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INTERNATIONAL R&D SPILLOVERS AND ECONOMIC PERFORMANCE OF FIRMS: AN EMPIRICAL STUDY USING RANDOM COEFFICIENT MODELS

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SUMMARY

The existence of R&D spillovers or externalities i.e. the effects of firms' research activities on other firms activities was theoretically established by Arrow 1962, but few empirical studies have addressed their effects on firms' economic performance (i.e., value-added) and technological performance (innovation output). In an open economy, firms' economic and technological performances depend on the position of these firms in their national and international technological environments. The main focus of this paper is identifying the different channels through which spillover occurs, specially the international technology spillovers (i.e., R&D activities of foreign firms; foreign technology payments; international intermediate inputs; and international R&D cooperation) and the mobility of engineers and scientists between firms.

Our statistical and econometric analysis determines that spillovers drive the production of individual firms together and link it to the incidence of innovations. Thus, using a pooling method based on segmentation of bunched (or grouped) individuals rather than those of usual individuals panel models and proposing an efficient new full information method (3SLS)[1], this empirical study shows that international spillovers are rather large compared to national spillovers. They account for a substantial fraction of the variation in firm production and innovation output in the French economy. The mobility of engineers and scientists help a firm to acquire knowledge externally so as to innovate and increase its production. The effects of technological policy tools used by the French government on the innovation and production are rather very high and incite firms to increase their R&D efforts. This study also demonstrates the existence of a potential simultaneity in the decision to impliment R&D and the spillover pools. The estimated coefficients obtained for the classical variables (capital and employment) are comparable to those obtained in the literature.

Key words : National and International Spillovers ; externalities; economic performance; productivity growth; innovation output; Random Coefficient Method.

JEL classification : C1,C3,F3,L2.

1. INTRODUCTION

This essay examines the effects of international R&D spillovers and the mobility of engineers and scientists on firms' technological and economic performances. The race towards newly acquired knowledge is regarded as the outcome of the globalisation of the economy, which places firms in a situation of cut-throat competition. In order to remain competitive, firms are bound to accumulate international knowledge. The international transfers of technology from one firm to another take place through different kind of channels. International spillovers arise because of a lack of suitability in the benefits derived from innovations and these may come through different routes, ranging from crude imitation or reverse engineering to R&D personnel mobility and transfers of foreign technologies.

Empirical work relating to the spillovers of knowledge among trading partners has been undertaken by several authors Coe, Helpman and Hoffmaister (1995); Keller (1995); and Helliwell (1992). They

establish a positive relationship between trade and technical progress. However, there is no pooling of individuals enterprises into European areas which analyse the consequences of spillovers on corporate activities.

In order to explore the determinant of corporate production and innovation activity, we construct a panel database of 2763 French firms belonging to 10 industrial sectors[2] over the period 1990-1996. This database enabled us to pick up four measures of international spillovers: inward foreign direct investments, foreign technology payments (which includes royalties, licensing, patents sales), international R&D collaboration and international intermediate inputs (purchases of machinery). The quantity and the detail of the available data together with the diversity of corporate behaviour suggest the use of an original econometric methodology.

In particular, we propose a new pooling method based on the segmentation of bunched or grouped individuals (groups represent sectors of industry sectors in our work) rather than individuals. The total number of observations for one group (industrial sector) varies according to the number of firms and the number of time periods per firm (Time[3] is fixed in our empirical study, but this is not a prerequisite).

In contrast with the usual fixed effects methods (Within and Between methods), an econometric methodology is proposed based on random coefficient models. We further the econometric research initiated by Hildreth and Houck (1968), Swamy (1970) and Balestra and Negassi (1992) in the case of a system of simultaneous equations which stems from models of individual behaviour. Our random coefficient method provides highly significant coefficients and improves estimation. As shown by the specialists of pooling estimation methods, the ordinary least squares are over-restrictive because they disregard the variability between clusters of firms, the covariance method, i.e., the use of dummy variables, goes too far the other way by taking out an excessive proportion of the variability that exists between the different clusters.

The remainder of the paper is organised as follows. The next section briefly reviews the theoretical motivation and outlines the important issue of R&D spillovers, the engineers' and scientists' mobility and the public R&D subsidies (Section 2). In Section 3, we review the different spillover variables construction. Section 4 examines empirical methodologies and develops a full information method (Random Coefficient Models-Three-Stage Least Squares) in the case of a simultaneous equation system. Finally, we discuss our results in (Section 5). The last Section (Section 6) provides concluding remarks.

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[1] The 2SLS estimators of a Random Coefficients Models are in our paper with Prof. Pietro BALESTRA (cf. BALESTRA P. and S. NEGASSI, 1992).
[2] See Table IX in Appendix 3.
[3] within a group each firm has the same number of periods

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2. THE THEORETICAL BASIS

The existence of R&D externalities was theoretically established by Arrow 1962. Following on from Bernstein and Nadiri (1989), Jaffe (1986), Bresnahan (1986) and Coe and Helpman (1993), technological appropriation is approached through the analysis of spillover effects. In these studies, firms which develop R&D activities cannot appropriate all benefits resulting from their efforts. It may therefore be of interest to quantify externalities. Arrow (1962a and 1962b) and Nelson (1959, 1962) have shown that spillover effects are inversely proportional to the degree of appropriation of new knowledge by the firm. They observe that the level of R&D investment is sub-optimal because the social rate of return on R&D investment is greater than the private rate of return. For Arrow, the gap between these two rates can be accounted for by the disproportion between the high costs of the R&D and the almost zero costs involved in the diffusion of new knowledge-hence public aid policies towards R&D. While examining the question of outputs in relation to appropriability, Arrow (1962) shows that the non-appropriability of research results accounts for the existence of public research, whereas extensive appropriation justifies a growing integration of public research.

Following a different line or research Schumpeter, (1950), Evenson and Kislev, (1973), Rosenberg (1974), Griliches (1979), Spence (1984) show that the degree of appropriation can have a positive effect on R&D expenditure within firms because a new and more efficient technology replaces the old and obsolete technology. The emphasis in this view is that the firm registers or purchases patents adjacent to the technology and that it benefits from a monopoly income.

The interactive innovation model expresses the view that firms learn from their environment: they can either learn from R&D that conducted outside the firm but they can also profit from the knowledge embodied in the capital goods they buy.

Complementarities between firms in R&D and others activities are a cornerstone in both the "new trade theory" and "new economic geography" literature throughout the last two decades.

The R&D carried out by one firm typically produces spillovers effects on other firms in the same industry and/or in the other industries. In principle, spillovers can be positive or negative. Positive spillovers can be of two kinds: rent spillovers and pure spillovers. The first type occurs when a firm buys from another firm R&D incorporating goods or services at prices which do not reflect their true value because of imperfect price discrimination, asymmetric information and transaction costs, or when the economist mis-measures the true value of a transaction because of a paucity of hedonic prices. The second types occur when an R&D project discloses new information which can be useful to another firm in doing its own research. Spillovers are negatives when new products outdate old products obsolete, when R&D is used as a strategy to prompt competition or when R&D competition leads to duplicative R&D.

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Much of the policy debate over support R&D and innovation centers on international competition and the "dynamic comparative advantage". The extent to which spillovers are "intranational" or "international" is therefore an important empirical issues. Inspired by these findings, Branstetter (1996) undertook a micro-econometric investigation using panel data for US and Japanese firms and he found evidence that spillovers are larger within each of the two countries than between them. These results are borne out both by Narin et al. (1987) who find substantial "excessive" self-citations when comparing citations across countries and by Eaton and Kortum (1997) who find that technology diffusion occurs considerably faster within countries than between countries.

Spillovers are international because there is no reason for R&D to remain within the confines of domestic borders, at least in open economies. Global system of innovation arise because of the globalisation of markets and information sources, the rise of multinationals and supra national politics and economic organisation. Some evidence has been obtained that lends support to the hypothesis that technological spillovers are geographically localised from data on the localisation of patenting firms (Acs and al., 1994; Jaffe and al., 1993; Adams and Jaffe, 1996). Of course, for small countries, like many European countries, geographically localised spillovers take on the dimension of international spillovers. Other research has even rejected the findings of geographically bounded knowledge spillover or rather traced the likely source of bounded spillover to tacit character of knowledge (Andretsch and Stephan, 1995; Zucker and Darby, 1998).

It seems likely that most technologically dynamic firms will be part of a broader system of international innovator activity. These purchase raw material, intermediate inputs and equipment from various international suppliers and sell to technologically knowledgeable customers. They require information about the scientific bases and technological achievements of their international competitors. They may enter into various collaboration agreements involving knowledge. Clearly, the less technologically dynamic the company and sector, the smaller external sources may be. Networks and technology flow reflect the general patterns of international trade. If some companies are efficient in producing particular types of equipment then technology and information will flow from them to the companies that purchase and use the capital goods they produce. In the case of multinational firm, information and know-how may be passed internationally within the confines of the organisation. Thus, product and process information may be passed directly, rather than in the case of physical trade, where the product innovation of one company becomes the process innovation of another. The flow of information through companies is seemingly a particular topic of significance, given the way in which multinational participate in EC funded programmes.

