Bureau d'économie théorique et appliquée (BETA)
UMR 7522

Documents de travail

« R&D cooperation versus R&D subcontracting : empirical evidence from French survey data »

Auteurs

Estelle DHONT–PELTRAULT, Étienne PFISTER

Document de Travail n° 2007–**17**

Mai 2007

Faculté des sciences économiques et de gestion
Pôle européen de gestion et d'économie (PEGE)
61 avenue de la Forêt Noire
F-67085 Strasbourg Cedex

Secétariat du BETA
Christine DEMANGE
Tél. : (33) 03 90 24 20 69
Fax : (33) 03 90 24 20 70
demange@cournot.u–strasbg.fr
http://cournot2.u–strasbg.fr/beta

R&D cooperation versus R&D subcontracting: empirical evidence from French survey data

Estelle Dhont-Peltrault [a,*], Etienne Pfister[a, b]

[a] Ministère de l'Education nationale, de l'Enseignement Supérieur et de la Recherche
Direction de l'Evaluation, de la Prospective et de la Performance (DEPP-C2)
61-65 rue Dutot, 75732 Paris cédex 15, France
estelle.dhont@education.gouv.fr

[b] BETA, Université de Nancy and CNRS
13 place Carnot, 54000 Nancy, France
etienne.pfister@univ-nancy2.fr

*Corresponding author.
Tel : +33 (1) 55 55 60 18
Fax : +33 (1) 55 55 70 29

Abstract

This paper uses a survey of French firms active in R&D to identify the determinants of R&D outsourcing and of the ensuing trade-off between R&D subcontracting and R&D cooperation. Internal R&D expenditures increase both the probability of outsourcing and the number of R&D partners. Investment in fundamental R&D, group belonging, and the sector's high R&D intensity positively influences the probability of R&D outsourcing but have less impact on the number of partners. R&D subcontracting is more likely than R&D cooperation when the relationship deals with generic, standardized R&D processes, as reflected in the influence of several qualitative proxies.

Keywords

R&D cooperation, R&D subcontracting, organizational choices.

1. Introduction

Innovation increasingly depends on the ability of firms to absorb external competences, knowledge and technologies (Becker and Dietz, 2004 ; Danzon et al., 2005 ; Deeds and Hill,1996 ; Hagedoorn, 2002 ; Hall et al., 2000 ; Kaiser, 2002 ; Noteboon, 1999 ; Shan et al.,1994 ; Veugelers,1997 ; Von Hippel, 1988). One recent trend in these R&D networks is the rise of R&D subcontracting, whereby one firm orders another to develop or test a particular technology according to detailed specifications (Arora et al., 2001 ; Barney, 1999 ; Brusoni and Principe, 2001 ; Chiesa et al., 2004 ; Gans and Stern, 2003 ; Mol, 2005;Quinn, 2000).

This trend remains somewhat puzzling to economists who have long stressed that the characteristics of the R&D process make market-like transactions in this area particular inefficient. For instance, high uncertainty makes contingent R&D contracts (where the seller is paid upon completion of the project) particularly risky for the subcontractor, increasing the cost of R&D outsourcing. Ex-ante payments will fall prey to moral hazard as the subcontractor may be tempted to use these funds to fulfil his own objectives rather than those of the principal. Some forms of control should therefore be exercised upon the subcontractor, which could either take the form of internalization or of close R&D cooperation schemes (such as joint venture, mutual engineering and so on). Besides contract theory, some insights have also been provided by the transaction costs setting, where the choice between alternative organizational schemes depends on the degree of asset specificity (Williamson, 1985, 1991). Given that R&D assets are generally held as specific, both the “seller” and the "customer" could seek to extract a higher share of the cooperation surplus. On the one hand, the “client” could threaten not to pay for the transaction unless the price is reduced. On the other hand, the seller could threaten not to transfer the whole technologies under contract or to sell part of them to competitors unless the client agrees to a price increase. Therefore, either external transaction should be confined to very generic technologies so that both the client and the seller should not feel threatened by the partner’s opportunism, or an alternative organizational structure (such as internalization or close cooperation) should be preferred. Beyond contract theory and transaction costs, other types of arguments have been developed in this area. Teece (1988) and Von Hippel (1988) consider that technologies cannot easily be transferred from one organization to another because they are tacit and context-dependent. Dyer and Singh (1998) as well as Zaheer et al. (1998) insist that the efficacy of R&D transactions depends on the extent of interpersonal interactions, which are said to increase with the degree of cooperation and of internalization of the transaction.

All in all, therefore, the advent and rise of R&D subcontracting contrasts with the organizational limitations that most economists associate it with. Given that context, this article pursues two objectives. First, it aims at providing a proper description of the characteristics (type of partner, functioning of the relationship, selection criteria of the partner) of R&D subcontracting. Although its features are rather well known when it comes to components supplying or auxiliary services (Sachetti and Sugden, 2003), it is far from certain that the characteristics usually associated with subcontracting (flexibility, prime influence of market-based criteria such as price, delays, quality, asymmetric bargaining powers) are also prominent in the case of R&D subcontracting. Rather, the specific characteristics of R&D and of technology could transform subcontracting into a more cooperative relationship.

Second, the article analyses the trade-off between R&D cooperation and R&D subcontracting. Indeed, while the determinants of R&D outsourcing have been thoroughly investigated, how firms make their choice between different types of external relationships has more rarely been considered. Moreover, given the recent trends in R&D outsourcing, differentiating R&D subcontracting from R&D cooperation will help us identify the reasons behind the increasing role played by R&D subcontracting. Two explanations are confronted to analyze this trade-off. What we call the “standardization hypothesis” posits that firms resort to R&D subcontracting (as opposed to cooperative R&D) when the technologies and R&D process under consideration are sufficiently standardized so that the advantages associated to a market-like coordination will be maximized while the inherent risks put forth by the transaction costs and contract theories will be diminished. The “incentive hypothesis” holds that R&D subcontracting is used to increase the innovation incentives of the partner, so that it should primarily be chosen for newer and strategic technologies, i.e. those where these increased incentives are worth their price in terms of risk-bearing, moral hazard and opportunism.

The dataset we use combines one survey on the extent and characteristics of R&D outsourcing (the “ERIE survey” made in France in 2003) with figures on R&D activity at the firm level taken from the French “Research survey“. Not only does it allow us to compute whether a firm has an external relationship in R&D and distinguish subcontracting from cooperation. We are also able to analyze the number of external relationships in R&D and to relate it to the R&D expenses of the firm. Hence, we are able to complement the already large literature on the determinants of external relationships in R&D. Further, the dataset describes 580 “strategic” interfirm relationships in R&D, enabling us to analyze the selection criteria of the partner, the objectives of the relationship, the type of the partner and so forth and to relate them to the trade-off between subcontracting and cooperation.

The remainder of this paper is structured as follows. The next section surveys the literature on the determinants of R&D outsourcing and on the choice between different outsourcing modes. It also formulates the “standardization” and “incentive” hypothesis. Section 3 describes the data and the empirical methodology. Section 4 presents some descriptive statistics and section 5 considers the econometric results. Finally, section 6 concludes.

2. R&D outsourcing: Literature review and hypothesis formulation

2.1. The determinants of external relationships in R&D

Size and R&D expenses/intensity are held to be among the major determinants of R&D outsourcing, whatever its form. Indeed, several studies conclude to a positive link between size (number of employees, turnover) and the probability that the firm has at least one external relationship in R&D or, more rarely, the number of external relationships in R&D (Bayona et. al., 2001 ; Belderbos et al., 2004 ; Cassiman and Veugelers, 2002 ; Colombo and Garrone, 1996 ; Fritsch and Lukas, 2001 ; Kaiser, 2002 ; König et al., 1994 ; Leiponen, 2001 ; Link and Bauer, 1987 ; Röller et al.,1997 ; Vonortas, 1997). The wide scope of a large firm’s activity makes these relationships necessary while the important internal resources in terms of financing and human capital render them possible. Tether (2002) also hints that large corporations may be more attractive to partners than smaller firms. They may also be in a better bargaining position, which increases the profitability of outsourcing. Some results point out that the role of size depends upon the type of partner (Adams et al., 2001 ; Belderbos et al., 2004 ; Fontana et al., 2004 ; Fritsch and Lukas, 2001 ; Kleinknecht and Reijnen, 1992 ; Tether, 2002 ;Veugelers and Cassiman, 2005). It may also depend on how the R&D capital of the firm is measured : more often than not, these empirical studies cannot directly measure the R&D expenses and resort to qualitative indicators[1]. Given that size and R&D investment are positively correlated, the influence of the former could stem from the imprecision of the latter. Veugelers (1997) concludes that once R&D expenses are integrated into the regressions, size exerts a negative influence upon the extent of R&D outsourcing but Fritsch and Lukas (2001) confirm the positive role of size even when R&D intensity is properly measured.

Some indicators of R&D expenses or intensity are often found to exert a positive influence on the extent of R&D outsourcing (Becker and Dietz, 2004 ; Belderbos et al., 2004 ; Colombo and Garrone, 1996 ; Fontana et al., 2004 ; Fritsch and Lukas, 2001 ; Röller et al., 1997 ; Veugelers, 1997 ; Vonortas, 1997)[2]. This mostly relates to the "absorptive capacity" dimension of internal R&D (Cohen and Levinthal, 1990). Shortly put, the higher the internal R&D budget, the more the firm is able to tab unto external knowledge capital and the more profitable external relationships are. Again, this influence seems to depend on the type of partner. For instance, Kleinknecht and Reijnen (1992) observe that the existence of an internal R&D department positively affects the probability of having at least one external relationship in R&D while R&D intensity itself has a positive impact only on the probability of an R&D relationship with a public research center. Fritsch and Lukas (2001) indicate that R&D intensity exerts a positive influence on the number of R&D relationships with suppliers and research centres, a negative one as far as R&D relationships with customers are concerned and is non significant in the case of horizontal R&D relationships – R&D intensity exerts a positive influence on the probability of having at least one R&D relationship in all cases however. Belderbos et al. (2004) conclude that the role of R&D intensity is lower in the case of relationships with competitors.

A variety of other variables have been apprehended in the empirical literature but our dataset will not allow us to make similar testing. Knowledge spillovers and ease of appropriation have been shown to positively influence the propensity to cooperate (Belderbos et al., 2004 ; Cassiman and Veugelers, 2002). Some other variables have been shown to exert a positive influence on cooperation such as the existence of a person in charge of collecting external information related to innovation (Fritsch and Lukas, 2001), the aim at introducing products new to the existing market (Fritsch and Lukas, 2001 ; Tether, 2002), market power (Link and Bauer, 1987), the risk associated to innovation, the costs of innovation, organizational constraints, the need to penetrate a new market (Belderbos et al., 2004 ; Cassiman and Veugelers, 2002 ;Tether, 2002 ; Tyler and Steensma, 1995).

More related to our own results is the belonging of the firm to a corporate group. Theoretically, the influence of group ownership on R&D outsourcing decisions is ambiguous : on the one hand, subsidiaries are able to draw the needed resources from within group but, on the other hand, subsidiaries have facilities to attract partners and to exploit the knowledge or R&D services and technologies transferred upon them. Tether (2002) finds that empirically, group subsidiaries, especially subsidiaries from foreign groups, are more prone to have at least one R&D relationship, especially with customers and universities. Miotti and Sachwald (2003) find that belonging to a group increases the propensity to cooperate in R&D, especially with foreign firms. Belderbos et. al. (2004) indicate that belonging to a group stimulates R&D outsourcing with suppliers or customers, but not with competitors or research institutions.

---

[1] Such as whether the respondent has an internal R&D department, whether R&D investment is occasional or systematic, or whether R&D investment exceeds a certain threshold.

[2] Accounting for the simultaneity that exists between the outsourcing and the R&D decisions does not seem to modify this conclusion (Becker and Dietz, 2004 ; Belderbos et al., 2004 ; Colombo and Garrone, 1996 ; Veugelers, 1997).

Finally, depending on the type of variable used to capture sector-specific dimensions related to technology, various results have been obtained[3], but it turns out that cooperation is generally more frequent in R&D intensive industries.

2.2. The trade-off between R&D subcontracting and R&D cooperation

The second part of our study considers the trade-off between R&D cooperation and R&D subcontracting. Following the theoretical literature on alternative organizational schemes, this issue can be analyzed through two distinct hypotheses.

The "standardization hypothesis"

According to this hypothesis, most of the limitations associated to R&D market transactions can be overcome if the technologies and R&D processes at stake are sufficiently generic or standardized. Indeed, the uncertainty and associated risks should be much lower and the result of the transaction easier to evaluate. Such characteristics should enable parties to write less incomplete contracts, with explicit or implicit contingency clauses that could lead to the optimal level of efforts. Further, opportunistic renegotiation strategies are unlikely given that the generic nature of the technologies allows each party to find another partner rapidly. Standardization of the technologies should also allow for greater competition between potential sub-contractors, thereby increasing the attractiveness of subcontracting for the client firm. It should also make the technology transfer easier, as repeated interactions and cooperative relationships are no longer needed. Also, the customer firm should not fear that the competences of the subcontractor generated by the contract diffuse to other competitors since these competences are probably of a generic, non-strategic, nature. Finally, standardization allows for scale and experience economies so that such technological processes should be delegated to a subcontractor with multiple contracts. Overall, therefore, greater standardization reduces the organizational costs associated to R&D subcontracting and increases its profitability.

Empirically, this explanation will be confirmed if, for instance, the selection of subcontractors is mainly made on criteria already found for the subcontracting of final products, such prices, delays, quality, or geographic proximity. Intuitively, the use of such criteria is possible only when the technologies at stake are sufficiently comparable for prices, delays, and quality to be specified ex ante and if they are sufficiently generic for a partner to be found in the vicinity of the client firm.

