firms may have greater linkages than smaller ones and be less intensive in technological cooperation. Though Colombo & Garrone (1996) have their own reasons for not engaging in this debate, they stress that it would be useful to find an alternative way to measure the propensity to cooperate[5]. Their main suggestion is the use of the rate of the number of agreements divided by R&D expenditure. However, the use of the rate of joint patents to the amount of R&D expenditures would cause problems, due to uneven patenting and R&D propensities across sectors[6]. In contrast, the use of the rate of joint patents to total patents is useful to control for some of the above mentioned biases. It may correct for differences in the patenting propensity of firms of different nationality, size and sector.

Dissimilarity and Absorptive Capacity

As traditionally used in the literature, the firm's absorptive capacity will be measured by one of two variables: R&D to sales rate and the total R&D expenditures. The first variable is more likely to capture the effect of a firms' R&D intensity on the propensity to cooperate; the second should catch the consequences of the size of the expenditure and therefore should present a firm size bias, that is, big firms are inclined to have greater R&D expenditures than smaller ones. In this sense, the R&D intensity variable will always be accompanied by a size variable, while the R&D expenditures will be used alone.

Dissimilarity will here be approached in three different ways. First, one should expect the probability of an asset being dissimilar to the firm's productive base to be a positive function of the level of the firm's technological specialization. The greater the firm's level of specialization, the higher the level of cooperation should be. Technological specialization is here measured by the rate of patenting in the firm's main sector of activity divided by the total number of patents. However, as there may be differences in technology opportunities across sectors and in the propensity to patent of technologies that have different importance levels across sectors, sectoral dummies should be used.

The probability of the occurrence of asset dissimilarity should also be an inverse function of the firm's level of productive specialization. This could be an inverse function of the level of productive integration of the firm. The literature has used the rate of total added value to total gross output. Unfortunately, data at the firm level was not available. An alternative measure used in this paper as a proxy for the level of integration is the sectoral rate of total added value to total gross output at the national level. Some biases may therefore arise: (i) multinational firms that participate in many economies will be represented by their home country's data; and (ii) some firms may have activities outside their main sector of production.

A third variable used to measure the effect of asset dissimilarity on its propensity to cooperate is the firm's size represented by its total sales. Bigger firms are more likely to be more technologically diversified and therefore

to easily access complementary technologies (Patel & Pavitt, 1994). Some side effects may also be captured by this variable. Bigger firms are more likely to invest in sunk costs associated with technology and should have easier access to financial funds.

2.2 Data Sources

Data was obtained for 72 firms – 27 Japanese, 23 European and 22 North-American – with activities in high technology sectors (see table 1). Data on joint patents filed by two or more firms in the European Office were obtained by the Bulletin CD-ROM of the European Patent Office for the years 1988 to 1992. Patents were selected by the firm name. Patents that were filed in the name of the firm's subsidiaries were also included. Joint patents between parent and subsidiaries or subsidiaries of the same group – according to the *who owns whom* criteria – were excluded. As a consequence, there should be no ownership linkages between firms jointly patenting in the database and the firms are not expected to have patents filed by subsidiaries that are not part of the database.

Table 1
Main Characteristics of the Firms in the Database

Variable	Mean	Standard Deviation	Minimum	Maximum
*R&D Expenditures**	1149	1182	3251	4979
R&D Intensity	7.422	3.3853	0.1	15.569
*Sales**	17985	19965	1412	108916
Joint Patents/Total Patents	0.041	0.105	0	0.781

Source: European Commission, *The European Report on Science and Technology Indicators*, Luxembourg, OOPEC, 1994. The number of joint patents is obtained by own manipulation of the *Bulletin Database in CD-ROM*, 1993.
*Billions of ECU's for 1992.

Data on the total number of patents and patents in the firm's main sector of activity between 1988 and 1992 and R&D data for 1992 were obtained from European Commission, *The European Report on Science and Technology Indicators*, Luxembourg, OOPEC, 1994. Data on sectoral rate of value added to gross production for each country was obtained from OECD, *The OECD Input-Output Database*, Paris, 1994. Companies were classified according to the nationality of its parent firm.