As suggested in the literature, international spillovers are transmitted through the following channels:

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- International trade in final goods, intermediate inputs, capital goods and high-tech products in particular,

- Foreign direct investment (FDI), especially if this comes with manpower training to operate the new machines and assimilate new production and management techniques,

- The migration of scientists, engineers, educated people in general, or their attendance at workshops, seminars,

- Publications in technical journals and scientific papers, invention revelations through patenting and patent citations,

- International research collaborations or international mergers and acquisitions,

- Foreign technology payments (including the financing of R&D conducted abroad).

The above listed channels can also be used as proximity measures between the sender and the potential receiver of R&D spillovers of the disembodied type: the more firm A trades with firm B, invests in B's economy, collaborates with B, the more A likely to diffuse its knowledge to B.

Public R&D subsidies. Public R&D subsidies are a common tool in technology policy. Public funding can contribute indirectly, by complementing and stimulating private R&D expenditure. Fostering the diffusion of innovations is becoming an important goal in public intervention within most European countries and especially in France, as technological change is acknowledged to be one of the main determinants of economic growth[4].

Public research institutes and universities have the human and capital resources required to undertake fundamental R&D or what is referred to as pre-competitive research by the EU. This is the means used by the EU to improve the competitiveness of European firms. The French government can participate by guaranteeing a market for the output of corporate in many ways: (i) by providing project-specific contracts to consortia of firms, as is the case with most EU euro-space projects. This substantially reduced the risk associated with R&D and equally improves the appropriability of innovation; (ii) by directly affecting the returns to innovators by creating a market for the product; (iii) by establishing a particular technology standard which may be proprietary to a particular firm and requires firms to comply to them. This prevents duplication of investment and it is achieved through establishing cross-licensing agreements; (iv) Government can help the diffusion of the results of basic research output produced either by government research institutes or private establishments to the relevant parties by creating a market where potential partners can meet and exchange information.

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[4] To address the relationship between publicly funded R&D, innovation and production, we constructed two variables: $Finpub_i$ and $Roicee_i$. The variable $Finpub_i$ represents the amount of subsidies spent by French government in its different interventions in research development. The variable $Roicee_i$ is the amount of subsidies a firm has received from the EU to finance a co-operation project with other firms from the EU.

Government can provide market access in exchange for technology to a domestic firm. They can insist that foreign-based MNE have minimum local content and thereby take a domestic partner in exchange for access the domestic market. Another important and growing role for government is in encouraging and monitoring cross-border R&D alliances. In addition, it reduces the   uncertainty that is caused by the increasing protection of multilateral intellectual property rights through agencies as EU and thereby improving the appropriability of innovation on both the domestical and international levels.

European systems have been encouraged by the framework programs, under the auspices of the European Commission. We would expect to see considerable interaction between EU Member States, partly because of their contiguity, their increasingly common culture and the greater cohesion brought about by EC-funded collaborative research networks and research joint-ventures.

The impact of scientists and engineers mobility on firm's production and innovation. Flows of technical knowledge help drive innovation and economic growth. Knowledge diffusion can flow from one firm to another or from government projects to commercial projects. It can flow horizontally, from one firm to another in the same business; or vertically, from laboratory to factory floor; or between end-product manufacturers and their suppliers. Knowledge spills in part through networks of engineers and scientists, linked in technological communities that exist independently of corporate organizations and government agencies.

Technological know-how acquired through experience is embedded in the scientist human capital. This knowledge becomes available to a competitor when scientists and engineers of the department of R&D switches jobs. Economists (Arrow 1962a; Stephan, 1996) have mentioned that the inter-firm mobility of scientists and engineers transmits technological know-how across firms. Levin et al. (1987) present survey evidence that firms consider the hiring of R&D employees from innovating firms as a means of learning about new technologies. Kerstetter (2000) provides several high profile examples of employees raid designed to gain access to competitors' technologies. Access to diffusion through the networks mobility of scientists is especially important for small French firms that do not implement R&D. Even in large firms, a principal function of research scientists and engineers is to recognize and help interpret R&D results from elsewhere. Technology does not flow easily. Learning is difficult. Ideas and know-how remain embedded in laboratories, design teams, and factories.

The 'network' approach offers some potential, combining with other forms of inquiry, to evaluate the complex relationship between human mobility the transfer of knowledge, and to promote our understanding of the impact of highly skilled, scientific, migration.

By using econometric evidence, our work is concerned with developing our understanding of the process shaping the mobility of high skilled scientists and the impact of this form of mobility on production and the innovation activities of the French firms.

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3. CONSTUCTION OF SPILLOVER MEASURES

We compute four variables of international spillovers on the material flows between firms in manufacturing and we also construct a measure of national technology proximity similar to that proposed by Jaffe (1986).

3.1 Measuring Spillovers from foreign firms

Calculating the pool of quasi-public knowledge generated by the R&D activities of foreign firms (the European, USA and Japanese) which are potentially available to French firm i in its industrial sector. In this study, we include 1174 plants for Europe, 91 for USA and 54 for Japan. These plants indicate in the enquiry realized by the French Ministry the amount of R&D of the group to which they belong and the cost of innovation (Tables XI, XII and XIII, in Appendix 3).

The empirical concept expresses firm i's technological proximity to firm j reflecting the firm i's ability to appropriate the R&D results of firm j. The closer these two firms are in the technological space the more they will be able to pick up each other's innovations. The international spillovers variable is one of the variables which reflect this concept. We use the firm's distribution of patents as an indicator of the distribution of its R&D activity in the technological space. The measure of proximity between firm i and firm j α_{ij} [5] is defined as in Jaffe (1986) and the international spillovers which are to the disposal of French firm i are calculated as follows:

$$Spill \, \text{int} \, er_{git} = \sum_{j \neq i} \alpha_{ij} RD_{jt}$$

Where

RD_j *:* Stock of R&D expenditure.

The stock of R&D expenditures (RD_j) constitutes the basis for construction of spillovers pools. The stock of R&D has been built on the basis of the permanent inventory method. We calculate it in the following manner: The rate of depreciation δ_{RD} is supposed constant over time. This rate of depreciation of R&D capital should generally be considered higher than of physical capital.

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[5] α_{ij} is defined as the cosine of the angle between two vectors of technology F_i and F_j. But if two vectors F_i and F_j represent the variables x and y respectively, then the cosine of the angle between them corresponds to a correlation between these variables. $\alpha_{ij} = \dfrac{F_i F_j'}{\left[(F_i F_i')(F_j F_j')\right]^{1/2}}$

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Technological knowledge generated by R&D loses its capacity to generate private profits as it is involuntarily disseminated to other firms in addition to becoming obsolete as new products and procedures are introduced. The knowledge stock (RD_{jt}) of foreign enterprise is determined by the perpetual inventory method, i.e.

$$RD_{jt} = (1 - \delta_{RD})RD_{j,t-1} + I_{RD,jt}$$

Where:

δ_{RD} is a constant and uniform depreciation rate of 25% while $I_{RD,jt}$ is defined as the (annual) investments.

. α_{ij} : Indicator of technological proximity.

The European Patent Office (EPO) is the source of information we use to calculate the technological proximity (α_{ij}). Indeed, this office supplies the firm's patent applications across technological classes according to the international Patent Classification (IPC) for the whole period 1982-1996. All firms reported R&D expenditures have applied for patents to the EPO over the period 1982-1996. The two-digit IPC classification allows one to identify the technological classes of patents applications. We calculated a table reporting the distribution of the firms' patents across 36 broader classes (corresponding to the NAF sectors of the French Ministry).

3.2 Measuring spillovers from imported machines tools

Positive rent spillovers from research embodied in intermediate inputs e.g. the flow of machines tools imported by the French firms may best be investigated using a spillover pool whose weights are based on intermediate input flows. The weights are usually considered a measure of the proximity between the French firms (customers) and the foreign firms (suppliers). But international data on firm level input-output to construct the weights is extremely rare. We propose to approximate the foreign R&D capital for machine tools of trade partners (developed countries) as the import-share-weight of domestic R&D stocks for machine tools by the French industry of i:

$$spillm_i = \sum_{j \neq i} \frac{m_i}{Tm_i} SRD_j$$

Where m_i is the flow of machines tools imported by the firm i in Euros from the world and Tm_i the total import of the industry of i from foreign countries. SRD_j is the domestic R&D capital stock for machine tools by the industry of i in Euros.

