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Drivers of the Offshore Outsourcing of R&D: Empirical Evidence from French Manufacturers

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Abstract

The pace of technological change and the challenges faced by companies to remain competitive in global markets have contributed to a global expansion of R&D transactions. This paper shows that French companies engaged in the offshore outsourcing of R&D are outward oriented essentially through exports. Further, single unit companies seem more active in this type of R&D transaction than companies belonging to a group. These findings suggest a stronger integration of small and medium size exporting companies into international networks of innovation. Technological sourcing seems to be leading this phenomenon more than cost-opportunities motivations.

JEL classification: L23; L24 ; O31; O32

Keywords: R&D Outsourcing, Offshore of Research and Development Activities, Globalization.

Outline

Non-Technical Summary

This paper presents an empirical investigation of the offshored outsourcing of R&D activities by manufacturing firms located in France over the years 1993-2001. There is plenty of anecdotal evidence that outsourcing of research and development (R&D) is becoming a central issue in business' strategies, is on the rise, and occurring in a global scale. The increase in the outsourcing of R&D is associated with the growing internationalization of technological activities, where the fragmentation of the R&D activities follows up the earlier process of globalization of value chains started with assembling and production. This ongoing transformation is influenced by the need to integrate international networks of innovation, driven both by cost-saving opportunities and technology sourcing motivations.

The upsurge of R\&D activities abroad has stimulated an intense policy debate; including implications on employment (i.e. the replacement of white collar employees), countries' innovation capacity, and by extension, the well-being of national economies. Hence a fundamental question on the phenomenon of R&D outsourcing is whether it levels off innovation by firms and under what conditions this works out. By permitting firms to optimize resources, both financial and technological, R\&D outsourcing might help firms level-off productivity of internal research by the virtues of specialization and flexibility in research, speeding product development and smoothing product life cycles, in addition to expanding the pool of knowledge (Cesaroni, 2004; Arora and Gambardella, 1994). It can be helpful to manage R&D costs and access specialized knowledge, use facilities and specialized infrastructure, amongst others. The externalization of activities is not an easy task for firms. There are important shortfalls: e.g. costs of integration, rejection of new knowledge by employees; difficulties in the exploitation of knowledge outsourced to third parties (notably the loss of proprietary rights, miss-specification of outcomes, etc.). These difficulties are much important when outsourcing R\&D takes place overseas. Contracting costs tend to be more seriously burdensome across national borders as they imply extra costs for communication in different languages and adjustments across different legal systems (Tomiura, 2005; Cusmano et al., 2006).

This analysis shows several important findings for the understanding of companies' use of international procurement of R&D services. Within the sample of domestic companies, the results show that companies that do not belong to a group are more likely to outsource R&D abroad. More importantly, integration to global markets, notably through exports is found as a meaningful driver of offshore outsourcing of R&D. Hence globalized companies are more likely to involve in international technology transactions as competition in the global product market pushes them to integrate global networks of innovation, without necessarily demanding a physical presence (cf. foreign direct investment) abroad. Lastly, consistent evidence is found on the predominance of technological sourcing motivation (searching of technological competencies) over cost-saving motivations (e.g. cost of researchers, tax-exemption on R&D, etc.). Hence having R&D linkages abroad is growing in importance as research activities grow in expense and complexity and new pools of technology creation emerge in the global landscape.

1 Introduction

There is plenty of anecdotal evidence that outsourcing of research and development (R&D) is becoming a central issue in business' strategies, is on the rise, and occurring in a global scale. For example, in a recent survey on 158 large European companies, 70% declared that they have significantly increased the share of R&D outsourcing (in total R&D expenses) over the past five years, almost in the same magnitude as internal R&D (LTT-Research, 2006). In a survey conducted in the United States (U.S.), almost half of the companies surveyed in a wide range of industries declared to be involved with outside organizations; 28% had research contracts with commercial labs, 22% with universities and 34% with other companies (R&D magazine, 2007). Furthermore, about 18% of these organizations declared to have offshored some of their work to China, and 19% of them to India.

These patterns are associated with the growing internationalization of technological activities, where the fragmentation of the R&D activities follows up the earlier process of globalization of value chains started with assembling and production. This ongoing transformation is influenced by the need to integrate international networks of innovation, driven both by cost-saving opportunities and technology sourcing motivations. There are others factors at stake. The accelerating pace of technological change, the shortening of product life cycles, in combination with higher costs of investment in many areas of technology, have all contributed to increase the reliance on external producers of technology. In parallel, transactions costs in global markets have decreased with international policy reforms (e.g. strengthening of intellectual property rights, less restrictions in technology and foreign direct investment) and new specialized producers of technology have emerged across the globe (Athreye and Cantwell, 2007; Arora et al., 2001). At the heart of this changing configuration the upsurge of information and communication technologies (ICT) has played a major role by making easier

the transfer of information and coordination through cross-border projects, and more in general, the ways of conducting geographically dispersed innovative activities (Santangelo, 2002).

This paper investigates company and technology drivers of offshore outsourcing of R&D by French manufacturing companies over the years 1993-2001[1]. It aims at increasing the understanding of the R&D offshore phenomenon. Although the internationalization of services is still in its early stages (cf. UNCTAD (2006)), the upsurge of R&D activities abroad has stimulated an intense policy debate; including implications on employment (i.e. the replacement of white collar employees), countries' innovation capacity, and by extension, the well-being of national economies. Hence a fundamental question on the phenomenon of R&D outsourcing is whether it levels off innovation by firms and under what conditions this works out. By permitting firms to optimize resources, both financial and technological, R&D outsourcing might help firms level-off productivity of internal research by the virtues of specialization and flexibility in research, speeding product development and smoothing product life cycles, in addition to expanding the pool of knowledge (Cesaroni, 2004; Arora and Gambardella, 1994). It can be helpful to manage R&D costs and access specialized knowledge, use facilities and specialized infrastructure, amongst others. The externalization of activities is not an easy task for firms.[2] There are important shortfalls: e.g. costs of integration, rejection of new knowledge by employees; difficulties in the exploitation of knowledge outsourced to third parties (notably the loss of proprietary rights, miss-specification of outcomes, etc.). These difficulties are much important when outsourcing R&D takes place overseas. Contracting costs tend to be more seriously burdensome across national borders as they imply extra costs for

[1]The term offshore outsourcing of R&D is used here to refer to the transfer of the responsibility for R&D operations to an external provider located in a different country than the recipient. Broadly speaking, offshore outsourcing of activities refer to a "different country location"; that is, they can be executed by an affiliated company (R&D laboratory set-up) or by a third company (non-affiliated). We designate the latter as offshore outsourcing of R&D. That is to say, the term offshore outsourcing still lacks a proper generally acknowledged definition.

[2]See for instance Veugelers (1997); Nakamura and Odagiri (2003); Cassiman and Veugelers (2002a)

communication in different languages and adjustments across different legal systems (Tomiura, 2005; Cusmano et al., 2006).[3]

While the topic offshore outsourcing attracts important policy concerns, the empirical examination still remains under-developed. There are not many statistics or data available on R&D offshore outsourcing since information from companies is very difficult to obtain. In addition, the few statistics available focus on the international R&D investments made by companies, rather than purchased R&D services. As a result, empirical evidence is scarce on the drivers of this phenomenon and its consequences on firms' technological performance. This paper attempts to fill this gap. It examines the company and technology drivers of offshore outsourcing of R&D. Our analysis shows several important findings for the understanding of companies' use of international procurement of R&D services. Within the sample of domestic companies, the results show that companies that do not belong to a group are more likely to outsource R&D abroad. More importantly, integration to global markets, notably through exports is found as a meaningful driver of offshore outsourcing of R&D. Hence globalized companies are more likely to involve in international technology transactions as competition in the global product market pushes them to integrate global networks of innovation, without necessarily demanding a physical presence (cf. foreign direct investment) abroad. Lastly, consistent evidence is found on the predominance of technological sourcing motivation (searching of technological competencies) over cost-saving motivations (e.g. cost of researchers, tax-exemption on R&D, etc.). Hence having R&D linkages abroad is growing in importance as research activities grow in expense and complexity and new pools of technology creation emerge in the global landscape.

