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R&D and Productivity in Corporate Groups: An Empirical Investigation Using a Panel of French Firms

P. BLANCHARD*, J.P. HUIBAN** and P. SEVESTRE***

ABSTRACT. – Using a panel of more than 3,100 French corporate groups' affiliates and parent companies, we estimate a production function model where we enable the productivity of a firm to depend on the knowledge produced by the R&D activities of the other companies in the group. We find indeed that a firm's productivity may significantly be enhanced thanks to the R&D capital of the other affiliates. This enhancement can be estimated to be, for the corporate group as a whole, between 30% and 40% of the "usual" estimate of the direct impact of firms' R&D expenses on their own productivity. However, this effect differs depending on whether the firm itself conducts some R&D or not. In case it does, the other affiliates' R&D does not appear to impact significantly on its own performances: those depend only on its proper R&D activity. At the opposite, the other affiliates' R&D has a very significant effect on the productivity of firms which do not conduct any R&D. These results emphasize the existence of group spillovers, which differ from the usual industry or geographical spillovers. In particular, they do not seem to require an "R&D based absorptive capacity" to pre-exist and they are clearly the result of an explicit strategy, defined at the group level. Finally, these results might lead to revise upwards our estimates of the private returns on R&D investments.

R&D et productivité au sein des groupes de sociétés : un test empirique sur un panel de firmes françaises

RÉSUMÉ. – Nous utilisons un panel de plus de 3100 firmes appartenant à un groupe pour estimer une fonction de production au sein de laquelle la productivité d'une firme dépend notamment de son capital de connaissance. Ce dernier est une fonction, non seulement de l'activité de R&D réalisée en propre par la firme, mais également de l'activité de R&D effectuée au sein des autres entreprises appartenant au même groupe de sociétés. L'impact de cette dernière composante apparaît très significativement positif, et la valeur du coefficient qui lui est associé représente entre 30 et 40 % du coefficient associé aux propres dépenses de R&D de la firme. La valeur obtenue varie selon que la firme conduit ou non sa propre activité de R&D. Lorsque la firme réalise elle-même une activité de R&D, l'impact de l'activité de R&D conduite au sein des autres firmes du groupe n'influe que peu sur le niveau de la productivité de la firme. Par contre, lorsque la firme n'effectue pas elle-même de R&D, la contribution apportée par la R&D conduite dans d'autres firmes du même groupe devient très significativement positive. Ces résultats concluent donc à l'existence d'un véritable effet spillover de groupe à l'instar des effets spillovers sectoriels ou géographiques déjà connus. Toutefois, les modalités de ces effets de spillovers diffèrent de celles usuellement mises en évidence. Alors que les effets sectoriels et géographiques constituent des externalités qui ne peuvent être captées que par les firmes qui font elles-mêmes de la R&D, et développent ainsi leur capacité d'absorption, les spillovers de groupe apparaissent comme l'expression d'une véritable stratégie entre entreprises parentes, destinée notamment à faire profiter des effets de la R&D commune les unités qui n'en conduisent pas elles-mêmes. Au total, ces résultats conduisent à réviser largement en hausse les estimations habituelles du taux de rendement privé (au sein d'un groupe de sociétés) de l'investissement en R&D.

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1 Introduction

Among Zvi Griliches's contributions to applied economics, those emphasizing the impact of R&D activities on firms' productivity are certainly the most seminal (e.g. see his book, GRILICHES [1998], and the paper presented by HALL [2003] at the conference organized in his memory). Indeed, there exists a bunch of studies showing that firms doing R&D are, *ceteris paribus*, more productive than others (e.g. see the surveys by MAIRESSE and SASSENOU [1991], and, more recently, by GRILICHES [1998]). No one would dispute about R&D being one of the main factors enhancing firms' performances.

This result does not only apply to firms *doing* R&D. It is also valid for those *buying* R&D. In other words, both in-house and outsourced R&D contribute to improving firms' performances (e.g. see FREEMAN [1991], ARORA and GAMBARDELLA [1994], VEUGELERS and CASSIMAN [1999], PEDERSEN, SOO and DEVINNEY [2002]). Indeed, looking at the way firms manage to get the necessary technological inputs sustaining their innovative capabilities, one can observe that R&D outsourcing has been one of the strong evolutions that have occurred in the 90s. In France, the share of outsourced R&D has grown significantly, in relative terms, from less than 15% of total R&D expenses at the beginning of the 80s to more than 20% in the 90s. It is worth noticing that most of this increase in externalisation can be attributed to corporate groups (PAUL, PLANÈS and SEVESTRE [1999]) as they account for about 80% of the total outsourced R&D expenses. At the international level, AMBEC and POITEVIN [2001] mention this phenomenon to be particularly important in the pharmaceutical industry where, apart from Merck, "for other top drug companies, the proportion of research done externally can reach 80%". In fact, this movement is quite general (see CAUDY [2001], and THAYER [1997] who show that other industries have experienced the same evolution).

This predominance of corporate groups in R&D expenditures is considerable as well for in-house R&D: in 1998, more than 90% of the internal R&D expenses by firms located in France were undertaken by firms controlled by a group¹. Restricted to the only 50 largest groups in manufacturing industry as it is done in the French "R&D expenses" survey, this proportion still remains important, at about two thirds (see GANDON and JACQUIN [2001]).

These features should not be ignored when evaluating the productive impact of R&D expenses and their private returns. Indeed, in a corporate group, some affiliates *not doing R&D, nor buying it*, may nevertheless take advantage of the new processes/new products elaborated in the group's other affiliates where R&D is actually conducted. Unfortunately, there does not seem to exist many empirical studies aiming at evaluating the impact of groups' R&D expenses on the productivity of their subsidiaries. The only study we are aware of is that of BIRKINSHAW and FEY [2000], who study, from a managerial point of view, what they call the "efficiency" and "effectiveness" of the organization of R&D activities in Swedish and British corporate groups. The reasons for that lack of statistical/econometric stud-

1 This figure has been obtained by summing up the internal R&D expenses by all firms that appeared to be controlled by a group as indicated in the French survey about firms' financial links (the "LIFI survey", see below).

ies devoted to the impact of such corporate group spillover effects are diverse. The first one is that it is difficult to gather all the necessary information about firms and groups: getting figures about their performances, their R&D expenses, their parent company and/or subsidiaries, if any, etc. does require, at least in France, to compile and merge several databases. Another reason is the complexity of the organization of R&D activities within corporate groups. Indeed, as shown by BIRKINSHAW and FEY [2000], this organization is very diverse and potentially difficult to measure. More specifically, a firm belonging to a corporate group can, without running itself any R&D activity, benefit from a “knowledge capital” made available by its “group”, i.e. built up upon the R&D results from other firms in the group. In some cases, this knowledge flow can be formalized so that it is accounted for by an “external” R&D expense but this is not necessarily the case and, as emphasized by BIRKINSHAW and FEY [2000], such flows can be quite difficult to identify. The difficulty of adopting a quantitative analysis for analysing R&D and innovation at the corporate group level is also emphasized in LARÉDO and MUSTAR [2001] who present the results of a qualitative survey about the organization of innovative activities in 82 large French industrial firms.