3.3 Measuring spillovers based on foreign patent acquisition, licensing agreements, and hiring foreign labour

We use the following measure:

$$Spillh_i = \left(\frac{PR_i}{\sum_{j \neq i} PR_j} + \frac{LKHA_i}{\sum_{j \neq i} LKHA_j} + \frac{HL_i}{\sum_{j \neq i} HL_j} \right) \sum_{j \neq i} ARD_j \, ,$$

Where:
- PR_i denotes the foreign patent rights acquired by firm *i* and PR_j by the others firms in the sector;
- $LKHA_i$ denotes the technology and know-how license fees paid by firm i to foreign firms and $LKHA_j$ by the firm j;
- HL_i denotes the hiring of foreign labour by firm i and HL_j by the firm j
- ARD_i is the investment in experimental development (the development potion of R&D) by firm j.

By importing intermediate inputs and particular capital goods, French Productivity can be increased if a larger variety of intermediate inputs and entirely new technologies become available. Imported products can also be copied by reverse engineering. Finally international trade creates contracts and learning through interactions with foreign customers. Some authors have isolated particular types of imports in relation with international R&D spillovers (Bernstein and Mohnen, 1998, Bernstein 1988).

3.4 Measuring international R&D Co-operation

The growing importance of collaborative R&D strategies is captured through budgets spends on co-operation. We have information of the form in which such co-operation prevails.

$$Spillcoop_i = \sum_{j \neq i} COOP_j$$

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Where

$COOP_{ji}$ Is budgets spent for co-operation by the other firm j which are in the sector of firm.

3.5 Measuring national R&D spillover indicator

The overall technological strength of a firm is directly related to its size and technological opportunity but acquiring technology from the outside (national environment) may not be neutral to its R&D decisions. The availability of external technology may discourage and hence substitute for own research investment.

The level of external R&D expenditure (firm's expenditures on R&D contracted out, including R&D contracting to other national firms, as well as research institutions) constitutes the basis for construction of spillover pools. The approach used here is based on each firm's evaluation of the important that own ideas might be copied. The question of imitation belongs to a group of questions on factors impeding innovative activity and was answered by the firms on a scale ranging from 1 (=very low) to 5 (=very high) in the CIS[6]. The sector-specific indicator for imitation in sector s is given by:

$$im_s = \frac{1}{n_s} \sum_j \frac{COP_{sj}}{5}$$

n_s is the number of firm j in the sector s and $COPY_{sj}$ the judgement of the jth firm for the imitation concerning their innovation. If all firms value imitation as « very high », the indicator takes on the value 1, and all firms gain from the R&D efforts of firm j in the same manner. The firm-specific spillovers (spillext) are calculated as the weighted sum of external R&D expenditures of all sectors minus own external R&D expenditures and R&D expenditures of foreign firms as follows:

$$Spillext_i = \sum_s \left[\sum_{j \neq i} \left[im_s (EXRD_{sj})(h_i + k_i) \right] \right]$$

Where:

. $Spillext_i$ is considered to measure the amount of external R&D technology sourcing and is the sum of two external technology sourcing variables:

- the intrasectoral spillovers which means that some firms are beneficiaries from other firms external expenditures whose operate in the same industry (horizontal relationships);
- the intersectoral spillovers indicate that in an input-output chain (vertical relationships) firms can have a common scientific basis for whatever knowledge they share;

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[6] CIS: Community Innovation Servey.

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. $EXRD_{sj}$ is the stock of external R&D expenditures (the stock is calculated in the same way as for in-house R&D). This R&D is the total R&D expenditures of the firms j in sector s (j≠i) and is available at corporate level in France (Table V in Appendix 3);

. (h_i+k_i) is a proxy of the firm's absorption capacity of external technology. h_i and ki denote respectively the share of white collars employees in total white collars employees of industry s and the R&D intensity of the firm i (R&D employees in firm i over total R&D employees in the industry s of firm i). The scientific profile of qualify person is related to his willingness to absorb, this could leave a higher absorptive capacity for French firms employing these persons.

4. EMPIRICAL FINDINGS

4.1 A Structural Model of Technological Spillovers, Production, Innovation output and R&D private effort in an Open Economy

Our study has been performed within a simple Cobb-Douglas production function framework where a pool of outside knowledge is included. In our work, we consider that the innovation process, the national spillover and the internal R&D are endogenous. Finally we have constructed a structural model explaining simultaneously at the firm level four economic variables: value-added (production), innovation, spillover and R&D. In what follow, we first present the model and give justification of simultaneity (sub-section 4.2) of these four variables.

As en example, we explore the French manufacturing sector from 1990 to 1996. Our sample includes 2763 innovator firms[7] in the period of 1990-1996. The purpose of this analysis is to show how knowledge created in particular sector- either domestic or foreign- is applied and used in the French economy. This analysis gives us both a clear picture of knowledge flows within the French manufacturing sector and the dimension to which imported knowledge is having

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[7] If a firm has declared innovator in CIS 1 and/or in CIS 2, it will include in our sample.

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$$\begin{cases}
Y_{git} = AK_{git}^{\alpha_1} . L_{git}^{\alpha_2} . RD_{git}^{\alpha_3} . MRD_{gi,t-2}^{\alpha_4} . Spillext_{git}^{\alpha_5} . Spillm_{git}^{\alpha_6} . Spillh_{git}^{\alpha_7} . Spill\,int\,er_{git}^{\alpha_8} . Spillcoop_{git}^{\alpha_9} . e^{\varepsilon_{gi}} \\
\hspace{11cm} (1a) \\[4pt]
Inno_{git} = RD_{git}^{\beta_1} . H_{git}^{\beta_2} . MRD_{gi,t-2}^{\beta_3} . Spillext_{git}^{\beta_4} . Spillm_{git}^{\beta_5} . Spillh_{git}^{\beta_6} . Spill\,int\,er_{git}^{\beta_7} . Spillcoop_{git}^{\beta_8} . \\[6pt]
\hspace{1cm} Finpub_{git}^{\beta_9} . Roicee_{git}^{\beta_{10}} . sh_{gi,t-1}^{\beta_{11}} . BRV_{git}^{12} . e^{\vartheta_{git}} \hspace{4cm} (2a) \\[6pt]
Spillext_{git} = RD_{git}^{\gamma_1} . MRD_{gi,t-2}^{\gamma_2} . Inno_{git}^{\gamma_3} . Spillcoop_{git}^{\gamma_4} . Finpub_{git}^{\gamma_5} . ROICEE_{git}^{\gamma_6} . Cots_{git}^{\gamma_7} . BRV_{git}^{\gamma_8} . e^{u_{git}} \\[8pt]
RD_{git} = Spillext_{git}^{\lambda_1} . Inno_{git}^{\lambda_2} . Spillcoop_{git}^{\lambda_3} . finpub_{git}^{\lambda_4} . Roicee_{git}^{\lambda_5} . SH_{gi,t-1}^{\lambda_6} . Cots_{g}^{\lambda_7} BRV_{git}^{\lambda_8} . e^{\omega_{git}} \\[4pt]
\hspace{11cm} (4a)
\end{cases}$$

Finally, equation (1a), (2a), (3a) and (4a) are rewritten in Log-form in order to perform the

estim

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$$\begin{cases} Lny_{git} = \alpha_0 LA + \alpha_1 LnK_{git} + \alpha_2 LnL_{git} + \alpha_3 LnRD_{git} + \alpha_4 Lnmrd_{gi,t-2} + \alpha_5 LnSpillext_{git} \\ \qquad + \alpha_6 LnSpillm_{git} + \alpha_7 LnSpillh_{git} + \alpha_8 LnSpill\,inter_{git} + \alpha_9 LnSpillcoop_{git} + \varepsilon_{git} \\ \\ LnInno_{git} = \beta_1 Lnrd_{git} + \beta_2 Lnh_{git} + \beta_3 Lnmrd_{gi,t-2} + \beta_4 LnSpillext_{git} + \beta_5 LnSpillm_{git} \\ \qquad + \beta_6 LnSpillh_{git} + \beta_7 LnSpill\,inter_{git} + \beta_8 LnSpillcoop_{git} + \beta_9 Lnfinpub_{git} \\ \qquad + \beta_{10} Lnroicee_{git} + \beta_{11} Lnsh_{gi,t-1} + \beta_{12} Lnbrv_{git} + \vartheta_{git} \\ \hspace{10cm} (2b) \\ Lnspillext_{git} = \gamma_1 Lnrd_{git} + \gamma_2 Lnmrd_{gi,t-2} + \gamma_3 Lninno_{git} + \gamma_4 Lnspillcoop_{git} + \gamma_5 Lnfinpub_{git} \\ \qquad + \gamma_6 Lnroicee + \gamma_7 \cot s_g + \gamma_8 Lnbrv_{git} + u_{git} \\ \\ Lnrd_{git} = + \lambda_1 Lnspillext_{git} + \lambda_2 Lninno_{git} + \lambda_3 Lnspillcoop_{git} + \lambda_4 Lfinpub_{git} \\ \qquad + \lambda_5 Lnroicee_{git} + \lambda_6 Lnsh_{gi,t-1} + \lambda_7 \cot s_g + \lambda_8 Lnbrv + \omega_{git} \\ \hspace{10cm} (4b) \end{cases}$$

Where

g=1.....G. indicator of groups; i=1.....M. indicator of firm; t=1.....T. indicator of time;

Ln = the natural logarithm.