Although the trade-off between R&D cooperation and R&D subcontracting has never been empirically investigated as such, there are several empirical studies that have sought to relate the characteristics of R&D external relationships (whether to outsource R&D or not, whether to acquire a participation in the capital of the partner, whether to include such and such clause in the contract, etc.) to the various intuitions put forth by the contract and transaction

---

[3] Belderbos et. al. (2004) observe that the speed of technical change tends to increase the outsourcing of R&D, except for relationships with suppliers. Fritsch and Lukas (2001) conclude that industry dummies are mostly insignificant to explain the propensity to cooperate but help explain the number of relationships. Tether (2002) notes that firms in high-technology service and industrial sectors are more likely to have at least one external R&D relationship, although the significance of this effect depends on the type of partner. Miotti and Sachwald (2003) also note that R&D cooperation is more likely in high and medium to high technology industries, but this effect is mostly prominent for cooperation with rivals and is a lot more ambiguous when it comes to vertical cooperation.

costs theory. For instance, it does seem that the probability of R&D outsourcing is reduced as the risk of opportunism increases, such as when the number of potential partners is limited or when the R&D projects require important investments, which are assumed to be specific as far as R&D is concerned (Pisano, 1990 ; Ulset, 1996). Equity joint ventures also seem to be more likely when R&D is implied, when patents are an ineffective appropriation mechanism or when the partnership involves several projects : the buying of equity should diminish the risk of opportunism, thereby increasing the efficiency of external relationships (Oxley, 1999). Finally, opportunism influences the number of contractual clauses and/or the presence, within external R&D relationships, of certain key clauses (Ciccotello and Hornyak, 2005 ; Helm and Kloyer, 2004 ; Reuer et al., 2006 ; Ulset, 1996). For instance, those relationships that are described as strategic, those where the partner was difficult to find or those involving high R&D investments will include a greater number of contractual clauses. Clearly, there might be cases where the contractual costs are so high that a more cooperative relationship has to be implemented either as a substitute or as a complement to those contracts.

Thus, there appears to be a rather consistent support for concerns related to opportunism to determine, at least in part, the governance structure of external R&D relationships : opportunism increases the costs of subcontracting while greeter cooperation helps reduce opportunism. Assuming that opportunism decreases as the technologies get more and more standardized, we would therefore expect relationships involving generic technologies and R&D processes to be dealt through subcontracting rather than R&D cooperation.

The "incentive" hypothesis

Several reports and academic studies have explored the limitations associated to R&D cooperation. For instance, the Reuters report on biotechnology explains that more than one-third of alliances in this industry are dissolved or renegotiated before their expected term (Reuters, 2004). Surveys by Kale et al. (2002) indicate that only 50 to 63 % of partnerships in the biotech industry are qualified as successful by the partners. Turning to the reasons of cooperation failure, it has long been stressed that one of the major impediments to R&D cooperation is the reduction in innovations incentives that the sharing of results might imply (Danzon et al., 2005 ; Tao and Wu, 1997). Indeed, each party might be tempted to act as a free rider on his partner's R&D efforts. Obviously, some control procedures can be implemented to overcome the free-riding problem but they can be quite burdensome and inadequate in the case of uncertain R&D[4]. Overall, the costs of cooperation may increase when the R&D processes at stake are too novel for efficient control procedures to be implemented. On the other hand, subcontracting could achieve a better level of R&D efforts by assigning exclusive property rights to the subcontractor, so that R&D subcontracting could be chosen for novel and uncertain technologies and/or those where the maximal level of partner's effort is needed. Some risks remain associated to subcontracting (such as technology diffusion to competitors for instance or opportunistic renegotiation), but they might have a low impact compared to the suboptimal effort level associated to cooperative R&D and/or they could be resolved ex ante through exclusive buyer clauses.

Under this hypothesis, subcontracting has the objectives to increase the innovation incentives. It should be therefore be associated to more strategic technologies. It might also imply long-term subcontracting relationships so that the subcontractor can face the uncertainties associated to the development of a new, specific, technology. By empirically analyzing the

[4] The Reuters report on the biotechnology industry (2004) stresses that one of the major impediments to efficient cooperative schemes is the great contractual complexity involved in these structures.

trade-off between subcontracting and R&D cooperation, this article helps to provide some evidence on this point, which had seldom been investigated before. Some previous empirical results are nonetheless indicative of the support that this explanation might find. For instance, Lerner and Merges (1998) observe that external R&D relationships in the biotechnology industry tend to allocate property rights to the partner with the greatest financial strength for he has the ability to increase his level of effort by a large margin if he is sufficiently motivated. More in line with this current analysis, Ulset (1996) notes that the property rights associated to a given R&D project are assigned to the subcontractor when the project is particularly novel or when its resale value is high. Indeed, efficiency requires that for such projects, the incentives to innovate should be maximized, thereby diminishing the attractiveness of cooperative structure where property rights could be shared between partners. Overall, there is at least some support that well-designed subcontracting relationships could increase the innovation performance through better market-based incentive schemes and less bureaucratic control procedures.

3. Data and methodology

3.1 Data

The sample used in this article comes from the matching[5] of two distinct datasets :

- *The survey on inter-firm relationships* (ERIE survey) conducted in 2003 by several French ministerial agencies under an European coordination, which provides data on the year 2002 ;
- *The survey on the means devoted to R&D in firms* (R&D survey) conducted in 2002 by the Direction of Prospective and Evaluation (DEP) of the French Ministry of Education, Higher Education and Research in 2002, which provides data on the year 2000.

The ERIE survey aims at describing the inter-firms relationships (others than strictly financial or standard customer-provider relationships) in five areas : supplying, production, commercialization, auxiliary services, R&D and innovation. For each of these aspects, firms were first asked to answer questions on the extent of their external relationships active in 2002 (notably the number of inter-firms relationships with a distinction between intra-group relationships and others). They were also required to describe (type of relationship, type of partner, localization of the partner, selection criteria, motivations, functioning of the relationship) one to three of their individual inter-firms relationships, which they deemed to be particularly strategic. Thus, the ERIE survey supplies quantitative as well as qualitative information on inter-firms relationships. For the “R&D and innovation” section, the surveyed firms belong to the manufacturing sector[6] (including energy and food industry) or to the services sector[7]. Firms investing more than € 150 000 in internal R&D in 2000 were also systematically investigated.

The R&D survey is conducted annually and provides the amount and the nature of the business enterprise expenditure on R&D and the business enterprise R&D personnel. The surveyed firms have a permanent and structured R&D department, i.e. they employ at least one researcher (in full time equivalent) during the year.

---

[5] The matching was made possible thanks to the use of a unique identification number of firms (the SIREN code) in both datasets.

[6] Firms with more than 20 employees or with a turnover of more than € 5 millions.

[7] Firms specialized in R&D services or with more than 30 employees and which belong to the following industries : postal services and telecommunications, computing services, services to firms, movie and video industry, radio and television, press agencies.

Deleting the firms of the agriculture, construction and non R&D related services leads to a sample of 1160 firms, all of which are involved in an internal R&D activity.

3.2. Sample, methodology and variables

3.2.1. Sample design

We use the inter-firms R&D relationships described in the « R&D and innovation » section of the ERIE survey to build a sample of R&D outsourcing relationships. Specifically, we drop the intra-group relationships for they involve only limited contractual and competitive risks and they are often initiated by the group rather than by the firm itself. We also exclude those relationships where the partner does not conduct an internal R&D activity. Finally, we also leave out those relationships where the respondent is a subcontractor (by opposition to a customer firm) for they cannot be analyzed as an outsourcing decision. Several types of external R&D relationships coexist in our sample : “subcontracting”, “research in cooperation”, “research consortia”, “cooperative research through the creation of a common structure”, “others”. We create a new category termed ”R&D cooperation” that includes those R&D relationships described as “research in cooperation”, “research consortia” and “cooperative research through the creation of a common structure”. The relationships qualified as “others” are not considered since we do not know whether they should be classified into “subcontracting” or “R&D cooperation”.

On the sample of 1160 firms, 580 external R&D relationships are thus described, whereof 179 are subcontracting relationships.

3.2.2. The decision to outsource R&D: methodology and dependent variables

In a first stage, we consider the firms’ decision to outsource part of their R&D activity to one or more external partners. In order to draw up the most discriminatory factors, our regressions will be run both on a dummy variable indicating whether part of the R&D has been outsourced at all and on the number of external R&D relationships (considered as a count variable). Two distinct specifications are thus applied onto the sample of 1160 firms :

- *a probit model* where the dependent variable takes on the value 1 if the firm has described at least one outsourcing R&D relationship ;
- *a zero-inflated negative binomial model* where the estimated coefficients in the first stage relate to the probability that the firm has no external R&D relationship and where, in the second stage, the dependent variable is the number of external, extra-group, R&D relationships stated by the firms[8]. The negative binomial model was confirmed by maximum likelihood tests (or “alpha-tests”). The zero-inflated process derives from highly significant (at 0.1 %) values of the Vuong test.

3.2.3. R&D subcontracting versus R&D cooperation: methodology and dependent variables

In a second stage, we analyze the trade-off between R&D subcontracting and R&D cooperation. Obviously, those firms faced with this trade-off had previously chosen to launch an external R&D relationship, and the possible sample selection bias that results should be accounted for in the regressions. Moreover, the trade-off between R&D subcontracting and R&D cooperation may be affected by firm characteristics as well as by transaction-specific

[8] Note that the relationships stated by the firms can include relationships excluded from our sample of outsourcing relationships: those with a partner with no R&D department, those as a subcontractor or those that could be qualified as “others”.

characteristics, which are only available for those firms with at least one external R&D relationship.

To analyze the determinants of this trade-off, we therefore need a sample of relationships that incorporate both firm and transaction characteristics. In order to include the totality of the sampled relationships without over-weighting firms with more than one relationship, we consider that each respondent has the possibility to manage up to three strategic outsourcing relationships in R&D. Therefore, our sample of 1 160 firms is turned into a sample of 3 480 possible relationships. This transformation is based on two assumptions. First, we assume that firms only describe the relationships that they consider to be strategic[9]; second, we assume that the individual relationships of a single firm are independent from one another.

A two-step probit model with selection is applied onto this sample. In the first stage, the selection equation isolates the impact of firm characteristics on the presence of an outsourcing relationship. Among the 3 480 possible relationships, the dependent variable takes on a unitary value if the relationship is described and 0 otherwise. Firms choose the type of the 580 described relationships in a second stage probit regression, where the dependent variable takes on a unitary value if it consists in R&D subcontracting and 0 otherwise (i.e. R&D cooperation).

3.2.4. Independent variables

The decision to outsource part of the R&D investment is analyzed through a range of firm-level variables usual in the literature.

Firm characteristics

We include different measures of the importance of the R&D activity of the firm : the *BERD* (the logarithm of the business enterprise expenditure on R&D) and two measures of *R&D intensity* : ratio of BERD to total employees and ratio of R&D employees to total employees. The rationale for using such distinct measurements is that *BERD* is strongly correlated with firm size (Pearson correlation coefficient of 72.4 %).

The *firm size* is measured by the logarithm of the number of employees or by dummy variables representing five size categories : *very large* for firms with more than 1 000 employees, *large* for firms with between 500 to 1 000 employees, *medium* for firms with between 250 to 500 employees, *small* for those with between 20 to 250 employees and *very small* for those with less than 20 employees. Four of these five dummy variables are included in the models (small firms being used as the reference).

We also consider the type of R&D investment, namely the shares of *fundamental research*, *applied research* and *experimental development* expenditures over the business enterprise expenditure on R&D. Only two of these three variables will be included in the models (the share of experimental development expenditures is used as the reference). All these variables relate to the year 2000 (R&D survey of 2002), so as to avoid any simultaneity bias with the R&D outsourcing decision taken in 2002.

---

[9] Note that 437 firms declare at least one extra-group relationship in R&D but only 335 (75 %) describe at least one external strategic relationship in R&D. In the same way, 312 firms declare at least two extra-group relationships in R&D but only 178 (57 %) describe at least two external strategic R&D relationships. Finally, 234 firms declare at least three extra-group relationships in R&D but only 67 (28 %) describe three external strategic R&D relationships. There are two explanations to this gap in description. On the one hand, the described relationships can only be a subgroup of the count of R&D relationships (the latter group includes relations as a subcontractor and relations with firms with no R&D department). On the other hand, it might be that the external relationships that firms consider to be strategic are not very numerous.