The paper is organized as follows. The first section discusses, briefly, the literature and exposes

[3]Other costs include: higher employee turnover; lack of coherence, delays in schedules, appropriation of competence by employees and other companies, etc. International outsourcing may thus entail exacerbated costs associated to asymmetric information and monitoring between parties.

our main hypotheses. The second section describes the recent patterns in outsourcing of R&D in the French manufacturing industries. Description of data and variables is discussed in the third section whereas the fourth section presents the results. The main conclusions and policy implications of this study are reported in the last section.

2 R&D Outsourcing and Offshored Outsourcing

Essentially the outsourcing of R&D addresses the question as to whether a company should make or buy technology (which can be inputs or outputs). Most commonly discussed in relation to the vertical chain of production, this issue has a long tradition in economics dating back to the seminal work of Coase (1937). The simplest logic implies that firms would prefer to buy as opposed to make as long as the costs of externalization are lower than in-house production.

Most of the underlying sources of transaction costs of R&D are similar to those of mature goods and services, including bounded rationality combined with uncertainty, and opportunism combined with non-redeployable assets (such as R&D sunk costs, customized R&D output and co-specialized complementary assets). Contrary to production, the cognitive and appropriable aspects of knowledge (von Hippel, 1988, 1994) make difficult the delegation of research activities to outside companies. The specificity of the asset to be transferred may raise information asymmetries between parties favoring supplier opportunistic behavior and creativity degradation (Pisano, 1990; Williamson, 1975). Incomplete contracting is another major factor deterring the outsourcing of activities. The partners might differ in incentives and pursue their own goals more than the common goal (e.g. few incentives to innovate by the supplier, few resources invested by the outsourcer), notably under the presence of outcome uncertainty and information asymmetry, e.g. the value of the resulting innovation (Grossman

and Hart, 1986; Hart, 1995; Aghion and Tirole, 1997).[4] In this kind of contexts, the ownership of property right on the results of research is a major element, because the owner can claim the residuals that have not been specified in the contract. These risks, notably regarding property rights, make R&D outsourcing less attractive. Others factors influence as well the viability of outsourcing compared to internalization. These are the bargaining power of the partners, the degree of competition in the suppliers' side, and the number of potentially partners, e.g. outsourcers (Grossman and Helpman, 2005).

Other reasons at stake are scale and scope economies. It is economically efficient to produce a certain product or service in a large volume or jointly with other products/services. The question of externalization arises however, if the input or good is required only in a limited quantity or in a temporary basis. It is less costly for the firm to buy them from specialized suppliers, which are more able to achieve economies of scale and scope in the provision of a specialized resource and so, more competitive prices. A crucial factor in the decision to externalize R&D concerns the type of technology and the nature of innovation. In comparison to the supply of goods and services in mature industries, the outsourcing of R&D is more difficult when the outcomes are uncertain, notably when R&D aims at developing radical innovation and creative technological solutions. Hence not surprisingly, R&D outsourcing is more frequent when it concerns generic technologies (Antras, 2005) and technologies involving codified knowledge (Trefler, 2005), which are easier to understand and assimilate.[5] However, as products and technologies become more complex and inter-dependent and innovation relies on an increasing range of specialized technological competencies, companies need to seek outside collaboration with organizations specialized in those required fields. External

[4] As explained by Aghion and Tirole (1997), although outsourcing helps to mitigate the managerial overload notably in innovation activities (e.g. search costs and management), it creates a hold-up problem, causing some of the rents of the owners to be dissipated to the supplier.

[5] Davidson and McFetridge (1984, 1985) found that the probability of internalization is higher the more radical the technology and the larger the R&D section of the firm.

specialized providers of technology complement internal R&D work, which makes innovative labor more properly devised between companies, and resources better allocated in industries (Arora and Gambardella, 1990; Coombs and Metcalfe, 1998; Quintas, 2003).

Increasingly, the delegation of R&D tasks takes the form of outsourcing to international suppliers. As regards internationalization of production, market and cost factors are at stake, in addition to those influencing transactions of technology. The motivations for the delegation or location of R&D activities abroad are basically two non-exclusive types: the search of costs advantages in the production of R&D and the access to new knowledge and specialized competencies.

For multinational companies, the conduct of R&D abroad responds to the need of designing products in consonance with local tastes, accelerating entry into foreign markets, and the lunching of new products as local firms are more familiar with national regulations.[6] At the same time, offshoring of R&D constitutes a way to deal with growing R&D costs by exploiting cross-country differentials in the costs of labor and technology (lower costs of scientists and engineers, more favorable tax treatments, etc.). In parallel, offshore outsourcing to specialized suppliers brings other benefits in addition to costs: access to 24/7 global processes so that research activities are non-stop, they can be passed on between two teams in two locations. This results in a compressed time for the project completion and speedier introduction of new products to market; higher volumes of innovation and ability to tailor goods and services to specific foreign markets.

The literature on the internationalization of R&D provides evidence on the growing importance of "technology sourcing" motivations, notably in R&D intensive industries. The survey-based studies by Florida (1997), Kuemmerle (1996, 1999) and Niosi and Godin (1999) suggest a rise of

[6]Researchers have long argued that when firms enter foreign markets, they face additional costs associated with doing business in unfamiliar environments where local competitors have both tangible and intangible advantages ("the liability of foreignness"). These costs involve expenditures associated with acquiring information regarding cultural, political and economic differences (Hymer, 1976).

knowledge seeking activities, with diversification purposes, and the emergence of globally-focused R&D activities in subsidiaries. More recently, Thursby and Thursby (2006) find in a survey that "market growth potential" and "R&D personnel quality" are the top two factors that drive multinational enterprises to offshore R&D to emerging economies.[7] As regards offshore outsourcing of R&D, cost and market factors have been also pointed as major motivations. Using survey data on offshore implementations initiated by U.S. firms between 1990 and 2006, Lewin et al. (2008) find that firms use R&D offshore more frequently in the search of "cost savings opportunities" to improve the efficiency of the innovation process and to increase "speed to market". Similar motivations are reported for Japanese companies (Ito et al., 2007): access to local market (e.g. design product in consonance with local demands, regulations, etc.) and the agglomeration of local firms and R&D institutions (universities, public research centers,..).

In comparison to domestic outsourcing, the viability of international outsourcing R&D relationships presents supplementary complications. The longer the technological, geographical, and cultural distance between the supplier and the outsourcing firm, the higher the costs of transactions. Contract costs tend to be more seriously burdensome across national borders, reflecting extra costs for communication in different languages and adjustments across different legal systems. Offshore outsourcing may entail additional costs associated to asymmetric information and monitoring between parties. The risks associated to intellectual property rights and the costs of knowledge integration, can be higher as compared to domestic outsourcing. Further, accessing and managing R&D teams in globally dispersed locations require particular coordination strategies as well as organizational forms for managing, sharing, and exploiting dispersed knowledge.

[7] Although the supply of scientists and engineers (S&E) professionals (e.g. China, India, Korea) in emerging markets seems an increasing attracting motivation, companies frequently declare that the quality of intellectual property protection is an inhibiting factor for R&D offshoring to these economies (Branstetter et al., 2006; Lewin et al., 2008).

3 Data and Trends

The analysis presented in this paper is based on the "Enquête Recherche et Developpement", annually realized by the French ministry of research for the period 1993-2001. It is a non-exhaustive survey addressed to firms having an internal R&D activity. It provides data on the characteristics of the firms as well as on their innovative activity. More specifically, it provides detailed information on the internal and external R&D strategies adopted by each firm. On this basis, our analysis of outsourcing activities focuses on R&D performers companies. This survey provides very rich information which has been rather unexploited to this date. External R&D can be decomposed into R&D outsourced from domestic sources, e.g. public organizations, universities and local firms, and foreign sources, e.g. international organizations and firms located abroad. We limit the data to manufacturing firms for which we have information on the production activity. Companies belonging to the R&D services sector (whose main activity is selling technology) are excluded from the sample. Data on the production activity is extracted from the firm annual survey "Enquête Annuelle d'Entreprises" (EAE) for manufacturing sectors realized by the French ministry of industry.