Insert Table I in Appendix 4

4.2 Justification of Simultaneity

Recent studies go one step further and insert R&D spillovers into a structural model explaining simultaneously other economic variables such as trade, patent applications in different countries, R&D, physical capital accumulation and GDP growth (Eaton and Kortum 1997; Meijl and Van Tongeren 1999).

The discussion on the linkage between internal an external R&D strategies[8] (i.e. source of spillovers) has made eminent that there exists a two-way causality, a simultaneous relationship between the two phenomena. It is clear that external R&D stimulate or discourage in-house R&D but also in-house R&D may enhance the efficiency of external by inducing those firms that have in-house R&D to be

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more engaged in external strategy. To tackle the simultaneity problem between external R&D (i.e. source of spillovers)and internal R&D (and also between innovation and spillovers), we use a structural equation model which takes into account the mutual relation between the two phenomena. The framework of a simultaneous equation model is the appropriate model to study the decision of firms on in-house R&D strategy and external R&D strategy. The industrial organization literature argues that for more basic research, spillovers are larger and hence induce firms to engage more in cooperative R&D in internalizing these spillovers.

The pool of knowledge does not only influence own R&D outlays but can also impulse the production (value-added) of firms. It is largely accepted that the pool of knowledge at the source of spillovers effects results mainly from R&D investments. Consequently, R&D expenditures from other firms as a source of technological spillovers can be thought to affect jointly production as well as own R&D expenditures of a firm. Besides this conception of R&D efforts as a source of externalities, we cannot ignore that firms evolve in a competitive environment and that their R&D decisions are not taken independently from R&D choices of competitions. So, R&D efforts are also a source of competitive interactions.

4.3 Econometric Specification

The richness of demerged information of our micro data initially suggests an individual exploration of each economic sector, the latter including several companies. This exploration offers the advantage of highlighting the specificity of each sector and of extracting a few common and fundamental patterns but it has the disadvantage of a very large heterogeneity. The χ^2 statistics (Fisher's test) for testing the validity of the random effects framework were calculated to be 17.52; 12.48; 14.18; 24.70 respectively for the four equations at 5%.

We have opted for a global econometric approach which preserves the individual information by the method of pooling and allows one to model heterogeneity effects of the firms. These effects are assumed to be constant over time and it is well known from the econometric literature that neglecting them may lead to biased estimated coefficients. For example, the capacity of the firm to integrate new technology or to discover new inventions is a typical unobserved variable of the firms. This capacity is likely to be different among firms and as a consequence the level research activity undertaken will be also different. To get around this problem, our proposition is a random coefficient model.

The extension of the random coefficients model (RCM) conceived for one single equation[9] will be considered in the case of a simultaneous equation system. The full-information estimation method by

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[8] In our study external R&D for firm i is the sum of R&D expenditures of others firms which are in the same industriel sector of firm i. This sum is used to calculate spillover indicators.

the instrumental variable method that we propose is totally new and will be computed in three stages. The first two stages are those of the Random Coefficient Models-Two-Stage Least Squares (RCM2SLS)[10]. Our new method requires a preliminary estimation of the parameters by the RCM2SLS prior to a global re-estimation of the model (the third stage). It is clear that the full-information methods (Random Coefficient Models-Three-Stage Least Squares (RCM3SLS)) are asymptotically efficient but rather sensitive to specification error and heavy on calculations and limited information ones (RCM2SLS) are less efficient but easy to calculate.

The system entails N structural equations (and therefore N endogenous variables) and M exogenous variables. The sample is made up of G groups, each group having an arbitrary number of statistical units (firms). The total number of observations for group g is T_g, which varies according to the number of firms and the number of time periods per firm (which is fixed in our empirical study[11], but need not to be so). We are adopting the assumption which specifies that all observations of the same group are taken from the same population (whatever the number of firms comprising the group). We are choosing a segmentation of the sample in group. If a group is made up of a single firm and all the firms are observed over the same T_g periods, we again witness the classical panel model.

 The normal matrix notation for a simultaneous equation system for each sector lends it self to the following expression:

$$Y_g \beta_g + X_g \Gamma_g = \varepsilon_g \qquad g = 1,...,G \qquad (5)$$

where

Y_g is the matrix T_g x N of the endogenous variables of sector g ;

β_g is the matrix N x N of the coefficients of the endogenous variables ;

X_g is the matrix T_g x M of the exogenous variables of sector g;

Γ_g is the matrix M x N of the coefficients of the exogenous variables;

ε_g is the matrix T_g x N of the terms of error.

$$Y_g = \begin{bmatrix} Lny_g \\ Lninno_g \\ LnSpillext_g \\ LnRD_g \end{bmatrix}, \text{ all the other variables are in } X_g = \begin{bmatrix} LnK_g \\ LnL_g \\ LnSpillm_g \\ LnSpillh_g \\ LnSpillcoop_g \\ .....etc\ all\ the \\ exogenous\ var iables \end{bmatrix}$$

---

[9] Swamy (1970).
[10] See Balestra and Negassi (1992).

It can obviously be surmised that the usual identification conditions of the structural parameters have been met. In addition, the simultaneous equations (1b,2b,3b and 4b) must be provided with a set of assumptions (the same as in Balestra and Negassi, 1992):

Assumption 1: The element of the coefficient matrix of the exogenous variables are assumed to be random (with group effect) while the element of the coefficient matrix of the endogenous variables are assumed to be fixed, nonstochastic because the randomness this second one raises intractable difficulties at the level of identification and estimation.

$\beta_g = \beta \quad \forall g$. β being non-singular of fixed (but unknown) elements. $\Gamma_g = \Gamma + U_g$. where Γ is a matrix of fixed elements and U_g is a matrix of random (unobserved) variables, with zero mean:

$E(U_g) = 0, \quad for\ all\ g$.

The matrix of variance-covariance is:

$$V(U_g) = E\left[(vecU_g)(vecU_g)' \right] = \Delta\ for\ all\ g,\ \Delta\ \text{being an (unknown) MNxMN matrix.}$$

$$\Delta = \begin{bmatrix} \Delta_{11} & \Delta_{12} & & \Delta_{1N} \\ \multicolumn{4}{c}{\dotfill} \\ \Delta_{N1} & \Delta_{N2} & & \Delta_{NN} \end{bmatrix}, \text{ where the block } \Delta_{NN} \text{ on the main diagonal represents the variance-}$$

covariance matrix of group effects of the nth equation, while the block Δ_{nm} reprsents the covariance matrix of the group effects between two different structural equations. The matrix Δ is non-negative definite to allow for fixed effects. As a special case, when only the constant term is random, we obtain the error component model with heteroscedasticity.

Assumption 2: We assume a full (non-diagonal)constant contemporaneous variance-covariance matrix and time independence. But, the variance-covariance matrix is allowed to vary from group to group.

For the sake of clarity and in order to establish operational analysis instruments, only individual heterogeneity will be considered in the estimations. The hypothesis of time homogeneity is not inconvenient when, as is usually the case with panel data, the number of firms is large and the number of periods rather small. However, the extension to the case where individual and time effects are simultaneously present does not pose problems (See Hsiao 1994).

Assumption 3 : The elements of ε_g and U_g are mutually independent.

---

[11]Within each sector, each firm has the same number of periods.

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4.3.1 STRUCTURAL PARAMETER ESTMATION BASED ON INSTRUMENTAL VARIABLE METHODE IN THE CASE OF RANDOM COEFICIENTS MODEL (RCM2SLS)

Our prior requirement is to specify the first structural equation. In compliance with the usual exclusion restrictions and the normalisation of the explained endogenous variable (the first one), the first equation for the group g is written in the following manner:

$$Y_{g1} = Y_{g1*}\beta_{1*} + X_{g1*}\Gamma_{g1*} - \varepsilon_{g1} \qquad (6)$$

where

. Y_{g1} is the T_g x 1 vector of the observations concerning the endogenous variable explained in the 1st equation (the first column of Y_g) ;

. Y_{g1*} is the $T_g x N_*$ ($with\ N_* \leq N - 1$) matrix of the observations concerning the explanatory endogenous variables (a selection of the columns of Yg. except for the first) ;

. β_{1*} is the $N_* x1$ vector of the coefficients of the explanatory endogenous variables, static and non-stochastic by assumption ;

. X_{g1*} is the matrix of order T_g x M_*, $where\ M_* < M$ is the number of the observations concerning the exogenous variables which appear in the first equation (a selection of the columns of X_g) ;

. Γ_{g1*} is the $M_* x1$ vector of the coefficients of the exogenous variables. In agreement with the chosen assumption, this vector comprises a static part Γ_{g1*} and a random part U_{g1*}. or:

$$\Gamma_{g1*} = \Gamma_{1*} + U_{g1*}$$

with U_{g1*} a selection of the lines of U_{g1}. U_{g1} being the 1st column of U_g.