Table 1
Description of independant variables

Variable name	Definition
	Firm characteristics
BERD	Logarithm of business enterprise expenditure on R&D
R&D intensity (BERD)	BERD / total employees
R&D intensity (R&D employees)	R&D employees / total employees
Firm size	Logarithm of number of employees
Very large	1 if the firm has more than 1000 employees, else 0
Large	1 if the firm has 500-1000 employees, else 0
Medium	1 if the firm has 250-500 employees, else 0
Small	1 if the firm has 20-250 employees, else 0
Very small	1 if the firm has less than 20 employees, else 0
High technology	1 if the firm belongs to a high-technology industry, else 0
Medium-high technology	1 if the firm belongs to a medium-high-technology industry, else 0
Medium-low technology	1 if the firm belongs to a medium-low-technology industry, else 0
Low technology	1 if the firm belongs to a low-technology industry, else 0
Knowledge intensive service	1 if the firm belongs to a knowledge-intensive service industry, else 0
Part of a corporate group	1 if the firm is part of a corporate groupe, else 0
Fundamental research	Percentage of BERD performed in fundamental research
Applied research	Percentage of BERD performed in applied research
Experimental development	Percentage of BERD performed in experimental development
	Management of the relationship
Strategic	1 if the relationship is strategic for the development of the firm, else 0
Cooperation	1 if the relationship implies an important cooperation with the partner, else 0
Communication	1 if the relationship implies specific communication mechanisms with the partner, else 0
Risk	1 if the relationship implies risk sharing, else 0
Investment	1 if the relationship implies a specific investment , else 0
Contract	1 if there is a written contract, else 0
Leader	1 if the conditions of the firm (price, delays..) are applied, else 0
Short-term	1 if the previsible duration is less than one year, else 0
Mid-term	1 if the previsible duration is between one and five years, else 0
Long-term	1 if the previsible duration is more than five years, else 0
	Motivations of the relationship
Scale economies	1 if search to scale economies, else 0
New markets	1 if access to new markets, else 0
Competences	1 if lack of adequate competences within the firm, else 0
Equipment	1 if lack of adequate equipment, else 0
Flexibility	1 if need for greater flexibility, else 0
	Expected results of the relationship
New products	1 if new products or processes, else 0
Prototypes	1 if prototypes, else 0
Patents	1 if patents, else 0
Co-publications	1 if co-publications, else 0
Software	1 if software, else 0
	Selection criteria of the partner
Technological competences	1 if the partner is selected for his technological competences, else 0
Notoriety	1 if the partner is selected for his notoriety, else 0
Prices	1 if the partner is selected for his prices, else 0
Quality	1 if the partner is selected for his quality guarantees (label, certificates, etc.), else 0
Proximity	1 if the partner is selected for his geographical proximity, else 0
Complementary of competences	1 if the partner is selected for the complementarity of his competences, else 0
Long-term contract	1 if the partner is selected for the guarantee of a long-term contract, else 0
	Partner type
Public	1 if the partner is an university, a public research centre or an association, else 0
Local	1 if the partner is located in the same region, else 0
National	1 if the partner is located in another region of France, else 0
Foreign	1 if the partner is located in a foreign country, else 0

Firm-level variables are derived from the 2002 R&D French Survey, whereas transaction-level variables are derived from the ERIE Survey.

The firm's principal sector of activity is also taken in account, either through 18 industry dummies, or through the use of five categorical variables reflecting the importance of technologies and R&D in these industries. Namely, we use the OECD and Eurostat classifications to distinguish among *high-technology* industries, *medium-high-technology* industries, *medium-low-technology* industries, *low-technology* industries and *knowledge-intensive services* [10]. Four of these five variables are included in the regressions (low-technology industries being used as the reference).

We finally include a dummy variable for firms that are *part of a corporate group*.

The trade-off between R&D subcontracting and R&D cooperation is analyzed both through the firm-level variables described above and the transaction-level variables (table 1) taken from the ERIE survey. Five groups of variables can be described.

Management of the relationship

A first group of dummy variables allows an evaluation of how the characteristics of the relationship itself influence the governance choice of that relationship. Firms replied to the question : "among the following items, what, are, according to you, those which best describe the relationship ?". Hence, *strategic* identifies a relationship that was described as strategic for the development of the firm ; *cooperation* considers whether extended cooperation mechanisms were involved in the relationship; *communication* identifies a relationship that implied specific communication mechanisms with the partner ; *risk* refers to whether the transaction has or will imply some risk sharing ; *investment* relates to whether a specific investment has or will be made through the relationship and *contract* considers whether a written contract has been made.

Following the "standardization hypothesis" outlined above, we would expect that the least strategic relationships, those that do not involve particular risks or specific investments and where only scant cooperation is needed, are coordinated through subcontracting. Under the "incentive hypothesis", this should not necessarily be so, as subcontracting is specifically chosen to increase the incentives to innovate, which should be more necessary when the invention is particularly strategic and novel (implying risk taking, non generic investments and cooperation). The variable *contract* has an ambiguous influence. Under the "standardization hypothesis", writing an R&D contract should be more feasible for R&D subcontracting since it should involve lower uncertainty. On the other hand, the subcontractor should be driven to the optimal level of effort by the pressure of competition and reputation, so that a detailed contract may not be necessary. On the other hand, R&D cooperation often reduces such pressures, so that a contract may be more necessary in this particular setting to induce the partner to provide the right level of effort. Finally, the communication between partners should be needed when the technologies at stake are particular novel and uncertain. Again, its effect should therefore depend on the hypothesis that is the most valid empirically.

Another aspect that is considered within this group of variables deals with the bargaining power within the relationship. The variable *leader* indicates whether the responding firms was able to impose his conditions (prices, delays, and so on) upon its partner.

By focusing on the generic dimension of the technologies transferred through R&D subcontracting, the "standardization" hypothesis obviously predicts that customer firms will resort to subcontracting when they enjoy a significant bargaining power over the subcontractor/partner. Conversely, the "incentive hypothesis" questions such an approach : indeed, the technologies may not be so generic and symmetric bargaining powers could

[10] These classifications of sectors are set out in the Annex.

enhance the innovation incentives of the subcontractor by letting him have a larger share of the surplus or a greater say in the terms of the contract.

Finally, this group of management-related variables also includes the expectable duration of the relationship: *short-term* for less than one year, *mid-term* for one to five years and *long-term* for more than five years.

Traditionally, subcontracting is associated to flexible and potentially more short-termed relationships (even though contracts can be frequently renewed), and the “standardization hypothesis” supports this vision : technologies will be generic and flexibility should be the norm in order to benefit from the gains associated to a quasi-market relationship. This should not necessarily be the case under the “incentive hypothesis” : technologies will be more uncertain and difficult to develop, so that long-term relationships may be necessary.

Motivations of the relationship

Five distinct motivations are outlined in the survey : search for *scale economies*, access to *new markets*, lack of adequate *competences* within the firm, lack of adequate *equipment*, need for greater *flexibility*.

The correspondence between these variables and the two hypothesis outlined in section 2 are difficult to circumscribe however. For instance, an ambiguity prevails as to the search for scale economies. On the one hand, it could foster subcontracting since this is one the objective usually associated with specialization and market transactions. On the other hand, some firms may cooperate in R&D precisely to share their fixed costs, thereby achieving some scale economies. Although no prediction can be made ex ante, however, interpretation of the results should help us link the results to one or the other of our assumptions. For instance, if the search for greater flexibility leads to subcontracting, we may infer that this is rather in support of the “standardization hypothesis” since it is unlikely that flexibility should be particularly sought for to enhance the partner’s incentive to innovate (while it is indeed valuable to reduce costs in the framework of the standardization hypothesis).

Expected result of the relationship

Dummy variables are also used to integrate the expected result of the relationship : *new products* or processes, *prototypes*, *patents*, *co-publications*, *software*.

Under the “standardization hypothesis”, subcontracting is unlikely to be chosen in order to coordinate a relationship that should lead to a patent deposit or a co-publication. Given the novelty requirement associated to the former and the fundamental nature of the R&D process involved in the latter, a quasi-market transaction will be hard to implement. It is also likely that such technologies are strategic for the firm, in which case a quasi-market transaction will be inappropriate. Finally, a co-publication requires repeated and sustained interactions that may be impossible to implement through a subcontracting relationship. On the contrary, under the “incentive hypothesis”, the prospect of a patent deposit should be particularly motivating for the subcontractor, especially if he is the exclusive owner of that patent. Generally speaking, risky and uncertain R&D processes are difficult to coordinate through cooperation : efforts are difficult to measure and control and a prisoner’s dilemma situation may arise. Such transactions should therefore be associated to R&D subcontracting in order to better motivate the partner/subcontractor. The other possible results are more difficult to interpret in our framework : given that we are dealing with R&D relationships, it is likely that any such relationship participated in a new product/process or prototype. No prediction can either be associated to the software dummy.

Selection criteria of the partner.

The selection criteria can inform us on the type of technology involved in the relationship. In particular, partner selection based on *prices*, *quality* certificates, *and geographical proximity* can clearly be associated with a standard technology. For a novel, non-generic technology, it is unlikely that price comparisons can be made, that a geographically close partner is found and, finally, that quality certificates have been established. Thus, the "standardization hypothesis" suggests that such selection criteria will rather be associated to R&D subcontracting. Conversely, if *notoriety* was associated to R&D subcontracting, this could come in support of our "incentive hypothesis" : for novel technologies, objective, quantitative selection criteria may not be available so that the firm will be more sensitive to the reputation of its potential partner. Further, attention to the partner's *technological competences* in the case of R&D subcontracting may also confirm the "incentive hypothesis". Indeed, contract theory predicts that increasing incentives should be provided to those firms most able to exert more effort thanks to their competences. On the other hand, as R&D subcontracting may involve less frequent interactions, the client firm may never or rarely be able to evaluate its partner's competences once the contract is signed, so it may as well try to evaluate (and compare) it ex ante. The other selection criteria presented by the survey (the *complementary of competences* and the guarantee of a *long-term contract*) are harder to relate to either of our hypothesis so we mainly use them as control variables. A dummy variable is created for each selection criteria, taking the value 1 if the respondent used it. Each respondent could only select two criteria at most.

Partner type

Two types of dummy variables are introduced in the regressions to take into account the type of partner. First, we make a distinction between private and *public* partners. The former group includes firms and technical centres. The latter ones comprises universities, public research centres and associations. Second, we distinguish whether the partner is located within the same region as the respondent, within the same country (but not in the same region) or in a foreign country.

Again, the type of partner should help us identify what type of technology is mostly being delegated to R&D subcontracting. Clearly, a relationship with a public partner involves research of a more fundamental nature than inter-firms partnerships. Conversely, geographically close partners should mostly transfer generic, non-specific technical services – it is unlikely that a firm could find a partner with the right specific competences within the same region. R&D subcontracting with public partners or foreign ones would rather come in support of the "incentive hypothesis"; the coordination of such relationships through R&D cooperation would rather be concordant with the "standardization hypothesis".

4. DESCRIPTIVE STATISTICS

4.1. The extent of R&D outsourcing

The table 2 presents some comparative statistics on the type of firm that chooses to outsource part of its R&D program. Almost 30 % of the respondents in our sample have at least one external R&D relationship. This proportion is higher for firms in knowledge intensive service sectors (46 %) and in high technology industries (41 %), as well as for firms spending more than € 15 millions in R&D internally (44 %). Whether the respondent is an independent firm or belongs to a group does not seem to influence the outsourcing decision. Firms with a low number of employees (less than 250) are also more likely to have an external R&D relationship. The probit estimation in section 5.1.1 will confirm most of these conclusions.

Those firms that stated at least one external relationship in R&D have 4.3 relationships on average. Large differences can be seen between different types of firms. In particular, firms in knowledge-intensive service sectors, those who spend more than € 15 millions in R&D internally and those who are not part of group have a higher number of relationships on average (14, 12 and 10 relationships, respectively). These results will be further analyzed through a zero-inflated negative binomial model in section 5.1.2.

Table 2

Extent and type of external relationships in R&D - Firm-level characteristics

	Number of firms	Share of outsourcing firms	Number of described relationships	Average number of stated relationships[a]	Share of subcontracting relationships
All firms[b]	1 160	29%	580	4.3	31%
High-technology	210	41%	141	3.0	32%
Medium-high-technology	343	20%	114	1.8	34%
Low-technology	201	19%	57	0.5	32%
Medium-low-technology	165	20%	60	1.8	30%
Knowledege-intensive service	241	46%	208	13.8	28%
Very small	94	35%	55	4.9	25%
Small	469	31%	238	4.3	36%
Medium	212	26%	97	5.5	38%
Large	186	27%	90	2.9	28%
Very large	199	26%	100	4,0	17%
BERD[c] less than M€ 0.15	121	20%	40	1.8	43%
BERD between M€ 0.75 - 3	336	25%	126	1.2	33%
BERD between M€ 3 - 15	346	27%	157	3.2	29%
BERD between M€ 0.15 - 0,75	250	36%	164	7.9	33%
BERD more than M€ 15	107	44%	93	12.0	24%
Part of corporate group	948	29%	468	3.1	31%

[a] For firms that described at least one external relationship.

[b] Agricultural, Mining and quarrying, Construction and Other services excluded.

[c] Business Enterprise Expenditure on R&D.

4.2. R&D cooperation versus R&D subcontracting

More than 30 % of the external R&D relationships described by the respondents – remember that these are supposed to be the most strategic relationships – are coordinated through subcontracting. The trade-off with R&D cooperation does not seem to be heavily influenced by firm-level characteristics. Only firms in knowledge intensive service sectors present a lower share of R&D subcontracting relationships (28 %). R&D investment mainly exerts some influence below the € 0.15 million threshold : firms with low internal R&D investments resort more frequently to R&D subcontracting, which represent 43 % of their external R&D relationships. Size has an indeterminate influence. Very small firms (less than 20 employees) and very large ones (more than 1000 employees) more frequently use R&D cooperation (respectively, 75 % and 83 % of their R&D relationships, to be compared with an average of 69 %). The sample selection probit estimations presented in section 5.2.1 mainly confirm that firm-level variables have only a low impact on the choice between R&D cooperation and R&D subcontracting.

Table 3
R&D subcontracting versus R&D cooperation - Transaction-level characteristics

	Subcontracting	Coopération	Chi-Square Statistic
Management of the relationship			
Strategic	51%	56%	1.39
Contract	43%	50%	2.17
Cooperation	33%	53%	18.13 ***
Investment	14%	18%	1.41
Communication	8%	10%	0.37
Risk	7%	22%	18.07 ***
Low-term	13%	6%	
Mid-term	52%	59%	8.65 **
Long-term	35%	35%	
Leader	21%	10%	12.04 ***
Motivations of the relationship			
Competences	56%	47%	3.78 *
Equipement	41%	23%	19.88 ***
Flexibility	23%	15%	5.82 **
New markets	16%	34%	19.55 ***
Scale economies	6%	15%	9.83 ***
Expected results of the relationship			
New products	76%	77%	0.00
Prototypes	26%	22%	1.29
Patents	17%	28%	8.35 ***
Co-publications	12%	20%	6.44 **
Software	10%	14%	1.90
Selection criteria of the partner			
Technological competences	70%	61%	4.40 **
Complementarity of competences	35%	51%	12.63 ***
Quality	18%	8%	13.16 ***
Prices	13%	1%	35.80 ***
Geographical proximity	9%	5%	4.21 **
Notoriety	8%	17%	8.13 ***
Long-term contract	5%	7%	0.79
Partner type			
Public	30%	41%	7.32 ***
Local	37%	23%	
National	39%	42%	14.42 ***
Foreign	24%	35%	

* p < 0.1.
** p < 0.05.
*** p < 0.01

Transaction-level characteristics present strikingly convergent patterns between R&D cooperation and R&D subcontracting (table 3). Part of this similarity stems from survey construction. Hence, given that the described relationships are the most strategic ones, it is unsurprising that both R&D subcontracting and R&D cooperation are described as strategic. Likewise, the one to five year period presented by the survey is long enough to capture most of the relationships despite the differences in duration that may coexist within that group. The strong presence of private firms within the sample of partners was also expected since private-public R&D relationships are notoriously weak in France. Conversely, some common features between the two types of R&D relationships do indicate that R&D subcontracting can act as a substitute to R&D cooperation. Hence, both coordination mechanisms participate in the development of new products/processes and they often involve symmetric bargaining powers. The know-how of the partner and the complementarity of its competences are the most frequent selection criteria both for R&D cooperation and for R&D subcontracting. Both types of relationships are mostly driven by the lack of internal competences. It thus seems that the most prominent characteristics are identical for both types of R&D outsourcing.

