The Outsourcing of Research and Development in Global Markets: Evidence from France

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The Outsourcing of R&D in Global Markets: Evidence from France

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The pace of technological change, the increasing need for multi-disciplinary competences and the rising costs of innovation have contributed to the global expansion of technological activities, including the international outsourcing of research and development (R&D). This paper shows that firms involved in international outsourcing of R&D are of a particular kind: they are highly outward oriented, more productive and R&D intensive. Furthermore, firms with patents are more intensely involved in this activity. Our results also suggest that the outsourcing of R&D in global markets by French firms is motivated by technology sourcing rather than cost-saving interests.

Keywords: R&D outsourcing, R&D offshoring, Technology sourcing, Firm Heterogeneity

I. Introduction

The trend of performing more research and development (R&D) outside the home country of the firm is often described as offshoring .There is plenty of anecdotal and business survey evidence indicating that globalization or "offshoring" of R&D is becoming a central issue in firms' strategies. A survey of 158 large European companies indicates that R&D offshoring –both within the multinational network and through R&D outsourcing- is a growing share of R&D investment by corporations (LTT-Tutkimus Oy, 2007).This trend has extended to new regions and countries. A recent report by Goldman Sachs identifies new and planned R&D facilities in China, India, and Brazil by companies as Pfizer, Ford, Microsoft, IBM, Boeing, Intel, and Cisco (Goldman Sachs Group, 2010). More specific examples include the case of the German multinational Siemens which had, in 2004, 49% of its R&D personnel located outside of Germany (UNCTAD, 2005). Intel is another example of a company engaging in R&D offshoring. According to UNCTAD (2005), in 2005 Intel had over 20000 R&D employees located in more than 30 countries including China, India and Russia. An Intel R&D laboratory in Shanghai is engaged in the development of software while the Intel India design Centre located in Bangalore delivers software solutions.

Statistics showing technology balances of payments indicate that in most OECD countries, technological receipts and payments from international contracting, including R&D contracting and other technology services, have increased sharply since the 1990s (OECD, 2008). These patterns clearly illustrate the growing internationalization of technological activities.

Among the reasons behind this ongoing evolution in technological activities are the increasing costs of R&D, the accelerated rhythm of innovation, the shortening of product life cycles, the growing complexity of technology and the need for multidisciplinary competences (OECD, 2008). In parallel, transaction costs in global markets have decreased considerably with international policy reforms (e.g. strengthening of intellectual property rights, fewer restrictions in technology and foreign direct investment emphasized in world trade agreements) and the information and communication technologies (ICT) revolution has facilitated international coordination of geographically dispersed technological activities (Santangelo, 2002). Lastly, the emergence of countries like India, China, Ireland, as new producers of technology and as sources of talent for science and technology (S&T) (Athreye and Cantwell, 2007; Arora *et al.*, 2001), is drawing a new landscape for the localization of R&D activities.

The internationalization of R&D activities is no longer restricted to large companies and multinational corporations. More and more firms, including small and medium sized ones, are engaging in cross-border technology alliances in order to access specialized knowledge or infrastructure and bring in new skills (OECD, 2008). Yet, in spite of these growing trends, the empirical examination of R&D offshoring remains underdeveloped. Most of the evidence is descriptive and aims to draw country and industry level patterns of internationalisation. Existing empirical studies focus mostly on the motives for R&D internationalization from the perspective of foreign direct investment (Le Bas and Sierra, 2002; Lewin *et al.,* 2009).

This paper attempts to fill this gap. We focus on the motivations driving global R&D outsourcing and following previous research on the internationalization of R&D (Florida, 1997; Kuemmerle, 1996; 1999; Branstteter, 2001; Criscuolo *et al*, 2005), we distinguish two types of motivations. Firms would look for R&D services across borders motivated by cost-saving reasons *("cost efficiency"),* this means, more competitive R&D costs (wages and infrastructure) or would seek to acquire new knowledge and technological competences lacking at home (*"technology sourcing")*. Our contribution is precisely this angle of analysis brought to the study of determinants of international R&D outsourcing. Understanding the drivers of R&D offshoring is crucial for the design of effective R&D policies that go beyond the traditional national approach and are in-line with the international division of R&D activities performed by firms. It is also important for the design of policies aiming at increasing the attractiveness of national economies as locations for R&D investments by foreign firms and at tackling the concerns associated with the internationalisation of R&D, mainly the erosion of home based R&D structures (OECD, 2008).

R&D decisions (and levels of investments) are fundamental to firms' competitiveness. A rich and intense literature has shown the effects of internal R&D in terms of innovation performance and productivity growth (see for instance Griliches and Mairesse, 1984; Griffith *et al.,* 2004; Hall and Mohnen, 2009). In this sense, outsourcing of R&D differs from the outsourcing of production in being core to firm knowledge, which translates into product or process innovation -and future technological competences. Acquiring knowledge outside of the firm is then more strategic than outsourcing other inputs (for production) as it may require firms to disclose their needs; engage in personal exchanges, and more generally, require involving outsiders in the firm process of innovation (OECD, 2008; Economist Intelligence Unit, 2007). Furthermore, because knowledge is appropriable and with uncertain results (Williamson, 1991), it is more difficult to contract-out compared to other production inputs.

We use several indicators, at the industry level, to identify such motivations. More specifically, we develop two indicators of the attractiveness of France's industries in terms of R&D specialisation and R&D costs; a relative technology advantage indicator and a relative international cost of technology. If technology sourcing and/or cost saving motives are significant, we would expect the relative attractiveness of French industries in terms of specialisation and cost to discourage R&D offshoring.

Moreover, we contrast between the national and the international sourcing of R&D in order to determine if the international outsourcing of R&D is special and dependent on a specific set of firm's characteristics. To our knowledge, very few papers explore the role of firm level characteristics in driving R&D outsourcing in global markets. Garcia-Vega and Huergo (2011) focus on the role of trade and financial constraints in determining the internationalisation of R&D, while Martinez-Noya *et al.* (2012) explores the role of technological and international expertise in the international outsourcing of R&D. Further, we are able to distinguish international R&D outsourcing within and outside the boundaries of the firm. This allows us to really differentiate between market-mediated technology transactions and transactions that are internalized within the firm.

Our results show that firms involved in R&D sourcing are different from the rest: they are larger, highly outward oriented, more productive and R&D intensive than other firms. We provide evidence that international R&D outsourcing is being driven by technology sourcing motivations. Cost-saving motivations do not seem to be significantly relevant. We also find evidence that although domestic and international sourcing of R&D share the same determinants, some determinants like productivity, the protection of intellectual property rights, and the extent of export activity are only relevant for the international sourcing of R&D.

This investigation contributes to the literature in several dimensions. While previous studies (for example, Florida, 1997 and Kuemmerle, 1999) have focused mostly on international R&D activities within a firm's own boundaries, our study focuses on R&D contracting outside of the firm in international markets. Further, our examination builds on the R&D survey, until now under-exploited, which provides supplementary advantages: this data allows the analysis of the decision to outsource R&D as well as its level of expenditure over time and moreover, comprises diverse subjects, composed of small and large firms, independent firms and those affiliated to groups.

This paper is organized as follows. Section II reviews the relevant literature and exposes our main hypothesis. Section III presents the data and discusses key trends and statistics. Section IV describes methodology and section V presents results. The last section of the paper concludes.

II. Drivers of the Internationalization of R&D

Motivations for International R&D Outsourcing

The literature identifies two main motives for the internationalization of R&D activities; the exploitation of home-base assets and home-base augmenting (Kummerle, 1996; 1997; Dunning and Narula, 1995). The latter, also called "technology sourcing" or "asset seeking" happens when firms seek to conduct R&D abroad in areas in which they lack technological expertise. Host locations are often leaders in that area of technology and so motivation has more to do with supply-side factors. Technology sourcing motivations address the need for access to specialized knowledge, technical skills and new research competences in foreign countries, which are found both in foreign firms and research institutions (Kuemmerle, 1996; 1999). Inversely, asset-exploiting R&D activities (or home-based exploiting activities) are demand-oriented and focus on the exploitation of technological competences, developed at the home country, in foreign markets. It involves basic adaptation and product customization activities that respond to the needs of the foreign market (Hymer, 1976).

More recently and because of the surge of technological capabilities in emerging countries like Brazil, China and India, firms are increasingly engaged in R&D offshoring in the aim of dealing with growing R&D costs (Lai *et al*, 2009)[1]. R&D offshoring allow firms to exploit cross-country differences in the cost of technology like the availability of lower cost scientists and engineers, more favourable tax treatments, etc. (UNCTAD, 2005). Yet despite the increase of R&D sourcing from developed economies the supply of critical factors such as access to specialized technology and knowledge competences, gaining externalities from competitors and local universities, combined with demand side motives, remain the major factors in the decision to conduct R&D activities offshore, not only through the multinational network but also through partnerships with foreign firms and institutions (LTT-Tutkimus Oy, 2007; OECD, 2008, Economist Intelligence Unit, 2007).