Thus:

$$E(U_{g1*}) = 0 \ and \ V(U_{g1*}) = \Delta_{11*} \ with \ \Delta_{11*} \ being \ the \ appropriate \ part \ of \ \Delta_{11} \ (see \ matrix \ \Delta).$$

ε_{g1} is the vector T_g x 1 of the errors of the first equation with $E(\varepsilon_{g1}) = 0$ and $V(\varepsilon_{g1}) = \sigma_{11g}I$.

It is assumed that the conditions of order and rank to identify the structural parameters are notably met with $M \geq N_* + M_*$.

By pooling the random components of (6). one can write:

$$Y_{g1} = Y_{g1*}\beta_{1*} + X_{g1*}\Gamma_{1*} + (X_{g1*}U_{g1*} - \varepsilon_{g1})$$
$$= Z_{g1}\alpha_1 + W_{g1} \qquad (7)$$

where

$$Z_{g1} = [Y_{g1*}\ X_{g1*}]$$
$$\alpha_1' = [\beta_{1*}'\ \Gamma_{1*}']$$
$$W_{g1} = X_{g1*}U_{g1*} - \varepsilon_{g1}$$

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$$E(W_{g1}) = 0 \quad and \quad E(W_{g1}W'_{g1}) = X_{g1*}\Delta_{11*}X'_{g1*} + \sigma_{11g}I \overset{d}{=} A_{g11}$$

The direct estimation of (7) by the OLS or GLS does not give rise to convergent estimators given the non zero covariance between Y_{g1*} and ε_{g1}. The difficulty is averted by using the instrumental variable method. The matrix X_g of the observations relating to all the exogenous variables of the sector g is the matrix of appropriate instruments in this study (there is no other available information). The instrumental variable method (IV) presents the following steps:

    1. The equation (7) is multiplied by a suitable instrument matrix ;

    2. The matrix of the variance-covariance derived from the previous processing is computed

    3. The model thus processed by the GLS method is finally estimated.

When the errors contain a spherical variance-covariance structure, such as in classical models, the procedure described above leads to the estimation by the classical IV's method:

$$\hat{\alpha}_{1g}(IV/CL) = \left[Z'_{g1}X_g\left(X'_gX_g\right)^{-1}X'_gZ_{g1}\right]^{-1}Z'_{g1}X_g\left(X'_gX_g\right)^{-1}X'_gY_{g1} \qquad (8)$$

Here the matrix of the variances-covariance A_{g11} has a full structure. Step (1) can logically be performed either by pre-multiplying by the matrix of the instruments X'_g, which gives the equivalent of the OLS for the estimation of the IV(IV/ OLS), or by pre-multiplying by the matrix $X'_gA_{g11}^{-1}$, which gives the equivalent of the GLS for the estimator of the IV(IV/GLS).

Estimators are thus respectively

$$\hat{\alpha}_{1g}(IV/OLS) = \left[Z'_{g1}X_g\left(X'_gA_{g11}X_g\right)^{-1}X'_gZ_{g1}\right]^{-1}Z'_{g1}X_g\left(X'_gA_{g11}X_g\right)^{-1}X'_gY_{g1} \qquad (9)$$

$$\hat{\alpha}_{1g}(IV/GLS) = \left[Z'_{g1}A_{g11}^{-1}X_g\left(X'_gA_{g11}^{-1}X_g\right)^{-1}X'_gA_{g11}^{-1}Z_{g1}\right]^{-1}Z'_{g1}A_{g11}^{-1}X_g\left(X'_gA_{g11}^{-1}X_g\right)^{-1}X'_gA_{g11}^{-1}Y_{g1}$$

$$(10)$$

We have then three distinct estimators of the IV. Admitting the hypothesis of exogenous instruments, the three are all convergent. The choice then has to be made according to efficiency criteria. The noteworthy feature in our model is that all three of the estimators lead straight to the same solution. This surprising result, shown in Appendix 1, has two important implications for the estimation. The first is that the equality among the three estimators means that given the estimation of the structural parameters, we can fall back on the classical IV method which does not depend on the (unknown) variance-covariance matrix. Furthermore, this method provides a convergent estimation of σ_{11g}. As a matter of fact, the error vector computed by the classical IV method is:

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$$\hat{W}_{g1} = Y_{g1} - Z_{g1}\hat{\alpha}_1 \qquad \text{(IV/GLS)}$$

$$= \left[I - Z_{g1}\left[Z_{g1}'X_g\left(X_g'X_g \right)^{-1}X_g'Z_{g1} \right]^{-1} Z_g'X_g\left(X_g'X_g \right)^{-1}X_g' \right]Y_{g1}$$

$$= Q_{g1}Y_{g1}$$

Let us note the following properties of the matrix Q_{g1}:

$$Q_{g1}Z_{g1} = 0$$
$$Q_{g1}X_{g1*} = 0 \text{ (because } X_{g1*} \text{ is a selection columns of } Z_{g1})$$
$$Q_{g1}Y_{g1} = Q_{g1}\left(Z_{g1}\alpha_1 + X_{g1*}U_{g1*} - \varepsilon_{g1} \right)$$
$$= -Q_{g1}\varepsilon_{g1}$$

Consequently, it is self-evident that the estimation:

$$\hat{\sigma}_{11g} = \frac{1}{T_g}\hat{W}_{g1}'\hat{W}_{g1} = \frac{1}{T_g}\varepsilon_{g1}'Q_{g1}'Q_{g1}\varepsilon_{g1} \qquad (11)$$

Equation (11) is convergent when $\dfrac{1}{T_g}Z_{g1}'X_g$ and $\dfrac{1}{T_g}X_g'X_g$ have full rank finite limits.

In parallel, it can be demonstrated that for two different structural equations, let us say the kth and l^{th}, the estimator $\hat{\sigma}_{klg} = \dfrac{1}{T_g}\hat{W}_{gk}'\hat{W}_{gl}$ is convergent for σ_{klg}.

These results provide an exhaustive response to the problem of the structural parameters estimation when the information relating to a single statistical unit (one single sector) is taken into account. At this juncture, it is necessary to envisage efficient use of the information pertaining to all the G groups.

In this case, it no longer holds true that the three methods of the IV's provide the same answer. Yet it still applies that the IV-OLS and the IV-GLS are similar and thus equally efficient (see appendix 1). Given the general properties of the generalized least squares method, both these methods are therefore more efficient than the method of the classical –IV.

The procedure requires pre-multiplying the first structural equation of each unit by X_g' respectively by $X_g'A_{g11}^{-1}$ and then applying the generalized least squares. By calling F_{g1} the following quantity:

$$F_{g1} = A_{g11}^{-1}X_g\left(X_g'A_{g11}^{-1}X_g \right)^{-1}X_g'A_{g11}^{-1}$$
$$= X_g\left(X_g'A_{g11}^{-1}X_g \right)^{-1}X_g' \qquad (12)$$

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which is therefore equal in both perspectives (the IV-OLS and the IV-GLS), the following estimator is derived:

$$
\begin{aligned}
\hat{\alpha}_1 &= \left[\sum_g \left[Z'_{g1} F_{g1} Z_{g1} \right]^{-1} \right]^{-1} \sum_g Z'_{g1} F_{g1} Y_{g1} \\
&= \left[\sum_g \left[Z'_{g1} F_{g1} Z_{g1} \right]^{-1} \right]^{-1} \sum_g \left(Z'_{g1} F_{g1} Z_{g1} \right) \left(Z'_{g1} F_{g1} Z_{g1} \right)^{-1} Z'_{g1} F_{g1} Y_{g1} \\
&= \left[\sum_g \left[Z'_{g1} F_{g1} Z_{g1} \right]^{-1} \right]^{-1} \sum_g \left(Z'_{g1} F_{g1} Z_{g1} \right) \hat{\alpha}_{1g}
\end{aligned}
\tag{13}
$$

where $\hat{\alpha}_{1g}$ is the estimator by the classical-IV of the sector g. Yet again, we attain the well known result that the global estimator is a matrix-weighted mean of the individual estimators.

The expression (13) is not directly applicable given that the parameters σ_{11g} and Δ_{11*} involved in matrix F_{g1} are unknown. As a result, a two-step procedure is conceived. It consists in a first step that estimates σ_{11g} and Δ_{11*} and subsequently applies the (13) with σ_{11g} and Δ_{11*} being replaced by the estimators obtained in the first step.