On the other hand, some significant differences between R&D subcontracting and R&D cooperation can be identified when it comes to less frequent features of R&D outsourcing. Hence, subcontracting involves less cooperation, less patents or co-publications, and less risk sharing. Relationships with public institutions are also seldom coordinated through R&D subcontracting, which frequently involves geographically close partner firms. Bargaining powers are more frequently asymmetric in subcontracting relationships. Flexibility as well as adequate equipments more often motivates subcontracting than R&D cooperation. Prices and quality certificates are selection criteria mostly used in R&D subcontracting. Conversely, R&D cooperation is more frequently driven by the search for scale economies and access to new markets, and notoriety is more often cited as a selection criteria of the partner.

5. ECONOMETRIC RESULTS

5.1. The R&D outsourcing decision

Firm-level characteristics conducive to R&D outsourcing are analyzed first through the existence of at least one external R&D relationship, then through the number of declared external R&D relationships.

5.1.1. Dependent variable : at least one external R&D relationship

In order to control for the correlation between the number of employees and internal R&D investment and for the existence of threshold effect in how R&D investment influences R&D outsourcing, several probit estimations are run over a dummy variable indicating whether the firm has at least one external R&D relationship (table 4).

As in several other contributions, the probability to have at least one external R&D relationship increases with BERD (models A1, A2, C1) or with the R&D intensity, regardless of how it is measured (BERD over total employees – models B1 and B2 – or R&D employees over total employees –models C1 and C2). Thus, an “absorption capacity” is needed to use R&D outsourcing.

Outsourcing is also more frequent in high technology industries as well as in knowledge-intensive service sectors. The prominent role of innovation in these sectors forces firms to forge relationships with other firms in order to increase their productivity in R&D, either by reducing costs, or by acquiring new knowledge and competences. Accordingly, firms who devote a large share of their R&D investment to fundamental research are also more likely to outsource part of the R&D, either because their need for outside knowledge is stronger or because the incoming and outgoing spillovers associated with fundamental R&D encourage outsourcing.

The influence of size is less clear-cut. Both the categorical and logarithmic variables related to the number of employees are significant only in those models where the R&D internal budget is also included. In that case, it turns out that larger firms less frequently outsource part of their R&D program, probably because they have larger capabilities to manage R&D programs internally than smaller enterprises. This contrasts with previous works, which mostly concluded that size has a positive impact on the extent of R&D outsourcing. These diverging results can be reconciled if we consider that most of these studies are unable to measure R&D investment very precisely[11]. Replacing the logarithmic measure of R&D with variables of R&D intensity makes the size variables either insignificant (columns B1 and B2) or positive (columns C1 and C2). Also, what is meant through R&D cooperation remains very vague in most studies, and it may not include R&D subcontracting as our sample does.

Members of corporate group display a higher probability of having at least one R&D relationship with another firm outside their group. Belonging to a group may be more attractive to external partners, but the significance level of 10 % is not systematically reached however.

All in all, the firms most likely to outsource part of their R&D activity have high internal R&D expenditures, with a relatively strong focus on fundamental research and belong to high technology industries or knowledge-intensive service sectors.

Table 4

Propensity to outsource R&D: results of probit estimations

	Model A1	Model A2	Model B1	Model B2	Model C1	Model C2
BERD	0.138 (0.031) ***	0.131 (0.033) ***			0.063 (0.026) **	
R&D intensity (BERD)			0.004 (0.001) ***	0.005 (0.001) ***		
R&D intensity (R&D employees)					0.610 (0.200) ***	0.859 (0.206) ***
Firm size		-0.085 (0.037) **		-0.031 (0.029)		0.052 (0.030) *
Very small	0.081 (0.170)		-0.163 (0.168)			
Medium	-0.166 (0.121)		-0.017 (0.120)			
Large	-0.183 (0.130)		0.037 (0.124)			
Very large	-0.440 (0.143) ***		-0.048 (0.122)			
High technology	0.380 (0.154) **	0.386 (0.154) **	0.556 (0.145) ***	0.543 (0.145) ***	0.431 (0.150) ***	0.512 (0.145) ***
Medium-high technology	-0.157 (0.141)	-0.152 (0.141)	-0.036 (0.137)	-0.043 (0.137)	-0.116 (0.140)	-0.064 (0.137)
Medium-low technology	-0.067 (0.152)	-0.061 (0.152)	-0.065 (0.152)	-0.073 (0.152)	-0.067 (0.152)	-0.071 (0.152)
Knowledge intensive service	0.534 (0.155) ***	0.526 (0.156) ***	0.616 (0.154) ***	0.601 (0.152) ***	0.447 (0.161) ***	0.478 (0.160) ***
Part of a corporate group	0.186 (0.125)	0.218 (0.124) *	0.210 (0.125) *	0.188 (0.125)	0.209 (0.121)	0.228 (0.124) *
Fundamental research	0.832 (0.334) **	0.841 (0.334) **	0.777 (0.336) **	0.783 (0.336) **	0.781 (0.337) **	0.740 (0.337) **
Applied research	0.158 (0.104)	0.158 (0.104)	0.121 (0.103)	0.135 (0.103)	0.142 (0.104)	0.119 (0.103)
Constant	-1.839 (0.239) ***	-1.485 (0.217) ***	-1.115 (0.171) ***	-1.286 (0.205) ***	-1.549 (0.213) ***	-1.460 (0.214) ***
Observations	1160	1160	1160	1160	1160	1160
Log likelihood	-642.99	-645.17	-647.08	-647.19	-643.18	-644.59
LR chi2	108.48	104.13	100.32	100.10	108.11	105.29
Pseudo R2	7.78%	7.47%	7.19%	7.18%	7.75%	7.55%

Standard errors in parentheses.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

5.1.2. Independent variable : number of external R&D relationships

The results of the zero-inflated negative binomial models (table 5) indicate that the number of R&D relationships managed by those firms with at least one R&D relationship is positively influenced by the internal R&D investment or by R&D intensity. Hence, the more firms invest in R&D, the larger their absorption capacity and the more they can rely on external partners to acquire new knowledge and technologies. This result reinforces that of the preceding paragraph, where R&D budget positively influenced the propensity to have at least one R&D relationship with an external firm.

On the other hand, several of the preceding results have to be amended. Hence, we had observed that the propensity to have at least one R&D relationship was higher in high-technology and knowledge intensive service industries; yet, it turns out that the *number* of these

[11] Veugelers (1997) has data on R&D expenses similar as ours and concludes that size has a negative impact on the propensity to cooperate with other firms.

relationships is significantly higher in low-technology industries (relative to other industries). We also note that the share of fundamental R&D expenses does not influence the number of relationships - although it had a positive impact on the propensity to have at least one relationship. Thus, we may conclude that firms in high tech industries as well as those who invest a larger share of their R&D budget in fundamental research more frequently need outside partners, yet that these needs are rather concentrated on specific tasks so that a limited number of partners may be sufficient. Similar results had been obtained by previous studies. Veugelers (1997) notes that once R&D expenses are adequately measured, firms in the high technology industries less frequently resort to outside partners. Fritsch and Lukas (2001) as well as Tether (2002) indicate that the most innovative firms (sector-level innovation as opposed to firm-level innovation) have a higher probability of cooperating with outside partners but also have a lower number of R&D relationships than firms with less innovative projects. It is also possible that innovations in low technology industries demand a greater variety of R&D competences pushing firms, which want to innovate to increase the number of their R&D relationships. Also, firms in medium-technology industries probably have more internal competences to satisfy their technological needs.

Table 5

Number of stated R&D relationships: results of zero inflated negative binomial models

	Model A1	Model A2	Model B1	Model B2	Model C1	Model C2
BERD	0,396 (0,083) ***	0,484 (0,105) ***			0,352 (0,069) ***	
R&D intensity (BERD)			0,009 0,004 **	0,010 0,004 ***		
R&D intensity (R&D employees)					1,247 (0,439) ***	2,691 (0,462) ***
Firm size		-0,118 (0,092)		0,289 (0,065) ***		0,334 (0,064) ***
Very small	-0,026 (0,364)		-0,977 (0,376) ***			
Medium	0,312 (0,300)		0,535 (0,270) **			
Large	-0,174 (0,316)		0,358 (0,289)			
Very large	-0,046 (0,368)		0,919 (0,283) ***			
High technology	-1,198 (0,412) ***	-1,346 (0,441) ***	-0,328 (0,384)	-0,207 (0,373)	-1,242 (0,399) ***	-0,625 (0,383)
Medium-high technology	-1,059 (0,416) **	-1,062 (0,446) **	-0,417 (0,400)	-0,234 (0,385)	-0,967 (0,418) **	-0,629 (0,393)
Medium-low technology	-1,486 (0,438) ***	-1,299 (0,471) ***	-1,859 (0,382) ***	-1,794 (0,374) ***	-1,383 (0,442) ***	-1,812 (0,447) ***
Knowledge intensive service	0,072 (0,424)	0,095 (0,452)	0,661 (0,405)	0,719 (0,405) *	-0,336 (0,414)	-0,062 (0,407)
Part of a corporate group	-1,100 (0,285) ***	-0,905 (0,328) ***	-1,10 (0,30) ***	-1,162 (0,294) ***	-0,659 (0,311) **	-0,438 (0,279)
Fundamental research	0,283 (0,709)	0,597 (0,766)	0,803 (0,792)	0,932 (0,786)	0,480 (0,733)	0,568 (0,767)
Applied research	-0,144 (0,272)	0,059 (0,286)	-0,054 (0,259)	-0,004 (0,252)	-0,014 (0,268)	-0,262 (0,255)
Constant	0,077 (0,670)	-0,207 (0,683)	1,908 (0,457) ***	0,457 (0,472)	-0,286 (0,615)	-0,237 (0,494)
Observations (nonzéro)	1160 (335)	1160 (335)	1160 (335)	1160 (335)	1160 (335)	1160 (335)
Log likelihood	-1628.68	-1631.24	-1631.43	-1632.74	-1625.64	-1627.04
LR chi2	143.63	142.31	133.13	132.90	145.58	141.34
Vuong test: z (Prob>z)	3,12 (0,001)	2,98 (0,001)	3,61 (0,000)	3,40 (0,000)	3,07 (0,001)	3,21 (0,001)

Standard errors in parentheses.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

Our previous conclusions on the link between size and R&D outsourcing also need to be deepened. Remember that size would have a negative influence when the logarithm of BERD is used, and is not significant when the R&D intensity variables are used. We note that compared to these conclusions, size does not seem to influence the number of R&D relationships when the logarithmic measure of R&D is used (models A1 and A2). Further, size has a positive influence on the number of relationships when the R&D intensity variables are used (models B1 to C2). Thus, it seems that larger firms enjoy a larger number of R&D relationships, but this effect is probably partly due to the correlation with R&D expenses.

Finally, members of corporate groups that resort to at least one external R&D relationship have fewer partners than independent firms, as a large part of their needs can be satisfied by subsidiaries within the group.

All in all, firms with high R&D expenditures, those in sectors with a low technological intensity and those independent from corporate groups tend to have a higher number of R&D partners. Firms belonging to a group, those in technology-intensive industries or knowledge-intensive service sectors or with a high share of fundamental research have a higher probability to outsource part of their R&D, but will focus their efforts on a rather limited number of partners.

5.2. The trade-off between R&D cooperation and R&D subcontracting

The tables 6a and 6b present the results of the sample selection probit estimations run over our sample of 3 480 possible R&D relationships. Given the high number of binary explanatory variables used in this dataset and their possible interrelations, we choose to incorporate the different types of qualitative variables (management related variables, motivations, expected results, selection criteria, type of partner) in a sequential fashion (models D2 to D6). Another reason for using these stepwise regressions is that most (if not all) of our independent variables are proxies for the type of technologies involved in the relationship. In model E1, these variables are included simultaneously. The model E2 considers only those explanatory variables that were significant in the models D2 to D6. The estimation results we present do not account for industry-specific variations : indeed, the industry dummies were mostly non-significant and their exclusion did not alter the results. Also note that in most cases, the rho coefficient is not significant, indicating that the error terms of the selection and the choice equations are not correlated. Actually, the results remain very similar, regardless of whether the selection equation is used in the estimation[12] as shown in model F (table 6b).

5.2.1. The impact of firm-level characteristics

Regardless of the model, it turns out that R&D intensive firms (measured by the ratio of internal R&D expenses over total number of employees) more frequently resort to R&D subcontracting to coordinate their strategic R&D relationships. Their absorption capacity may help them define the tasks that they wish to outsource to a subcontractor. It may also facilitate the management of the relationship. In the framework of the “standardization hypothesis”, we may say that the absorption capacity helps reduce the transaction costs. On the other hand, we may relate the R&D intensity to the strategic role played by innovation for the firm’s competitiveness. In that case, firms could choose a quasi-market relationship in order to increase the innovation incentives of the partner. Thus, this result could also come in support of the « incentive hypothesis ».