The firms, in our sample, are concentrated in few sectors; 19% in mechanical equipment industry, 17% in the chemical industry, 15% in electric equipment industry, 8% in the pharmaceutical industry and 8% in the electronic component industry. In France, the share of outsourced R&D has grown sharply, in relative terms, from less than 15% of total R&D expenses at the beginning of the 80s' to more than 23% in the 90s' (Blanchard et al., 2004).[8] According to the "Research and Development" survey, more than half of the firms in the sample outsource part of their R&D activity during the period 1993-2001. A first look to the data shows that foreign firms, on average, have a smaller external R&D activity than French firms.

[8]Further, this evolution appears stronger in knowledge intensive industries: Birch (2003) reports a 14.6% average annual rate growth of R&D outsourcing between 1997 and 2001 in the pharmaceutical industry.

Moreover, among the French firms, those belonging to a group have, on average, the greatest external R&D activity.[9]

Figure 1 illustrates the evolution of the intensity of outsourcing and offshored outsourcing R&D by French manufacturing firms for the total sample. Domestic firms as well as foreign affiliates present a similar evolution of their R&D activities. It shows that the domestic outsourcing is larger than the international outsourcing and both types of outsourcing have been steadily increasing over the period of the sample, especially international outsourcing.

Before reporting summary statistics, several points need to be mentioned regarding the data on R&D outsourcing from this survey. First, outsourcing of non production overhead services "External-RD" stands for the total expenditures regarding the outsourcing of R&D activities, "Domestically-RD" stands for the domestic outsourcing of R&D while "Offshored-RD" represents total expenditures regarding the outsourcing of R&D overseas. Second, contracting-out to own subsidiaries is not separated in the outsourcing expenditure, as this information (intra-firm and extra-firm outsourcing) is only available for very few years. Third, arm's length purchases or licensing payments are not included, as they do not imply R&D activities as defined in the survey (OECD, 2002).

Figure 1

Table 1 reports the percentage of firms, in each industry, engaged in the outsourcing of R&D, and at the national and international levels respectively. Table 2 reports the intensity of R&D outsourcing (expenditure per employee) for these companies. On average, 30% of French companies outsourced some R&D tasks to externals over the period 1993-2001; but the majority of this activity was conferred to national providers of R&D services. Only 3% of manufacturing companies in our sample are engaged into outsourcing of R&D activities abroad. This very low

[9]However, there is no significant difference between foreign firms, French affiliates and French independent firms in regards of the internal R&D activity.

share indicates that a very specific type of companies is able to overcome international transaction costs and access global technology markets. Another point to remark is the important cross-industry variability (table 1). The industries with a relatively high percentage of firms engaged in the outsourcing of R&D activities include the pharmaceutical; coke, refined petroleum and nuclear fuel industry; the industry of other transport equipments, other non metallic mineral products; and electrical machinery and apparatus. The industries more intensively active abroad are also the same ones that report the highest activity in domestic markets and in total outsourcing. Coke and refined petroleum and fuel, followed by pharmaceuticals appear as the two largest sectors being involved in international R&D markets. Interestingly, in addition to the five most active sectors in outsourcing activities, the industry of motor vehicles, trailers, and other transports, appears quite involved internationally: 5% of companies are active in this activity compared to the mean of the sample (3%).

A better picture is given by looking at the expenditure per employee by sector: the sectors more intensively outsourcing R&D are: the industry of mechanical equipment, the pharmaceutical industry and the industry of electronic components. Interestingly, in pharmaceuticals, the level of outsourcing represents around 80% of internal R&D investment per employee. In this sector, outsourcing of R&D is almost as much as important as internal investment in R&D. Other high R&D intensive industries such as electrical machinery and apparatus; office, accounting and computing; or radio, tv and communication equipment, report outsourcing intensities above the mean. In the industry of coke, refined petroleum products, the level of expenditure is much higher than the internal investment, reflecting the importance of technology exchanges for innovation. Other sectors such as the clothing articles and leather, wearing apparel products are rather inactive in this field.

Table 1: Outsourcing of R&D in Manufacturing Industries

	Outsourcing R&D	**Domestically**	**Offshore**
Basic Metals	0.26	0.26	0.03
Chemicals exc. Pharmaceuticals	0.31	0.28	0.03
Coke, refined petroleum products	0.69	0.62	0.15
Electrical mach. and apparatus	0.28	0.25	0.02
Fabricated Metal Products	0.26	0.24	0.01
Leather, leather products & footwear	0.12	0.12	0
Machinery and Equipment	0.2	0.18	0.01
Manufacturing nec	0.26	0.23	0.02
Medical, precision and optical	0.31	0.28	0.02
Motor Vehicles, trailers, etc.	0.22	0.17	0.05
Office, accounting and computing	0.24	0.21	0.02
Other Transport equipment	0.41	0.39	0.09
Other non metallic mineral products	0.43	0.41	0.02
Pharmaceuticals	0.65	0.62	0.11
Printing and publishing	0.18	0.15	0.02
Pulp, paper and paper products	0.28	0.23	0.03
Radio, TV and commu. Equipment	0.28	0.25	0.02
Rubber and plastic products	0.26	0.23	0.01
Textiles	0.21	0.18	0.01
Wearing apparel	0.08	0.08	0
Wood and products of wood	0.35	0.31	0.01
Total	**0.30**	**0.27**	**0.03**

4 Methodology

In this section we proceed to analyze the drivers of outsourcing and offshore outsourcing of R&D activities. The censured nature of the data to zero (46% of the firms depend exclusively on in-house investments in R&D and only 14.5% are engaged in the offshore outsourcing of R&D) requires a special statistical treatment. An approach generally used to deal with the problem of censured samples is the Tobit model.

By assuming that the disturbance term follows a normal distribution, the Tobit model combines the probabilistic and ordinary regression with the method of maximum likelihood (Amemiya, 1973; Tobin, 1958; Wooldridge, 2001). The likelihood function for a tobit model involves then two distinct components: (1) the process that determines whether the outcome variable is fully observed or not and (2) the process that determines the score on the dependent variable for individuals whose outcome is fully observed.

Table 2: Intensity of internal and external R&D (expenditures by employee)

	Internal R&D	**Outsourcing R&D**	**Domestically**	**Offshore**
Basic Metals	21.46	3	2.76	0.23
Chemicals exc. Pharmaceuticals	60.19	9.97	7.59	2.39
Coke, refined petroleum products	32.55	58.12	52.32	5.81
Electrical mach. and apparatus	74.64	8.28	6.94	1.34
Fabricated Metal Products	19.99	1.22	1.06	0.16
Leather, leather products & footwear	15.21	0.46	0.46	0
Machinery and Equipment	30.74	2.53	2.1	0.43
Manufacturing nec	21.35	2.3	1.89	0.41
Medical, precision and optical in	63.35	7.47	6.02	1.45
Motor Vehicles, trailers, etc.	41.64	12.53	11.7	0.83
Office, accounting and computing	118.17	13.98	11.05	2.93
Other Transport equipment	56.57	15.94	9.99	5.95
Other non metallic mineral products	22.8	3.37	2.99	0.39
Pharmaceuticals	71.89	55.41	42.01	13.4
Printing and publishing	20.73	1.86	1.75	0.11
Pulp, paper and paper products	11.08	2.46	2.09	0.37
Radio, tv and commu. equipment	136.94	15.67	13.48	2.19
Rubber and plastic products	23.9	2.89	2.45	0.44
Textiles	36.04	1.72	1.35	0.37
Wearing apparel	37.37	0.95	0.77	0.18
Wood and products of wood	13.91	1.19	1.03	0.15
Total	**49.32**	**10.74**	**8.54**	**2.2**