A convergent estimation of σ_{11g} has previously been supplied (formula 11). As regards Δ_{11*} the following estimator is recommended

$$
\hat{\Delta}_{11*} = \frac{1}{G-1} \sum_g \left(\hat{\Gamma}_{1*g} - \hat{\bar{\Gamma}}_{1*} \right) \left(\hat{\Gamma}_{1*g} - \hat{\bar{\Gamma}}_{1*} \right)'
\tag{14}
$$

where $\hat{\Gamma}_{1*g}$ is the part of $\hat{\alpha}_{1g}$ relating to the unique exogenous variables and $\hat{\bar{\Gamma}}_{1*}$ is equal to:

$$
\hat{\bar{\Gamma}}_{1*} = \frac{1}{G} \sum \hat{\Gamma}_{1*g} .
$$

So as to ensure the efficiency of the described procedure (asymptotically at least), the estimator must be convergent. The convergence attribute can easily be proved. Let us firstly note that $\hat{\Gamma}_{1*g} = L'_g \hat{\alpha}_{1g}$ and therefore $\hat{\Delta}_{11*}$ can be written:

$$
\hat{\Delta}_{11*} = \frac{1}{G-1} \sum_g L'_g \left(\hat{\alpha}_{1g} - \hat{\bar{\alpha}}_1 \right) \left(\hat{\alpha}_{1g} - \hat{\bar{\alpha}}_1 \right)' L_g
\tag{15}
$$

We set down:

$\hat{\alpha}_{1g} = P_g Y_{g1}$. Where $P_g = \left[Z'_{g1} X_g \left(X'_g X_g \right)^{-1} X'_g Z_{g1} \right]^{-1} Z'_{g1} X_g \left(X'_g X_g \right)^{-1} X'_g$ and acknowledge the following properties:

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$$P_g Z_{g1} = I$$

$$P_g Y_{g1} = P_g \left(Z_{g1} \alpha_1 + W_{g1} \right) = \alpha_1 + P_g W_{g1} = \alpha_1 + P_g \left(X_{g*} U_{g1*} - \varepsilon_{g1} \right) = \alpha_1 + P_g \left(Z_{1g} L_g U_{g1*} - \varepsilon_{g1} \right)$$

$$= \alpha_1 + L_g U_{g1*} - P_g \varepsilon_{g1}$$

It follows that

$$\hat{\alpha}_{1g} - \alpha_1 = L_g \left(U_{g1*} - \overline{U}_{1*} \right) - P_g \left(\varepsilon_{g1} - \overline{\varepsilon}_g \right)$$

so that:

$$\hat{\Delta}_{11} = \frac{1}{G-1} \Sigma \left(U_{g1*} - \overline{U}_{1*} \right)\left(U_{g1*} - \overline{U}_{1*} \right)' + remainder \qquad (16)$$

As $L'_g L_g = I$. The remainder tends towards zero when the number of observations grows.

The principal term of (15) tends towards Δ_{11*}, when g tends towards infinity. There is thus proof

of the convergence of $\hat{\Delta}_{11*}$.

Likewise, it is shown that for both structural equations k and l the estimator is:

$$\hat{\Delta}_{kl*} = \frac{1}{G-1} \sum_g \left(\hat{\Gamma}_{k*g} - \hat{\overline{\Gamma}}_{kg} \right)\left(\hat{\Gamma}_{l*g} - \hat{\overline{\Gamma}}_{lg} \right)'$$ is a convergent estimator of Δ_{kl*} (the corresponding part

of Δ_{kl}).

Finally, due to the general properties of the estimators of the instrumental variables, the two-step

estimator $\hat{\alpha}_1$ is asymptotically normal. A convergent estimator of the asymptotic

variance-covariance matrix is provided by the inverse matrix of (13), the first right-hand term, by

using the convergent estimators fund in (11) and (14) for σ_{11g} and Δ_{11*}.

4.3.2 FULL INFORMATION Method in the case of random coefficient models: THREE-STAGE LEAST SQUARES (RCM3SLS)

We now turn to the simultaneous estimation of all the structural parameters. The method suggested

that of three stages least squares, is asymptotically efficient on condition that the specification of

all the equations is correct.

Using the same notations as in the previous paragraph, the N equations for group g can be written

in the following manner:

$$
\begin{cases}
Y_{g1} = Z_{g1}\alpha_1 + W_{g1} \\
.... \\
Y_{gN} = Z_{gN}\alpha_N + W_{gN}
\end{cases}
\Leftrightarrow
\begin{bmatrix} Y_{g1} \\ .... \\ Y_{gN} \end{bmatrix}
=
\begin{bmatrix} Z_{g1} & & \\ & .... & \\ & & Z_{gN} \end{bmatrix}
\begin{bmatrix} \alpha_1 \\ ..... \\ \alpha_N \end{bmatrix}
+
\begin{bmatrix} W_{g1} \\ .... \\ W_{gN} \end{bmatrix}
\tag{16}
$$

where

$$
Z_{gn} = \begin{bmatrix} Y_{gn*} & X_{g1*} \end{bmatrix}
$$
$$
\alpha'_n = \begin{bmatrix} \beta'_{n*} & \Gamma'_{gn*} \end{bmatrix}
$$
$$
W_{gn} = X_{gn*}U_{gn*} - \varepsilon_{gn}
$$
$$
n=1,...,N
$$

The symbol *, as in the previous case, denotes a selection of the relevant vector and matrix elements, which differs from one equation to another. The statistical properties of the perturbation vectors, in accordance with the hypotheses chosen, are the following:

$$
E(W_{gn}) = 0
$$
$$
V(W_{gn}) = X_{gn*}\Delta_{nn*}X'_{gn*} + \sigma_{nng}I \overset{d}{=} A_{gnn}
$$
$$
E(W_{gn}W'_{gs}) = X_{gn*}\Delta_{ns*}X'_{gs*} + \sigma_{nsg}I \overset{d}{=} A_{gns}
$$

Where the matrixes Δ_{ns*} are appropriate selections of the matrixes Δ_{ns}.

In compact form and again for the sector g, we have the following representation:

$$
\widetilde{Y}_g = \widetilde{Z}_g\alpha + \widetilde{W}_g
\tag{17}
$$

Where

$$
\widetilde{Y}_g = VecY_g = \begin{bmatrix} Y_{g1} \\ .... \\ Y_{gN} \end{bmatrix},
\widetilde{Z} = \begin{bmatrix} Z_{g1} & & \\ & .... & \\ & & Z_{gN} \end{bmatrix},
\alpha = \begin{bmatrix} \alpha_1 \\ ..... \\ \alpha_N \end{bmatrix},
\widetilde{W}_g = \begin{bmatrix} W_{g1} \\ .... \\ W_{gN} \end{bmatrix}
$$

We then obtain:

$$
E(W'_g) = 0
$$
$$
V(\widetilde{W}_g) = [A_{gns}] \overset{d}{=} A_g
$$

The matrix Ag may be written

$$A_g = \widetilde{X}_{g*}\Delta_* X_{g*} + \sum\nolimits_g \otimes I_{T_g}$$

Where

$$\widetilde{X}_{g*} = \begin{bmatrix} X_{g1*} & & & \\ & \cdot & & \\ & & \cdot & \\ & & & \cdot \\ & & & X_{gN*} \end{bmatrix}, \quad \Delta_* = \begin{bmatrix} \Delta_{11*} & \ldots & \Delta_{1N*} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \Delta_{N1*} & \ldots & \Delta_{NN*} \end{bmatrix}$$

A convergent estimator of α within the model (17) is obtained by the instrumental variable method. As for the two stages least squares. three variants can be considered:

. IV/CL: each equation is pre-multiplied by X'g and GLS is applied as if the variance-covariance matrix of the processed model was $\sum\nolimits_g \otimes X'_g X_g$ (and thus disregarding the terms in Ug*) ;

.IV/OLS: each equation is pre multiplied by X'g and GLS is applied .

. IV/GLS: each equation is pre-multiplied by $X'_g A_g^{-1}$ and the GLS are applied.