Survey-based and patent-based studies provide indications that the importance of technology sourcing in international R&D projects by multinational firms has increased and is especially prominent in R&D intensive industries such as pharmaceuticals or electronics (e.g. Florida, 1997; Kuemmerle, 1996; 1999; Branstteter, 2001). Moreover, Lewin *et al.* (2009), using data on US companies, show that shortages of highly skilled science and engineering workers in the US and the need to access a highly qualified labour force are the main drivers of the internationalization of R&D by American firms. For European companies, the empirical evidence suggests that firms with overseas R&D activities are driven both by technology sourcing and home-based technology exploitation motivations, although the former seems to be growing in importance. Using patent citation data, Criscuolo *et al* (2005) show that European multinationals are engaged in both types of activities. Le Bas and Sierra (2002) examined the characteristics of location for technological activities by 345 European and Japanese multinational companies using patent data and found that European firms are combining technology sourcing motivations with exploitation of home advantages. Miotti and Sachwald (2003) found that French firms that co-operate with US partners belong to sectors in which

[1] Lai *et al* (2009) build a principle/agent framework of R&D outsourcing where cost reduction is the main driver the decision to outsource. However, because of imperfect contracting, R&D outsourcing leads to knowledge leakages.

the US exhibits a comparative advantage. They also found that French firms that co-operate in R&D with US firms perceive a lack of technological skill as an important obstacle for innovation.

We investigate the relevance of these motives by creating several measures reflecting the technological performance and competitiveness of French industries and regions. We expect the relative attractiveness of France in terms of R&D productivity and cost to discourage French firms from engaging in R&D activities abroad. We also control for the intensity of internationalization at the firm level. We expect firms engaged in international activities like exporting and foreign direct investment to seek external sources of R&D in order to adapt their products to foreign markets and to remain competitive in these markets.

Firms' Characteristics

The literature on international trade and on offshoring has highlighted the role of firm heterogeneity. Firms engaged in the offshoring of inputs tend to be large and highly productive (Antras and Helpman, 2004; Tomiura, 2009). However, the role of firm heterogeneity has been relatively overlooked in the analysis of the offshoring of R&D.

Important sunk costs are involved in accessing global markets in general and the markets of technology in particular. In international contexts, contracting costs would tend to be more seriously burdensome as they imply extra costs for communication in different languages and adjustments across different legal systems, such as intellectual property systems and cultures (Tomiura, 2005; Branstetter *et al.,* 2006; Cusmano *et al.,* 2010). Other problems include the lack of coherence across research agendas, delays in schedules, difficulties in the exploitation of results and misappropriation of core competences by external employees and other companies. As a result, only a particular set of firms would be able to deal with transactions costs and with the problem of decentralization of knowledge-related activities.

The theoretical and empirical literature on internationalization and outsourcing (Helpman *et al.*, 2004; Antras and Helpman, 2004) stresses the relevance of firm efficiency for overcoming important fixed costs. This literature shows that only the most productive firms are able to engage in international activity like, FDI, exporting or international outsourcing. This literature also shows that internationalized firms are usually larger than their domestic counterparts (Mayer and Ottaviano, 2008, Garcia-Vega and Huergo, 2011). Finally, access to finance was shown to be a significant contributor to the internationalization of firms (Greenaway *et al*, 2007, Garcia-Vega and Huergo, 2011).

To account for the role played by firm's heterogeneity we consider several variables that control for firms' characteristics like scale, productivity and the presence of financial constraints. We also consider the firms' capacity to overcome transaction costs by controlling for their outsourcing experience and the stock of patent rights that they own. We expect firms with a significant experience in production outsourcing to have the required knowledge in terms of finding partners, negotiating deals and enforcing contracts that will enhance their willingness to outsource R&D internationally. We also expect firms that benefit from a protection to their property rights to be less reluctant to engage in R&D outsourcing.

A second key issue that should justify firms' use of external technology providers is the existence of "synergies" between outside knowledge (external R&D) and internal R&D competences. Precisely, an extensive literature suggests that external R&D can complement internal R&D through different mechanisms (Cohen and Levinthal, 1989; 1990; Veugelers, 1997; Veugelers and Cassiman, 1999; Kamien and Zang, 2000; Nakamura and Odagiri, 2003). External R&D can help firms to leverage productivity of internal research by virtue of specialization and flexibility while allowing firms to expand their pool of knowledge and acquire new technical competences. Moreover, internal R&D enhances the absorption capacity of firms, allows them to better identify, assimilate and exploit external technology and improves their knowledge of the market for technology and their bargaining position. To sum up, R&D outsourcing can help firms to specialize and optimize their R&D efforts, which leverage the productivity of internal R&D (Arora and Gambardella, 1990; 1994; Cesaroni, 2004).

However, these findings are less consistent in the case of international R&D sourcing. In a study of Italian firms, Cusmano *et al.* (2010) found that the level of R&D activity is positively associated with the probability of outsourcing R&D, but it was not influential on international contracting of R&D. Conversely, Aggarwal (2000) for Indian companies, Braga and Willmore (1991) and Johnson (2002) for Brazilian firms, all provide evidence of a complementary relationship between the purchasing of foreign technology, including technology licensing and other technology services and internal R&D investment. We investigate the interaction between internal R&D and R&D sourcing by controlling for internal R&D expenditures and the intensity of researchers in the labour force.

III. Data and Trends

Our empirical analysis is based on the Research and Development Survey, *Enquête Recherche et Developpement*, annually compiled by the French Statistics Office for Research and Innovation within the French Ministry of Education. It is a non-exhaustive survey addressed to firms with internal R&D activity. The analysis is conducted on French manufacturing firms over the period 1993-2001. The survey provides detailed information on the internal and external R&D activities adopted by each firm. On this basis, our analysis of R&D sourcing focuses on firms performing R&D. Each firm has a unique identification code which allows us to combine the R&D Survey with the Annual Firm Survey, *Enquête Annuelle d'Entreprises (EAE)*, compiled by the French Ministry of Industry, and with the Financial Liaisons Survey, *Liaisons Financiaires (LIFI)*, compiled annually by the French national statistics office (INSEE). The Annual Firm Survey complements the R&D Survey by providing information on a wide set of firms' characteristics. The Financial Liaison Survey covers the financial links between firms, identifies the firm's affiliation to a group and identifies the country of origin of the group. Both surveys cover the period between 1990 and 2001.

We limit the data to manufacturing firms for which we have information on production activity[2] and focus our analysis on domestic firms. Firms belonging to the R&D services sector, whose main activity is selling technology, are excluded from the sample, as are firms in the aerospace industry.[3] We also exclude from the sample affiliates of foreign groups. The analysis of offshoring by foreign

[2] The sample of firms present in both the firm annual survey and the R&D survey.
[3] These firms are engaged in large European research programs involving important governmental support. The internationalization of R&D by these firms does not reflect the decisions and activities adopted by average manufacturing firms.

affiliates would require further information and particular data on their activity at headquarters and across the global network.

From the initial number of 9723 firms, corresponding to 29754 observations, we are left with 2778 firms (28% of the initial number), corresponding to 8118 observations.[4] The firms in our sample are, on average, larger, more productivity and more export-oriented than the average firm in the total sample of manufacturing enterprises.[5] The heterogeneity of firms in the sample reflects the specificity of R&D activity and the selection criteria of the Research and Development Survey. Investing in R&D is costly and risky, and not all firms are able to engage in this activity. Even though our sample is not representative of the French manufacturing industry, we believe that it is suitable for the analysis of the offshoring of R&D given the strong complementarily between internal and external R&D investments.

The firms in our final sample are concentrated in few sectors: 17% in the mechanical equipment industry, 16% in the chemical industry and 16% in the electric and electronic products industry (Table 1). Regarding group affiliation, 63% of the firms are affiliated to a French group: of these, 47% are affiliated to a French multinational group and 16% are affiliated to domestic groups.[6]

We make three calculations of external R&D: "Total Sourcing" refers to the total volume of contracted-out R&D activities regardless of the location of the partners, "National Sourcing" refers to R&D contracted-out to local partners (public organizations, local universities and local firms) and "International Sourcing" refers to R&D contracted out in foreign markets (international organizations and foreign firms). For the sub-sample of firms affiliated to a French multinational group we create two additional variables: "Intra-Group R&D" and "Extra-Group R&D". "Intra-Group R&D" measures the R&D activity contracted-out to firms affiliated to the same group and located overseas,

[4] Firms in non-manufacturing industries account for 14942 observations (44% of the total number of observations), firms in the aerospace industry count for 224 observations (0.75% of the total number of observations), and foreign affiliates count for 6102 observations (20.5% of total number of observations).
[5] In the total sample of French manufacturing firms, the average size is 147 employees, the average productivity gap is 2.82 and the average export intensity is 0.15.
[6] French multinational groups are groups that control at least one affiliate located overseas. French domestic groups control affiliates only located within France.

while "Extra-Group R&D" measures the R&D activity sourced from unaffiliated firms located abroad.[7]

According to the R&D survey more than half of the firms in the sample contract out part of their R&D activity, however, only 12% are engaged in international R&D sourcing (within and outside the boundaries of the firm). This lower share indicates that a very specific type of firms is able to overcome the costs of international transactions. According to our data, contracted-out R&D represents, on average, 17% of total R&D investments. National contracted-out R&D has a similar structure as total external R&D. The share of offshored R&D in total R&D is only 6% on average, however in the case of some firms international R&D represents 84% of total R&D investments.[8]

Table 1 reports the shares of "Total Sourcing", "National Sourcing" and "International Sourcing" in total R&D expenditures. It also reports the intensity of Total, National and International contracted-out R&D measured as expenditures per employee. The figures for the share and intensity of contracted-out R&D are the industry averages calculated over the sample of firms. An important point to make is the significant cross-industry variability. The reliance on external sources of R&D is the highest in the pharmaceutical and the coking, refined petroleum and nuclear fuel industries where contracted-out R&D represents 30% of total R&D expenditures by the firms engaged in the outsourcing of R&D. The share of international sources of R&D, in total R&D expenditures of the firms engaged in international outsourcing of R&D, is the highest in the wood and paper industry (9%), followed by the textile and the pharmaceutical industries. A similar picture emerges from looking at the expenditure per employee.