In 8 of the 9 models, firms with less than 20 employees have a significantly higher probability to implement a cooperative rather than a subcontracting relationship. In the transaction cost framework, small size is often associated to a limited number of interactions : in that case, the subcontractor may not be willing to invest in a relationship with this small client, and a cooperative relationship is preferred by the firm in order to better control the partner’s efforts. Also note that firms with more than 1000 employees also seem to use subcontracting less frequently – in that case, however, the coefficient is significant in only 2 of the 9 models.

[12] The results of the selection model are similar to those obtained in the R&D outsourcing section and are not presented in the table. The independent variables of this selection equation are those of the model C2 in table 5.

The other firm-level variables are not significant, even in the model D1 where only firm-level variables are considered. In particular, neither firms in the high tech industries, nor those firms particularly involved in fundamental research display a higher probability of choosing either subcontracting or cooperation. Thus, the determinants of the trade-off between R&D subcontracting and R&D cooperation should mainly be sought in transaction-level variables.

Table 6a

Choice of the relationship type: sample selection probit estimations

	Model D1	Model D2	Model D3	Model D4	Model D5	Model D6
R&D intensity (BERD)	0.003 (0.002) **	0.003 (0.001) **	0.003 (0.001) **	0.003 (0.001) **	0.003 (0.001) **	0.003 (0.001) **
Very small	-0.347 (0.192) *	-0.531 (0.236) *	-0.349 (0.215)	-0.394 (0.199) **	-0.369 (0.206) *	-0.402 (0.205) **
Medium	0.091 (0.124)	0.096 (0.135)	0.123 (0.141)	0.079 (0.126)	0.069 (0.137)	0.051 (0.134)
Large	-0.107 (0.150)	-0.066 (0.166)	-0.119 (0.168)	-0.115 (0.149)	-0.155 (0.172)	-0.147 (0.162)
Very large	-0.318 (0.215)	-0.302 (0.242)	-0.401 (0.214) *	-0.239 (0.205)	-0.301 (0.225)	-0.342 (0.216)
High technology	0.202 (0.192)	0.347 (0.199) *	0.248 (0.209)	0.253 (0.188)	0.196 (0.204)	0.148 (0.206)
Medium-high technology	0.069 (0.177)	0.142 (0.203)	0.174 (0.202)	0.104 (0.183)	0.132 (0.195)	0.058 (0.187)
Medium-low technology	-0.079 (0.203)	-0.068 (0.227)	-0.076 (0.238)	-0.091 (0.205)	-0.124 (0.216)	-0.097 (0.215)
Knowledge intensive service	0.195 (0.223)	0.259 (0.244)	0.247 (0.236)	0.240 (0.218)	0.244 (0.228)	0.111 (0.239)
Part of a corporate group	-0.020 (0.132)	-0.062 (0.145)	-0.087 (0.150)	-0.027 (0.134)	0.003 (0.142)	-0.045 (0.140)
Fundamental research	0.375 (0.366)	0.448 (0.393)	0.264 (0.412)	0.491 (0.369)	0.384 (0.380)	0.377 (0.392)
Applied research	0.090 (0.122)	0.117 (0.136)	0.140 (0.136)	0.081 (0.123)	0.101 (0.129)	0.093 (0.127)
Strategic		-0.332 (0.133) **				
Cooperation		-0.410 (0.149) ***				
Communication		0.144 (0.186)				
Investment		-0.070 (0.138)				
Risk		-0.528 (0.207) **				
Contract		-0.129 (0.109)				
Leader		0.328 (0.159) **				
Short-term		0.357 (0.204) *				
Long-term		0.075 (0.039) *				
Scale economies			-0.478 (0.220) **			
New markets			-0.355 (0.156) **			
Competences			0.005 (0.116)			
Equipment			0.339 (0.126) ***			
Flexibility			0.285 (0.145) **			
New products				-0.065 (0.115)		
Co-publications				-0.221 (0.135)		
Patents				-0.288 (0.140) **		
Prototypes				0.128 (0.110)		
Software				-0.218 (0.155)		
Technological competences					0.344 (0.139) **	
Notoriety					-0.351 (0.184) *	
Prices					1.103 (0.377) ***	
Quality					0.512 (0.197) ***	
Proximity					0.443 (0.213) **	
Complementary of competences					-0.059 (0.108)	
Long-term contract					-0.060 (0.208)	
Public						-0.350 (0.125) ***
Local						0.393 (0.141) ***
Foreign						-0.124 (0.119)
Constant	-1.574 (0.445) ***	-1.269 (0.657) **	-1.466 (0.521) ***	-1.479 (0.478) ***	-1.908 (0.443) ***	-1.388 (0.506) ***
Observations (uncensored)	3480 (580)	3480 (580)	3480 (580)	3480 (580)	3480 (580)	3480 (580)
Log likelihood	-1819.87	-1791.18	-1798.33	-1812.86	-1787.04	-1806.26
LR test: chi2 (Prob>chi2)	2.78 (0.095)	1.55 (0.214)	2.13 (0.144)	2.37 (0.124)	2.33 (0.127)	2.42 (0.120)

Standard errors in parentheses.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

Table 6b

Choice of the relationship type: sample selection probit estimations and simple probit estimation

	Model E1	Model E2	Model F
R&D intensity (BERD)	0,004 (0,002) **	0,004 (0,002) **	0,003 (0,001) ***
Very small	-0,596 (0,267) **	-0,582 (0,258) **	-0,639 (0,273) **
Medium	0,103 (0,166)	0,064 (0,160)	0,077 (0,183)
Large	-0,186 (0,209)	-0,161 (0,199)	-0,270 (0,202)
Very large	-0,344 (0,256)	-0,369 (0,252)	-0,475 (0,211) **
High technology	0,363 (0,247)	0,313 (0,242)	0,239 (0,256)
Medium-high technology	0,245 (0,247)	0,226 (0,235)	0,304 (0,254)
Medium-low technology	-0,047 (0,272)	-0,053 (0,264)	0,032 (0,288)
Knowledge intensive service	0,231 (0,296)	0,258 (0,284)	0,014 (0,257)
Part of a corporate group	-0,152 (0,178)	-0,175 (0,175)	-0,197 (0,186)
Fundamental research	0,482 (0,463)	0,404 (0,446)	0,398 (0,506)
Applied research	0,123 (0,157)	0,155 (0,151)	0,088 (0,170)
Strategic	-0,331 (0,143) **	-0,277 (0,132) **	-0,366 (0,142) ***
Cooperation	-0,406 (0,153) ***	-0,366 (0,143) ***	-0,456 (0,140) ***
Communication	0,154 (0,221)		0,173 (0,243)
Investment	-0,125 (0,172)		-0,148 (0,185)
Risk	-0,484 (0,214) **	-0,459 (0,204) **	-0,545 (0,209) ***
Contract	-0,165 (0,135)		-0,182 (0,147)
Leader	0,316 (0,176) *	0,319 (0,170) **	0,345 (0,183) *
Short-term	0,251 (0,219)	0,264 (0,216)	0,286 (0,233)
Long-term	0,052 (0,046)	0,059 (0,044)	0,060 (0,049)
Scale economies	-0,501 (0,265) *	-0,527 (0,258) **	-0,557 (0,270) **
New markets	-0,218 (0,175)	-0,188 (0,155)	-0,252 (0,185)
Competences	0,027 (0,145)		0,040 (0,159)
Equipment	0,284 (0,153) *	0,290 (0,144) **	0,304 (0,161) *
Flexibility	0,102 (0,173)	0,091 (0,156)	0,114 (0,191)
New products	0,073 (0,153)		0,081 (0,168)
Co-publications	0,084 (0,175)		0,105 (0,190)
Patents	-0,161 (0,159)	-0,163 (0,149)	-0,193 (0,170)
Prototypes	0,154 (0,145)		0,166 (0,159)
Software	-0,336 (0,204)		-0,376 (0,212) *
Technological competences	0,454 (0,181) **	0,371 (0,152) **	0,507 (0,172) ***
Notoriety	-0,245 (0,213)	-0,245 (0,197)	-0,273 (0,227)
Prices	0,811 (0,345) **	0,799 (0,339) **	0,906 (0,327) ***
Quality	0,541 (0,228) **	0,523 (0,213) **	0,602 (0,222) ***
Proximity	0,187 (0,255)	0,198 (0,240)	0,199 (0,283)
Complementary of competences	0,014 (0,136)		0,012 (0,151)
Long-term contract	0,112 (0,252)		0,097 (0,279)
Public	-0,491 (0,174) ***	-0,472 (0,166) ***	-0,552 (0,148) ***
Local	0,354 (0,161) **	0,359 (0,154) **	0,389 (0,163) **
Foreign	-0,026 (0,144)		-0,031 (0,159)
Constant	-1,340 (0,796) *	-1,353 (0,762) *	-0,472 (0,389)
Observations (uncensored)	3480 (580)	3480 (580)	580 (580)
Log likelihood	-1746.88	-1751.08	-271.98
LR test: chi2 (Prob>chi2)	0,93 (0,336)	0,99 (0,319)	

Standard errors in parentheses.

* Significant at 10%.

** Significant at 5%.

*** Significant at 1%.

5.2.2. The impact of transaction-level characteristics

Introducing the different management-related variables in model D2 comes in support of many of the considerations traditionally associated with subcontracting. First, a relationship where much cooperation between both partners is needed will less frequently be coordinated through R&D subcontracting : authority and individual incentives therefore are the main forces coordinating behaviours in a subcontracting relationship. Indeed, a relationship where the firm wishes or needs to impose its will over the partner will more often be of a subcontracting type. Asymmetric bargaining power is one of the features usually associated to subcontracting in auxiliary services or component supply, and this feature is also shared (at least partly) by R&D subcontracting.

R&D cooperation will also more frequently be chosen when the transaction is rated as strategic by the respondent or when it should involve risk-sharing between partners. We may therefore infer that R&D subcontracting is restricted to transactions involving only generic technologies, i.e. non-strategic and with a low level of uncertainty, which support the predictions of the "standardization hypothesis".

More ambiguous conclusions follow from the results on relationship duration. Indeed, it turns out that both short-term (less than a year) and long term (more than five years) relationships will more frequently be coordinated through R&D subcontracting- Hence both of our assumptions are confirmed. Short-term R&D subcontracting implies that technologies are generic and require no long-term commitment. Long-term R&D subcontracting may concern technologies whose development is long and therefore difficult to control : an increase in the innovation incentives might therefore be necessary, which could enhance the attractiveness of R&D subcontracting. Yet, long term R&D subcontracting may also be used with exchanges of standard technologies for which quality cannot be measured ex ante : long term contracts may facilitate the subcontractor' commitment to a right level of effort.

Although the correspondence between the motivations of the R&D relationship (as expressed by the R&D survey) and our hypothesis is not clear-cut, the results displayed by the model D3 rather support the "standardization hypothesis". Hence, it turns out that those external relationships driven by the lack of adequate equipment will mostly be coordinated through R&D subcontracting : indeed, it is probably easier to define the function of the subcontractor and to compare potential partners in terms of prices and equipments, so that quasi-market transactions are relatively easy and efficient to implement. Further, external relationships formed in order to gain some flexibility will more frequently be coordinated through R&D subcontracting. For some reason, R&D cooperation thus turns out to be less flexible than R&D subcontracting. It could be argued that flexibility is mainly beneficial for those technologies that are standard enough for substitute partners to be found (possibly within the firm) if the subcontractor fails to fulfil his commitments.

Conversely, R&D cooperation is more frequently chosen when the objective of the relationship is to gain access to a new market. Such an objective implies that a product needs to be adapted to new market specifications, which could imply more repeated interactions between partners. Further, the will to access a new market may also reflect new competences to be gained, and this transfer may not be easily operated through R&D subcontracting. The negative coefficient associated to the scale economies motivation is more surprising, as market transactions like R&D subcontracting are said to promote specialization (generating scale economies in the process). Maybe the responding firm wishes to increase the profitability of an existing asset within the firm by sharing its costs and use with another firm. Apparently, this sharing will be more efficiently implemented through R&D cooperation. Finally, note that the lack of adequate competences cannot discriminate between R&D subcontracting and R&D cooperation. Given this was the primary motivation of both types of relationships, it thus turns out the trade-off between R&D cooperation and R&D subcontracting is only influenced by secondary motivations.

Model D4 looks at how the expected results of the relationship influence its governance type. Given that the R&D relationships generally insert themselves in the process of creating a new product/process or even prototype, it is not surprising that neither of these objectives can discriminate between R&D subcontracting and R&D cooperation. Actually, neither those relationships orientated towards software creation, nor those aiming at a co-publication are disproportionately coordinated through subcontracting or cooperation. At least for co-publication, this stands out as rather surprising, yet note that a (non-significant) negatively signed coefficient is obtained. Only those relationships aiming at patent deposits are less frequently governed by R&D subcontracting. As explained, this comes in support of the "standardization hypothesis" : R&D subcontracting deals mainly with generic technologies, so that the results produced by such relationships are not novel or inventive enough to be patentable.

Model D5 considers how the selection criteria of R&D partners impact on the type of relationship. Although selection on technical and know-how grounds was the most frequent for both types of relationships, the regression results indicate that this selection procedure is more likely to lead to a subcontracting relationship. This is rather consistent with the preceding conclusion that firms looking for adequate equipments will more frequently use subcontracting (model D3) Yet, it remains ambiguous as to our two hypotheses. On the one hand, the important role given to the technological competences of the partner may indicate that the tasks delegated upon him will not be of an obvious, generic or non-strategic type. The choice of R&D subcontracting in those cases supports the "incentive" hypothesis. On the other hand, selecting partners through technical criteria may only be feasible for standardized know-how, which should encourage subcontracting according to the "standardization hypothesis". Further, checking the technological competences of the partner before-hand may be particularly relevant for subcontracting, given that once the contract is signed, the interactions with the subcontractor are less frequent and close than with an R&D cooperation partner.