4.1 Explanatory factors

We relate the outsourcing of R&D to several company and industry characteristics. Our dependent (s) variable (s) is the intensity of outsourced R&D -total, domestic and overseas -, to the firm's scale, in separated models. On the right-hand side, the explanatory variables include company characteristics: company size, intensity of internal R&D, export activity, the outsourcing of manufacturing tasks, technology gap, a dummy indicating whether the company is an affiliate of a French group, and a dummy indicating whether the company is an affiliate of a foreign group. The choice of these firm level covariates is guided by theoretical considerations as well as empirical evidence. All covariates, except for the ones representing the status of the firm[10], are lagged by one period in order to mitigate potential endogeneity

[10]These variables are dummies representing the affiliation of the firm to French or foreign group as well as the involvement of the firm in the outsourcing of manufacturing tasks. These variables do not vary within the time period of our study.

concerns. Further, a set of industry and time dummies is included.[11]

The intensity of outsourcing is explained first by the intensity of in-house R&D expenditures scaled by the workforce of the firm. Theory and empirics tend to confirm that R&D intensive firms are more likely to engage in the outsourcing of technology and in open innovation strategies in general (Kaiser, 2002; Cassiman and Veugelers, 2002b; Mol, 2005) .[12] As Cohen and Levinthal (1989, 1990) and Kamien and Zang (2000) demonstrate, internal R&D increases the benefit of external knowledge. Internal R&D plays a double role: it constitutes the capacity to generate new knowledge while allowing the firm to better identify and assimilate external knowledge (e.g. integrate it to the innovation process and manufacturing). This argument is advanced by the open-innovation paradigm (Chesbrough, 2003) that is increasingly being adopted in numerous industries where interactions with externals by means of buying or licensing technology from other companies are necessary for being at the forefront of innovation. The relationship is less clear-cut regarding offshore outsourcing of innovation activities and there are not many studies on this topic. Recently, in a study of outsourcing activities by Italian companies, Cusmano et al. (2006) found that the level of R&D intensity explains significantly outsourcing activities but it was not influential on offshore outsourcing of R&D.[13] In principle, as companies are more R&D intensive, one would expect these companies to have products which are more complex and that are embedded with company-specific competencies. These R&D tasks would demand a close interaction between providers and the company. In addition, as knowledge is more central to the company, concerns are strong regarding full appropriability of R&D outcomes.

We include an additional indicator on the technological nature of the company. We take into

[11] The dependent (s) variable (s) as well as all of the explanatory variables, except for the dummies and the research intensity variable, are expressed in natural logarithm.

[12] At the industry level, for a sample of Dutch manufacturing industries, Mol (2005) finds that R&D intensity became a positive predictor for changes in outsourcing levels over the 1990s, suggesting firms in R&D intensive industries have increasingly started to rely on partnership relations with outside suppliers.

[13] A similar finding is reported by Tomiura (2006) on outsourcing of manufacturing abroad.

account a measure of the quality of research proxied by the number of researchers over total employees. At the difference of R&D expenditures per employee which would measure intensity in terms of volume of R&D, and includes all types of R&D resources (technicians, engineers, researchers and other related human skills for R&D); this indicator reflects the level of sophistication of skills conducted in the company. The relationship with outsourcing is ambiguous; in one hand, companies with high-level human capital would tend to focus on core competencies while leaving to the market the provision of complementary downstream technologies. On the other hand, this type of companies would be less likely to interact with outsiders as they may found more risky and difficult to delegate R&D tasks that could be more complex and delicate to implement and require a high level of sophisticated human capital.[14] The empirical evidence tends to suggest that larger firms are more likely to engage into outsourcing (Veugelers and Cassiman, 1999; Cassiman and Veugelers, 2002a,b) as they are more able to overcome transaction and agency costs and have a higher bargaining power (Veugelers, 1997). Furthermore, it is often argued that their propensity to delegate R&D activities is higher as these firms can have stronger financial resources allowing them to afford more important capabilities in intellectual property practice.[15] Small and medium enterprises have difficulties in achieving economies of scale and scope in the provision of tertiary functions and they are less actives in R&D outsourcing as they have less and simpler needs than larger companies. By extension, it is expected that size matters more for outsourcing overseas. However, recent evidence casts doubts about the relationship of size and outsourcing of R&D abroad. Using a recent survey on offshoring activities by U.S. companies, Lewin et al. (2008) found that smaller firms have higher probability of offshoring product development projects, indicating that

[14]More broadly, according to Cusmano et al. (2006) and Tomiura (2005), qualified human skills are deemed essential for contracting abroad, since this activity requires high level skills such as interacting with partners in foreign languages and concluding contracts under different legal systems.

[15]According to Veugelers and Cassiman (1999), small firms are more likely to restrict their innovation strategy to an individual strategy (to make or to buy), whilst the largest firms tend to combine external and internal strategies.

offshoring enables smaller and more agile companies to augment their innovation capabilities in contrast to larger and more resourceful companies. We include in all our regressions a measure of the firm's size represented by the total number of employees.

One can expect that the companies outsourcing R&D are different in terms of technological needs and endowments, and notably, in terms of market orientation and production strategies. Two indicators convey information on the firm business experience in foreign countries: we include a dummy indicating whether the firm is affiliated to a French or a foreign group, respectively, and variable representing the firm's export intensity (the share of the exported output in the firm's total output). We expect that firms who are active into international markets through exports are more prone to be in contact with international suppliers of technology, as they face a more fierce technology based competition. Further, if the company is a part of a conglomerate, given that they are embedded in an international production network (through their relationship with the parent and other affiliates abroad), they may be expected to have a better access to networks of external providers of services (and potential clients), and better bargaining position than companies that are not part of a group. Likewise, the origin of the firm's group should matter for the use of outside contractors. Foreign establishments, which are by definition part of a multinational enterprise, can be expected to use higher levels of technology internationally due to their technology specific assets, but lower levels at the domestic level as domestic firms might be better informed about the local suppliers of technology, regulatory aspects, national support for local alliances, etc.

A variable representing the extent of transaction costs in the domestic market is also included. We use the number of potential buyers as a measure of transaction costs. If the potential buyers are numerous, the supplier is not dependent upon a single partner and the spreading of sunk costs over a larger size of customers permits the achievement of scale economies and lower prices. However, the smaller the number of potential outsourcers, the bigger the bargaining

power of a firm relative to any given partner (Tyler and Steensma, 1995; Pisano, 1990). We include a dummy variable indicating if the firm is engaged in the outsourcing of manufacturing inputs. We postulate that the outsourcing of manufacturing inputs influences positively the reliance on external producers of R&D. We would expect that firms more frequently delegating tasks across the chain of production, as they have more experience and abilities in negotiating contracts, are more prone to engage into outsourcing and offshoring of R&D.

We include in all regressions indicators of the technical efficiency of the firm. Technical efficiency is proxied by the total factor productivity (TFP) index, estimated using the methodology proposed by Olley and Pakes (1996). We build a measure of the technology gap as the difference between the firm's productivity level and the highest productivity level within the same industry.[16] According to Acemoglu et al. (2002), for more productive firms -closer to the technological frontier-, innovation is more important than for technologically lagging companies.[17] For more efficient firms, which can handle management overload, outsourcing is a way to stimulate innovation-related investment, by sharing ex-post rents and increasing returns to specialization. Moreover, efficient firms are expected to engage more frequently in offshoring because the outsourcing across borders entails high fixed costs Tomiura (2005, 2006); Jabbour (2008).[18] We also add the cash flow (scaled by the firm's total employment) as well as the R&D subsidy received by the firm. While there is no defined theoretical argument about their role, we would expect that financially constraints hinder all modes of investing in technology, either in-sourcing or outsourcing. Public aids to conduct R&D are expected to have

[16]We estimate TFP (total factor productivity) industry by industry, following the two digits French classification, on the basis of the entire Enquête Annuelle d'Entreprises sample.