[7] The distinction between "Intra-Group" and "Extra-Group" is not possible for National external R&D except for the most recent years of the sample. The number of available observations is not sufficient for analysing these two strategies separately.

[8] These average figures, as well as those presented in Table 1 are calculated over the range of positive values.

IV. Methodology

We investigate the drivers of international R&D outsourcing by linking the intensity of contracted-out R&D to a vector of firm level and industry level variables.[9] In order to analyse the specificity of our variable of interest, we also investigate the drivers of national R&D sourcing. The fact that a large number of observations are zero - 46% of the firms depend exclusively on in-house investments in R&D and only 12% are engaged in the international outsourcing of R&D –, requires special statistical treatment. An approach generally used to deal with the problem of censored 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). Traditionally the data used in analysis of strategies of innovation are from innovation surveys. However, as these surveys evaluate one point in time, the control of past activities and tracking of changes in strategies over time are limited. As our data set span over several years, we are able to conduct a panel analysis. Our empirical analysis consists of estimating the following equation:

$$R\&D\ sourcing^{*}_{ijt} = \beta X_{ijt} + \gamma Z_{jt} + d_j + d_t + \alpha_i + \varepsilon_{it}$$

$$R\&D\ sourcing_{ijt} = 0\ \ if\ \ R\&D\ sourcing^{*}_{ijt} \leq 0$$

$$R\&D\ sourcing_{ijt} = R\&D\ sourcing^{*}_{ijt}\ \ if\ \ R\&D\ sourcing^{*}_{ijt} > 0$$

where *i, j* and *t* represent firms, industry and years respectively. R&D Outsourcing takes the value, in different specifications, of total sourcing, national sourcing, international sourcing, intra-group international sourcing and extra-group international sourcing. These measures are expressed relative to the firms' scale. X is the vector of firm level variables, Z is the vector of industry level variables, d_j represents industry level fixed effects at the 2-digit level and, d_t represents time level fixed effects. α_i is an unobserved random variable that follows the normal distribution $N(0, \sigma^2_\alpha)$ and ε_{it} is a normally distributed error term ($N(0, \sigma^2_\varepsilon)$).

[9] We have also considered a binary choice model that focuses on the decision to engage in R&D outsourcing. The results are similar to the ones discussed below.

Table 2 reports frequencies and R&D sourcing intensities by types of firms. There are three in the sample: affiliates of French multinational groups, affiliates of domestic groups and independent firms. Table 2 shows that, for all types of firms, the intensity of R&D international sourcing is significantly lower than that of national sourcing. Table 2 also shows a significant degree of heterogeneity across types of firms; affiliates of French multinational groups have the highest propensity and intensity of external R&D at the national and international levels. The difference between independent and affiliates of domestic French groups is limited in the case of national sourcing but significant in the case of international R&D sourcing.

We relate R&D sourcing to different firm and industry characteristics. All explanatory variables are lagged by one year and all regressions include a set of time and 2-digit industry dummies.

Technology Sourcing and Cost Saving

We investigate the motivations for international R&D outsourcing by creating three industry level variables: the cost efficiency of domestic R&D (*"Cost Efficiency")*, the technological advantage of national industries *("Technological Efficiency"),* and the availability of R&D resources at the domestic level *("Agglomeration")*.

"Cost Efficiency" is measured as the ratio of the number of patent applications per euro of R&D produced in a 3-digit French industry, relative to the average in OECD countries for the same industry. This is therefore a measure of the international relative cost efficiency of R&D in national industries. A higher value of this variable means that the French industry generates more patent per euro of R&D investment, relative to the OECD average, and that R&D investment in this particular industry is more productive than the OECD average. If firms internationalize their R&D investment in order to reduce costs of innovation, we expect this variable to have a negative effect on R&D offshoring.

The *"Technological Efficiency"* variable is the revealed technological advantage (RTA) indicator (Soete and Wyatt, 1983). This is the most frequently used indicator referring to technological specialization. We calculate the index on the basis of patents filed at the European Patent Office

(EPO) and data is from the OECD Patent Database. The RTA of an industry corresponds to the ratio of the share of patents applied to the EPO and made by French inventors in that industry out of the total number of patents filed by France, over the share of worldwide patents in the same industry out of the world total number of patents. This indicator is computed over patenting activity incurred in the past four years (excluding the current year of observation). If an industry's share of the total of French patents is higher than the world share, this means that France possesses a technological advantage in this particular industry. Firms motivated by technology sourcing will engage R&D offshoring in order to benefit from the specialization advantage of foreign locations. We therefore expect this variable to have a negative effect on R&D offshoring if technology sourcing motives are important. Industry classifications, adopted to create these two indicators, have been constructed using the concordance table between technologies and industries developed by Schmoch *et al* (2003).[10]

Technology sourcing motives, as discussed in the previous section, are triggered by limited availability of R&D resources, lack of technological competences and R&D infrastructure, and insufficient supply of qualified researchers and engineers in the home country. We add an additional indicator of the availability of domestic R&D resources by creating a variable measuring the "*Agglomeration*" of domestic R&D activities at a regional level. This variable is measured as the share of the firm's region in the total investment in fundamental R&D within the same 4-digit industry.[11] We exclude from the measurement of "*Agglomeration*" the R&D investment of the firm itself to avoid measurement bias from large R&D investors in small regions. We argue that regions with agglomerated R&D activities will offer adequate R&D resources in terms of infrastructure, spillovers and availability of human capital and that firms located in these regions, if technology sourcing motives are significant, will be less likely to engage in R&D offshoring.

[10]As industrial indicators, these variables capture broad characteristics of national industries in the production of technology. While cost efficiency may also reflect cross-country differences in labour markets and wages, technological efficiency is a wider indicator of the technological dynamism and may also reflect the level of skills, and the availability of specialized engineers and technicians of the country in a given industry.

[11] We follow the French administrative definition of regions, or departments, according to which Metropolitan France is decomposed into 95 administrative regions.

Firm Level Variables

At the firm level, the sourcing of R&D is explained by the intensity of in-house R&D expenditures scaled by the workforce *("Internal R&D Intensity")*. We include the number of researchers over total employees *("Researcher Intensity")* as a measure of human capital. A positive impact is expected, as firms with a high-level of human capital would be more able to absorb diverse external sources of knowledge. Further, according to Cusmano *et al.* (2010) and Tomiura (2005), advanced qualifications 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. However, if the externalisation of R&D responds to the need to acquire skills that are not available in house (Lewin et al., 2009), firms intensive in researcher may have a lower need to engage in R&D sourcing strategies.

We control for the capacity of firms to overcome search and contracting costs by including an indicator of the firm's *"Scale"* measured by the total number of employees. We also account for the efficiency of the firm proxied by total factor productivity estimated using the methodology proposed by Olley and Pakes (1996). Some research has shown that firms' decision to vertically integrate depends on the company's distance to the technological frontier.[12] We build a measure of the technology gap and productive efficiency *("Productivity Gap")* measured as the difference between the firm's productivity level and the highest productivity level within the same 2-digit industry.[13] For more efficient firms, which can better handle management overload, international sourcing is a way to stimulate investment in innovation, by sharing ex-post rents and increasing returns to specialization. Moreover, efficient firms are more likely to engage in offshoring because this activity entails high fixed costs (Tomiura, 2005, 2009; Jabbour, 2012). We also add an indicator of the firm's financial situation measured as the firm's "*Cash Flow*", scaled by the firm's total employment.

[12] 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. However, closer to the frontier the value of innovation increases, encouraging the outsourcing of innovation activities.

[13] We estimate total factor productivity industry by industry, following the 2-digits French classification, using the total number of firms in the Annual Firm Survey.

Three variables convey information about a firm's experience in foreign countries: two dummy variables indicating whether the firm is affiliated to a French local group (*"Domestic Group")* or a French multinational group *("Multinational Group")* and a variable representing the firm's export intensity measured as the export share in the firm's total sales *("Export Intensity")*. We assume that firms who are active in international markets are more prone to be in contact with international suppliers of technology, as they face fiercer technology-based competition, need to adapt their product to the requirements of foreign markets and the taste of foreign consumers.

We also control for the firm's experience in the outsourcing of manufacturing inputs. We include a dummy variable indicating whether the firm is engaged in the outsourcing of manufacturing inputs *("Manufacturing Outsourcing").* This variable takes the value 1 if the firm has been engaged in manufacturing outsourcing for at least three consecutive years (between t-3 and t).[14]We would expect firms that more frequently delegate tasks across the chain of production to be more likely to outsource R&D, since they are those with experience and abilities in negotiating and enforcing contracts.

We also control for any potential correlation between national and international sourcing. When explaining "*National sourcing*", we include the variable *"International R&D Share"* measured as the share of internationally sourced R&D in total R&D expenditures. Similarly, when explaining "*International sourcing*", we include the variable *"National R&D Share"* measured as the share of domestically sourced R&D in total R&D expenditures.