3. Empirical Analysis

3.1 The Model

The dependent variable, propensity to cooperate, defined as the rate of joint patents to total patents (*JP*) varies between 0 and 1. The use of ordinary least squares regressions would then be inadequate. To overcome this problem, two different routes were taken. The first route maintains *JP* as the dependent variable and uses a double censored (limits = 0 and 1) tobit model, corrected for heteroscedasticity. The second imposes a logit transformation on the dependent variable to *ln(JP)/(1 - ln(JP))*. In both types of model, two different equations are presented to capture possible effects of R&D expenditures over the propensity to cooperate. One equation tries to control the effect of R&D expenditure by firm size. In this respect, it uses an R&D intensity variable R&D/SALES and a size measure, SALES together with the specialization variables and the nationality dummies. The other equation does not control for size effects, using R&D expenditures and omitting the size variable.

TABLE 2

Dependent Variable	LN(JP)/(1-LN(JP))			JP	
	Least Squares			*Tobit*	
Constant	-0.12887	*-0.39394**	*Constant*	0.15019	0.10077
	(-0.377)	*(1.668)*		(1.582)	(1.751)
LN R&DINT	0.012585		*R&D INT*	0.0042631	
	(0.73)			(0.936)	
LN R&D		*-0.003992*	*R&D*		-0.14472*E-8
		(-0.471)			(-0.144)
LN SALES	-0.011448		*SALES*	-3.12/5E-10	
	(1.057)			(-0.496)	
LN AVGO	-0.'4144'	*-0.096845**	*AVGO*	-0.50293E-2'	-0.0032/2'
	(-2.119)	*(1.818)*		(-2.064)	(-1.857)
LN SPECIAL	0.019513	*0.025711**	*SPECIAL*	0.098709'	0.11458'
	(1.191)	*(1.669)*		(1.938)	(2.265)
EUDUM	-0.0080911	*0.01296*	*EUDUM*	-0.030133	-0.020492
	(0.313)	*(-0.508)*		(-1.028)	(-1.036)
JPDUM	0.084772'	*0.077621'*	*JPDUM*	0.023764	0.026052
	(2.058)	*(2.648)*		(0.652)	(1.152)
			σ	0.090838	0.091575
R-square	.24099	*0.35463*			
F	6.27'	*7.25'*			
Log-L	68.9842	*82.3393*		70.4941	89.95933
N	72			72	72

t-statistics in parenthosis
*Significant at the 10% level
'Significant at the 5% level
'Significant at the 1% level

3.2 The Results

Absorptive Capacity

The R&D expenditures variable is negative and non-significant in both equations where it is included while the R&D intensity variable is positive and non-significant in the equations where it is present. The results suggest that the level of R&D efforts undertaken by a firm does not have a unidirectional influence on the firms' propensity to cooperate. In fact, it can be observed that the sales variable has negative sign, though not significant in the equations it is included. Therefore, the R&D expenditures variable may be capturing part of the size effect. As a consequence, the hypothesis that higher levels of R&D expenditure would facilitate the absorption of externally produced knowledge would not therefore be confirmed by the results of the regressions presented in table 2.

Nonetheless, it should be stressed that cooperation is not totally external to the firm's activities and thus it should be understood as a particular case of knowledge produced outside firms' boundaries. Moreover, one should be careful to make any further assertion due to the characteristics of the sample. The paper gathers data only on big, technology intensive firms (see table 1). There could be a threshold R&D level for firms to absorb external knowledge. In this case, the technological cooperation would increase with R&D intensity when the level of R&D was very low until it reached intermediary intensity[7]. As pointed out above, Veugelers (1997) using a wider size distribution sample and a bivariate dependent variable concludes for a positive and significant relationship between R&D expenditures and the probability to cooperate, controlling for firm size. One should also be

careful to generalize this finding because in the use of a bivariate variable he does not differentiate between differences in the relative propensity to cooperate. Another shortcoming of the analysis is due to the characteristic of the dependent variable, that deals with codified knowledge (patents). Maybe the effect of R&D expenditures and intensity on the absorptive capacity would be greater in situations where non-codified knowledge has greater importance.