[17]Some research has shown that firms' decisions to vertically integrate depends on the company (country) distance to the technological frontier. Acemoglu et al. (2002) develop a model based on managerial overload and technological frontier, in an imperfect contracts framework. Accordingly, far from the technology frontier, imitation activities are more important to quickly catch up and vertical integration is preferred. Closer to the frontier, the value of innovation increases, encouraging outsourcing of (innovation) activities.

[18]In a study of determinants of production outsouring, Tomiura (2005) finds a greater relevance of productivitiy for international outsourcing than for generic outsourcing. Accordingly, foreign contracting entails high fixed costs which might more likely to be incurred by high productivity companies.

a reversed impact, increasing both modes of R&D investment; and decreasing the propensity (and intensity) to conduct R&D activity abroad (both within and outside the boundaries of the firm).

Two major technology factors should be helpful in explaining offshore outsourcing of R&D: the cost efficiency of domestic R&D (cost-motivation) and the technological advantage (technological motivation) of national industries. The former indicator is the ratio of the number of patents per R&D produced in the French industry relative to the average in the OECD countries for the same industry. It is thus a measure of the international relative cost efficiency of R&D in the national industries. The latter is the revealed technological advantage (RTA) indicator, measuring the level of the technological specialization of French industries. The RTA of a certain industry corresponds to the ratio of the share of patents made by French inventors in this industry in the total number of patents produced by France over the share of worldwide patents in the same industry in the world total number of patents. If the share of an industry in the total of French patents is higher than the world share, this means that France possesses a technological advantage in this particular industry.

As industrial structural indicators, these variables capture broader characteristics of the national industries in the production of technology. While cost efficiency may also reflect cross-country differences in labor markets and wages, technological efficiency is a wider indicator of the technological dynamism of the country in a given industry. It reflects in a more general way the quality of research infrastructure, including universities and public research centers, the availability of specialized scientists and engineers, etc. As pointed in the previous section, we would expect that R&D offshoring, when driven by cost motivations, will be negatively influenced by the cost efficiency in the industry relative to the world (OECD) standards. When cost-driven motivations are less important than technology motivations, we would expect that the reliance on outsourcing overseas will be lower, the higher the level of

specialization found in national industries.

5 The Estimation Results

5.1 Comparison of strategies

We will now describe some characteristics of the companies engaged into the R&D outsourcing and R&D offshore outsourcing activities. Table 3 reports the means of some key variables and t-statistics for comparison of means between types of companies. It provides some first insights on the drivers of the outsourcing of R&D. The third and fourth columns compare firms that do not outsource to those that are engaged in outsourcing agreements. The fifth column presents the mean comparison test between these two types of firms. The sixth and seventh columns compare between firms that outsource exclusively at the domestic level and those that are engaged in international outsourcing while the last column presents the mean comparison test between these two types of firms. Accordingly, outsourcing firms, especially the ones that offshore, are larger, both in term of output and number of employees (scale); are more intensive in internal R&D (relatively to the number of employees), have a larger export activity and are closer to the technology edge. However, there is no significant difference between the level of productivity of these companies and the level of companies that concentrate their outsourcing activities to national R&D providers. The difference between these two types of companies in terms of intensity of manufacturing outsourcing (this measure focus only on manufacturing outsourcing in national markets) is not enormous neither.

Table 3: Summary Statistics and Comparative Tests (t-test)

Variable	Mean	No outsourcing companies	Outsourcing companies	Outsourcing> No Outsourcing	Outsourcing Domestically	Offshored Outsourcing	Offshored> Domestic
Internal R&D	49.32	40.6	56.77	-7.04***	46.94	83.35	-4.69***
Scale	623.91	399.38	815.55	-14.93***	543.42	1551.59	-12.47***
Output	855975	408246.6	1238100	-12.22***	634744.5	2870055	-9.53***
Export Intensity	0.5	0.48	0.52	-1.71**	0.48	0.64	-7.08***
Manufacturing outsourcing	0.53	0.52	0.54	-2.13**	0.53	0.56	-2.34***
Technology gap	0.4	0.38	0.42	-2.81***	0.41	0.43	-0.71
Cash flow	56019.7	32021.06	76501.94	-8.58***	51906.35	143028.1	-5.74***
R&D subsidy	0.04	0.04	0.05	-3.22***	0.05	0.04	2.25
Nb Obvesrvations	16023	7380	8643		6310	2333	

Note: t-tests adjusted for unequal variance between groups. Internal R&D (per employee), scale (number of employees), output, export intensity , manufacturing outsourcing, technology gap, R&D subsidy. All variables are lagged one year respect to outsourcing and internal R&D activities.

5.2 The empirical determinants

Tables 4 and 5 display the results of the tobit model taking account of the endogeneity of the in-house R&D investment.[19] Even thought that explanatory variables are lagged one year, it is likely that a spurious association between the unobservable terms and these variables exists, notably regarding internal R&D. Ignoring this endogeneity leads to inconsistent estimates using traditional Tobit estimation. The question of endogeneity or weak exogeneity of lagged R&D investments might be more important in the case of R&D outsourcing abroad; more precisely this link may be influenced by self-selection.[20] It could be that only the most productive firms might expand their operations abroad, including contracting out R&D services abroad. Offshoring of production and R&D activities can be part of a wider growth and diversification strategy to serve foreign markets and we may see a similar or even higher level of technological competence of these firms. We first evaluate whether there is a problem of weak exogeneity of right hand side variables and proceed then to find proper instruments

[19]Tables 4 and 5 report marginal effects related to the level of outsourced R&D conditional on a positive outcome while tables 6 and 7 report marginal effects related to the probability of engaging in the outsourcing of R&D.

[20]Theoretical as well as empirical research has argued that firm heterogeneity leads to a selection-bias in the internationalization strategies of firms (Helpman et al., 2004; Head and Ries, 2003).

for these variables to alleviate this situation.[21]

The first column, of every table, reports estimates on the total outsourcing of R&D expenditure made by the firm. The chi-2 tests (Wald) on the null hypothesis of exogeneity of the in-house R&D variable is rejected (chi2=15.6 with probability >chi2=0.000). The Amemiya Lee Newey chi2 statistic confirms the validity of instruments used to correct the endogeneity. We have used as instruments for the in-house R&D intensity, an industry level indicator on market concentration and the market power of the company (based on domestic market sales). The instrumental variables are measured at the 2 digit French classification level and are lagged one year. Noteworthy findings are as follows.

In line with previous works (Veugelers, 1997; Cassiman and Veugelers, 2002a), the intensity of internal R&D and the size of the firm both increase the expected propensity and intensity of R&D outsourcing. We corroborate the hypothesis of complementarity between in-house technological investment and contracted-out R&D and the predominance of larger firms in making use of independent suppliers of technology. Bigger firms are more likely to deal and overcome transactional costs and more able to negotiate better prices in outsourcing markets. The elasticity with respect to the firm's scale is 0.036, in the probability of a positive expenditure, whereas it is 0.083 in the model of levels of investment per employee (for above zero investment observations). Larger firms are more financially able to buy external services and more likely to diversify research and forced to tap into a wider range of technological competencies.

The sign of the coefficient on our measure of human capital intensity indicates a negative association with respect to outsourcing likelihood. We interpret this result as evidence for the

[21]Smith and Blundell (1986) have proposed a Wald (chi2) test of the endogeneity for the Tobit model. This test models the null hypothesis of zero correlation between residuals and right-hand variables under the distribution F(m, N-k), where m is the number of explanatory variables potentially endogenous. Relying on a two-stage estimation of the tobit model, we instrument therefore the corresponding variables. Valid instruments must be orthogonal to the error process in the structural equation.

complexity of tasks and autonomy. Firms with a high percentage of scientists and researchers in total employment are less prone to delegate specialized work to outsiders as a high level of quality and sophistication of research is needed which is more difficult to contract-on. Past experience in outsourcing of production seems to be of weak influence in determining outsourcing of R&D activities. This finding suggests that these two activities are different and that determinants for contracting out are not exactly the same. Experience in outsourcing of production stages or inputs do not necessarily enable companies to have better skills in drafting, negotiating and searching suitable partners in the production of technology.