This is however the ambition of this paper to try to identify and measure the impact of the R&D conducted in one affiliate of a corporate group onto the other affiliates’ productivity. To achieve this goal, we proceed in several steps. In Section 2, we provide some empirical facts about R&D in corporate groups. Section 3 is devoted to the presentation of our dataset while the models we estimate and our econometric results are presented and discussed in Section 4. Section 5 concludes.

2 R&D in corporate groups: a brief overview

For a long time, corporate groups have organized their R&D activities in a very centralized way, due to the perceived strategic character of these activities. However, both the evolution of the organization of corporate groups (with subsidiarization and outsourcing becoming management tools in many activities) and changes in the R&D activity itself (e.g. the need to get access to resources that can be located anywhere) have induced rather strong changes in the organization of R&D activities in large corporate groups. Several studies have shown a strong diversity in the way corporate groups organize their R&D activities. For example, in a managerial study devoted to the organization of R&D in several large companies, BIRKINSHAW and FEY [2000] notice that “Research in ABB² is split, with some taking place in the ten corporate research centres and the rest taking place in specific business units... Ericsson has no corporate research as such, in that all R&D activities are held at the business unit level. There is, however, a vice president responsible for corporate research, and his job is to integrate the research activities of the three business units to ensure that technology is shared and new projects are coordi-

2 ABB is an international group operating in automation and power technologies.

nated” while “HP (Hewlett-Packard) operates a pure model in which research is done in four corporate labs”. MOSQUET, BILLÈS-GARABÉDIAN and LOBMEYR [1999], provide other examples of the diversity of the organization of R&D activities in corporate groups. The same diversity can be observed across French based groups which exhibit rather different organizations of their R&D activity (e.g. see LARÉDO and MUSTAR [2001]). As BIRKINSHAW and FEY [2000] point out, some groups may chose a “market-like” type of organization, with relationships between R&D units and other units in the group based upon contracts associated with specific projects, while others opt for a more “traditional” organization in which R&D is funded by a tax levied upon business units and the results disseminated “for free” in the group.

It is important to emphasize that both the organization of the R&D activity itself and that of the diffusion of its results within the boundaries of the corporate group are strategic decisions, taken in order to minimise costs at the group level. Indeed, LARÉDO and MUSTAR [2001] show that during the 90s, an increasing number of large French firms have incorporated people from their R&D departments in their board, so that the R&D policy is coordinated at the highest decision level. Then, a complete evaluation of the effects of R&D at the group level should take account of the organization of this activity: it would indeed be interesting to check whether there appear more efficient organization modes and/or to identify the conditions ensuring that a particular organization is more efficient than another (see again LARÉDO and MUSTAR [2001]). However, the R&D organization is so diverse across groups that it is very difficult, at least in a first step of analysis as the one we are conducting here, to be able to answer those questions properly. Then, we shall deliberately stick here to a firm’s level analysis and limit our ambition to explaining the effects on a firm’s productive efficiency of the R&D conducted in other affiliates of the same corporate group.

However, even staying at the firm level does not make it so simple. In particular, it is not very easy to measure the R&D inputs on which firms in corporate groups can rely to produce goods and services. It is worth clarifying the various components of R&D of which we would like to measure the impact and those for which we shall indeed be able to do so.

A corporate group affiliate can possibly take advantage of R&D from different sources:

- 1) “In-house R&D”, i.e. R&D conducted within the firm itself.
- 2) “Within-group outsourced R&D”, i.e. R&D explicitly bought from the parent company or from the other affiliates of the same corporate group and as such, being compensated by a direct or indirect financial transaction.
- 3) “Other within-group R&D”, i.e. R&D made outside the firm but still in the corporate group either by the parent company or by the other affiliates but not giving rise to any financial transaction.
- 4) “Outside outsourced R&D”, i.e. R&D bought from firms outside the corporate group.
- 5) “Other outside R&D”, i.e. R&D conducted by other firms outside the corporate group.

Most empirical studies based on firm-level data have stressed the impact of the first and last components: the first is both clearly non ignorable and the easiest to

measure. The last one can be assimilated to the spillover effect that has been shown to exist, both at the sectoral and at the geographical levels (e.g. see the recent survey by KELLER [2004]). The other three components are much more difficult to measure statistically and only the impact of the sum of the second and fourth components, i.e. the total “outsourced R&D”, has been analysed (e.g. see C. FREEMAN [1991], S. ARORA and A. GAMBARDELLA [1994], R. VEUGELERS and B. CASSIMAN [1999], T. PEDERSEN, C. SOO and T. DEVINNEY [2002]).

Unfortunately, the French survey about R&D expenses is directed to firms which do have their own R&D activity and provide information about external expenses only as supplementary information (see Appendix 1 for more details). Then, firms that fully externalise their R&D do not appear in the file, which prevents from using this information to build a correct measure of the possible “knowledge flows” between firms belonging to the same corporate group. This means that we only have a partial information about these second and fourth components of the R&D expenses. This is why we are constrained to use another decomposition, defined as follows:

- 1) “In-house R&D”, i.e. R&D conducted within the firm itself.
- 2) “Within-group R&D”, i.e. R&D made outside the firm but still in the corporate group either by the parent company or by the other affiliates of the same corporate group.
- 3) “Outside R&D”, i.e. R&D conducted by other firms outside the corporate group.

The second component (“corporate groups R&D”) is at the core of our analysis. It can give rise to a market relation, but not necessarily, depending on the organization chosen by the corporate group. Indeed, in groups having a “market-like” organization, R&D flows should have a financial counter-part allowing to identify those “knowledge flows”. Unfortunately, as already stated, the French survey about R&D expenses provides information about external expenses only for firms/affiliates that do run some R&D themselves. Moreover, when the group has chosen a centralized organisation, clearly identifying any related expense may not be easy, because there might be, strictly speaking, no payment by the business units to the R&D laboratories or research units for the R&D results they use. This does not mean of course that these firms do not have access to the technological innovations that have been elaborated in the R&D units. Moreover, one can think that, even in the case of the market-like organization, the results of a given research project can be spread out in the subsidiaries of the group beyond the only unit that may have initiated the project. It is then very tempting to analyze these flows in terms of “group-spillover effects” as those spillovers rely on “knowledge flows” that do not necessarily have an explicit financial counterpart, making it difficult to identify them statistically. However, we must recognize that this effect does not strictly conform to the usual definition of a spillover, as stated by BRANSTETTER [1998], p. 521: “*A knowledge spillover occurs when firm A is able to derive economic benefit from RD activity undertaken by firm B without sharing in the cost firm B incurred in undertaking its RD*”. In our case, we cannot be sure that the firms who benefit from the R&D activity conducted by other firms in the same corporate group do not contribute, either formally or informally, to provide resources to the R&D firms.