We also control for the patenting activity at the firm level as a measure of the exercise of formal protection of intellectual assets. We create two variables that represent this activity: a dummy variable *"Patent"* indicating if the firm has a patent granted at time t. This variable takes the value one from the moment a firm is granted a patent. The other variable ("*Number of Patents*") is measured as the stock of patents granted to the firm in year t. This variable is measured as the cumulative number of patents granted to the firm from the beginning of the sample's period to the year t. The variable *"Number of Patents*" controls for the innovation activity by the firm, while the *"Patent"* dummy

[14] We create this variable using the information provided by the Annual Firm Survey that covers the period 1990-2001. It is thus possible to account for the pre-sample (before 1993) manufacturing outsourcing activity of the firms included in our sample.

controls for the fact of having patent protection. Patent data represents patents granted at the European Patent Office to French companies. This data has been produced by matching methods at the French national statistics office (INSEE).

We also account for the presence of a research centre within the group. That is, we control for companies that are affiliated to a group that has a subsidiary whose main activity is *research* with the dummy *"R&D Centre"*. Not accounting for this activity will lead to a downward bias in total R&D activity, both internal and external, made by the affiliate and/or parent companies.

Table 3 reports the means of firm level variables and t-statistics for comparison of means between types of R&D activities. It provides initial insights into the role of firm heterogeneity as a driver of the sourcing of R&D. The second and third columns compare firms that do not source with those that are engaged in sourcing agreements. The fourth column presents the mean comparison test between these two types of firms. The fifth and sixth columns compare firms that source exclusively at the national level with those that are engaged in international sourcing, and the seventh column presents the mean comparison test between these two types of firms. The last three columns compare affiliates of French multinational groups that offshore their R&D exclusively within the boundaries of their group to those that engage in extra-group R&D offshoring. Table 3 shows that firms that source R&D, especially the ones that outsource internationally, are larger, more intensive in internal R&D, have higher export activity and are closer to the cutting edge of technology (have a significantly smaller productivity gap). These firms are also significantly more active in terms of innovation and patenting. Table 4 presents summary statistics of all variables. All monetary variables are expressed in thousands of Euros and are deflated using sector level price indices.[15]

V. Results

Table 5 displays the results of the random effects Tobit model and Tables 6 and 7 report marginal effects. Table 6 presents the marginal effect of independent variables on the expected value of positive outcomes, while Table 7 presents marginal effects on the probability of observing positive

[15] Table A6, in the appendix, presents a correlation matrix of all variables.

outcomes. Both sets of marginal effects are based on the estimation of the random effect tobit models presented in Table 5. The first column of each table reports estimates on the total sourcing of R&D expenditure made by the firm. The second column reports estimates on the R&D expenditures contracted-out by the firm at the national level. The third column reports estimates on the offshoring of R&D. The fifth and sixth columns report estimates on intra-group offshoring and the extra-group offshoring respectively.[16]

With regard to technology drivers for international R&D sourcing, we find that technology sourcing motivations are significant. Variable representing the technological advantage of French industries have the expected negative coefficient. For multinational firms, technology sourcing motives are only relevant for market transactions (extra-group). This finding indicates that when seeking to acquire technology from abroad French firms favour international outsourcing relationships. According to these results, technological dynamism of national industries discourages firms from offshoring R&D. Inversely, this implies that if the industry has a relative disadvantage in technology, with respect to the world average, firms will be more likely to go beyond national borders to acquire lacking technological competencies. This result is in line with recent survey studies (LTT-Tutkimus Oy, 2007; Ito et al., 2007).

The *"Agglomeration"* variable has the expected negative coefficient indicating that firms located in regions offering the required resources and infrastructure for R&D investment do not require to source R&D from foreign locations. The effect of the *"Agglomeration"* variable is equivalent in magnitude to that of *"Technological Efficiency"* however this variable is only relevant for non-multinational firms. This result provides additional support for the assumption of technology sourcing motives.

The variable *"Cost efficiency"* is only significant in the case of national sourcing and extra-group transactions albeit its impact is rather small. We should mention though that this finding must be interpreted with care. Due to data limitations, the *"Cost Efficiency"* indicator has been computed only with respect to the OECD average; this average therefore does not capture the effect of costs by non-

[16] Both columns report estimates based on the sub-sample of affiliates of French multinational groups.

OECD countries.[17] In spite of this shortcoming, we argue that although R&D costs are dramatically lower in some emerging countries, their technological performance measured with patents still remains very low. Moreover, survey based studies like the ones by Madeuf and Lefebvre (2001) and Miotti and Sachwald (2003) show that French firms limit the internationalization of their R&D investments to developed economies like Europe, North America and Japan.

In terms of firm level characteristics, our results confirm the predominance of large firms in making use of external suppliers of technology. Large firms develop economies of scale and scope that are leveraged with external R&D. Lastly; bigger firms might be more likely to overcome transaction costs, more likely to diversify research and be forced to tap into a wider range of technological competencies. As expected, the cash flow variable has a positive effect on all forms of R&D externalisation, except in the case of affiliates of multinational groups. Firms affiliated to a multinational group do not face the same financial constrains faced by single firms or firms affiliated to small groups.

We also show that the more distant the position of the company in terms of productive efficiency – its "technology gap" – the less attractive the externalization of R&D. However although the variable reports the expected sign, the technology gap variable is only significant in the case of R&D offshoring. In the case of multinational French groups, technology gap is only significant in explaining international outsourcing intra-group.

Regarding the relationship between external and internal R&D our results are in line with previous works (e.g. Veugelers, 1997; Cassiman and Veugelers, 2002), the intensity of internal R&D increases the expected propensity and intensity of R&D outsourcing. Our results corroborate the hypothesis of complementarity between in-house technological investment and contracted-out R&D. [18] The human capital level does not appear as a critical determinant explaining the sourcing of R&D even at the international level. This result suggests that the two opposite effects of this variable (absorptive

[17] The lack of significance on the cost efficiency and technological efficiency variables may be due to the limited variance of these variables within each industry. However, even when we exclude industry level fixed effects the coefficient on the cost efficiency variable remains non-significant for international sourcing.

[18] The coefficients on the intensity of internal R&D must be interpreted with care though. As mentioned earlier, all firms in our sample are active in internal R&D. These coefficients mean that as the intensity of internal R&D increases, the extent of outsourcing R&D by these firms also increases.

capacity and availability of skills) are cancelling each other. The lack of significance of this variable may be due to its high correlation with the internal R&D intensity, suggesting that researcher intensity does not exercise an impact of R&D sourcing decision that goes beyond the impact of internal R&D capabilities as measured by internal R&D intensity,

Having patents and the number of patents influence the sourcing of R&D in different ways. The number of patents is associated positively with total and national sourcing of R&D, but the patent dummy has no impact in these equations. On the contrary, the patent dummy does explain significantly and is positively correlated to R&D offshoring and, notably, offshoring outside the boundaries of the group. In this sense, when contracting with foreign unaffiliated partners, what matters is patent protection rather than the quantity or size of the patent portfolio. This indicates that the firm has the ability to protect itself in international contracts and to better negotiate deals.

Our results indicate that the intensity of firm internationalization also plays a role. The higher the export intensity of a firm, the more it outsources its R&D activities in global markets. This finding confirms the intuition that firms active in international markets are more likely to be involved in international R&D transactions: competition in the global product market pushes them to outsource technological resources needed to achieve international standards of innovation and competitiveness.[19]

Our results show no significant difference between affiliates of domestic groups and independent firms in terms of the sourcing of R&D. On the contrary, firms that belong to multinational French groups are more likely to source research at the national level. However, there is no significant distinction between the three categories in terms of R&D offshoring. The internationalization of R&D by multinational groups may be managed at the headquarter level of R&D centres affiliated to the group and not at the affiliate level.

[19] Besides the competition-effect, it could be possible that this strategy is fostered overseas by the clients themselves. That is, clients of firms in foreign markets put the firm in contact with technology specialized firms, in order to achieve quality standards and ensure the provision-specific technology inputs in exports. In that sense, exporting relationships are an instrument to improve technology, learn, customise products and integrate customers' networks in the production of technology (see for instance Crespi *et al*, 2008).

Our results indicate a positive correlation between national and international R&D outsourcing. However, these correlations can simply result from the presence of unobserved firm heterogeneity that drives both national and international sourcing strategies. Past experience in manufacturing outsourcing seems to be of no influence in determining the sourcing of R&D activities both at the national and international levels. This finding suggests that these two activities are different and that determinants for contracting-out are not the same. Experience in outsourcing of inputs does not necessarily give firms better skills in drafting, negotiating and searching for suitable partners in the production of knowledge. Lastly, the presence of a research centre within the group has a positive effect on the total sourcing of R&D and the national sourcing of R&D.[20]

VI. Robustness Checks

Instrumental variables Estimations

We have applied several alternative methodologies to test the robustness of our results. We have estimated an instrumental variable Tobit model to test for the endogeneity of the internal R&D variable. Even though the 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. R&D investments might be more important in the case of R&D offshoring; more precisely this link may be influenced by self-selection. It could be that only the more R&D intensive firms expand their operations abroad. The 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 within these firms.