In line with Cusmano et al. (2006), outward orientation of the company raises the bar on technology competition, pushing companies to be more open and integrated into innovation networks. Further, as expected, companies affiliated to a group are involved more frequently and outsource more R&D as opposed to domestic companies not belonging to a group. The opposite occurs for foreign multinational groups, which are less frequently and intensively involved in outsourcing, as opposed to this reference group. Affiliates of French groups are 8.5% more likely to outsource research whereas foreign affiliates are 4.4% less probable, when compared to domestic non-group firms (table 6). These results hold as well in the equation of domestic outsourcing. These results must be interpreted with care as the functioning of foreign groups is intrinsically different (the decisions on R&D investment and outsourcing being made on a global basis and throughout the network) and complicates the assessment of the orientation or origin of transactions. Outsourcing of R&D activities by foreign groups might essentially be made (and accounted for) in the home country, by the headquarter firm.

Besides, aligned with some theoretical studies the more distant the position of the company in terms of productive efficiency -technology gap-, the less beneficial and attracting the externalization of R&D. Recall, that according to some models (Acemoglu et al., 2002), vertical integration of the production chain activities benefits the lagging company as it will permit the

building of knowledge competencies through imitation and thereby the catching up in productivity.

The results in the column 2 concern domestically outsourced R&D (expenditures per employee). The coefficients are pretty much similar to the equation on total R&D outsourcing. There are one remarkable difference; the outsourcing of manufacturing is now positive and highly significant. Further, the impact of affiliation to a foreign group is amplified. The result on the dummies on domestic and foreign multinationals suggests that there is a natural inclination by domestic firms to use domestic producers of technology: domestic firms are better informed about the R&D markets and know better the local institutional and regulatory frameworks, etc.

The third column reports estimates on the model of offshored R&D outsourcing. There are quite important differences in the drivers when compared to total and domestically outsourced R&D. While the company size, internal R&D and the outward orientation of the firm's activity appear as significant factors, as in the case total R&D outsourcing, the human capital level does not appear as a critical determinant explaining the outsourcing of R&D beyond national borders. This result suggests that the complexity of research seems not to be influential in the decision to contract abroad (neither on the amount of outsourcing). It may also mean that the level of sophistication of human capital is not important to explain this type of outsourcing. The international outsourcing of R&D is positively and strongly associated with the export intensity of the firm. Moreover, the affiliation to a foreign group increases the propensity and the intensity of R&D offshoring. This finding confirms the intuition that companies active in the international market are more likely to involve in international R&D transactions as competition in the global product market pushes them to outsource technological resources needed to achieve international pressures on innovation.

Not surprisingly neither the experience in outsourcing of manufacturing nor the number of potential buyers are determinant in the propensity to outsource abroad (these indicators are

built only on national basis). Firms involved in the defragmentation of the production chain, are not necessarily applying this strategy to upstream activities beyond national borders. Lastly, the effect of the technology gap is significant: the less efficient the company compared to the leader in the same industry the less she will be engaged into the outsourcing of R&D overseas. The fourth and fifth columns report regressions restricting the sample exclusively to domestic companies. We test here the relevance of the industry level indicators on technological advantages and R&D cost-effectiveness. The company drivers of offshore outsourcing of R&D are pretty much similar as those reported for the total sample although the size of the coefficients slightly changes. Surprisingly, French groups appear less prone to outsource R&D abroad, as opposed to non-affiliated domestic companies. This result may imply that, since affiliates of French group benefit from the privileged position of the group within the French Economy, connections to a large network suppliers, a large scale and high bargaining power, that is not matched at the international level they are more keen to outsourcing domestically compared to non-affiliate firms. It is important to note that we are not in measure of determining if parent firms of French groups control affiliates located abroad. The status of multinational of a French group may have an implication on the offshore outsourcing activity but, due to data limitations, we are not able to distinguish between multinational French groups and purely domestic ones. The firm scale effect is related to the fixed sunk costs of searching for and contracting with technology producers in foreign countries. Larger firms may find foreign contracting partners more easily due to their high reputation or stronger bargaining power in the marketplace. Neither manufacturing outsourcing (experience), nor researchers' intensity seems to affect this decision and the amount of normalized expenditure. The results on scale, export intensity and technology gap are the same as in the previous model. With regard to technology drivers for offshore outsourcing of R&D, the findings are quite interesting. Although international industry differences in R&D cost effectiveness appear as a

significant (negative) factor on the model, technology sourcing motivations appear much more influential. Technological dynamism of national industries discourages companies from going overseas to outsource R&D activities. This implies that if the industry has a relative disadvantage in technology (with respect to the world average), companies will be more likely to go beyond national borders to acquire lacking technological competencies. This result is in line with recent survey studies (LTT-Research, 2006; Ito et al., 2007). In consequence, this result indicates that French manufacturing companies outsourcing R&D activities abroad are driven by knowledge sourcing motivations; e.g. accessing foreign pools of talent, S&E resources, etc. We should mention though that this finding must be interpreted very carefully. Due to data limitations, this indicator (number of patents per R&D expenditure) has been computed only with respect to the OECD average; this average therefore does not capture the effect of costs by non OECD countries. In spite of such shortcoming, we argue that although R&D costs are dramatically lower in some emerging countries, their technological performance measured with patents remains yet very low.

5.3 Offshore Outsourcing of R&D to Public and Private Institutions

We would like to know now whether there are differences in outsourcing abroad to public and private institutions. As mentioned previously, specialized providers located abroad do not only concern private companies but also public institutions of research. As evidenced in surveys, there is an increasing interest in accessing scientific capabilities in reputed institutions world-wide. Table 5 displays regressions on the separated outsourcing forms: domestic outsourcing to private and public institutions; and offshore outsourcing to these two types of organizations, respectively.

We focus essentially on the drivers of offshore outsourcing of R&D from public institutions and private companies. Three main findings stem from this analysis. First, private sources abroad

Table 4: Outsourcing and Offshoring of the R&D Activity: Marginal Effects

	(R&D Outsourcing)	(Domestic R&D) (Outsourcing)	(R&D Offshoring)	(R&D Offshoring) (Domestic Firms) (Only)	(R&D Offshoring) (Domestic Firms) (Only)
Internal R&D	0.553***	0.453***	0.093***	0.070***	0.069***
	(0.101)	(0.043)	(0.021)	(0.015)	(0.016)
Manufacturing Outsourcing	–0.063	0.077**	0.003	0.004	0.004
		(0.030)	(0.014)	(0.011)	(0.011)
Researcher Intensity	–1.832**	–0.687**	–0.189	–0.160	–0.165
	(0.910)	(0.292)	(0.191)	(0.127)	(0.126)
Scale	0.083***	0.060***	0.029***	0.025***	0.025***
	(0.014)	(0.011)	(0.005)	(0.004)	(0.004)
Export Intensity	0.007***	0.005**	0.005***	0.003***	0.003***
	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)
Technology Gap	–0.045**	–0.050***	–0.021***	–0.016***	–0.016***
	(0.018)	(0.014)	(0.006)	(0.005)	(0.005)
Potential Buyers	–0.093***	–0.090***	–0.008	0.002	–0.002
	(0.024)	(0.017)	(0.008)	(0.007)	(0.007)
Foreign Group	–0.099***	–0.176***	0.055***		
	(0.030)	(0.022)	(0.013)		
French Group	0.206***	0.226***	–0.008	–0.021**	–0.021**
	(0.059)	(0.038)	(0.013)	(0.009)	(0.008)
R&D Subsidy	0.034***	0.027***	0.005**	0.004**	0.004**
	(0.007)	(0.005)	(0.002)	(0.002)	(0.002)
Cash Flow	0.070***	0.097***	0.023***	0.014***	0.014***
	(0.015)	(0.014)	(0.005)	(0.004)	(0.004)
Technological Efficiency					–0.073*
					(0.041)
Cost Efficiency					–0.010***
					(0.004)
No. of obs	9708	9708	9708	6959	6959
Wald chi 2	2232	2618.7	941.5	786.28	771.9
Prob> chi2	0.000	0.000	0.000	0.000	0.000
Wald test of exogeneity (chi2)	12.6	30.69	5.28	3.12	2.99
Prob> chi2	0.000	0.000	0.02	0.07	0.08
Test of overidentifying restrictions :					
Amemiya-Lee-Newey chi2 statistic	0.36	0.001	0.068	0.012	0.001
P-value	0.54	0.97	0.79	0.91	0.97