Before presenting the data we have used to perform our analysis, it is worth mentioning that the third component of R&D that we consider in the above decomposi-

tion (i.e. the “outside R&D”) has not explicitly been included as a separate R&D component in our model but has implicitly been accounted for through the inclusion of industry dummies. Indeed, there are mainly two “channels” through which this “outside R&D” is generally considered to impact on a firm’s productivity: sectoral and geographical spillovers (e.g. see JAFFE, TRAJTENBERG and HENDERSON [1993], ADAMS and JAFFE [1996], and KELLER [2002]). Unfortunately, we cannot evaluate the latter as we do not have information about the geographical location of all firms. As regards the former channel, we are facing a multicollinearity problem between that variable and the industry dummies aimed at capturing systematic differences across sectors (such as the capital/labor ratio or the R&D intensity). Even though, for each firm, the group’s R&D should be subtracted from the sectoral R&D, this aggregate R&D variable remains broadly constant within sectors and its impact can hardly be estimated as long as we leave industry dummies in the model, which we think is necessary.

3 The sample

The data used for the econometric analysis is obtained by merging three databases³:

- The first one is obtained from the French annual R&D survey (*« Enquête sur les moyens consacrés à la recherche »*) from which we know total R&D expenses, internal expenses (i.e. expenses associated with in-house R&D), external expenses (i.e. outsourced R&D expenses) as well as some more details about those expenses outsourced within the same group (for firms belonging to a corporate group) or outside the group, etc. Again, it is important to remind here that only firms having a significant R&D activity are registered in the file (see the appendix 1 for details). Initially, this database contains between 2,700 and 3,450 firms per year over the period 1989-1998. It is almost exhaustive as far as large firms are concerned while smaller firms are sampled and interviewed every two years. This last characteristic has led us to compute the unknown R&D expenses for the missing year by a simple interpolation of the observed value during the preceding and following years.

- The second database comes from the annual survey about financial links (*« Enquête sur les liaisons financières – LIFI »*). From this database, which is also almost exhaustive for large firms, we get information about which firms belong to a group and the identity of the group. Because the quality of the survey has improved over time and because corporate groups have experienced numerous restructurings, we had some strongly varying groups’ R&D capital. Three options were possible: the first one was to take these figures as they were, which was very likely to exaggerate the volatility of groups’ R&D expenses just because of changes in the definition of their perimeter. Another option was to discard those firms for which too many changes in the head of the group occurred. We feared that this might induce a selection bias and did not take this option either. The last one, taken here, has been to keep as the head of the group the one that was identified for the last year of presence in the sample.

3 For a more detailed description of the sources of our data, see the appendix 1.

In 1998, the number of firms that were controlled by a private French group was about 44,000⁴. More precisely, there were about 7,000 French corporate groups controlling more than one firm (other than the head of the group), accounting for a large fraction of total production and employment (these groups employ more than 4 million workers). However, many of these groups are very small as there are less than 1,000 groups employing more than 1,000 people.

– Finally, the last database we use come from the stacked annual surveys about firms' activity (« *Enquête annuelle d'entreprise* »). This survey is conducted for firms in all industries and we then have data about firms in manufacturing industries, trade and services. From this survey, we gather information about sales, value-added, fixed assets and/or investment and provisions for depreciation, employment, and some other variables (see Appendix 1 for more details).

Unfortunately, these three surveys are not directed to exactly the same set of firms. This means that merging those databases induces a significant loss in the number of observations. Moreover, because it is not possible to get any information about the foreign subsidiaries of non-French groups, we have decided to discard all firms that are controlled by a foreign group. Finally, as it is unfortunately common in such micro-level databases, we are faced with the problem of missing data and outliers. In order to avoid the latter, we decided to discard all observations that were below the 1st and above the 99th percentiles of the distribution of the following variables: labor productivity, capital/labor ratio, growth rates of labor productivity, of employment, of fixed capital, of the firm internal R&D expenses, and, of the corporate group internal R&D expenses; we also discarded those firms for which internal R&D expenses were greater than their added value. We ended up with an unbalanced sample containing 68,257 observations about 16,710 firms. Given the lags associated with the use of the GMM estimation method, we restricted the sample to firms observed at least seven consecutive years between 1989 and 1998. Our initial sample then contained 3,141 firms and 27,266 observations. Finally, we restricted the estimation period to 1994-1998, which led us to a sample of 3,141 firms and 11,561 observations on the whole. Since, as far as large firms are concerned, the coverage of the three databases used to build our sample is correct, we can expect our sample to be correctly representative of this population.

As mentioned above, because of the lags used for instruments, we have kept in the sample only those firms which are present continuously during at least seven years over the period 1989-1998. Table 1 below provides some information about the number of years of presence of firms in our sample:

TABLE 1
Number of Firms by Years of Presence

Number of years of presence	Number of firms
7 years	669
8 years	787
9 years	563
10 years	1,122
Total	3,141

4 This figure is slightly different from those given in CHABANAS [2002]) but is still comparable.

As the next table shows, firms in our sample come from all industries with “food processing”, “equipment goods”, “intermediate goods” and “trade” particularly well represented.

TABLE 2
Sectoral Breakdown of the Sample

Industry	Number of firms
Agriculture	5
Food processing and transformation of agricultural products	412
Consumption goods manufacturing industry	244
Car manufacturing industry	71
Equipment goods manufacturing industry	353
Intermediary goods manufacturing industry	930
Energy	33
Trade	730
Transport	27
Construction	22
Services to households	37

Note: The available data from the « Enquête annuelle d'entreprise » stop in 1996 for services and in 1997 for trade.

As regards firms' R&D activity, the next table gives the breakdown of firms depending on whether or not they have their own R&D activity and whether their group has such an activity or not (the R&D activity of the firm itself being excluded to avoid a double-counting).

TABLE 3
R&D Activity of Firms and Corporate Groups in 1994

	Firms having their own R&D activity	Firms not having their own R&D activity	Total
Firms controlled by a group with an R&D activity other than their own	546	835	1,381
Firms controlled by a group with no R&D activity other than their own	324	1,436	1,760
Total	870	2,271	3,141

Then, from the 70% of firms in our sample which do not undertake any R&D, about two thirds belong to a group that has no R&D activity either but one third are controlled by a group where there is R&D run in another affiliate or in the parent company. These proportions are inverted as regards the 30% of firms that run some

R&D, with a predominance of firms doing R&D in a corporate group where some other affiliates also have an R&D activity.

Finally, the next table provides some general information about the basic features of the firms in our sample. These statistics show the very important dispersion that exists in our sample.