In the case considered here and contrary to what occurs within the framework of a single structural equation, the three estimators are not identical. Anyway, as demonstrated in Appendix 1, the last two estimators are equal (and asymptotically more efficient than the first). By denoting the following amount by Fg (which is equal to the last two variants):

$$F_g = A_g^{-1}\widetilde{X}_g\left(\widetilde{X}'_g A_g^{-1}\widetilde{X}_g\right)^{-1}\widetilde{X}_g A_g^{-1} = \widetilde{X}_g\left(\widetilde{X}'_g A_g \widetilde{X}_g\right)^{-1}\widetilde{X}'_g$$

By using the data pertaining to sector g, the RCM3SLS estimator is given by

$$\hat{\alpha}_g = \left[\widetilde{Z}'_g F_g \widetilde{Z}_g\right]^{-1}\widetilde{Z}'_g F_g \widetilde{Y}_g \qquad (18)$$

When the information on all the G group is used (again due to the independence of the group), the estimator takes the following form:

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$$\hat{\alpha} = \left[\sum_g \widetilde{Z}_g' F_g \widetilde{Z}_g \right]^{-1} \sum_g \widetilde{Z}_g' F_g \widetilde{Z}_g \widetilde{Y}_g$$

$$= \left[\sum_g \widetilde{Z}_g' F_g \widetilde{Z}_g \right]^{-1} \sum_g \widetilde{Z}_g' F_g \widetilde{Z}_g \left(\widetilde{Z}_g' F_g \widetilde{Z}_g \right)^{-1} \widetilde{Z}_g' F_g \widetilde{Y}_g$$

$$= \left[\sum_g \widetilde{Z}_g' F_g \widetilde{Z}_g \right]^{-1} \sum_g \widetilde{Z}_g' F_g \widetilde{Z}_g \hat{\alpha}_g \qquad (19)$$

The expected result is again achieved, in that the global estimator on all the groups is a matrix weighted mean of the estimators by group. So that the estimator defined in (19) can be functional (an asymptotically efficient), it suffices to replace the unknown elements σ_{nsg} and σ_{ns*} by the convergent estimators. As mentioned in previous paragraph, the latter are provide by the two stage least squares.

The full information estimation that we have just developed completes the tools available to the econometricians in order that he may deal with simultaneous equation systems with random coefficients. The sectorial segmentation has given us a degree of generality that exceeds our extension to the work conducted by Swamy. In fact, the calculation of the estimators that we have proposed can be performed without any major difficulties.

5. Interpretation of results

The reader will find estimates of output elasticities obtained through three panel methods: Between, Within and Random Coefficient Models-Three-Stage Least Squares in Appendix 2.

Our results highlight a simultaneity in the decision to impliment R&D and the spillover pools.

The Random Coefficient Models-Three-Stage Least Squares method provides estimators which are more significant than the Between and Within methods. The results indicate that the within-firm method underestimate more the effect of the exogenous variables on the endogenous variables. What follows includes our comments are based on the Random Coefficient Models-Three-Stage Least Squares (RCM3SLS) results.

Production output. To a large extent, the estimated elasticities obtained for physical capital and employment (K and L) are positive, significant (respectively, 0.3066 and 0.4194) and similar to those obtained in other studies. The elasticity of the stock of internal R&D (0.2598) is also comparable with those in the literature. The stock of R&D is a cumulative measure of how much research and development has been done in France over those years. R&D investment emphasizes the strength in

production (value-added). French firms with R&D activity reap large benefits from their investments. However, a fraction of these benefits spills over the firms without permanent R&D activities.

In the production equation, the explanatory variables include the logarithm of our scientist and engineer mobility measure (Lnrmd). We find a positive and significant coefficient estimate (elasticity equal to 0.0860) of the Lnrmd variable. This is consistent with the possibility that mobility raises the profitability of research projects and increases value-added.

As far as international spillovers are concerned, we observed that all variables are globally positive and significant. They are expected to provide an estimation of technological non-rivalry. This means that the French firms are the potential beneficiaries of research activity in foreign firms through international trade. The level of international spillovers is differentiated into multinational activity and import activity of French firms. International trade enables France to consume products and to use inputs that were developed and finalized in other countries. Such inputs can differ in quality from those available at home or they can perform functions that complement domestic inputs. The flow of machine tools imported by the French firms from the world is quite considerable and Lnspillm variable measures the technology which spills through this machinery. The significant and positive (elasticity equal to 0.1084) impact for Lnspillm variable means that there is a complementarity between the latter and the firms' own R&D. In addition, trade partners present France with a market in which it can sell its products and services. The foreign patent acquisition, licensing agreements, and hiring of foreign labour as well as the flow of machines tool imported (Lnspillh and Lnspillm variables) can also be used as proximity measures between the sender (foreign firms) and the potential receiver (French firms) of R&D spillovers of the disembodied type: the more foreign firms trade with French firms, invest in the French economy, collaborate with French firms, the more foreign firms are likely to diffuse their knowledge to French firms. These measures of proximity are dependent on economy transactions and are expected to essentially capture the rent spillovers.

The traditional literature emphasised gains from trade that stem from comparative advantage-based specialisation, where comparative advantage derives from technological differences or differences in factor endowments. Finally, dynamic scale economies and learning mechanism are introduced by these (Lnspillm and Lnspillh) variables. This sort of learning applies to manufacturing techniques, organisational methods and market conditions. In either case the acquired knowledge boosts France productivity and competitiveness.

The contribution to firm production (value-added) of the local stock knowledge (i.e., Lnspillext variable) is higher than the one associated to each international spillover (elasticity equal to 0.2009). An inverse contributive effect is obtained for the national stock of technology if all the international categories of spillovers are combined.

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By making available products and services that embody knowledge and by providing foreign technologies (R&D activities), the foreign firms in our model demonstrate their potential to make productivity gains in France. The R&D activities of foreign firms or inward foreign direct investment (i.e., Lnspillinter variable) due to the investment in the sector of French firm by the European, USA and Japanese plants (1174 plants for Europe, 491 for USA and 54 for Japan) is significant but very low (elasticity equal to 0.0112). This lesser impact of the inward foreign direct investment could result from the high specialization of economies seemingly less complementary at the national environment than at the international environment. This coefficient confirms that there is a small amount of spillover from inward FDI and that it is comparable with those in the literature (Hadad and Harrison, 1993; Aitken and Harrison, 1994; Chung and Al., 1996).

The international cooperation (Lnspillcoop) variable is considered as an external sourcing strategy. Cooperative engagements do not have a significant impact on French firms' production.

Innovation output. As far as innovation is concerned, our study had the following objectives in mind: 1) How important are spillovers and mobility of scientists in innovation generation compared to internal factors, such as R&D investment and human capital? 2) How important are national spillovers compared to international spillovers ? 3) Is formal co-operation a determinant influence in innovation output? Does formal co-operation create synergies or knowledge which may not be appropriated by non-member firms?

Concerning the first point, simple calculations show that internal factors, i.e., highly skilled employees (R&D employees and human capital) are responsible for about 45 % of the innovation value, while mobility account for one tenth and externalities account for about one fourth.

The mobility measure exhibits a pronounced, statistically, positive and significant effect (elasticity equal to 0.1427) on innovation. This can be interpreted as an increase of 0.1247 % in innovating products due to 1% increase in the turnover of number of engineers and scientists in the research department. These findings on the effect of mobility have implications for the literature on spillovers. The movement of researchers among firms may be an important mechanism for the transmission of spillovers. More precisely, while working in an innovator firm scientists and engineers develop technical knowledge that they can subsequently exploit at a rival firm. Because this technological knowledge has a value for other new employers, it is general human capital which the scientist is willing to pay for. Our results show that mobility of scientists can develop new knowledge or help the firm to acquire knowledge externally. Thus, including a measure of mobility is as natural as including a measure of R&D budgets. Furthermore, our findings provide rare econometric evidence that technological innovations are passed on among firms by mobile personnel.

It should be also noted that human capital with an elasticity of 0.2628 seems as significant as the R&D capital investments (elasticity equal to 0.3543). From the proficiency stand point, our results are

therefore validated by the conclusion as well as the fact that an innovating firm contains highly skilled employees. The important positive coefficients confirm that the skills related to the hiring of skilled personnel favour the carrying of innovation projects. The presence of these highly skilled employees is all the more important for the firm if it has an organization enabling it to manage the individual competence it possesses: in addition human capital also appears to be a means of capturing externalities. These externalities result from the appropriation by the firms of stocks of technological knowledge found in their environment. Accordingly, enterprises without research benefit from externalities by hiring qualified employees.

The importance of spillovers, however, is likely to be underestimated as internal factors enhance a firm's ability to exploit spillovers. Moreover, the significance of our variable for national pure spillover (Lnspillext variable) with a small coefficient (elasticity equal to 0.1274) might be due to a level of aggregation (the sector) which is too high. If further tests using a lower decomposition level should modify this result, the overall explication rate of spillovers would be increased. Looking at international and national spillovers, we find that international spillovers are more considerable than national spillovers (the total amount of elasticities for international spillovers is equal to 0.1719). This can be interpreted as an increase of 0.1719 % in the turnover due to innovating products for a 1% increase in the international technology spillovers. The effect of international spillovers on innovation is even likely to be under-estimated, as international competition is also likely to decrease the turnover that can be made thanks to innovation.

Now looking at the different vectors of externalities, it can be seen that formal co-operation has a very low (but positive and significant) influence on innovation output (less 5 %). Participants in spillovers do create synergies and knowledge, but either this knowledge is not so significant or most of it is also appropriated by non-member firms. This could then explain the generally high rate of failures in R&D co-operation agreements, which in turn also lessens the innovative efficiency of co-operation. Hence, the question raised by this result is *why do firms co-operate at all*?