All regressions include time fixed effects and industry fixed effects. Robust Standard Errors in parentheses. ***, ** and * represent respectively statistical significance at the 1%, 5% and 10% levels.

are associated to scale effects as the impact of the intensity of internal R&D is significantly associated to this type of outsourcing whereas this factors seems not be at stake for outsourcing R&D activities from foreign public institutions. Likewise, companies associated to a group are significantly less involved than their counterpart in the use of offshore outsourcing to foreign private companies but there is no striking difference between these two types of companies in engaging into outsourcing from foreign public institutions. And third and most relevant, the coefficients on technological efficiency are negatively associated to the two types of offshore outsourcing. In consequence, there is consistent evidence on the "knowledge sourcing" motivation of companies. This factor in conjunction with the scale of the firm, are the only explanatory determinants of offshore outsourcing from public research organizations. In addition and reinforcing the finding on the importance of technology sourcing, the R&D cost-effectiveness indicator by industry losses significance when conducting separated estimations on the types of offshore outsourcing.

6 Conclusion

In this paper we propose an empirical analysis of the R&D outsourcing and offshoring strategies by French manufacturing firms. The pace of technological change and the challenges faced by companies to remain competitive in global markets have contributed to a global expansion of R&D markets. This evolution coincides with the rise of new pools of technological activity and talent world-wide, which are attracting off-shoring of R&D to these locations, both through outsourcing and location of R&D by global companies. This paper investigates company and technology drivers of offshore outsourcing of R&D by French manufacturing companies. Our results show that internationally oriented companies are more likely to outsource R&D abroad. These findings suggest an easier integration of these type of companies

Table 5: Outsourcing and Offshoring to Public and Private Establishments: Marginal Effects

	(Domestic-Public)	(Domestic-Private)	(Foreign-Public)	(Foreign-Private)
Internal R&D	0.181***	0.446***	0.004	0.064***
	(0.026)	(0.066)	(0.006)	(0.016)
Manufacturing Outsourcing	0.038***	0.067*	0.004	–0.003
	(0.015)	(0.034)	(0.005)	(0.012)
Researcher Intensity	–1.144***	–1.498**	0.046	–0.107
	(0.261)	(0.665)	(0.055)	(0.138)
Scale	0.036***	0.131***	0.008***	0.037***
	(0.005)	(0.011)	(0.002)	(0.004)
Export Intensity	0.004***	0.002	0.001	0.003***
	(0.001)	(0.003)	(0.001)	(0.001)
Technology Gap	0.001	–0.026	–0.002	–0.014***
	(0.007)	(0.016)	(0.002)	(0.005)
Potential Buyers	–0.008	–0.072***	0.004	0.002
	(0.009)	(0.019)	(0.003)	(0.007)
Foreign Group	–0.082***	–0.214***		
	(0.011)	(0.024)		
French Group	–0.058***	0.164***	0.001	–0.019**
	(0.015)	(0.045)	(0.004)	(0.009)
R&D Subsidy	0.026***	0.025***	0.002**	0.004**
	(0.002)	(0.006)	(0.001)	(0.002)
Cash Flow	0.006	0.041***	0.001	0.013***
	(0.005)	(0.013)	(0.001)	(0.004)
Technological Efficiency			–0.070***	–0.126***
			(0.024)	(0.042)
Cost Efficiency			–0.001	–0.004
			(0.002)	(0.004)
No. of obs	9713	9713	6963	6963
Wald chi 2	933.8	1713.7	202.8	1554.25
Prob> chi2	0.000	0.000	0.000	0.000
Wald test of exogeneity (chi2)	30.44	23.56	0.38	3.15
Prob> chi2	0.000	0.000	0.53	0.07
Test of overidentifying restrictions :				
Amemiya-Lee-Newey chi2 statistic	0.15	0.004	0.022	0.017
P-value	0.69	0.94	0.88	0.89

All regressions include time fixed effects and industry fixed effects. Robust Standard Errors in parentheses. ***, ** and * represent respectively statistical significance at the 1%, 5% and 10% levels.

in global networks of innovation. We also find that single unit companies seem to be more likely to outsource R&D overseas than companies belonging to a group. This reflects an internalization strategy pursued by corporations compared to single unit entities which seems more likely to engage into external and international networks of R&D. Furthermore, consistent evidence is found on the technological sourcing motivation. The decision to offshore by domestic firms is significantly affected by the technological advantage of the French industries. Firms located in an industry that benefits from a technological advantage are less likely to outsource their R&D activities overseas. Hence not only cost reductions matters for the offshoring of R&D in general, but also the quality of competencies and notably, access to specialized pools of technological expertise.

There are several lines of research on the question of R&D offshoring to be addressed in the future analysis. Little is known about its consequences on technological and innovative performance by companies. This evaluation also concerns the nature of technology that is outsourced at a much more detailed level: which kind of R&D task is outsourced (e.g. product development, basic research, prototype testing, etc.)? What is the nature of innovation externalized (radical or incremental) and how it integrates internal R&D process? Our next step is then to associate R&D outsourcing activities the technological performance of companies and the type of innovation they produced; product and process innovation, new technologies.

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Table 6: Outsourcing and Offshoring of the R&D Activity: Probability of A Positive Outcome

	(R&D Outsourcing)	(Domestic R&D) (Outsourcing)	(R&D Offshoring)	(R&D Offshoring) (Domestic Firms) (Only)	(R&D Offshoring) (Domestic Firms) (Only)
Internal R&D	0.240***	0.216***	0.051***	0.042***	0.051***
	(0.044)	(0.020)	(0.013)	(0.010)	(0.011)
Manufacturing Outsourcing	–0.011	0.037**	–0.000	0.001	0.003
		(0.015)	(0.009)	(0.008)	(0.008)
Researcher Intensity	–0.795**	–0.328**	–0.085	–0.082	–0.122
	(0.395)	(0.139)	(0.116)	(0.083)	(0.093)
Scale	0.036***	0.029***	0.016***	0.015***	0.019***
	(0.006)	(0.005)	(0.003)	(0.003)	(0.003)
Export Intensity	0.003***	0.003**	0.003***	0.002**	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Technology Gap	–0.019**	–0.024***	–0.013***	–0.010***	–0.012***
	(0.008)	(0.007)	(0.004)	(0.003)	(0.004)
Potential Buyers	–0.040***	–0.043***	–0.003	0.002	–0.001
	(0.010)	(0.008)	(0.005)	(0.005)	(0.005)
Foreign Group	–0.044***	–0.087***	0.039***		
	(0.014)	(0.011)	(0.007)		
French Group	0.085***	0.102***	–0.005	–0.015***	–0.016**
	(0.023)	(0.016)	(0.008)	(0.006)	(0.006)
R&D Subsidy	0.015***	0.013***	0.002	0.002	0.003**
	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)
Cash Flow	0.030***	0.047***	0.014***	0.008***	0.010***
	(0.007)	(0.007)	(0.003)	(0.002)	(0.003)
Technological Efficiency					–0.054*
					(0.031)
Cost Efficiency					–0.007***
					(0.003)
No. of obs	9713	9713	9713	6963	6963