The other results displayed by this model clearly support the "standardization hypothesis", however. Hence, the attention to quality certifications and to prices will more frequently be done with R&D subcontracting partners. It is very probable that such criteria can only be implemented for relatively generic technologies. R&D subcontracting is also more frequent when geographical proximity is a selection criterion. Yet, this can only be the case for those technologies that are generic enough for geographically close partners to be found. Conversely, the relationship will more frequently turn out to be R&D cooperation when notoriety is used as a selection criterion. Given the novelty of technologies at stake in those relationships, there are no available objective criteria and the respondent therefore relies on more subjective yet more encompassing criteria such as reputation.

Regardless of the type of relationship, the majority of partners belongs to the private profit sector (in 70 % of the R&D subcontracting relationships and in 59 % of the R&D cooperation relationships). Yet, the model D6 indicates that R&D cooperation is preferred when the partner is a public laboratory, an association or a foundation. An interpretation coherent with the "standardization hypothesis" is relatively easy to formulate. The competences involved in the public sector are probably science-related, with a high proportion of fundamental research. Such competences would be harder to assimilate through R&D subcontracting (given that interactions between partners are less frequent). The uncertainty associated to fundamental R&D also makes this type of contract harder to implement, as contingent payments will not be feasible. Model D6 also isolates the role of partner localization. All else equal, foreign partners are not treated differently than national ones. On the other hand, partners located within the same region will more probably be governed through R&D subcontracting, probably because the competences involved in the transaction are not very specific or strategic (otherwise, finding a partner within the same region would be more difficult). This result confirms the link between selections made on geographical proximity and R&D subcontracting. Overall, therefore, this model again supports the "standardization hypothesis".

Model E1 includes all the independent variables simultaneously and generally confirms these results. Some variables are no longer significant though, like market access, flexibility, geographical proximity, notoriety or patents. Their influence is probably captured by other independent variables. Those results are generally confirmed when only those independent variables that were significant in model D2 to D6 are included. Bypassing the selection equation (model F) does not alter our conclusions either.

6. Conclusion

The rise of R&D subcontracting contrasts with the numerous organizational obstacles to this type of quasi-market relationships. To explore this divide between a recent empirical trend and the traditional, theoretical, view of most organizational economists, this article sought to identify the determinants of the trade-off between R&D cooperation and R&D subcontracting using quantitative and qualitative data from a French survey on external R&D relationships. More precisely, a sample of 1160 firms is used to analyze the determinants of R&D outsourcing (be it through subcontracting or through cooperation). Both the propensity to have at least one relationship and the number of relationships are analyzed through probit and zero-inflated negative binomial estimations, respectively. Then, a sample of 580 relationships (among 3 480 possible relationships) is analyzed through a sample selection probit estimation to isolate the determinants of R&D subcontracting (as opposed to R&D cooperation).

Our regressions first confirm the role of absorptive capacity, technological opportunities and fundamental research in (positively) influencing the decision to have at least one external relationship in R&D. Group subsidiaries are also more frequently involved, though this effect is not systematically significant. When their R&D effort is correctly measured, larger firms are less prone to have at least one relationship in R&D. The number of R&D relationships also depends on the absorptive capacity, but the investment in fundamental research no longer has an impact. For those firms with at least one relationship, being in a technologically intensive industry diminishes the number of relationships, and so does the affiliation to a group. Larger firms turn out to have a larger number of relationships, but this effect probably stems from their higher R&D budget. Though some differences can be noted (on the role of size for instance), the majority of these results confirm the conclusions of the literature.

We have argued that theoretically, the choice of R&D subcontracting can be explained in two ways. The greater standardization and diffusion of generic technologies facilitate the implementation of markets contracts in R&D ("standardization hypothesis"). An alternative view considers that subcontracting enhances the innovation incentives of the partners, implying that technological development delegated to subcontractors can be of a strategic, non-generic, type ("incentive hypothesis"). Empirically, many of our results support the "standardization hypothesis". Hence, R&D subcontracting will be more frequent when prices, quality certifications and geographical proximity are important selection criteria. It will be of a lesser use when the partners are public institutions and when patents are the expected outcome of the relationship (though this particular result is not robust in all estimations). Those relationships judged to be strategic as well as those necessitating some risk sharing will be more frequently framed into R&D cooperation.

On the other hand, there are some more ambiguous conclusions that are derived from this study. We observe that selection criteria based on technological grounds are prominent in R&D subcontracting, which should not have been the case if the technologies delegated to the subcontractors are of a generic type. It may be that such selection can be made only for standardized technologies. We also note that more R&D intensive firms resort more frequently to R&D subcontracting, possibly because their absorptive capacity decreases the transactions costs associated quasi-market relationships in R&D and enhances their ability to capture external competences even when cooperation and interactions are rare. More generally, it turns out that R&D subcontracting contracts cannot be circumscribed to a marginal organization process in the R&D strategies of innovative firms. They represent one-third of the "strategic" R&D relationships formed by firms. On average, they also share many of the characteristics of cooperative R&D like a symmetric bargaining power or a search for competences absent within the responding firm.

Data constraints may explain part of the ambiguity in our results and conclusions. First, our variables are (almost) all proxies for the type of technology delegated to the partner. Measuring the characteristics of the transferred technology directly would clearly be an advantage. Note however that the empirical literature on organization forms often relies on proxy to measure transaction costs or asset specificity for instance. Second, we are only able to observe the type of the relationship, but not the differing characteristics within each type. Indeed, there are several types of R&D subcontracting just like there are several types of R&D cooperation. In particular, subcontracting of newer, more strategic technologies may not be implemented in the same fashion as the subcontracting of generic R&D developments. This question remains open to future explorations.

References

Adams, J., Chiang, E., Starkey, K., 2001. Industry–university cooperative research centres. Journal of Technology Transfer 26, 73–86.

Arora, A., Fosfuri, A., Gambardella, A., 2001. Markets for Technology. The Economics of Innovation and Corporate Strategy, Cambridge, Mass.

Barney, J.B., 1999. How a firm's capabilities affect boundary decisions. Sloan Management Review 40 (3), 137–145.

Bayona, C., Garcia-Marco, T., Huerta, E., 2001. Firms' motivations for cooperative R&D : An empirical analysis of Spanish firms. Research Policy 30, 1289–1307.

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., Diederen, B., Lokshin, B., Veugelers, R., 2004. Heterogeneity in R&D cooperation strategies. International Journal of Industrial Organization 22, 1237–1263.

Brusoni, S., Prencipe, A., 2001. Unpacking the black box of modularity : Technologies, products and organizations. Industrial and Corporate Change 10, 179–205.

Chiesa, V., Manzini, R., Pizzurno, E., 2004. The externalisation of R&D activities and the growing market of product development services. R&D Management 34, 65–75.

Cassiman, B., Veugelers, R., 2002. R&D cooperation and spillovers : Some empirical evidence from Belgium, American Economic Review 92 (4), 1169–1184.
Ciccotello, C.S., Hornyak, M.J., 2000. Cooperation via contract : An analysis of research and development agreements. Journal of Corporate Finance 6, 1–24.
Cohen, W.M., Levinthal, D.A., 1990. Absorptive capacity : A new perspective on learning and innovation. Administrative Science Quarterly 35, 128–152.
Colombo, M., Garrone, P., 1996. Technological cooperative agreements and firm's R&D intensity : A note on causality relations. Research Policy 25, 923–932.
Danzon, P.M., Nicholson, S., Sousa Pereira, N., 2005. Productivity in Biotech-Pharmaceutical R&D : The role of experience and alliances, Journal of Health Economics 24, 317–339.
Deeds, D.L., Hill, C.W.L., 1996. Strategic alliances and the rate of new product development : an empirical study of entrepreneurial biotechnology firms. Journal of Business Venturing 11, 41– 55.
Dyer, J.H., Singh, H., 1998. The relational view : cooperative strategy and sources of interorganizational competitive advantage. Academy of Management Review 23 (4), 660–679.
Fontana, R., Aldo G., Matt M., 2004. Firm size and openness : the driving forces of university–industry collaboration. Paper presented at the EARIE 2004 conference, Berlin 2–5 September, 2004.
Fritsch, M., Lukas, R., 2001. Who cooperates on R&D? Research Policy 30, 297–312.
Gans, J.S., Stern, S., 2003. The product market and the market for "ideas" : commercialization strategies for technology entrepreneurs. Research Policy 32, 333–350.
Hagedoorn, J., 2002. Inter-firm R&D partnerships : an overview of major trends and patterns since 1960. Research Policy 31, 477–492.
Hall, B.H., Link, A., Scott, J.T., 2000. Universities as research partners, NBER working paper 7643.
Helm, R., Kloyer M., 2004. Controlling contractual exchange risks in R&D interfirm cooperation : An empirical study. Research Policy 33, 1103–1122.
Kaiser, U., 2002. An empirical test of models explaining research expenditures and research cooperation : Evidence for the German service sector. International Journal of Industrial Organization 20, 747–774.
Kale, P., Dyer, H., Singh, H., 2002. Alliance Capability, Stock Market Response, and Long-Term Alliance Success : The Role of the Alliance Function. Strategic Management Journal 23, 747–767.
Kleinknecht, A., Reijnen, J.O.N., 1992. Why do firms cooperate on R&D? An empirical study. Research Policy 21, 341–360.
Konig, H., Licht, G., Staat, M., 1994. F&E-Kooperationen und Innovationsaktivitat. In: Gahlen, B., Ramser, H.J., Hesse, H. (Eds.), Okonomische Probleme der europaischen Integration : Schriftenreihe des wirtschaftswissenschaftlichen Seminars Ottobeuren 23, Mohr, Tubingen.
Leiponen, A., 2001. Why do firms not collaborate? The role of competencies and technological regimes. In: Kleinknecht, A., Mohnen, P. (Eds.), Innovation and Firm Performance : Econometric Exploration of Survey Data. Palgrave, 253–277.
Lerner, J., Merges, R.P., 1998. The Control of Technology Alliances : An Empirical Analysis of the Biotechnology Industry. Journal of Industrial Economics 46, 125–156.
Link, A.N., Bauer, L.L., 1987. An economic analysis of cooperative research. Technovation 6, 247–260.

Miotti, L., Sachwald, F., 2003. Co-operative R&D : why and with whom? An integrated framework analysis. Research Policy 32, 1481–1499.

Mol, M.J., 2005. Does being R&D intensive still discourage outsourcing? Evidence from Dutch manufacturing. Research policy 34, 571–582

Nooteboom, B., 1999. Inter-Firm Alliances : Analysis and Design. Routledge, London.

Oxley, J.E.,1999. Institutional environment and the mechanisms of governance : The impact of intellectual property protection on the structure of inter-firm alliances, Journal of Economic Behavior and Organization 38, 283–309.

Pisano, G.P., 1990. The R&D boundaries of the firm : an empirical analysis. Administrative Science Quarterly 35, 153–176.

Quinn, J.B., 2000. Outsourcing innovation : the new engine of growth. Sloan Management Review 41, 13–28.

Reuer, J., Arin, A., Mellewigt, T., 2006. Entrepreneurial alliances as contractual forms. Journal of Business Venturing, 21, 306–325.

Reuters Business Insights, 2004. Pharmaceutical and Biotech Growth Strategies : Future Drivers and Opportunities, London.

Röller, L.H., Siebert R., Tombak, M. 1997. Why firms form research joint ventures : Theory and evidence. CEPR Discussion Paper.

Sachetti, S., Sugden, R., 2003. The governance of networks and economic power: the nature and impact of subcontracting relationships, Journal of Economic Surveys, 17, 5, 669.

Shan, W., Walker, G., Kogut, B., 1994, Interfirm cooperation and start-up innovation in the biotechnology industry. Strategic Management Journal 15, 387–394.

Tao, Z., Wu, C., 1997. On the organization of cooperative research and development : theory and evidence. International Journal of Industrial Organization 15, 573–596.

Teece, D.J., 1988. Technological change and the nature of the firm. In: Dosi, G., Freeman, C., Nelson, R., Silverberg, G., Soete, L. (Eds.), Technological Change and Economic Theory. Francis Pinter, London.

Tether, B.S., 2002. Who co-operates for innovation and why? an empirical analysis. Research Policy 31, 947–967.

Tyler, B.B., Steensma, K.H., 1995. Evaluating technological collaborative opportunities : a cognitive modelling perspective. Strategic Management Journal 16, 43–70.

Ulset, S., 1996. R&D outsourcing and contractual governance : an empirical study of commercial R&D projects. Journal of Economic Behavior and Organization 30, 63–82.

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

Veugelers, R., Cassiman B., 2005. R&D cooperation between firms and universities. Some empirical evidence from Belgian manufacturing. International Journal of Industrial Organization 23, 355–379.

Von Hippel, E., 1988. The Sources of Innovation. Oxford University Press, Oxford.

Vonortas, N.S., 1997. Research joint ventures in the US. Research Policy 26, 577–595.

Williamson, O.E., 1985. The Economic Institutions of Capitalism. Free Press, New York.

Williamson, O.E., 1991. Comparative Economic Organizations : The analysis of discrete alternatives. Administrative Science Quaterly 36, 269–296.

Zaheer, A., McEvily, B., Perrone, V., 1998. Does trust matter? Exploring the effects of interorganizational and interpersonal trust on performance. Organization Science 9 (2), 141–159.