TABLE 4
Descriptive Statistics; Year 1994

Variable	Mean	Standard error	Min	Max
Employment	593	1,957	6	59,346
Labor productivity	337	177	66	1,721
Capital/labor ratio	398	409	5	3,524
Internal annual R&D expenses/ added value (for all those doing R&D)	9.9%	12.5	0.2%	98%
Firm's R&D expenses / group's R&D expenses (for those doing R&D and which are controlled by a group with at least another affiliate conducting R&D)	25.6%	29.2	0.01%	99.3%

1. In thousand Francs.

4 Econometric estimates of the “within-group spillovers”

In order to evaluate the “group-spillover” effect, we have resorted to a very simple model, consisting of a slight extension of the reduced form of the “R&D – Innovation – Productivity” model proposed by CRÉPON, DUGUET and MAIRESSE [1998], as it has often been estimated (e.g. see MAIRESSE and HALL [1996], among many others): we consider a production function into which, besides employment and fixed capital, we include an “R&D capital” built from the accumulation of the firm's R&D expenses⁵. The term “Knowledge Capital” could also be used, but one has to keep in mind that knowledge can be issued from other sources than R&D, while we only consider R&D-issued knowledge.

Moreover, besides the firm's own R&D capital, we have included a “group's R&D capital” to account for within-group spillover effects, i.e. for knowledge flows across firms within corporate groups.

5 See below for details about the construction of this R&D capital series.

Our specification is a simple Cobb-Douglas production function:

$$\ln(Q_{it}) = b_0 + b_1 \ln(L_{it}) + b_2 \ln(C_{it}) + b_3 \ln(KF_{it}) + b_4 \ln(KG_{it}) + d_1 DUMKF_{it} \\ + d_2 DUMKG_{it} + \sum_{\tau=1}^{\tau=T-1} d_{3\tau} DUMTEMP_{\tau it} + \sum_{s=1}^{s=S-1} d_{4s} DUMSEC_{sit} + \mu_i + \varepsilon_{it}$$

where Q represents the firm's value-added, L its employment, C its fixed capital, KF its R&D capital and KG that of the group.

The measures of these variables are as follows:

- Q : Value-added, deflated by the value-added price indices at the industry (NES16) level⁶,
- L : Employment as of December 31 each year,
- C : Fixed capital stock. This variable is taken as the fixed assets when available in the survey and computed by the accumulation of passed investments when information about the stock of fixed assets was not present. In this last case, the initial value of the capital stock was taken as the employment of the firm at that date multiplied by the sectoral median of the capital/labor ratio. In the same way, the rate of depreciation was taken as the sectoral median of the ratio of provisions for depreciation over fixed assets when data were available, and was arbitrarily set to 10% otherwise,
- KF : The R&D stock of the firm. It is built by using the usual dynamic accumulation equation of the firm's past R&D expenses (using an initial value of the capital set to 5 times the initial R&D expenses and a depreciation rate of 15%). Since this variable equals 0 for all firms not having any R&D activity, we have set the logarithm of this variable to zero for all observations with $KF = 0$ (having checked that $KF > 1$ for all firms with $KF > 0$),
- KG : The R&D capital of the group. It is given by the sum of the R&D capital of all firms controlled by the group, minus that of the firm itself to avoid double-counting. The same definition as above has been applied to $\ln(KG)$: it has been set to 0 as long as KG was zero.

In order to take account of those firms and/or of corporate groups not doing R&D, we have added specific dummies (DUMKF and DUMKG), taking value 1 when KF and/or $KG = 0$, following MAIRESSE and CUNEO [1985]. These variables first enable us to include the firms that do not perform R&D activities, but can also be used to estimate the effect of knowledge capital accumulated by other means than R&D (see below). Finally, the model also includes time and sectoral dummies. As we have previously mentioned, these sectoral dummies implicitly account for any industry-specific characteristic and in particular for possible sectoral spillover effects that might exist.

Several sets of estimates are provided. We first present estimates obtained on the whole firm population (section 4.1). Then, we keep the same model but we split our population into different sub-samples and perform estimations on each of them (section 4.2.1). Finally, we make a complementary estimation of an alternative but comparable specification (section 4.2.2).

6 Although we know that this is not totally satisfactory, this is probably not where we should look for a possible explanation of unsound econometric results when they occur (see MAIRESSE and DESPLATZ [2003]).

4.1 Estimates of the model on the whole population

Looking first at the within estimates provided in the last column of the table, one can infer from the very low estimated values of both the fixed capital and knowledge capital coefficients that those variables are very likely to be subject to some measurement errors. Indeed, as shown by GRILICHES and HAUSMAN [1986], the Within estimator is very sensitive to these problems of measurement. Moreover, the discrepancy that exists between the OLS and within estimators is an indication of a likely correlation between the individual effects and some of the regressors. This is why we have estimated our model by GMM, using lagged values of the first differences of the regressors as instruments for the model in levels. The validity of this approach is asserted by the Sargan statistics, which are well below their theoretical threshold. Moreover, as the comparison between the first two columns indicates, the IV and GMM provide very similar results. Finally, the often mentioned “negative bias” in the 2nd step GMM estimates of the standard errors seems to be nonexistent in our case. This is likely to be a consequence of the size of our sample since we have more than 3,100 firms and 11,000 observations. Indeed, CRÉPON and MAIRESSE [1996] have shown that the above mentioned bias disappears for large sample sizes. Finally, another indication of the robustness of our results is that using lags of all capital variables instead of their current values as regressors does not change the results.

TABLE 5
Sample period: 1994-1998; 3,141 firms, 11,561 observations

	GMM LEVELS 1 st step	GMM LEVELS 2 nd step	GMM LEVELS 2 nd step (lagged regressors)	OLS	WITHIN
$\ln C_{it}$	0.310 (0.048)	0.275 (0.045)	0.293 (0.049)	0.197 (0.0092)	0.084 (0.015)
$\ln L_{it}$	0.762 (0.067)	0.761 (0.063)	0.773 (0.067)	0.754 (0.011)	0.745 (0.021)
$\ln KF_{it}$	0.115 (0.058)	0.119 (0.053)	0.099 (0.056)	0.080 (0.008)	0.013 (0.007)
$\ln KG_{it}$	0.077 (0.025)	0.067 (0.022)	0.075 (0.023)	0.017 (0.004)	-0.001 (0.006)
Dummy for $KF_{it} = 0$	1.116 (0.579)	1.134 (0.534)	0.941 (0.555)	0.717 (0.079)	0.125 (0.073)
Dummy for $KG_{it} = 0$	0.785 (0.263)	0.718 (0.241)	0.757 (0.239)	0.168 (0.051)	0.014 (0.056)
Sargan(<i>p</i> -value)		21.23 (0.775)	20.63 (0.804)		

Notes: Robust standard errors in parentheses. Time and industry dummies are included in all equations and not reported. Instruments used: intercept, $\Delta \ln L_{it-4}$, $\Delta \ln C_{it-3}$, $\Delta \ln KF_{it-3}$, $\Delta \ln KG_{it-3}$, $\Delta D(KF_{it-4} = 0)$, $\Delta D(KG_{it-4} = 0)$ and time and industry dummies.