Table 7: Outsourcing and Offshoring to Public and Private Establishments: Probability of A Positive Outcome

	(Domestic-Public)	(Domestic-Private)	(Foreign-Public)	(Foreign-Private)
Internal R&D	0.169***	0.210***	0.005	0.058***
	(0.024)	(0.031)	(0.008)	(0.014)
Manufacturing Outsourcing	0.036**	0.032*	0.005	–0.003
	(0.014)	(0.016)	(0.006)	(0.011)
Researcher Intensity	–1.067***	–0.707**	0.059	–0.097
	(0.244)	(0.314)	(0.071)	(0.124)
Scale	0.033***	0.062***	0.010***	0.033***
	(0.004)	(0.005)	(0.003)	(0.004)
Export Intensity	0.004***	0.001	0.001	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
Technology Gap	0.001	–0.012	–0.003	–0.013***
	(0.007)	(0.007)	(0.003)	(0.005)
Potential Buyers	–0.007	–0.034***	0.005	0.002
	(0.008)	(0.009)	(0.004)	(0.006)
Foreign Group	–0.079***	–0.105***		
	(0.010)	(0.012)		
French Group	–0.056***	0.074***	0.002	–0.017**
	(0.014)	(0.019)	(0.005)	(0.008)
R&D Subsidy	0.024***	0.012***	0.003**	0.004**
	(0.002)	(0.003)	(0.001)	(0.002)
Cash Flow	0.006	0.019***	0.001	0.012***
	(0.005)	(0.006)	(0.002)	(0.003)
Technological Efficiency			–0.090***	–0.113***
			(0.028)	(0.038)
Cost Efficiency			–0.001	–0.003
			(0.002)	(0.003)
No. of obs	9713	9713	6963	6963

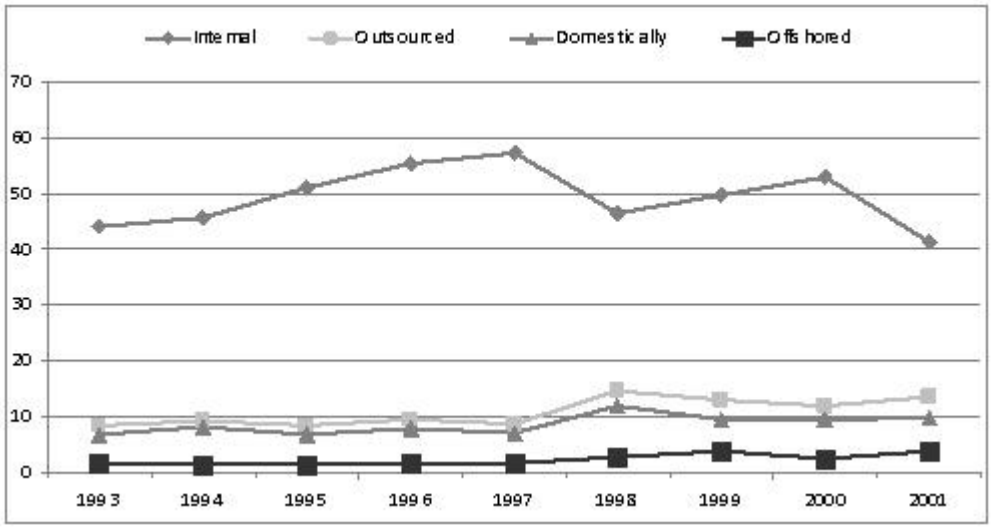
Table 8: Correlation Matrix

Variable	R&D Outsourcing	R&D Domestic Outsourcing	R&D Offshore Outsourcing	R&D Domestic Outsourcing (Pub)	R&D Domestic Outsourcing (Pri)	R&D Offshore Outsourcing (Pub)	R&D Offshore Outsourcing (Pri)
R&D Outsourcing	1						
R&D Domestic Outsourcing	0.9364	1					
R&D Offshore Outsourcing	0.4821	0.3028	1				
R&D Domestic Outsourcing (Pub)	0.4243	0.4464	0.2397	1			
R&D Domestic Outsourcing (Pri)	0.7367	0.7745	0.2776	0.2236	1		
R&D Offshore Outsourcing Outsourcing (Pub)	0.1784	0.1231	0.3317	0.1692	0.1429	1	
R&D Offshore Outsourcing (Pri)	0.3909	0.207	0.7343	0.1843	0.3204	0.0899	1
Internal R&D	0.2613	0.2621	0.2784	0.1999	0.3056	0.1062	0.2016
Manufacturing Outsourcing	-0.0057	-0.0047	-0.032	-0.0171	0.0287	0.0146	0.0011
Researcher Intensity	0.2003	0.2059	0.2094	0.1403	0.2454	0.0571	0.1541
Scale	0.0026	-0.0295	-0.1956	0.0064	0.1228	0.039	0.1374
Export Intensity	0.0333	0.0048	-0.0485	0.0164	0.0489	0.0274	0.0971
Technology Gap	-0.1039	-0.0984	-0.0379	-0.0871	-0.1395	-0.0376	-0.1048
Potential Buyers	0.0187	0.016	0.0592	0.0389	-0.002	0.0332	-0.0055
French Group	0.1613	0.1717	-0.0007	0.0714	0.2497	0.0492	0.0779
Foreign Group	-0.0693	-0.1301	-0.023	-0.0259	-0.0624	-0.002	0.0823
R&D Subsidy	0.1385	0.1551	0.0728	0.101	0.1009	0.0088	0.04
Cash Flow	0.1665	0.1453	0.1093	0.1364	0.1849	0.0794	0.1491
Technological Efficiency	-0.1885	-0.1843	-0.1624	-0.1889	-0.1625	-0.0878	-0.1013
Cost Efficiency	0.0434	0.0427	0.0266	0.0355	0.0285	0.0184	0.016

	Internal R&D	Manufacturing Outsourcing Intensity	Researcher	Scale Intensity	Export Gap	Technology Buyers	Potential
Internal R&D	1						
Manufacturing Outsourcing	-0.0191	1					
Researcher Intensity	0.5844	-0.0353	1				
Scale	-0.1795	0.11	-0.253	1			
Export Intensity	-0.0413	0.1001	-0.0859	0.4408	1		
Technology Gap	-0.0547	0.0768	-0.0512	-0.2014	-0.0833	1	
Potential Buyers	0.1999	-0.0498	0.0558	-0.1737	-0.0387	0.2342	1
French Group	0.1229	0.0314	0.0286	0.3337	0.1176	-0.185	-0.0718
Foreign Group	-0.006	0.0204	-0.0727	0.24	0.1692	0.0115	0.0825
R&D Subsidy	0.1447	-0.0087	0.186	-0.0429	0.0005	-0.038	-0.0259
Cash Flow	0.1999	0.086	0.1073	0.0427	0.1211	-0.1384	0.0331
Technological Efficiency	-0.2947	0.0648	-0.2261	0.1075	0.0571	0.0485	-0.3173
Cost Efficiency	0.0562	0.3325	-0.0034	-0.0173	-0.0059	0.0152	0.0193

	French Group	Foreign Group	R&D Subsidy	Cash Flow	Technological Efficiency	Cost Efficiency
French Group	1					
Foreign Group	-0.2485	1				
R&D Subsidy	0.0778	-0.1405	1			
Cash Flow	0.0695	0.1067	-0.0698	1		
Technological Efficiency	-0.0477	-0.0352	-0.0049	-0.1879	1	
Cost Efficiency	0.0087	-0.0223	-0.0319	0.0541	-0.1123	1

Figure 1: The Evolution of Internal and External R&D



Source:Recherche et Developpement, 1993-2001 (only manufacturing companies). Total Expenditure per Employee, 1995 francs.