Annex
OECD classification of manufacturing industries by technology and EUROSTAT classification of knowledge-intensive services

OECD classification of manufacturing industries based on technology	
High-technology	Aerospace (Nace 35.3); Pharmaceuticals (24.4); Computers, office machinery (30); Electronics-communications (32); Scientific instruments (33)
Medium-high-technology	Electrical machinery (31); Motor vehicles (34); Chemicals - excl. pharmaceuticals (24 excl. 24.4); Other transport equipment (35.2+35.4+35.5); Non-electrical machinery (29)
Medium-low-technology	Coke, refined petroleum products and nuclear fuel (23); Rubber and plastic products (25); Non metallic mineral products (26); Shipbuilding (35.1); Basic metals (27); fabricated metal products (28)
Low-technology	Other manufacturing and recycling (36+37); Wood, pulp, paper products, printing and publishing (20+21+22); Food, beverages and tobacco (15+16); Textile and clothing (17+18+19)
EUROSTAT classification of knowledge-intensive services	
Knowledge-intensive high-tech services	Post and Telecommunications (64); Computer and related activities (72); Research and development (73)
Knowledge-intensive market services (excl. financial intermediation and high-tech services)	Water transport (61); Air transport (62); Real estate activities (70); Renting of machinery and equipment without operator, and of personal and household goods (71); Other business activities (74)
Knowledge-intensive financial services	Financial intermediation, except insurance and pension funding (65); Insurance and pension funding, except compulsory social security (66); Activities auxiliary to financial intermediation (67)
Other knowledge-intensive services	Education (80); Health and social work (85); Recreational, cultural and sporting activities (92)

Documents de travail du BETA

2000–**01** *Hétérogénéité de travailleurs, dualisme et salaire d'efficience.*
Francesco DE PALMA, janvier 2000.

2000–**02** *An Algebraic Index Theorem for Non–smooth Economies.*
Gaël GIRAUD, janvier 2000.

2000–**03** *Wage Indexation, Central Bank Independence and the Cost of Disinflation.*
Giuseppe DIANA, janvier 2000.

2000–**04** *Une analyse cognitive du concept de « vision entrepreneuriale ».*
Frédéric CRÉPLET, Babak MEHMANPAZIR, février 2000.

2000–**05** *Common knowledge and consensus with noisy communication.*
Frédéric KŒSSLER, mars 2000.

2000–**06** *Sunspots and Incomplete Markets with Real Assets.*
Nadjette LAGUÉCIR, avril 2000.

2000–**07** *Common Knowledge and Interactive Behaviors : A Survey.*
Frédéric KŒSSLER, mai 2000.

2000–**08** *Knowledge and Expertise : Toward a Cognitive and Organisational Duality of the Firm.*
Frédéric CRÉPLET, Olivier DUPOUËT, Francis KERN, Francis MUNIER, mai 2000.

2000–**09** *Tie–breaking Rules and Informational Cascades : A Note.*
Frédéric KŒSSLER, Anthony ZIEGELMEYER, juin 2000.

2000–**10** *SPQR : the Four Approaches to Origin–Destination Matrix Estimation for Consideration by the MYSTIC Research Consortium.*
Marc GAUDRY, juillet 2000.

2000–**11** *SNUS–2.5, a Multimoment Analysis of Road Demand, Accidents and their Severity in Germany, 1968–1989.*
Ulrich BLUM, Marc GAUDRY, juillet 2000.

2000–**12** *On the Inconsistency of the Ordinary Least Squares Estimator for Spatial Autoregressive Processes.*
Théophile AZOMAHOU, Agénor LAHATTE, septembre 2000.

2000–**13** *Turning Box–Cox including Quadratic Forms in Regression.*
Marc GAUDRY, Ulrich BLUM, Tran LIEM, septembre 2000.

2000–**14** *Pour une approche dialogique du rôle de l'entrepreneur/managerdans l'évolution des PME : l'ISO comme révélateur ...*
Frédéric CRÉPLET, Blandine LANOUX, septembre 2000.

2000–**15** *Diversity of innovative strategy as a source of technological performance.*
Patrick LLERENA, Vanessa OLTRA, octobre 2000.

2000–**16** *Can we consider the policy instruments as cyclical substitutes ?*
Sylvie DUCHASSAING, Laurent GAGNOL, décembre 2000.

2001–**01** *Economic growth and CO2 emissions : a nonparametric approach.*
Théophile AZOMAHOU, Phu NGUYEN VAN, janvier 2001.

2001–**02** *Distributions supporting the first–order approach to principal–agent problems.*
Sandrine SPÆTER, février 2001.

2001–**03** *Développement durable et Rapports Nord–Sud dans un Modèle à Générations Imbriquées : interroger le futur pour éclairer le présent.*
Alban VERCHÈRE, février 2001.

2001–**04** *Modeling Behavioral Heterogeneity in Demand Theory.*
Isabelle MARET, mars 2001.

2001–**05** *Efficient estimation of spatial autoregressive models.*
Théophile AZOMAHOU, mars 2001.

2001–**06** *Un modèle de stratégie individuelle de primo–insertion professionnelle.*
Guy TCHIBOZO, mars 2001.

2001–**07** *Endogenous Fluctuations and Public Services in a Simple OLG Economy.*
Thomas SEEGMULLER, avril 2001.

2001–**08** *Behavioral Heterogeneity in Large Economies.*
Gaël GIRAUD, Isabelle MARET, avril 2001.

2001–**09** *GMM Estimation of Lattice Models Using Panel Data : Application.*
Théophile AZOMAHOU, avril 2001.

2001–**10** *Dépendance spatiale sur données de panel : application à la relation Brevets–R&D au niveau régional.*
Jalal EL OUARDIGHI, avril 2001.

2001–**11** *Impact économique régional d'un pôle universitaire : application au cas strasbourgeois.*
Laurent GAGNOL, Jean–Alain HÉRAUD, mai 2001.

2001–**12** *Diversity of innovative strategy as a source of technological performance.*
Patrick LLERENA, Vanessa OLTRA, mai 2001.

2001–**13** *La capacité d’innovation dans les regions de l’Union Européenne.*
Jalal EL OUARDIGHI, juin 2001.

2001–**14** *Persuasion Games with Higher Order Uncertainty.*
Frédéric KŒSSLER, juin 2001.

2001–**15** *Analyse empirique des fonctions de production de Bosnie–Herzégovine sur la période 1952–1989.*
Rabija SOMUN, juillet 2001.

2001–**16** *The Performance of German Firms in the Business–Related Service Sectors : a Dynamic Analysis.*
Phu NGUYEN VAN, Ulrich KAISER, François LAISNEY, juillet 2001.

2001–**17** *Why Central Bank Independence is high and Wage indexation is low.*
Giuseppe DIANA, septembre 2001.

2001–**18** *Le mélange des ethnies dans les PME camerounaises : l’émergence d’un modèle d’organisation du travail.*
Raphaël NKAKLEU, octobre 2001.

2001–**19** *Les déterminants de la GRH des PME camerounaises.*
Raphaël NK AKLEU, octobre 2001.

2001–**20** *Profils d'identité des dirigeants et stratégies de financement dans les PME camerounaises.*
Raphaël NKAKLEU, octobre 2001.

2001–**21** Concurrence Imparfaite, Variabilité du Taux de Marge et Fluctuations Endogènes.
Thomas SEEGMULLER, novembre 2001.

2001–**22** *Determinants of Environmental and Economic Performance of Firms : An Empirical Analysis of the European Paper Industry.*
Théophile AZOMAHOU, Phu NGUYEN VAN et Marcus WAGNER, novembre 2001.

2001–**23** *The policy mix in a monetary union under alternative policy institutions and asymmetries.*
Laurent GAGNOL et Moïse SIDIROPOULOS, décembre 2001.

2001–**24** *Restrictions on the Autoregressive Parameters of Share Systems with Spatial Dependence.*
Agénor LAHATTE, décembre 2001.

2002–**01** *Strategic Knowledge Sharing in Bayesian Games : A General Model.*
Frédéric KŒSSLER, janvier 2002.

2002–**02** *Strategic Knowledge Sharing in Bayesian Games : Applications.*
Frédéric KŒSSLER, janvier 2002.

2002–**03** *Partial Certifiability and Information Precision in a Cournot Game.*
Frédéric KŒSSLER, janvier 2002.

2002–**04** *Behavioral Heterogeneity in Large Economies.*
Gaël GIRAUD, Isabelle MARET, janvier 2002.
(Version remaniée du Document de Travail n°2001–**08**, avril 2001).

2002–**05** *Modeling Behavioral Heterogeneity in Demand Theory.*
Isabelle MARET, janvier 2002.
(Version remaniée du Document de Travail n°2001–**04**, mars 2001).

2002–**06** *Déforestation, croissance économique et population : une étude sur données de panel.*
Phu NGUYEN VAN, Théophile AZOMAHOU, janvier 2002.

2002–**07** *Theories of behavior in principal–agent relationships with hidden action.*
Claudia KESER, Marc WILLINGER, janvier 2002.

2002–**08** *Principe de précaution et comportements préventifs des firmes face aux risques environnementaux.*
Sandrine SPÆTER, janvier 2002.

2002–**09** *Endogenous Population and Environmental Quality.*
Phu NGUYEN VAN, janvier 2002.

2002–**10** *Dualité cognitive et organisationnelle de la firme au travers du concept de communauté.*
Frédéric CRÉPLET, Olivier DUPOUËT, Francis KERN, Francis MUNIER, février 2002.

2002–**11** *Comment évaluer l'amélioration du bien–être individuel issue d'une modification de la qualité du service d'élimination des déchets ménagers ?*
Valentine HEINTZ, février 2002.

2002–**12** *The Favorite–Longshot Bias in Sequential Parimutuel Betting with Non–Expected Utility Players.*
Frédéric KŒSSLER, Anthony ZIEGELMEYER, Marie–Hélène BROIHANNE, février 2002.

2002–**13** *La sensibilité aux conditions initiales dans les processus individuels de primo–insertion professionnelle : critère et enjeux.*
Guy TCHIBOZO, février 2002.

2002–**14** *Improving the Prevention of Environmental Risks with Convertible Bonds.*
André SCHMITT, Sandrine SPÆTER, mai 2002.

2002–**15** *L'altruisme intergénérationnel comme fondement commun de la courbe environnementale* ***à la*** *Kuznets et du développement durable.*
Alban VERCHÈRE, mai 2002.

2002–**16** *Aléa moral et politiques d'audit optimales dans le cadre de la pollution d'origine agricole de l'eau.*
Sandrine SPÆTER, Alban VERCHÈRE, juin 2002.

2002–**17** *Parimutuel Betting under Asymmetric Information.*
Frédéric KŒSSLER, Anthony ZIEGELMEYER, juin 2002.

2002–**18** *Pollution as a source of endogenous fluctuations and periodic welfare inequality in OLG economies.*
Thomas SEEGMULLER, Alban VERCHÈRE, juin 2002.

2002–**19** *La demande de grosses coupures et l'économie souterraine.*
Gilbert KŒNIG, juillet 2002.

2002–**20** *Efficiency of Nonpoint Source Pollution Instruments with Externality Among Polluters : An Experimental Study.*
François COCHARD, Marc WILLINGER, Anastasios XEPAPADEAS, juillet 2002.

2002–**21** *Taille optimale dans l'industrie du séchage du bois et avantage compétitif du bois–énergie : une modélisation microéconomique.*
Alexandre SOKIC, octobre 2002.

2002–**22** *Modelling Behavioral Heterogeneity.*
Gaël GIRAUD, Isabelle MARET, novembre 2002.

2002–**23** *Le changement organisationnel en PME : quels acteurs pour quels apprentissages ?*
Blandine LANOUX, novembre 2002.

2002–**24** *TECHNOLOGY POLICY AND COOPERATION : An analytical framework for a paradigmatic approach.*
Patrick LLERENA, Mireille MATT, novembre 2002.

2003–**01** *Peut–on parler de délégation dans les PME camerounaises ?*
Raphaël NKAKLEU, mars 2003.

2003–**02** *L'identité organisationnelle et création du capital social : la tontine d'entreprise comme facteur déclenchant dans le contexte africain.*
Raphaël NKAKLEU, avril 2003.

2003–**03** *A semiparametric analysis of determinants of protected area.*
Phu NGUYEN VAN, avril 2003.

2003–**04** *Strategic Market Games with a Finite Horizon and Incomplete Markets.*
Gaël GIRAUD et Sonia WEYERS, avril 2003.

2003–**05** *Exact Homothetic or Cobb–Douglas Behavior Through Aggregation.*
Gaël GIRAUD et John K.–H. QUAH, juin 2003.

2003–**06** *Relativité de la satisfaction dans la vie : une étude sur données de panel.*
Théophile AZOMAHOU, Phu NGUYEN VAN, Thi Kim Cuong PHAM, juin 2003.

2003–**07** *A model of the anchoring effect in dichotomous choice valuation with follow–up.*
Sandra LECHNER, Anne ROZAN, François LAISNEY, juillet 2003.

2003–**08** *Central Bank Independence, Speed of Disinflation and the Sacrifice Ratio.*
Giuseppe DIANA, Moïse SIDIROPOULOS, juillet 2003.

2003–**09** *Patents versus ex–post rewards : a new look.*
Julien PÉNIN, juillet 2003.

2003–**10** *Endogenous Spillovers under Cournot Rivalry and Co–opetitive Behaviors.*
Isabelle MARET, août 2003.

2003–**11** *Les propriétés incitatives de l'effet Saint Matthieu dans la compétition académique.*
Nicolas CARAYOL, septembre 2003.

2003–**12** *The 'probleme of problem choice' : A model of sequential knowledge production within scientific communities.*
Nicolas CARAYOL, Jean–Michel DALLE, septembre 2003.

2003–**13** *Distribution Dynamics of CO_2 Emissions.*
Phu NGUYEN VAN, décembre 2003.

2004–**01** *Utilité relative, politique publique et croissance économique.*
Thi Kim Cuong PHAM, janvier 2004.

2004–**02** *Le management des grands projets de haute technologie vu au travers de la coordination des compétences.*
Christophe BELLEVAL, janvier 2004.