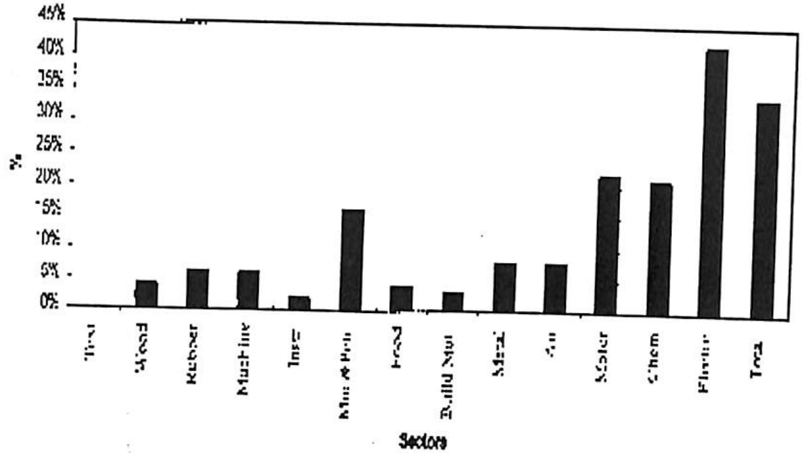
Dissimilarity and Specialization

The productive specialization variable, AVGO, has negative sign and is statistically significant in all equations, suggesting that firms that produce in sectors with lower participation of the added value in the total production have greater propensity to cooperate than firms that produce in sectors with smaller rate of added value to total production. This would add evidence to the hypothesis that firms producing in sectors where there is greater division of labor in the same productive chain have greater propensity to collaborate. However, more precise and robust results should be sought in further work trying to develop a variable to capture productive specialization at the level of the firm.

The technological specialization variable "special" is positive in all equations, though it is significant only in three of them. It is interesting to observe in the least squares equations that the technological specialization variable becomes significant when "sales" are not present. This may imply that this variable is capturing part of the size effect, that is, as more specialized firms tend to be smaller, the omission of size would determine greater significance for the technological specialization variable. This suggests that the level of specialization may be affecting the firm's propensity to cooperate technologically. Technological cooperation may be an alternative strategy to overcome constraints of narrow competence formation. This result may oppose some of the literature that state the need for firms to be technologically diversified in order to access complementary assets (Patel & Pavitt, 1994, Granstrand et al., 1997). Some remarks should however be made in this respect. First, the analysis here undertaken does not fully assess a firm's technology base. Some of the more specialized firms may still hold some technological competencies in those technical fields where they are cooperating. Further tests should still be held with other measures of technological specialization in order to have a robust result. Second, not all technological cooperation may involve the absorption of knowledge. Some of the firms in the sample may be suppliers of inputs to other firms and in this respect their greater technological specialization may be an important asset, though they still need some information on the specification of the product to be produced.

The firm size variable, sales, has shown a negative sign in the two equations where it is present in table 2, though it is not significant. Therefore, one cannot confirm the hypothesis that smaller firms are more likely to cooperate than big firms. The bias of the sample towards big firms may explain the lack of significance of this variable. Using a wider range of firm size, Veugelers (1997) finds a negative relationship between size and the probability to cooperate. Further investigation is still needed for robust results to arise.

Figure 1 - Percentage of Intra-sectoral Patents



Source: Own manipulation of the *Bulletin Database in CD-ROM*, 1993 and *The European Report on Science and Technology Indicators*, 1994

The results shown in this section seem to confirm the hypothesis of the importance of the acquisition of complementary and dissimilar assets for the undertaking of cooperation. More specialized, and (sometimes) smaller firms that cannot internally access some knowledge intensive asset because either they lack competencies or they are not sufficiently productively diversified show a greater propensity to cooperate than more diversified firms. Some further information may be collected from figure 1 that shows that most of the inter-firm technological linkages involve partners that belong to different productive sectors at a very high level of aggregation[8]. These partners are most likely to hold dissimilar competencies[9]. Furthermore, the analysis of the patents involved in most of the intra-sectoral alliances reveals that they are mainly associated with vertical relationships. In the motor vehicle sector, for instance, auto part producers establish linkages with auto assemblers; producers of electrical cables have connections with firms in the telecommunications sector, etc. As a conclusion, in most cases, when intra-sectoral patents are involved, the partners are most likely dealing with the exchange of specialized knowledge as a consequence of a greater inter-firm division of labor in the productive chain. These features demonstrate that the location of firms in the input-output matrix may be an important influence on the determination of the choice of partners. As firms become more productively specialized, they may need greater level of communication with supplier firms. Therefore, the need to access dissimilar competencies in more specialized firms may be an important element in the determination of the level of technological cooperation.

Nationality

The European dummy is negative but it has no statistical significance. The Japanese dummy is positive in all equations, but significant only in the least squares equation. Japanese firms seem to be more likely to cooperate than Western ones. Similar results have been achieved in a number of case studies (Hamel, 1991, and Chesnais, 1988) though the majority of the analysis undertaken using big databases show no particular tendency for bigger firms to have higher levels of cooperation, due to biases in their information sources (Chesnais, 1988, Hagedoorn, 1995). Thus, the result does not present great novelty.