Coming to the economic interpretation of our results, we can first notice that the estimated elasticities of production with respect to labor and fixed capital appear quite reasonable, even though, taking the knowledge capital coefficients into account, we get slightly increasing returns to scale.

As regards the “usual” R&D coefficient (i.e. that of the firm’s own capital knowledge, KF), we get an estimate of about 0.12, which is well in the range of usual estimates of the impact of R&D on productivity (e.g. see MAIRESSE and MOHNEN [1999]).

The estimate we get for the “group-spillover effect”, that is, the impact of R&D done by an affiliate of a corporate group onto the productivity of other affiliates in the same group is significantly positive. Although it is well below the impact of R&D conducted within a firm on the firm’s own productivity, this figure is far from being negligible. It is important to emphasize that this result is about the double of usual “sectoral spillover effect” estimates that one can find in the literature. As shown in HARHOFF [2000], or in MAIRESSE and MOHNEN [1999], the estimates of such spillovers vary a lot according to the estimation level and the technical or geographical distance used, but the estimates are usually lower (about 0.01 to 0.05) than our estimated “group spillover” effect.

This result has an important consequence when one is interested in the measurement of the private return on R&D expenses. Showing that knowledge generated by a firm’s R&D disseminates among other affiliates within the same group, and goes well beyond its direct impact on the firm’s own performance, should lead to an increase in the estimates of such returns. Indeed, the usual computation of this return at the firm level ignores this “group-spillover effect” and is thus very likely to be under-estimated: spending 1 Franc in R&D activities in a corporate group induces higher productivity not only in the firm that conducts this activity but also in other affiliates in a non negligible way, as this estimate clearly indicates. More precisely, measuring the private return on R&D in corporate groups should be done according to the following formula:

$$\frac{\partial Q_G}{\partial KRD_A} = \frac{\partial Q_A}{\partial KRD_A} + \sum_{j \neq A} \frac{\partial Q_j}{\partial KRD_A}$$

in which R&D is assumed to be conducted in affiliate A where it contributes to increase productivity, as well as it improves performances in other affiliates j within the group. As an illustration, consider the simple case where R&D in a corporate group is only conducted by firm A but also benefits to the other affiliates, which we consider to have the same size in terms of value-added. Then, given that, for the year 1994, the average R&D capital per firm (KF) in the sample is 87 MF (millions of Francs) while that of the group R&D capital (KG) is 1,555 MF and the average value-added is 201 MF, the total return on 1 Franc spent on R&D is, at the group level, equal to:

$$\begin{aligned} \frac{\partial Q_G}{\partial KRD_A} &= \varepsilon_{Q_A/KRD_A} \cdot \frac{Q_A}{KRD_A} + \sum_{j \neq A} \varepsilon_{Q_j/KRD_A} \frac{Q_j}{KRD_A} \\ &= 0.119 \times (201/87) + 14 \times 0.067 \times (201/1555) \\ &= 0.275 + 0.121 \\ &= 0.396 \end{aligned}$$

per year since groups have 14 affiliates on average in our sample. This estimate is significantly higher than the return obtained at the single firm (A) level (0.275). Given the depreciation rate of 15% that we have assumed in building our R&D capital measure, this gives a “net” return of 24% at the group level, which is about the double of that at the firm level (about 12% per year). Those figures can be compared with the estimated net return on fixed assets (12% net per year), based on the assumption of a depreciation rate of 7% per year (corresponding to a length of life of about 15 years). It is however likely that this evaluation of the return on R&D capital at the group level is over-estimated as it is assumed here that R&D enables to increase the productivity of any affiliate of the group, which is probably a bit too optimistic. One must however notice that the complementary econometric estimates provided in the subsequent section show that this result is qualitatively robust to changes in the sample that we consider. Before going to those further results, it is worth noticing that the estimates for dummies associated with firms and groups not conducting R&D are significantly positive, which is an indication that formal R&D expenses are not the only way for firms to accumulate knowledge. Some other factors exist, that are unobserved here. Assuming that the elasticity of production with respect to this unobserved accumulated knowledge is equal to that of production to R&D capital, one can compute an implicit evaluation of those unobserved knowledge stocks⁷. They are respectively equal to 13.8 MF for the firm and 45.1 MF for the group, which is, as expected, well below the mean of observed R&D capital for firms and groups respectively.

4.2 Robustness checks

4.2.1 Estimating the model on specific sub-groups

The previous estimates clearly show the importance of “group-spillover effects”. However, the fact that we have estimated the model over the whole sample might bias our results if, for example, production technology were different in firms doing R&D and in those not doing so or if the impact of the group’s R&D on a firm productivity differed whether the firm does some R&D itself or not⁸. In order to check the robustness of our estimates, we have then split our sample according to two criteria. First, we have isolated firms doing R&D (at least during parts of the period we consider) from those never doing R&D and, second, we have considered two further sub-populations, depending on whether the other affiliates within the same group conduct any R&D or not (see table 6).

As was the case for the previously presented estimates, these results are satisfactory from a statistical point of view. The coefficients are significant and take plausible values and the Sargan statistics do not lead to a rejection of the estimated models. Before going to R&D coefficients, one can notice that the elasticities of production to labor and capital are different across the two sub-populations, firms

7 Let us call α the elasticity of production to firms’ (resp. groups’) R&D and β the estimated coefficient of the dummy for those enterprises (resp. groups) not doing R&D but still accumulating knowledge. Then, assuming that the elasticity of production to this unobserved knowledge is equal to α , one can

write $\beta = \alpha \ln(KRD_{unobserved})$ so that $KRD_{unobserved} = \exp(\beta / \alpha)$.

8 Although on the other hand, splitting the sample in such a way might lead to a selection bias if groups locate their R&D activities in firms where the expected return is the highest.

doing R&D and those not doing R&D. The labor elasticity estimates are significantly higher for the former, while it is the opposite as regards elasticities to fixed capital. Several explanations for this discrepancy may be given: first, the composition of labor. It is obvious that firms doing R&D employ workers with higher education/skill level, which may explain the stronger response of their production to a given increase in the number of employees (HUIBAN and BOUHSINA [1998]). Second, there is a difference in the two group firms' size (firms doing R&D are significantly larger, on average, than those not doing R&D; see appendix 2); indeed, if we consider that the marginal productivity of capital should equalize across firms and sectors, larger firms, which are often more capital intensive, then appear to have a lower elasticity of production to capital, but higher labor elasticity, which is what we observe here.