We apply the Wald (chi2) test proposed by Smith and Blundell (1986) to test for the endogeneity in Tobit models. We use, as instruments, one year lags of the market share of the firm in the domestic 2-digits industry and, in the case of total and national sourcing the agglomeration variable defined

[20]The "R&D Center" variable controls for the presence of a research center within the French national boundaries which might explain the lack of significance of this variable as a determinant of international outsourcing. The data does not allow us to control for the presence of a R&D center at the international level.

above, while in the case of international, intra-group and extra-group sourcing the total patent variable defined above. The market share variable represents the competitive pressures facing the firm and its position within the industry. We argue that this instrument reflects market-level attributes that are significant drivers for firm level investments in internal R&D. The agglomeration and total patents variables had no significant correlation with external R&D in the corresponding specifications presented in Table 5 and we argue that these variables are closely related to the intensity of in-house R&D. The Wald (Chi2) test does not allow us to reject the null-hypothesis of exogeneity of internal R&D. Moreover, the over-identification test confirms the validity of the instruments and the Stock and Yogo's test strongly rejects the null hypothesis of weak instruments (Stock and Yogo, 2005).[21] The results obtained from the instrumental variable Tobit model are presented in Table A1 in the appendix. These confirm the ones presented in Table 5 however when we instrument internal R&D, the positive correlation between internal R&D and measures of R&D sourcing is no longer significant.

Multivariate Tobit

We have also estimated two multivariate Tobit models to test for possible simultaneity between the different strategies of R&D sourcing. In the first multivariate Tobit model we have considered the interaction between national and international sourcing strategies. The estimated "correlation parameter" is positive and significant, indicating a positive correlation between the error terms relative to the two equations and a co-dependence between the two sourcing strategies. In the second multivariate Tobit model we have considered the simultaneity between the intra-group and extra-group offshoring of R&D by affiliates of multinational groups. In this case the "correlation parameter" is also positive and significant. These results must be interpreted with care. The positive correlation between the error terms may simply result from the omission of variables that significantly influence both strategies. As we are not able to control for firm heterogeneity in the multivariate Tobit

[21] The Stock and Yogo test was performed after a linear instrumental variable regression because it is not available after instrumental variable tobit estimators.

models and this heterogeneity may play a central role in determining the outsourcing strategies, we do not wish to draw strong conclusions from the multivariate Tobit models. Results presented in Table A2, in the appendix, are similar to the one presented in Table 5.

The instrumental variables and multivariate Tobit are only available for cross-section analysis. Since the results provided by these models are similar to the one provided by the random-effect Tobit and since the endogeneity of internal R&D has been rejected, we prefer to take advantage of the panel structure of the data and comment on the random-effect Tobit model.

Alternative measures of technology efficiency and cost efficiency

In order to check the robustness of our measures of technology efficiency we have considered an indicator of the attractiveness of domestic industries based on the R&D activity by foreign affiliates. R&D investment by foreign affiliates in host locations may be an indicator of the R&D attractiveness of this location, especially when these investments are more than proportional to the production activities of these affiliates (Harfi and Mathieu, 2008). R&D investment by foreign affiliates follows the same motivation for R&D internationalization discussed above. We create a variable *"Foreign Affiliates R&D",* measured as the ratio of R&D expenditures by foreign affiliates over total value-added by foreign affiliates in France over the mean of the R&D to value-added ratio of foreign affiliates in the OECD countries. This variable is constructed using data extracted from the OECD "Statistics on Measuring Globalisation" dataset. Our indicator "*R&D Competitiveness*" is equal to one if the variable *"Foreign Affiliates R&D"* is higher than one and zero otherwise. Results reported in Table A3, in the appendix, show that this indicator has a strong negative effect on R&D offshoring confirming the results presented in Tables 5-7.[22] We have also considered alternative measures of cost efficiency by constructing two variables representing the competitiveness of French industries in terms of variable R&D costs. The first, *"Current Costs"* is measured as the ratio of the share of current R&D costs in total R&D costs for each French 3-digits industry over the mean share of current

[22] Because the indicator "*R&D Competitiveness*" has limited variability across industries, results presented in table are based on random effect tobit model that does not include industry fixed effects. For this reason we do not wish to draw strong conclusions from this table.

R&D costs in OECD countries for the same 3-digits industry. The second, *"Labour Costs"* is constructed in a similar way but measures the competitiveness of French industries in terms of labour R&D costs. Data required for the construction of these variables is extracted from the OECD "Science, Technology and R&D Statistics" dataset. Both variables have no significant impact on the offshoring of R&D by French firms confirming the results presented in Table5.[23] It is clear however that further work needs to be done in this respect. It would have been useful to have firm level information on wages and benchmark these to international wages of researchers.

Finally, we have tried to distinguish between internationalized and non-internationalized firms (exporting and non-exporting companies) in order to explore the presence of factors that affect the international outsourcing of R&D differently from the process of internationalization. However, a very large share (94%) of the firms in the sample is engaged in exporting activities. Because of the limited number of observations, the estimation of the Tobit model on the sub-sample of non-internationalized firms did not reach convergence.

VI. Conclusions

We present an empirical analysis of the determinants of R&D offshoring by French manufacturing firms. Our goal has been to contribute to the ongoing effort to better understand the growing internationalization of technological activities. We provide evidence of the particular profile of firms and industry contexts where R&D offshoring occurs more intensively.

Our results show that firms that outsource R&D in international markets are knowledge intensive, productive (they are close to the technology frontier) and more integrated in global markets. Nevertheless, although these firms are good economic performers, they are localized in sectors where the home country is technologically lagging behind the rest of the world. Our evidence confirms that R&D outsourcing is driven by a combination of technology sourcing and asset-exploiting motivations.

The policy implications of this analysis are that R&D offshoring appears to work in tandem with internal R&D activities and goes in hand with other international economic activities. Hence this

[23] Results are presented in Tables A4 and A5 in the appendix.

evidence suggests that globalization opens up a way to firms in technology lagging industries to catch up technologically and acquire technological competences.

This investigation is a first step in the analysis of the offshoring of innovation activities. Further research is needed to better understand how R&D contracting-out works and under what conditions. What kind of R&D task is offshored (e.g. product development, basic research, prototype testing, etc.)? What is the nature of innovation that is externalized (radical or incremental) and how does it integrate into the internal R&D process of firms? Our next step is then to associate R&D offshoring activities with the types of inventions that are generated, their novelty and quality and, notably, the acquisition of new technological competences, as reflected in the technology aspect of new inventions). These evaluations will allow us to assess whether R&D offshoring provides learning to the firm and enables it to increase the quality of inventions and the entry into new technological arenas.

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Table 1: The sourcing of R&D by industry (Frequency and average expenditure per employee in thousand 2000 Euros)

Industry	Percent of firms sourcing R&D	Percent of firms offshoring R&D	Importance of R&D sourcing in total R&D			R&D sourcing expenditure per employee		
			Total sourcing	National	International	Total sourcing	National	International
Leather & Apparel	25.50%	1.70%	13.48%	12.19%	3.69%	0.28	0.21	0.05
Printing & Publishing	40.26%	10.38%	19.64%	19.19%	2.63%	0.72	0.71	0.23
Pharmaceuticals	80.11%	35.62%	**30.15%**	27.15%	6.88%	**12.88**	10.48	5.53
Household equipment	50.70%	11.42%	17.18%	14.79%	6.62%	1.77	1.45	0.94
Auto industry	45.60%	16.53%	14.06%	12.50%	3.82%	8.54	8.92	0.51
Other transportation	56.60%	7.08%	16.69%	16.11%	5.28%	0.66	0.61	0.22
Mechanical products	45.60%	5.30%	13.07%	12.77%	3.30%	0.91	0.89	0.24
Electric & electronic products	51.20%	11.13%	12.95%	11.98%	5.52%	3.39	3.05	2.1
Minerals	68.40%	7.77%	20.37%	19.98%	5.43%	0.91	0.84	0.71
Textile	44.20%	5.55%	10.17%	9.37%	7.55%	0.55	0.51	0.54
Wood & paper	49.40%	4.60%	21.65%	20.76%	9.60%	0.87	0.85	0.24
Chemicals, rubber & plastics	57.20%	13.25%	14.17%	13.11%	4.73%	2.1	1.89	0.98
Metals	49.70%	9.18%	18.04%	17.22%	5.53%	0.67	0.62	0.2
Electronic components	56.90%	14.33%	11.28%	10.10%	5.07%	1.53	1.37	0.73
Coking, refined petroleum & nuclear fuel	91.80%	41.80%	**29.04%**	27.22%	5.10%	**12.58**	11.98	1.91
Water, electricity & gas	80%	50.9	19.43%	17.82%	2.52%	0.5	0.44	0.09
Total	**55.80%**	**15.40%**	**17.50%**	**16.40%**	**5.20%**	**3.05**	**2.8**	**0.95**

Table 2: Outsourcing of R&D: main trends by type of firm

Sourcing Intensity *(expenditure per employee in thousands 2000 Euros)*	Nb of Observations	Propensity of sourcing (% firms engaged)	Mean	SD	Min	Max
			Independent Firms			
Sourcing (Total)	3015	0.43	0.77	6.3	0	280.79
National sourcing	3015	0.42	0.7	6.2	0	280.79
International sourcing	3015	0.06	0.07	0.7	0	15.44
			Domestic Groups (affiliates and headquarters)			
Sourcing (Total)	1310	0.48	1.2	10.7	0	242.48
National sourcing	1310	0.47	0.9	7.1	0	196.54
International sourcing	1310	0.08	0.3	5.2	0	159.82
			Multinational Groups (affiliates and headquarters)			
Sourcing (Total)	3792	0.66	2.8	26.7	0	997.14
National sourcing	3792	0.65	2.4	23.1	0	954.71
International sourcing	3792	0.18	0.36	7.1	0	348.07

Table 3: Comparative statistics between firms depending on R&D outsourcing strategies