The literature on technological cooperation is very rich in justifications for the greater level of cooperation in Japan. Chesnais (1988) justifies it by three main

reasons: (i) the existence of business groups in Japan; (ii) the State interference in the formation of inter-firm technological alliances; and (iii) the very early recognition in Japan of the advantages of cross-sectoral horizontal cooperation.

Cooperation inside business groups does not seem to be a useful explanation for the results here obtained. Using information for joint patenting activities of 139 Japanese firms, Rocha (1995) has concluded that only about 15% of the total domestic partnerships involved firms inside the same business group. The state intervention should also provide limited explanation. Technological cooperation stimulated by the Japanese government take the form of consortia (Mowery & Rosenberg, 1989, and Chesnais, 1988), that are usually associated with a large number of firms. Nonetheless, less than 5% of the total patents in the database were filed by more than two firms. The third reason given by Chesnais (1988), still requires refinement and therefore it is not here analyzed.

Aoki (1988) adds some insights to the explanation of Japanese behavior. He claims that the ownership structure of the Japanese firm – Bank and employee control – has many consequences on the functioning of firms. One of these differences is that the protection of incumbent employee's interests in Japanese firms impose restrictions for the hiring of new labor. As a consequence, Japanese firms often spin-off a large number of labor intensive activities. One outcome of this spinning-off is the greater specialization inside the same production chain. The result of this behavior would be a high correlation between the Japanese dummy and the productive specialization variable. In fact, whenever the productive specialization variable is taken out of the regression (2) of table 2, the Japanese dummy becomes significant.

Second, Aoki (1988) emphasizes the role played by labor market rigidities in Japanese firms in the establishment of cooperation. According to him, Japanese firms are not allowed to hire mid-career scientists because they would be breaking organizational rules for contracting labor[10]. Therefore, the acquisition of competencies in fast moving technological fields would depend either on slow young scientists hiring or on external sources or firm acquisition. Cooperation should be a solution for this kind of dilemma. This should be represented by a greater technological specialization of Japanese firms.

Conclusions

The paper adds some evidence about the debate on the substitutive and complementary character of technological cooperation. The database here used shows no support for the hypothesis that greater R&D intensity or expenditures are needed when firms are to absorb external knowledge produced through inter-firm alliances. This result suggests that one should be cautious to apply Cohen & Levinthal's (1989) hypothesis when alliances involve joint production of knowledge. Moreover, a firm's level of specialization may influence its degree of cooperation. In this case, the intensity of cooperation seems to be higher in smaller, technologically less diversified and productively specialized firms. This could pose some doubts about the complementary character of technological cooperation as the level of R&D intensity or expenditure does not rise with the propensity to cooperate. On the contrary, the variables on specialization prove to have the right signals and are significant in most equations. This would support the substitutive character of technological cooperation, that is, firms that are more

specialized would need to access necessary complementary and dissimilar assets and therefore would have an increasing relation between the specialization of firms and the propensity to cooperate. Some additional evidence that confirm the substitutive character of collaborative efforts was obtained from the partner choices firms make.

Nonetheless, the results are still preliminary and one of the main conclusions of the paper is the need for further research on the subject. One important line of investigation would be to continue in the same line of investigation in search of more robust results involving bigger samples. A second line of investigation would be to analyze the technical profiles of firms and compare them with the technical fields where they cooperate, trying to identify if cooperation occurs in fields where they have revealed productive advantage or where they lack competencies, relating the results with some of the firms' productive characteristics.

Notas

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2 There is a great number of consequences of this problem: (i) investment in human capital is specific involving sunk costs; and (ii) there is the risk of the firm losing coherence in its technology base.

3 Together they answer for more than 70% of the events in each technological field.

4 See Chesnais (1988).

5 "Using a 'relative' variable such as the ratio of the number of agreements to R&D expenses or to firms sales instead of TCA's (total cooperative agreements) to capture firm's propensity for cooperation would partially prevent us from entering the methodological debate that is our main concern" (Colombo & Garrone 1996:928)".

6 When ln Patents are regressed against ln R&D, the R2 = 0.34, the coefficient is positive and significant at 0,0001%.

7 This type of effect was tested for this sample using a quadratic form with no satisfactory results.

8 Data on joint patenting activity of 536 firms belonging to 14 different two-digit sectors. Joint patent among firms with ownership relations were eliminated. It should be emphasized that the lower the level of aggregation is, the more likely it should be to find that partner firms produce in different sectors.

9 This is a result found by Patel & Pavitt (1994) and Jaffe (1986).

10 Either associated with corporate culture and the discipline in intra-firm labor market or with inter-firm agreements against raids over each other's labor force.

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