2004–**03** *Pour une approche dialogique du rôle de l'entrepreneur/manager dans l'évolution des PME : l'ISO comme révélateur …*
Frédéric CRÉPLET, Blandine LANOUX, février 2004.

2004–**04** *Consistent Collusion–Proofness and Correlation in Exchange Economies.*
Gaël GIRAUD, Céline ROCHON, février 2004.

2004–**05** *Generic Efficiency and Collusion–Proofness in Exchange Economies.*
Gaël GIRAUD, Céline ROCHON, février 2004.

2004–**06** *Dualité cognitive et organisationnelle de la firme fondée sur les interactions entre les communautés épistémiques et les communautés de pratique..*
Frédéric CRÉPLET, Olivier DUPOUËT, Francis KERN, Francis MUNIER, février 2004.

2004–**07** *Les Portails d'entreprise : une réponse aux dimensions de l'entreprise « processeur de connaissances ».*
Frédéric CRÉPLET, février 2004.

2004–**08** *Cumulative Causation and Evolutionary Micro–Founded Technical Change : A Growth Model with Integrated Economies.*
Patrick LLERENA, André LORENTZ, février 2004.

2004–**09** *Les CIFRE : un outil de médiation entre les laboratoires de recherche universitaire et les entreprises.*
Rachel LÉVY, avril 2004.

2004–**10** *On Taxation Pass–Through for a Monopoly Firm.*
Rabah AMIR, Isabelle MARET, Michael TROGE, mai 2004.

2004–**11** *Wealth distribution, endogenous fiscal policy and growth : status–seeking implications.*
Thi Kim Cuong PHAM, juin 2004.

2004–**12** *Semiparametric Analysis of the Regional Convergence Process.*
Théophile AZOMAHOU, Jalal EL OUARDIGHI, Phu NGUYEN VAN, Thi Kim Cuong PHAM, Juillet 2004.

2004–**13** *Les hypothèses de rationalité de l'économie évolutionniste.*
Morad DIANI, septembre 2004.

2004–**14** *Insurance and Financial Hedging of Oil Pollution Risks.*
André SCHMITT, Sandrine SPAETER, septembre 2004.

2004–**15** *Altruisme intergénérationnel, développement durable et équité intergénérationnelle en présence d'agents hétérogènes.*
Alban VERCHÈRE, octobre 2004.

2004–**16** *Du paradoxe libéral–parétien à un concept de métaclassement des préférences.*
Herrade IGERSHEIM, novembre 2004.

2004–**17** *Why do Academic Scientists Engage in Interdisciplinary Research ?*
Nicolas CARAYOL, Thuc Uyen NGUYEN THI, décembre 2004.

2005–**01** *Les collaborations Université Entreprises dans une perspective organisationnelle et cognitive.*
Frédéric CRÉPLET, Francis KERN, Véronique SCHAEFFER, janvier 2005.

2005–**02** *The Exact Insensitivity of Market Budget Shares and the 'Balancing Effect'.*
Gaël GIRAUD, Isabelle MARET, janvier 2005.

2005–**03** *Les modèles de type Mundell–Fleming revisités.*
Gilbert KOENIG, janvier 2005.

2005–**04** *L'État et la cellule familiale sont–ils substituables dans la prise en charge du chômage en Europe ? Une comparaison basée sur le panel européen.*
Olivia ECKERT–JAFFE, Isabelle TERRAZ, mars 2005.

2005–**05** *Environment in an Overlapping Generations Economy with Endogenous Labor Supply : a Dynamic Analysis.*
Thomas SEEGMULLER, Alban VERCHÈRE, mars 2005.

2005–**06** *Is Monetary Union Necessarily Counterproductive ?*
Giuseppe DIANA, Blandine ZIMMER, mars 2005.

2005–**07** *Factors Affecting University–Industry R&D Collaboration : The importance of screening and signalling.*
Roberto FONTANA, Aldo GEUNA, Mireille MATT, avril 2005.

2005–**08** *Madison–Strasbourg, une analyse comparative de l'enseignement supérieur et de la recherche en France et aux États–Unis à travers l'exemple de deux campus.*
Laurent BUISSON, mai 2005.

2005–**09** *Coordination des négociations salariales en UEM : un rôle majeur pour la BCE.*
Blandine ZIMMER, mai 2005.

2005–**10** *Open knowledge disclosure, incomplete information and collective innovations.*
Julien PÉNIN, mai 2005.

2005–**11** *Science–Technology–Industry Links and the 'European Paradox' : Some Notes on the Dynamics of Scientific and Technological Research in Europe.*
Giovanni DOSI, Patrick LLERENA, Mauro SYLOS LABINI, juillet 2005.

2005–**12** *Hedging Strategies and the Financing of the 1992 International Oil Pollution Compensation Fund.*
André SCHMITT, Sandrine SPAETER, novembre 2005.

2005–**13** *Faire émerger la coopération internationale : une approche expérimentale comparée du bilatéralisme et du multilatéralisme*.
Stéphane BERTRAND, Kene BOUN MY, Alban VERCHÈRE, novembre 2005.

2005–**14** *Segregation in Networks.*
Giorgio FAGIOLO, Marco VALENTE, Nicolaas J. VRIEND, décembre 2005.

2006–**01** *Demand and Technology Determinants of Structural Change and Tertiarisation : An Input–Output Structural Decomposition Analysis for four OECD Countries.*
Maria SAVONA, André LORENTZ, janvier 2006.

2006–**02** *A strategic model of complex networks formation.*
Nicolas CARAYOL, Pascale ROUX, janvier 2006.

2006–**03** *Coordination failures in network formation.*
Nicolas CARAYOL, Pascale ROUX, Murat YILDIZOGLU, janvier 2006.

2006–**04** *Real Options Theory for Lawmaking.*
Marie OBIDZINSKI, Bruno DEFFAINS, août 2006.

2006–**05** *Ressources, compétences et stratégie de la firme : Une discussion de l'opposition entre la vision Porterienne et la vision fondée sur les compétences.*
Fernand AMESSE, Arman AVADIKYAN, Patrick COHENDET, janvier 2006.

2006–**06** *Knowledge Integration and Network Formation.*
Müge OZMAN, janvier 2006.

2006–**07** *Networks and Innovation : A Survey of Empirical Literature.*
Müge OZMAN, février 2006.

2006–**08** *A.K. Sen et J.E. Roemer : une même approche de la responsabilité ?*
Herrade IGERSHEIM, mars 2006.

2006–**09** *Efficiency and coordination of fiscal policy in open economies.*
Gilbert KOENIG, Irem ZEYNELOGLU, avril 2006.

2006–**10** *Partial Likelihood Estimation of a Cox Model With Random Effects : an EM Algorithm Based on Penalized Likelihood.*
Guillaume HORNY, avril 2006.

2006–**11** *Uncertainty of Law and the Legal Process.*
Giuseppe DARI–MATTIACCI, Bruno DEFFAINS, avril 2006.

2006–**12** *Customary versus Technological Advancement Tests.*
Bruno DEFFAINS, Dominique DEMOUGIN, avril 2006.

2006–**13** *Institutional Competition, Political Process and Holdup.*
Bruno DEFFAINS, Dominique DEMOUGIN, avril 2006.

2006–**14** *How does leadership support the activity of communities of practice ?*
Paul MULLER, avril 2006.

2006–**15** *Do academic laboratories correspond to scientific communities ? Evidence from a large European university.*
Rachel LÉVY, Paul MULLER, mai 2006.

2006–**16** *Knowledge flows and the geography of networks. A strategic model of small worlds formation.*
Nicolas CARAYOL, Pascale ROUX, mai 2006.

2006–**17** *A Further Look into the Demography–based GDP Forecasting Method.*
Tapas K. MISHRA, juin 2006.

2006–**18** *A regional typology of innovation capacities in new member states and candidate countries.*
Emmanuel MULLER, Arlette JAPPE, Jean–Alain HÉRAUD, Andrea ZENKER, juillet 2006.

2006–**19** *Convergence des contributions aux inégalités de richesse dans le développement des pays européens.*
Jalal EL OUARDIGHI, Rabiji SOMUN–KAPETANOVIC, septembre 2006.

2006–**20** *Channel Performance and Incentives for Retail Cost Misrepresentation.*
Rabah AMIR, Thierry LEIBER, Isabelle MARET, septembre 2006.

2006–**21** *Entrepreneurship in biotechnology : The case of four start–ups in the Upper–Rhine Biovalley.*
Antoine BURETH, Julien PÉNIN, Sandrine WOLFF, septembre 2006.

2006–**22** *Does Model Uncertainty Lead to Less Central Bank Transparency ?*
Li QIN, Elefterios SPYROMITROS, Moïse SIDIROPOULOS, octobre 2006.

2006–**23** Enveloppe *Soleau et droit de possession antérieure : Définition et analyse économique.*
Julien PÉNIN, octobre 2006.

2006–**24** *Le territoire français en tant que Système Régional d'Innovation.*
Rachel LEVY, Raymond WOESSNER, octobre 2006.

2006–**25** *Fiscal Policy in a Monetary Union Under Alternative Labour–Market Structures.*
Moïse SIDIROPOULOS, Eleftherios SPYROMITROS, octobre 2006.

2006–**26** *Robust Control and Monetary Policy Delegation.*
Giuseppe DIANA, Moïse SIDIROPOULOS, octobre 2006.

2006–**27** *A study of science–industry collaborative patterns in a large european university.*
Rachel LEVY, Pascale ROUX, Sandrine WOLFF, octobre 2006.

2006–**28** *Option chain and change management : a structural equation application.*
Thierry BURGER–HELMCHEN, octobre 2006.

2006–**29** *Prevention and Compensation of Muddy Flows : Some Economic Insights.*
Sandrine SPAETER, François COCHARD, Anne ROZAN, octobre 2006.

2006–**30** *Misreporting, Retroactive Audit and Redistribution.*
Sandrine SPAETER, Marc WILLINGER, octobre 2006.

2006–**31** *Justifying the Origin of Real Options and their Difficult Evaluation in Strategic Management.*
Thierry BURGER–HELMCHEN, octobre 2006.

2006–**32** *Job mobility in Portugal : a Bayesian study with matched worker–firm data.*
Guillaume HORNY, Rute MENDES, Gerard J. VAN DEN BERG, novembre 2006.

2006–**33** *Knowledge sourcing and firm performance in an industrializing economy : the case of Taiwan in the 1990s.*
Chia–Lin CHANG, Stéphane ROBIN, novembre 2006.

2006–**34** *Using the Asymptotically Ideal Model to estimate the impact of knowledge on labour productivity : An application to Taiwan in the 1990s.*
Chia–Lin CHANG, Stéphane ROBIN, novembre 2006.

2006–**35** *La politique budgétaire dans la nouvelle macroéconomie internationale.*
Gilbert KOENIG, Irem ZEYNELOGLU, décembre 2006.

2006–**36** *Age Dynamics and Economic Growth : Revisiting the Nexus in a Nonparametric Setting.*
Théophile AZOMAHOU, Tapas MISHRA, décembre 2006.

2007–**01** *Transparence et efficacité de la politique monétaire.*
Romain BAERISWYL, Camille CORNAND, janvier 2007.

2007–**02** *Crowding–out in Productive and Redistributive Rent–Seeking.*
Giuseppe DARI–MATTIACCI, Éric LANGLAIS, Bruno LOVAT, Francesco PARISI, janvier 2007.

2007–**03** *Co–résidence chez les parents et indemnisation des jeunes chômeurs en Europe.*
Olivia ÉKERT–JAFFÉ, Isabelle TERRAZ, janvier 2007.

2007–**04** *Labor Conflicts and Inefficiency of Relationship–Specific Investments : What is the Judge's Role ?*
Bruno DEFFAINS, Yannick GABUTHY, Eve–Angéline LAMBERT, janvier 2007.

2007–**05** *Monetary hyperinflations, speculative hyperinflations and modelling the use of money.*
Alexandre SOKIC, février 2007.

2007–**06** *Detection avoidance and deterrence : some paradoxical arithmetics.*
Éric LANGLAIS, février 2007.

2007–**07** *Network Formation and Strategic Firm Behaviour to Explore and Exploit.*
Muge OZMAN, février 2007.

2007–**08** *Effects on competitiveness and innovation activity from the integration of strategic aspects with social and environmental management.*
Marcus WAGNER, février 2007.

2007–**09** *The monetary model of hyperinflation and the adaptive expectations : limits of the association and model validity.*
Alexandre SOKIC, février 2007.

2007–**10** *Best–reply matching in Akerlof's market for lemons.*
Gisèle UMBHAUER, février 2007.

2007–**11** *Instruction publique et progrès économique chez Condorcet.*
Charlotte LE CHAPELAIN, février 2007.

2007–**12** *The perception of obstacles to innovation. Multinational and domestic firms in Italy.*
Simona IAMMARINO, Francesca SANNA–RANDACCIO, Maria SAVONA, mars 2007.

2007–**13** *Financial Integration and Fiscal Policy Efficiency in a Monetary Union.*
Gilbert KOENIG, Irem ZEYNELOGLU, mars 2007.

2007–**14** *Mise en œuvre du droit du travail : licenciement individuel et incitations.*
Yannick GABUTHY, Eve–Angéline LAMBERT, avril 2007.

2007–**15** *De l'amiante au chrysotile, un glissement stratégique dans la désinformation.*
Gisèle UMBHAUER, avril 2007.

2007–**16** Le *don tel qu'il est, et non tel qu'on voudrait qu'il fût.*
Frédéric LORDON, mai 2007.

2007–**17** *R&D cooperation versus R&D subcontracting : empirical evidence from French survey data.*
Estelle DHONT–PELTRAULT, Étienne PFISTER, mai 2007.

La présente liste ne comprend que les Documents de Travail publiés à partir du 1er janvier 2000. La liste complète peut être donnée sur demande.
This list contains the Working Paper writen after January 2000, 1rst. The complet list is available upon request.