	Sourcing	Non Sourcing	Sourcing> Non Sourcing	International Sourcing	National Sourcing	International> National	Offshoring Extra Group	Offshoring Intra Group	Extra Group> Intra Group
Internal R&D intensity	8.3	6.3	***	13.7	6.7	***	20.1	14.62	n.s.
Scale	1005.3	329.6	***	2900.7	469.4	***	4422.17	2631.68	**
Manufacturing Outsourcing	0.85	0.8	***	0.89	0.83	***	0.91	0.92	n.s.
Exports Intensity	0.31	0.25	***	0.37	0.3	***	0.39	0.41	n.s.
Cash Flow Intensity	26,8	13.8	***	51.12	19	**	51.22	18.9	*
Researcher Intensity	0.06	0.06	n. s.	0.07	0.05	**	0.07	0.06	n.s.
Productivity Gap	2.52	2.64	***	2.38	2.56	***	2.31	2.34	n.s.
Patent	0.18	0.07	***	0.29	0.15	***	0.35	0.35	n.s.
Number of Patents	3.23	0.65	***	8.6	1.7	***	30.6	16.64	**

Note: The comparison is based on a mean comparison test (t-test) adjusted for unequal variance between groups

Table 4: Summary Statistics

Variable	Observations	Mean	St. Deviation
Total sourcing Intensity (expenditure per employee)	8117	1.78	19.21
National sourcing Intensity(expenditure per employee)	8117	1.5	16.5
International sourcing Intensity (expenditure per employee)	8117	0.24	5.3
Intra-Group R&D Intensity (expenditure per employee)	3792	0.16	5.7
Extra-Group R&D Intensity (expenditure per employee)	3792	0.17	4.1
Internal R&D Intensity (expenditure per employee)	8117	7.4	27.8
Total sourcing /Total R&D	8118	0.09	0.16
National sourcing /Total R&D	8118	0.08	0.15
International sourcing /Total R&D	8118	0.007	0.04
Manufacturing Outsourcing (share of production that is outsourced)	8118	0.83	0.37
Researcher Intensity (number of researchers in total employment)	8117	0.06	0.09
Scale (number of employees)	8118	698.22	4435.5
Exports Intensity (exports in total sales)	8118	0.29	0.25
Technology Gap (difference in total factor productivity respect to the leader in the sector)	7927	2.57	0.83
Cash Flow	8117	20.91	160.23
Cost Efficiency (Industry R&D cost per patent relative to the OECD industry average R&D cost per patent)	8071	1.38	1.34
Technological Efficiency (relative technological advantage, see section 2.11)	8071	1.04	0.13
Agglomeration (Share of the firm's region in fundamental research expenditures within each 2-digit's industry)	8118	0.05	0.11
French Group	8118	0.62	0.48
Multinational Group (firms that are affiliates or are headquarters of a multinational group)	8118	0.46	0.49
Domestic Group (firms that are affiliates or headquarters of a French local group: no subsidiaries abroad)	8118	0.16	0.36
R&D Centre (dummy equal to one if the firm has a R&D centre subsidiary locally)	8118	0.14	0.34
Patent Dummy (equal to one if the firm has filed patents at the EPO in the last 5 years)	8118	0.13	0.34
Number of Patents (stock of patents)	8118	2.06	23.24

Table 5: The Sourcing of the R&D Activity (expenditure per employee): random effects Tobit

	Total sample			Multinational Groups	
	Total Sourcing	National Sourcing	International Sourcing	Intra-Group	Extra-Group
Internal R&D	0.52***	0.52***	1.8***	3.02***	1.7***
	(0.17)	(0.14)	(0.33)	(0.76)	(0.49)
Manufacturing Outsourcing	0.1	0.11	-0.48	-1.24	-1.82*
	(0.3)	(0.28)	(0.67)	(1.79)	(1.09)
National R&D Share			5.23***	6.54**	3.69
			(1.5)	(2.84)	(2.3)
International R&D Share		3.4*			
		(2.04)			
Researcher Intensity	1.02	1.3	2.9	10.3	8.09
	(1.5)	(1.6)	(3.66)	(9.16)	(6.5)
Scale	0.68***	0.64***	2.5***	3.63***	2.65***
	(0.15)	(0.15)	(0.32)	(0.65)	(0.43)
Export Intensity	0.94	0.78	4.18***	2.82	3.53**
	(0.64)	(0.6)	(1.2)	(2.7)	(1.82)
Technology Gap	-0.05	-0.02	-0.5**	-1.22**	-0.18
	(0.1)	(0.09)	(0.25)	(0.56)	(0.37)
Multinational Group	0.99***	1.1***	-0.79		
	(0.34)	(0.35)	(0.8)		
Domestic Group	0.3	0.38	0.5		
	(0.4)	(0.38)	(0.84)		
R&D Centre	1.08***	1.11***	0.78	2.02	0.003
	(0.36)	(0.43)	(0.78)	(1.31)	(0.96)
Cash Flow	0.34***	0.32***	0.48**	0.49	0.19
	(0.09)	(0.09)	(0.2)	(0.44)	(0.3)
Patent	0.24	0.27	1.2**	1.89	1.79**
	(0.31)	(0.29)	(0.64)	(1.33)	(0.89)
Number of Patents	0.33**	0.34*	0.42	-0.009	-0.11
	(0.17)	(0.16)	(0.37)	(0.6)	(0.47)
Cost Efficiency	0.1*	0.1*	-0.06	0.1	0.42**
	(0.05)	(0.05)	(0.12)	(0.27)	(0.19)
Technological Efficiency	-2.32	-2.56*	-5.11*	-6.76	-10.9**
	(1.5)	(1.5)	(2.92)	(6.39)	(4.5)
Agglomeration	0.65	0.8	-5.4**	-1.3	-1.43
	(1.06)	(0.96)	(2.4)	(4.00)	(2.9)
Constant	-8.06***	-8.2***	-35.7***	-61.36	-32.07
	(2.73)	(2.5)	(5.98)	(13.03)	(8.4)
Observations	5513	5513	5513	2952	2952
Number of firms	1689	1689	1689	814	814
Log Likelihood	-10870.347	-10777.211	-3303.25	-976.50	-1615.34
Wald Chi2	628.21	577.00	234.82	79.57	116.14
Prob> Chi2	0.000	0.000	0.000	0.000	0.000

SE are reported in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Table 6: Marginal effects: positive expenditures

	Total sample			**Multinational Groups**	
	Total Sourcing	National Sourcing	International Sourcing	Intra-Group	Extra-Group
Internal R&D	0.33***	0.33***	0.2***	0.06***	0.14***
	(0.09)	(0.08)	(0.037)	(1.04)	(0.4)
Manufacturing Outsourcing	0.06	0.06	-0.05	-0.03	-0.17*
	(0.17)	(0.17)	(0.077)	(0.47)	(0.47)
National R&D Share			0.56***	0.13***	0.29
			(0.16)	(2.2)	(0.84)
International R&D Share		2.4*			
		(1.2)			
Researcher Intensity	0.65	0.8	0.31	0.2	0.65
	(1.1)	(0.9)	(0.39)	(3.5)	(1.89)
Scale	0.43***	0.4***	0.26***	0.07***	0.21***
	(0.09)	(0.09)	(0.037)	(1.25)	(0.59)
Export Intensity	0.6	0.48	0.45***	0.055	0.3**
	(0.38)	(0.38)	(0.13)	(0.97)	(0.8)
Technology Gap	-0.03	-0.014	-0.05**	-0.023**	-0.014
	(0.07)	(0.06)	(0.027)	(0.42)	(0.05)
Multinational Group	0.63***	0.7***	-0.084		
	(0.25)	(0.22)	(0.087)		
Domestic Group	0.2	0.24	0.05		
	(0.3)	(0.24)	(0.09)		
R&D Centre	0.71***	0.66***	0.087	0.04	-0.0002
	(0.23)	(0.28)	(0.09)	(0.75)	(0.08)
Cash Flow	0.21***	0.2***	0.051**	0.009	0.015
	(0.05)	(0.06)	(0.022)	(0.17)	(0.42)
Patent	0.15	0.17	0.14**	0.039	0.15**
	(0.16)	(0.18)	(0.075)	(0.68)	(0.42)
Number of Patents	0.21**	0.21*	0.04	-0.0001	-0.009
	(0.1)	(0.1)	(0.04)	(0.01)	(0.04)
Cost Efficiency	0.06*	0.06*	-0.02	0.002	0.033**
	(0.3)	(0.3)	(0.02)	(0.03)	(0.09)
Technological Efficiency	-1.4	-1.5*	-0.55*	-0.13	-0.9**
	(0.9)	(0.9)	(0.31)	(2.33)	(2.4)
Agglomeration	0.4	0.5	-0.58**	-0.02	-0.11
	(0.67)	(0.6)	(0.25)	(0.45)	(0.4)
Observations	5513	5513	5513	2952	2952
Number of firms	1689	1689	1689	814	814