TABLE 6

Estimates by sub-groups; Sample period: 1994-1998

	Firms never undertaking R&D (whatever the other affiliates do)	Firms never undertaking R&D (while the other affiliates do)	Firms undertaking R&D (whatever the other affiliates do)	Firms undertaking R&D (while other affiliates also do)
$\ln C_{it}$	0.286 (0.046)	0.363 (0.071)	0.144 (0.062)	0.161 (0.066)
$\ln L_{it}$	0.698 (0.064)	0.552 (0.108)	0.858 (0.094)	0.800 (0.104)
$\ln KF_{it}$	-	-	0.133 (0.048)	0.168 (0.046)
$\ln KG_{it}$	0.089 (0.026)	0.078 (0.028)	0.031 (0.026)	0.014 (0.020)
Dummy for $KF_{it} = 0$			1.233 (0.468)	1.576 (0.454)
Dummy for $KG_{it} = 0$	0.997 (0.295)	0.996 (0.295)	0.306 (0.276)	0.072 (0.211)
Sargan(p-value)	11.01 (0.89)	14.98 (0.66)	28.03 (0.41)	31.62 (0.25)
Sample				
Nb of obs.	6,846	3,014	4,715	3,313
(Nb of ind.)	(2,005)	(843)	(1,136)	(793)

Notes: Robust standard errors in parentheses. Two step GMM estimates. Time and industry dummies are included in all equations and not reported. Instruments used: intercept, $\Delta \ln C_{it-3}$, $\Delta \ln L_{it-4}$, $\Delta \ln KF_{it-3}$, $\Delta \ln KG_{it-3}$, $\Delta D(KF_{it-4} = 0)$, $\Delta D(KG_{it-4} = 0)$ and time and industry dummies.

As regards R&D coefficients, one can first notice that although the estimated “direct effect” of R&D expenses on a firm’s productivity is slightly higher than the one presented above (between 0.13 and 0.17), the net (direct) return on one Franc spent on R&D is in both cases about 5%-6% per year, which is a bit lower than the previous estimate⁹. More importantly for our analysis, our results strongly confirm that firms not conducting any R&D activity significantly benefit from that done in other affiliates within the same group. We find again here an estimate of the « group-spillover effect » around 0.08, very close to that obtained before. Moreover, this result does not change whether we include all groups’ affiliates (whether they belong to a group conducting R&D or not) or when we restrict the sample to those groups doing R&D. Even if the R&D activity is not conducted in the firm itself, its existence in a corporate group makes the firm better off. This is consistent with the ranking of firms based on their productivity that clearly appears in table B1 (appendix 2): firms are more productive when they perform R&D and/or when they belong to a group doing R&D¹⁰.

On the other hand, as it clearly appears from the last two columns of Table 6, the impact of other affiliates’ R&D expenses on the productivity of a firm having its own R&D department appears to be much smaller and even not significant. Firms doing R&D are, from that perspective, « autarkical » with respect to the other affiliates’ R&D activities. This result is in opposition to the « usual » spillover literature in which firms which perform R&D are more capable than others to capture the effect of the R&D performed by other firms, from the same sector or spatial area. Here, we get an opposite result: the associated elasticity is higher for firms that do not perform R&D.

It is also worth noticing that the effect of the implicit unobserved knowledge capital that can be estimated through the dummy coefficients (see footnote 7 above) is also much higher for firms not doing R&D than for firms having their own R&D activity. This implicit knowledge capital is estimated to be equal to 73.3 MF and 351.2 MF for firms not doing R&D against 19.4 MF and 0.2 MF for those doing R&D. This reinforces the conclusion that the R&D of other affiliates is more profitable to firms not doing R&D than to those having their own R&D department.

This clearly shows that the knowledge transmission mechanism between firms within a corporate group is not of the same nature than the sectoral or geographical spillover effects. Because of the organization of activities within groups, the problem for a firm not doing R&D *within a group* is not to “capture” some knowledge from others, but to make use of this knowledge *made available by the group* in its production process. Moreover if we explicitly start from a cost-minimization assumption at the whole group level, the strategy is indeed concerned with where to perform R&D (the most efficient or the costless places to do so) and how to disseminate its results across the group’s affiliates. Having a full understanding of the way R&D affects the performances of corporate groups should then also require explaining its organization within the group. But this question is clearly beyond the scope of this paper.

Finally, going back to the issue of the estimation of the return on R&D expenses at the group level, and assuming as above that R&D is conducted only in firm *A*,

9 See below for the computation.

10 Although we are aware that this discrepancy may come from other characteristics of these firms.

one gets estimates which are qualitatively close to the one previously presented but probably more reliable¹¹:

$$\begin{aligned}\frac{\partial Q_G}{\partial KRD_A} &= \varepsilon_{Q_A/KRD_A} \cdot \frac{Q_A}{KRD_A} + \sum_{j \neq A} \varepsilon_{Q_j/KRD_A} \frac{Q_j}{KRD_A} \\ &= 0.133 \times (362 / 239) + 15 \times 0.078 \times (109 / 2296) \\ &= 0.201 + 0.056 \\ &= 0.257.\end{aligned}$$

This shows that the return on one Franc spent by the group on R&D conducted in an affiliate of the group does not have a very strong impact on the productivity of another firm not doing R&D. However, the overall return, at the group level, is significantly increased by taking this “group-spillover” effect into account, given it is assumed to impact on all affiliates’ productivity. It is likely that restricting the spillover effect to those affiliates that could be expected to really benefit from it would increase the magnitude of the impact for the affiliate itself, but it is difficult to predict the impact for the whole group as this would induce a decrease in the number of affiliates taken into account.

4.2.2 An alternative specification

Also for the sake of checking the robustness of our estimates, we have estimated an alternative model. Indeed, as proposed by Z. GRILICHES [1986], there is an alternative way of specifying a production function where inputs can be split into several components. GRILICHES [1986] has suggested a way to estimate a model with a formal distinction between basic and applied R&D. In our framework, this amounts to considering the following production function, where the (unobserved) total capital knowledge available to the firm (KK_{it}^*) is made of the two above defined components, KF_{it} and KG_{it} , with a weight accounting for a possible difference in their relative productivity: $KK_{it}^* = \gamma KF_{it} + KG_{it}$, where γ is a measure of the relative productivity of the firm’s own in-house R&D productivity to that conducted in other affiliates of the group:

$$\begin{aligned}\ln(Q_{it}) &= b_{0t} + b_1 \ln(L_{it}) + b_2 \ln(C_{it}) + b_3 \ln(KK_{it}^*) + \mu_i + \varepsilon_{it} \\ &= b_{0t} + b_1 \ln(L_{it}) + b_2 \ln(C_{it}) + b_3 \ln(\gamma KF_{it} + KG_{it}) + \mu_i + \varepsilon_{it} \\ &= b_{0t} + b_1 \ln(L_{it}) + b_2 \ln(C_{it}) + b_3 \ln(KF_{it} + KG_{it} + (\gamma - 1)KF_{it}) + \mu_i + \varepsilon_{it} \\ &= b_{0t} + b_1 \ln(L_{it}) + b_2 \ln(C_{it}) + b_3 \ln[(KF_{it} + KG_{it})(1 + (\gamma - 1)\frac{KF_{it}}{KF_{it} + KG_{it}})] + \mu_i + \varepsilon_{it}\end{aligned}$$

which, assuming that the fraction $KF/(KF + KG)$ is not too large, can be approximated by

$$\begin{aligned}&= b_{0t} + b_1 \ln(L_{it}) + b_2 \ln(C_{it}) + b_3 \ln(KF_{it} + KG_{it}) + b_3(\gamma - 1)\frac{KF_{it}}{KF_{it} + KG_{it}} + \mu_i + \varepsilon_{it} \\ &= b_{0t} + b_1 \ln(L_{it}) + b_2 \ln(C_{it}) + b_3 \ln(KG_{it} + KF_{it}) + b_4 \frac{KF_{it}}{KF_{it} + KG_{it}} + \mu_i + \varepsilon_{it}\end{aligned}$$