Table 7: Marginal effects: probability of a positive outcome

	Total sample			Multinational Groups	
	Total Sourcing	National Sourcing	International Sourcing	Intra-Group	Extra-Group
Internal R&D	0.03***	0.03***	0.03***	0.012***	0.026***
	(0.007)	(0.007)	(0.006)	(0.18)	(0.05)
Manufacturing Outsourcing	0.005	0.006	-0.008	-0.005	-0.03*
	(0.01)	(0.016)	(0.012)	(0.08)	(0.06)
National R&D Share			0.09***	0.03***	0.05
			(0.027)	(0.4)	(0.12)
International R&D Share		0.22*			
		(0.11)			
Researcher Intensity	0.06	0.07	0.05	0.04	0.12
	(0.09)	(0.09)	(0.065)	(0.63)	(0.27)
Scale	0.04***	0.036***	0.04***	0.015***	0.04***
	(0.008)	(0.009)	(0.005)	(0.22)	(0.08)
Export Intensity	0.05	0.04	0.07***	0.011	0.05**
	(0.03)	(0.03)	(0.02)	(0.17)	(0.11)
Technology Gap	-0.002	-0.001	-0.008**	-0.004**	-0.002
	(0.006)	(0.006)	(0.004)	(0.07)	(0.007)
Multinational Group	0.06***	0.06***	-0.014		
	(0.02)	(0.02)	(0.014)		
Domestic Group	0.017	0.02	0.008		
	(0.02)	(0.02)	(0.015)		
R&D Centre	0.06***	0.06***	0.014	0.008	-0.00005
	(0.02)	(0.02)	(0.015)	(0.13)	(0.01)
Cash Flow	0.02***	0.02***	0.008**	0.002	0.003
	(0.004)	(0.005)	(0.003)	(0.03)	(0.007)
Patent	0.014	0.015	0.022**	0.008	0.03**
	(0.014)	(0.017)	(0.012)	(0.12)	(0.58)
Number of Patents	0.019**	0.02*	0.007	0.00003	-0.001
	(0.009)	(0.01)	(0.006)	(0.002)	(0.008)
Cost Efficiency	0.005*	0.005*	-0.001	-0.0004	0.006**
	(0.003)	(0.003)	(0.002)	(0.006)	(0.013)
Technological Efficiency	-0.13	-0.14*	-0.09*	-0.03	-0.16**
	(0.08)	(0.08)	(0.05)	(0.4)	(1.35)
Agglomeration	0.03	0.04	-0.09**	-0.005	-0.02
	(0.06)	(0.05)	(0.04)	(0.08)	(0.06)
	0.03***	0.03***	0.03***	0.012***	0.026***
Observations	5513	5513	5513	2952	2952
Number of firms	1689	1689	1689	814	814

Appendix

Table A1: Instrumental Variable Tobit

	Total sample			Multinational Groups	
	Total Sourcing	National Sourcing	International Sourcing	Intra-Group	Extra-Group
Internal R&D	0.56	0.54	1.63	3.53	1.28
	(0.86)	(0.89)	(1.25)	(2.36)	(1.60)
Manufacturing Outsourcing	0.58**	0.57*	-0.036	-1.59	-0.72
	(0.29)	(0.29)	(0.77)	(1.71)	(1.21)
National R&D Share		13.3***			
		(2.37)			
International R&D Share			6.69***	11.7***	2.07
			(1.84)	(3.42)	(2.40)
Researcher Intensity	0.74	0.47	4.55	-4.55	11.4
	(4.71)	(4.84)	(7.41)	(20.5)	(13.5)
Scale	0.51***	0.48***	2.07***	2.92***	2.50***
	(0.12)	(0.12)	(0.19)	(0.29)	(0.22)
Export Intensity	1.38***	1.13**	4.60***	1.69	5.64***
	(0.44)	(0.44)	(0.95)	(1.77)	(1.34)
Technology Gap	0.064	0.089	-0.68**	-1.10	-0.38
	(0.16)	(0.16)	(0.35)	(0.78)	(0.52)
Multinational Group	1.10***	1.19***	-0.71		
	(0.29)	(0.30)	(0.68)		
Domestic Group	0.26	0.34	0.57		
	(0.30)	(0.30)	(0.78)		
R&D Centre	0.99***	0.91**	0.82	2.68**	0.77
	(0.37)	(0.38)	(0.78)	(1.30)	(0.93)
Cash Flow	0.57***	0.56***	0.54**	0.69	0.043
	(0.12)	(0.12)	(0.25)	(0.48)	(0.35)
Patent	0.98***	0.92***	3.01***	2.19**	1.96***
	(0.27)	(0.27)	(0.55)	(0.99)	(0.68)
Number of Patents	0.39*	0.41*			
	(0.21)	(0.21)			
Cost Efficiency	0.14*	0.14*	-0.11	-0.25	0.37
	(0.072)	(0.072)	(0.17)	(0.35)	(0.24)
Technological Efficiency	-4.64***	-4.66***	-11.3***	-6.89	-18.1***
	(1.24)	(1.25)	(2.87)	(5.87)	(3.87)
Agglomeration			-1.34	-3.85	-6.64
			(2.73)	(6.29)	(4.66)
Constant	-2.67	-3.02	-25.2*	-64.5***	-19.7
	(8.90)	(9.19)	(13.6)	(25.0)	(16.7)
Observations	5513	5513	5513	2952	2952
Log Likelihood	-19044.861	-18897.02	-10656.62	-4739.34	-5430.47
Wald Chi2	0.02	0.02	0.17	0.00	0.3
Prob> Chi2	0.88	0.89	0.67	0.98	0.58

SE are reported in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Table A2: Multivariate Tobit Estimation

	Total Sample		Multinational Groups	
	National Sourcing	International Sourcing	Intra-Group	Extra-Group
Internal R&D	0.43**	1.71***	2.42***	1.92***
	(0.17)	(0.38)	(0.55)	(0.36)
Manufacturing Outsourcing	0.57	0.22	-0.55	-0.94
	(0.39)	(0.92)	(1.88)	(1.18)
Researcher Intensity	1.33	2.20	1.27	4.81
	(2.07)	(5.00)	(9.21)	(5.96)
Scale	0.47***	2.25***	3.16***	2.57***
	(0.16)	(0.33)	(0.42)	(0.28)
Export Intensity	1.24**	5.08***	1.33	5.44***
	(0.62)	(1.42)	(1.95)	(1.30)
Technology Gap	0.086	-0.68*	-1.09*	-0.47
	(0.15)	(0.38)	(0.66)	(0.44)
Multinational Group	1.18***	-0.64		
	(0.43)	(1.02)		
Domestic Group	0.35	0.34		
	(0.45)	(1.19)		
R&D Centre	0.95**	1.54	4.12***	0.86
	(0.44)	(0.95)	(1.03)	(0.71)
Cash Flow	0.59***	0.73**	1.37***	0.11
	(0.12)	(0.31)	(0.47)	(0.30)
Patent	1.01***	3.00***	2.22**	1.99***
	(0.38)	(0.88)	(1.11)	(0.76)
Number of Patents	0.38	0.19	0.15	-0.20
	(0.25)	(0.51)	(0.67)	(0.50)
Cost Efficiency	0.14**	-0.073	-0.033	0.076
	(0.069)	(0.16)	(0.64)	(0.39)
Technological Efficiency	-4.73***	-12.1***	-11.3**	-18.2***
	(1.63)	(3.76)	(5.23)	(3.73)
Agglomeration	1.21	-2.13	-1.16	-3.51*
	(1.19)	(2.85)	(2.92)	(2.13)
Constant	-4.09	-38.4***	-102	-72.5
	(3.35)	(7.62)	(50,008)	(85,763)
Observations	5513		2952	
Number of firms	1689		814	
Rho	0.46***		0.43***	
	(0.03)		(0.04)	

SE are reported in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Table A3: Alternative Measures of Technology Sourcing. Random Effects Tobit

	Total sample			**Multinational Groups**	
	Total Sourcing	National Sourcing	International Sourcing	Intra-Group	Extra-Group
Internal R&D	0.62***	0.62***	2.08***	3.23***	2.11***
	(0.12)	(0.12)	(0.32)	(0.69)	(0.46)
Manufacturing Outsourcing	0.025	0.039	-0.49	-1.26	-1.88*
	(0.25)	(0.25)	(0.67)	(1.80)	(1.10)
International R&D Share		4.16**			
		(1.99)			
National R&D Share			6.59***	8.59***	5.82**
			(1.51)	(2.76)	(2.27)
Researcher Intensity	1.04	1.29	2.26	6.09	4.73
	(1.42)	(1.44)	(3.63)	(9.17)	(6.6)
Scale	0.71***	0.67***	2.43***	3.43***	2.62***
	(0.14)	(0.14)	(0.32)	(0.62)	(0.42)
Export Intensity	0.61	0.46	3.52***	1.75	2.56
	(0.55)	(0.55)	(1.26)	(2.61)	(1.82)
Technology Gap	-0.08	-0.06	-0.46*	-1.25**	-0.16
	(0.09)	(0.09)	(0.25)	(0.54)	(0.35)
Multinational Group	0.96***	1.07***	-0.96		
	(0.31)	(0.31)	(0.81)		
Domestic Group	0.23	0.30	0.37		
	(0.3)	(0.31)	(0.85)		
R&D Centre	1.51***	1.48***	1.16	2.82**	0.054
	(0.35)	(0.36)	(0.77)	(1.26)	(0.94)
Cash Flow	0.41***	0.39***	0.61***	0.66	0.39
	(0.08)	(0.08)	(0.2)	(0.44)	(0.3)
Patent	0.28	0.32	1.23*	2.13	1.96**
	(0.28)	(0.28)	(0.64)	(1.33)	(0.89)
Number of Patents	0.35*	0.35*	0.43	-0.02	-0.12
	(0.19)	(0.2)	(0.38)	(0.62)	(0.48)
Cost Efficiency	0.11**	0.12**	-0.043	-0.091	0.42**
	(0.04)	(0.04)	(0.13)	(0.28)	(0.19)
R&D Competitiveness	-0.32	-0.34*	-1.34**	-1.11	-2.16**
	(0.2)	(0.2)	(0.55)	(1.2)	(0.8)
Constant	-10.8***	-10.8***	-49.5***	-76.2***	-54.0***
	(1.55)	(1.56)	(4.1)	(9.9)	(6.18)
Observations	5513	5513	5513	2952	2952
Number of firms	1689	1689	1689	814	814
Log Likelihood	-10905.22	-10813.44	-3321.26	-984.99	-1629.1
Wald Chi2	223.03	223.3	211.86	81.51	102.09
Prob> Chi2	0.000	0.000	0.000	0.000	0.000