11 See table A1 in Appendix 2 for the statistics used in this computation. Although the average number of affiliates for the group of firms we consider here is 38, this figure is due to a particular and quite large group and we prefer to provide an estimate based on a more reasonable number of affiliates.

In other words, we have estimated the following model:

$$\ln(Q_{it}) = b_{0t} + b_1 \ln(L_{it}) + b_2 \ln(C_{it}) + b_3 \ln(KG_{it} + KF_{it}) + b_4 \ln(PKF_{it}) \\ + d_1 DUMKF_{it} + d_2 DUMKG_{it} + \sum_{\tau=1992}^{\tau=1998} d_{\tau} DUMTEMP_{\tau it} + \sum_{s=1}^{s=S} d_s DUMSEC_{sit} + \mu_i + \varepsilon_{it}$$

with : $PKF_{it} = KF_{it}/(KF_{it} + KG_{it})^{12}$.

Table 7 below provides the results of this model estimation together with a reminder of the previous results.

The estimation of this alternative model leads to broadly comparable results as the comparison of the two columns of coefficient estimates clearly shows. This is not really surprising as those two models mainly differ in the way they are parameterized and as they should be equivalent as long as the approximation on which the share model relies is valid. However, this is not necessarily the case here as there is a number of groups in which only one affiliate conducts an R&D activity, thus leading to a share of 100% for which the approximation is clearly not satisfactory.

TABLE 7

An Alternative Model; Sample Period: 1994-1998; 3,141 firms; 11,561 observations

“share model”	GMM 2 nd step	“level model”	GMM 2 nd step
Ln C_{it}	0.257 (0.046)	Ln C_{it}	0.275 (0.045)
Ln L_{it}	0.741 (0.061)	Ln L_{it}	0.761 (0.063)
Ln $(KF + KG)_{it}$	0.117 (0.026)	Ln $(KF)_{it}$	0.119 (0.053)
PKF_{it}	0.427 (0.146)	Ln $(KG)_{it}$	0.067 (0.022)
Dummy for $KF_{it} = 0$	0.171 (0.110)	Dummy for $KF_{it} = 0$	1.134 (0.534)
Dummy for $KG_{it} = 0$	1.262 (0.286)	Dummy for $KG_{it} = 0$	0.718 (0.241)
Sargan (p-value)	24.85 (0.583)	Sargan (p-value)	21.23 (0.775)

Notes: Robust standard errors in parentheses. Two step GMM estimates. Time and industry dummies are included in all equations and not reported. Instruments used: intercept, $\Delta \ln C_{it-3}$, $\Delta \ln L_{it-4}$, $\Delta \ln PKF_{it-3}$, $\Delta \ln KG_{it-3}$, $\Delta D(KF_{it-4} = 0)$, $\Delta D(KG_{it-4} = 0)$ and time and industry dummies.

12 From those estimates, we can calculate the marginal productivity of the firm’s own R&D expenses relatively to the marginal productivity of the other group’s affiliates. It is equal to: $\gamma = 1 + b_4/b_3$.

Nevertheless, the significance of the estimated coefficient of the share of the firms' capital knowledge (relative to that of the group) and the fact that it takes a reasonable finite value can be seen as a confirmation that the other affiliates' capital knowledge partly contributes to each firm's productivity within the same group. Indeed, if this capital had no effect, its marginal productivity would be close to zero and thus, the coefficient measuring the relative marginal productivities (γ) would be very large, which is clearly not the case here.

5 Conclusion

Using a panel of more than 3,100 firms observed over 10 years, we have estimated a production function model where we enable the productivity of a firm within a corporate group to be enhanced through the diffusion of the knowledge produced by other affiliates in the group via their own R&D activities.

We find indeed that the impact of a firm's R&D capital on the productivity of other affiliates in the same group is significant and can be estimated to be, at the group level, between 30% and 40% of the "usual" estimate of the direct impact of firms' R&D expenses on their own productivity. However, an important distinction must be made, depending on whether the firm itself conducts some R&D or not. In case it does, the other affiliates' R&D does not appear to impact significantly on its own performances: those depend only on its proper R&D activity. On the contrary, the other affiliates' R&D has a very significant effect on the productivity of firms not doing R&D but belonging to the same corporate group. Given that we allow for industry effects, this result cannot be considered as an indirect estimation of a sectoral spillover effect as those often pointed out (e.g. see ADAMS and JAFFE [1994]). An interesting consequence of our result is that it should lead to revise our estimates of the private returns on R&D in corporate groups as one should account for those significant group-spillover effects.

However, further research is needed to check the robustness of this result and to qualify it. In particular, restricting the "group spillover" effect to those affiliates which are "closer" to the firm undertaking R&D, looking at a possible asymmetry between the parent company and its affiliates or trying to characterize the organization of R&D in corporate groups and see whether it affects the group's performances are questions of interest for future research. ■

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APPENDIX 1

A. Presentation of the surveys used to build the database

The data we use come from three different sources:

1) the « Enquête Annuelle d'Entreprise », is a survey aiming at getting information about the activity of the firm and the resources used (turnover, investment, employment, etc. are among the most basic items the firms are inquired about),

2) the « Enquête sur les moyens consacrés à la Recherche et au Développement », is a survey about the R&D activity of firms and resources devoted to it,

3) the « Enquête sur les Liaisons Financières (LIFI) », is a survey aiming at tracing the financial links between corporate firms and at identifying corporate groups and their subsidiaries.

Let us present these three surveys in more details.

1) The « Enquête Annuelle d'Entreprise » (EAE).

This is an annual series of surveys directed to firms. There are different surveys depending on the nature of the main activity of the firm:

– a survey about firms in the manufacturing industry (except those in the food industry (IAA), but including the energy sector),

– a survey about firms in the food industry (IAA),

– a survey about firms in the trade sector,

– a survey about firms in the service sector,

– a survey about firms in the construction and transport sectors¹³.

Each of these surveys concerns all firms with a number of employees or with a turnover above given thresholds, whose main activity (in terms of turnover) belongs to the corresponding industry. In other sectors than the manufacturing industry, smaller firms are also surveyed but not exhaustively, the sampling scheme depending on the sector. Moreover, these smaller firms are asked to answer a simplified questionnaire (e.g. the decomposition of investment into tangible and intangible assets is not asked for).

There are some differences across sectors: currently, the minimum number of employees for an automatic inclusion in the list of surveyed firms is set at 20 employees for firms in the manufacturing industry and in the trade sector (although it is fixed at 50 employees for some sub-sectors in the gross trade sector). The threshold is 30 employees or a turnover of at least 8 million Euros for most of the service sectors. Indeed, in some sub-sectors devoted to services for firms (cleaning, hiring of temporary workers) the minimum number of employees is raised to 100 and 200 respectively.

¹³ Although some firms in our sample belong to these two sectors, we did not have access to the files for these sectors. These firms were in fact present in the other surveys databases, due either to a mis-classification or to a change in their main activity during the period.

- For our period of analysis, the number of firms surveyed
- ranged from 24,400 in 1989 to 22,300 in 1998 in the manufacturing sector,
 - ranged from 7,000 in 1989 to 6,500 in 1998 in the food industry,
 - stayed around 38,000 firms per year, from 1989 to 1997 in the trade sector,
 - ranged from 101,500 in 1989 to 55,700 in 1996 in the service sector.

The exact list of items about which firms are inquired varies depending on their sector, but the following items are asked for, generally as of December 31st:

- Turnover,
- Exports,
- Intermediate consumption,
- Wage workers,
- Other employees,
- Tangible fixed assets,
- Intangible fixed assets,
- Investment,
- Production,
- Wage bill (excluding employers' social taxes),
- Gross profit,
- Net profit.

As it is always the case with such micro databases, there are lots of missing observations and the degree of heterogeneity is very strong. The following table provides a few figures to illustrate these two characteristics as of 1996¹⁴.

TABLE A1

Descriptive Statistics about the EAE Files for 1996

	Food industry	Manufacturing industry	Trade sector	Service sector
Number of firms in the initial file	6,676	22,319	37,797	55,692
% of missing obs. about employment	11,3%	0,00%	29,5%	23,4%
5 th percentile for Employment	9	21	1	1
95 th percentile for employment	262	410	74	123
Median Employment	28	44	6	8
% of firms with at least 20 employees	64%	97%	22%	30%

2) The « Enquête sur les moyens consacrés à la recherche ».

This is an annual survey directed to firms that are likely to undertake some significant R&D. Indeed, although about 15,000 firms are currently surveyed, only

14 1996 is the final year of our database for firms in the service sector. This is why we have chosen this year. Another point worth being noticed is that it is likely that the sample about manufacturing firms was trimmed before being provided to us, which explains its better original quality.

those effectively running a permanent and organized research and development activity (corresponding to at least one full-time researcher or the equivalent) are included in the file made available. In particular, firms that sub-contract all of their R&D do not appear in this file¹⁵.

Large firms having a “regular” R&D activity are systematically surveyed while smaller firms are surveyed every two years. This has had an important consequence for us as we had to impute the missing data for these firms through an interpolation.

The items covered in the survey are essentially the following ones:

- Turnover,
- Number of employees,
- Number of employees involved in the R&D activity,
- Number of researchers,
- Total expenses devoted to the internal R&D activity, splitted into:
 - General expenses,
 - Wage bill of employees,
 - Capital expenses,
- External expenses devoted to the R&D activity (sub-contracted), splitted into:
 - Expenses paid to other firms within the same corporate group,
 - Expenses paid to other firms outside the group,

as well as other information about the nature of the R&D conducted by the firm and its financing.

The initial file that was provided to us contains about 3,000 firms per year (2,698 firms in 1989 and 3,325 in 1998). The following table provides some characteristics of the firms in the initial sample as of 1996.

TABLE A2

Descriptive Statistics about the “R&D” File for 1996

Number of firms in the initial file	3,363
Median employment	143
Median turnover ¹	127,404
5 th percentile for DIRD/Turnover	0.30%
95 th percentile for DIRD/Turnover	80.0%
Median ratio DIRD/Turnover	4.05%

1. In thousand Francs.

As easily seen from the above table, the number of firms doing R&D is quite small. Another well-known fact that also clearly appears here is that firms doing R&D are larger than the average (e.g. see table A1 above).

15 This last point has an important consequence for our analysis as it prevents us from using information about the R&D external expenses paid to other firms in the same corporate group to measure the “knowledge flows” between firms in the same group. Indeed, this information is known only for those firms who themselves run some R&D. This would lead to a systematic under-estimation of these knowledge flows since all those existing between firms doing no R&D would be ignored.

3) The « Enquête sur les liaisons financières » (see CHABANAS [2002]).

This is an annual survey directed to firms that are likely to be part of a corporate group. More precisely, firms are surveyed as long as they satisfied one of the following conditions the year before:

- They employed more than 500 people,
- Their turnover was more than 60 million Euros,
- They owned shares for more than 1.2 million Euros,
- They were the head of a corporate group,
- They were directly controlled by a foreign group.

In the survey, firms are asked about the owners of their capital, to identify which firm possibly has the control on them. They are also asked about their share portfolio, to identify which firms they control. Then, an algorithm is used to find out the ultimate owner of a firm through the cascade of financial links.

Over our period of analysis, there were from about 1,700 private French groups in 1989, controlling about 19,000 firms and those figures increased to 6,200 groups and about 44,000 firms in 1996 respectively.

TABLE A3

Descriptive Statistics about the "LIFI" Files for 1996

Number of firms in the initial file (LAR)	84,871
Number of private French groups (TG)	6,215
Number of affiliates of French groups	44,687

APPENDIX 2

B. *Some descriptive statistics for our sub-samples*

TABLE B1
Mean Statistics for Various Sub-Samples; Year 1994

Variable	All firms	Firms not doing R&D	Firms not doing R&D in a group not doing R&D	Firms not doing R&D in a group doing R&D	Firms doing R&D	Firms doing R&D in a group doing R&D
Number of firms	3,141	2,005	1,162	843	1,136	793
Labor productivity ¹	337 KF	330 KF	321 KF	343 KF	350 KF	359 KF
Capital/labor ratio ¹	398 KF	360 KF	338 KF	391 KF	465 KF	468 KF
Mean fixed capital ²	290 MF	122 MF	109 MF	139 MF	587 MF	706 MF
Firms' R&D capital ²	87 MF	-	-	-	239 MF	307 MF
Groups' R&D capital (net of firm's capital) ²	1,555 MF	965 MF	-	2,296 MF	2,595 MF	3,718 MF
Number of affiliates	14	16	8	38 ³	10	17

1. *In thousand francs.*

2. *In million francs.*

3. *This figure is due to a group having almost 1000 registered affiliates.*