SE are reported in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Table A4: Alternative Measures of Cost Saving: Current Costs. Random Effects Tobit

	Total sample			**Multinational Groups**	
	Total Sourcing	National Sourcing	International Sourcing	Intra-Group	Extra-Group
Internal R&D	0.52***	0.53***	1.85***	3.07***	1.72***
	(0.13)	(0.13)	(0.33)	(0.76)	(0.5)
Manufacturing Outsourcing	0.073	0.09	-0.47	-1.15	-1.9*
	(0.25)	(0.25)	(0.68)	(1.8)	(1.09)
International R&D Share		3.9**			
		(1.99)			
National R&D Share			5.16***	6.59**	3.43
			(1.53)	(2.88)	(2.3)
Researcher Intensity	0.85	1.13	3.09	10.7	7.27
	(1.42)	(1.44)	(3.66)	(9.19)	(6.55)
Scale	0.67***	0.63***	2.44***	3.61***	2.62***
	(0.14)	(0.15)	(0.32)	(0.66)	(0.43)
Export Intensity	0.88	0.73	4.2***	3.03	3.29*
	(0.55)	(0.55)	(1.27)	(2.7)	(1.82)
Technology Gap	-0.074	-0.046	-0.45*	-1.22**	-0.28
	(0.098)	(0.099)	(0.25)	(0.55)	(0.36)
Multinational Group	0.99***	1.11***	-0.78		
	(0.31)	(0.31)	(0.81)		
Domestic Group	0.31	0.38	0.48		
	(0.3)	(0.31)	(0.84)		
R&D Centre	1.11***	1.06***	0.73	1.99	0.11
	(0.35)	(0.36)	(0.78)	(1.33)	(0.96)
Cash Flow	0.33***	0.31***	0.49**	0.51	0.15
	(0.080)	(0.082)	(0.20)	(0.44)	(0.31)
Patent	0.2	0.24	1.25*	1.95	1.64*
	(0.28)	(0.28)	(0.64)	(1.33)	(0.89)
Number of Patents	0.34*	0.35*	0.43	0.023	-0.028
	(0.19)	(0.19)	(0.38)	(0.61)	(0.48)
Current Costs	-0.41	-0.48	-1.00	12.4	-4.07
	(1.59)	(1.62)	(4.16)	(8.54)	(6.48)
Technological Efficiency	-2.24*	-2.48*	-4.98*	-7.64	-10.8**
	(1.22)	(1.2)	(2.95)	(6.47)	(4.6)
Agglomeration	0.74	0.88	-3.21	-0.26	-1.32
	(1.18)	(1.19)	(2.5)	(4.5)	(3.16)
Constant	-2.28	-2.2	-34.8***	-75.0***	-25.4***
	(2.97)	(3.0)	(7.34)	(15.9)	(10.8)
Observations	5513	5513	5513	2952	2952
Number of firms	1689	1689	1689	814	814
Log Likelihood	-10872.48	-10779.33	-3305.15	-975.57	-1617.56
Wald Chi2	293.02	296.3	231.74	80.13	115.02
Prob> Chi2	0.000	0.000	0.000	0.000	0.000

SE are reported in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Table A5: Alternative Measures of Cost Saving: Labour Costs. Random Effects Tobit

	Total sample			**Multinational Groups**	
	Total Sourcing	National Sourcing	International Sourcing	Intra-Group	Extra-Group
Internal R&D	0.52***	0.52***	1.85***	2.98***	1.74***
	(0.13)	(0.13)	(0.33)	(0.75)	(0.5)
Manufacturing Outsourcing	0.07	0.08	-0.47	-1.36	-1.87*
	(0.25)	(0.25)	(0.68)	(1.78)	(1.09)
International R&D Share		3.88*			
		(1.99)			
National R&D Share			5.17***	6.57**	3.52
			(1.53)	(2.87)	(2.3)
Researcher Intensity	0.87	1.14	3.11	9.85	7.28
	(1.42)	(1.44)	(3.66)	(9.17)	(6.56)
Scale	0.67***	0.63***	2.44***	3.56***	2.61***
	(0.14)	(0.15)	(0.32)	(0.65)	(0.43)
Export Intensity	0.86	0.71	4.2***	2.5	3.31*
	(0.55)	(0.55)	(1.27)	(2.69)	(1.82)
Technology Gap	-0.071	-0.044	-0.45*	-1.31**	-0.31
	(0.097)	(0.099)	(0.25)	(0.57)	(0.36)
Multinational Group	0.99***	1.11***	-0.78		
	(0.31)	(0.31)	(0.81)		
Domestic Group	0.31	0.38	0.48		
	(0.3)	(0.31)	(0.84)		
R&D Centre	1.11***	1.11***	0.73	1.96	0.11
	(0.35)	(0.36)	(0.78)	(1.32)	(0.96)
Cash Flow	0.33***	0.31***	0.49**	0.44	0.16
	(0.08)	(0.082)	(0.2)	(0.44)	(0.31)
Patent	0.2	0.23	1.25**	1.85	1.69*
	(0.28)	(0.28)	(0.64)	(1.33)	(0.89)
Number of Patents	0.34*	0.35*	0.43	0.054	-0.032
	(0.19)	(0.19)	(0.38)	(0.61)	(0.48)
Labour Costs	-0.56	-0.48	-0.15	2.31	0.69
	(0.6)	(0.62)	(1.71)	(4.36)	(2.67)
Technological Efficiency	-2.3*	-2.55*	-5.08*	-6.66	-10.9**
	(1.21)	(1.2)	(2.92)	(6.37)	(4.5)
Agglomeration	0.75	0.9	-5.17**	-0.2	-1.32
	(1.18)	(1.19)	(1.53)	(4.4)	(3.1)
Constant	-1.82	-1.93**	-35.6***	-63.0***	-30.8***
	(2.7)	(2.7)	(6.4)	(14.1)	(9.38)
Observations	5513	5513	5513	2952	2952
Number of firms	1689	1689	1689	814	814
Log Likelihood	-10872.08	-10779.07	-3305.18	-975.88	-1617.72
Wald Chi2	293.8	296.82	231.69	81.68	115.05
Prob> Chi2	0.000	0.000	0.000	0.000	0.000

SE are reported in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Table A6: Correlation Matrix

Total Sourcing	1.00																			
National Sourcing	0.98	1.00																		
International Sourcing	0.42	0.33	1.00																	
Intra-Group	0.24	0.20	0.56	1.00																
Extra-Group	0.33	0.26	0.80	0.30	1.00															
Internal R&D	0.18	0.18	0.21	0.16	0.18	1.00														
Manufacturing Outsourcing	0.05	0.05	0.06	0.04	0.04	-0.07	1.00													
Researcher Intensity	0.04	0.03	0.06	0.01	0.08	0.48	-0.14	1.00												
Scale	0.20	0.20	0.22	0.22	0.16	-0.17	0.25	-0.37	1.00											
Export Intensity	0.12	0.11	0.11	0.07	0.09	0.09	0.05	-0.03	0.20	1.00										
Technology Gap	-0.09	-0.09	-0.09	-0.07	-0.07	-0.07	0.00	-0.04	-0.14	-0.07	1.00									
Multinational Group	0.22	0.22	0.15	0.15	0.10	0.02	0.18	-0.19	0.60	0.21	-0.14	1.00								
Domestic Group	-0.08	-0.07	-0.05	-0.07	-0.03	-0.06	-0.01	0.01	-0.11	-0.09	0.01	-0.41	1.00							
R&D Centre	0.25	0.24	0.21	0.22	0.16	0.12	0.09	-0.04	0.35	0.12	-0.19	0.40	-0.14	1.00						
Cash Flow	0.20	0.20	0.15	0.11	0.12	0.20	0.00	0.11	0.05	0.18	-0.20	0.17	-0.02	0.19	1.00					
Patent	0.20	0.20	0.19	0.13	0.13	0.10	0.12	-0.07	0.32	0.18	-0.05	0.25	-0.08	0.14	0.12	1.00				
Number of Patents	0.17	0.16	0.17	0.15	0.12	0.09	0.08	-0.06	0.33	0.14	-0.06	0.21	-0.07	0.13	0.06	0.60	1.00			
Cost Efficiency	0.04	0.04	0.03	0.02	0.03	0.01	-0.01	-0.03	0.02	0.01	0.00	0.04	0.01	0.08	0.04	0.03	-0.01	1.00		
Technological Efficiency	-0.17	-0.17	-0.14	-0.08	-0.12	-0.29	0.05	-0.20	0.09	0.00	0.05	-0.01	0.04	-0.14	-0.13	-0.02	0.00	-0.10	1.00	
Agglomeration	0.14	0.14	0.10	0.10	0.08	0.10	0.05	0.00	0.22	0.08	-0.09	0.17	-0.08	0.21	0.10	0.12	0.15	0.06	-0.11	1.00