Significant and positive coefficients obtained for cooperation variables suggest that alliances are a means of improving the skills of the firm or of acquiring new ones. Cooperation like this translates into organizational forms. They are then distinguished by a higher learning capacity than other alternative forms involving the organization or transaction of goods. What is more, alliances are specific organizational forms calling for particular management to monitor external opportunities, selecting partners, controlling the alliance and passing on knowledge and ability towards the inside of the organization, so as to appropriate the fruit of the alliance. The alliance also offers a gain in flexibility.

The high estimation result for the market share suggests that firms that enjoy a leadership are also those likely to accomplish major future innovations, thus reinforcing their leaderships.

A last and interesting result is the high estimation result that is obtained for the patent variable. Its influence on innovation is equal to about a third of all the influence of external factors. This influence can not only be accounted by patent disclosure, as the statistical survey shows. We would rather interpret this result as being due to the high importance of imitation (or "invention around the patent") in innovation output. Ease of imitation (high elasticity related to the variable BRV) or a low degree of appropriability of R&D results is a crucial trait which drives a wedge between private and social returns.

R&D. The channels through which spillovers occur are manifold. Based on French CIS data, we find that the most effective means of learning from rivals are: internal R&D, licensing and reverse engineering. These results seem to contest the Cohen and Levintahl model (1989) where firms need to conduct R&D to be able to assimilate spillovers. For our survey, the most largest external sources of information are suppliers and customers (see CIS questionnaire analysis by Favre and François, 1998).

As exogenous variables in explaining the R&D preference, many spillovers pools are used (the Lnspillext and Spillcoop variables). In fact, the impact of Spillext and Spillcoop (spillovers variables) can be both positive and negative for the level of R&D from the theoretical model. The national spillovers (Lnspillext) variable increases the efficiency of the R&D investment from the theoretical. The positive effect of this variable can be explained by the various possibilities of using R&D results in different products or by a reduction in innovation risk due to a presence in different markets. Our result (positive and significant elasticity of 0.2039) upholds the existence of the complementarity effects and large R&D spillovers. Moreover, the R&D is thought to generate incentives to the individual firm.

Unfortunately, the international cooperation activity (Lnspillcoop) spillovers have negative and significant effects (elasticity equal to -0.1320) on the R&D. There is a potential substitution of the decision to cooperate and the decision to be engaged in R&D.

In our model, the size of the market is one of the main determinant of R&D activity (the Lnsh variable with an elasticity equal to 0.2243). The impact of competition between firms provides an incentive for them not only to capture any research advantage but also to maximise their market share at the expense of their closest rivals. The positive sign of the coefficients shows that the effect of knowledge diffusion dominates the effect of knowledge protection.

The amount of government and EC subsidies are examined through the variables Lnfinpub and Lnroicee variables. These variables are positive and significantly (elasticity equal to 0.1809 and 0.1230) related to the R&D. For the French government's R&D (Lnfinpub) subsidy, this can be interpreted as an increase of 0.1809 % in internal R&D spending for a 1% increase of public R&D subsidy. The interpretation also applies to the EC subsidy to French firms (Lnroicee), an increase of

0.1230% for 1% increase of EC spending. Finally, our interpretation of the empirical results is that public subsidies have an impact on firms R&D activities and we advocate the existence of the complementarity effects of both subsidies on private R&D spending[12]. Moreover, the R&D is thought to generate incentives to the individual firm. This is due to the policy of research conducted by the French government and EC. They seem to stimulate R&D investment and domestic firms' competitiveness under foreign competitive pressure.

Our results indicate that firm size and market power or strategic behaviour has encourages the undertaking of R&D activities.

The positive impact of patents (Brev) to conduct R&D can be explained by different possibilities. The coefficients of our measure of patents (registered in Europe by French firms) is positive and significant (elasticity equal to 0.1990). Consequently, French firms which operate in Europe where the patent system is perceived as an effective means of protecting intellectual property and appropriating the benefits of innovation are generally able to receive economic rents. In many cases, patent laws protect a firm from others copying its new knowledge. Only a small part of new knowledge spills over to the rest of the firms due to the effectiveness of patents for protecting technological knowledge.

Spillover pools. Through this equation, we model the ability of a firm to assimilate « free available » knowledge more directly. The decision to conduct R&D has a significantly positive (elasticity equal to 0.5376) impact on spillovers pools. This can be interpreted as an increase of 0.5376 % in the ability of a firm to capture external knowledge (i.e., the spillovers pools or externalities) for a 1% increase of the R&D employees.

The negative elasticity (equal to − 0.1900) of the cooperation variable could mean that the French firms spend less in cooperation to appropriate external knowledge.

As exogenous variables in explaining the R&D, the spillovers pools have shown a positive marginal effect. There is a potential simultaneity of the decision to be engaged in R&D and the spillovers pools. French firms seem to accelerate their own R&D effort rather than developing cooperation to capture external knowledge.

Two opposite effects are present in our model: the sharing of R&D results leads to an increased spill over pools efficiency and thus induces R&D savings effects. At the same time, incentives from the internalization of spillovers for exposures in R&D occur and thus stimulate R&D.

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[12] These results are different than those fund by Wallsten (2000). This author uses a three-stage least square firm-level model on SBIR (Small Business Innovation Research) funded companies and shows that public R&D subsidies lead to over 80% crowding out of private R&D spending.
The results of empirical studies on the effects of public subsidies remain ambiguous because public subsidies are not always randomly assigned to the private firms, which implies endogeneity of public funding. Including an endogenous variable in lenear model, as do many authors, will cause biased estimators if there exists correlation with the regression's error term.

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Promoting diffusion of innovations is becoming a paramount goal of public intervention in France. The coefficient of the public subsidies is positive and significant (elasticity equal to 0.1236). This indicates that public R&D expenditure help firms to appropriate technological knowledge by lowering indirect costs (appropriation of external knowledge requires accumulation of human capital and the acquisition of machines and patents etc., by the firm).

Certain recommendations can be made to any country, to absorb knowledge spillovers emanating from abroad. Quite a large number of R&D spillovers is transmitted by trade in intermediate inputs and in capital goods.

There is a role for government in providing information to help identify synergies, complementarities and opportunities since there are market imperfections in the markets for partners. There is another important and growing role for government in encouraging and monitoring cross-border R&D alliances and reducing the uncertainty that comes with the development of multilateral intellectual property rights protection through agencies through agencies as the EU thereby improving appropriability of innovation, both domestically and internationally. The positive and significant regression coefficient of BREV gives weight to this interpretation.

Internalization of external effects by increasing absorption capacity of firm seems to be successful in the case of French economy.

6. CONCLUSION

The dissemination of technologies allows firms to appropriate and benefit from R&D externalities.

Our study demonstrates that international spillovers arise because of imperfect appropriability of the innovations' benefits and they may occur via different routes, ranging from crude imitation or reverse engineering to R&D personnel mobility and transfers of foreign technologies. International R&D spillovers play a prominent role in the explanation of production and innovation. With the increase in trade, economic integration, spread of multinationals and globalisation of economy, we would expect an ever increasing importance of foreign technology sourcing.

The presence of international R&D spillovers puts into question the conduct of purely national science and technology policies. If the benefits of publicly funded R&D accrue to some other countries, why should the national taxpayers bear the burden of it? May be technology promotion policies should conduct jointly, in collaboration, by various countries, to maximising the net outcomes for each. Intellectual property protection rules should be negotiated on an international level to preserve their role as incentives to research and development.

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A certain recommendations can be made to any country, to absorb knowledge spillovers emanating from abroad. A fair deal of R&D spillovers is transmitted by trade in intermediate inputs and in capital goods. Those goods incorporate the latest technology developments. It thus pays for a country to trade with the outside world instead of pursuing an import-substitution policy. To be able to capture the knowledge type of R&D spillovers, a country needs the requisite absorption capacity, which means a sufficient number of educated people and investment in the acquisition of new skills. As part of knowledge remains tacit, collaboration with foreign researchers is to some extent the fastest way to acquire advanced knowledge.

APPENDIX 1

EQUALITY BETWEEN ORDINARY AND GENERALIZED PROCEDURES IN INSTRUMENTAL VARIABLES ESTIMATION WITH RANDOM COEFFICIENTS MODEL

In this appendix we present a number of important results concerning estimation by the instrumental variable method in the context of a random coefficients simultaneous equation system.

a) Case of a Structural Equation for a Single Group

It is a question of showing that the three estimators from the instrumental variable method given in the text (formulae 8, 9 and 10) are identical. First, we observe that X_{g1*} is a selection of the columns of Xg a well as a selection of the columns of Z_{g1}. Therefore

$$X_{g1*} = X_g L_1$$
$$X_{g1*} = Z_{g1} L_{1*}$$

L_1 and L_{1*} are the matrixes of the appropriate selection. Let us now compute the following two products:

$$. A_{g11} X_g = \left(X_{g1*} \Delta_{11*} X_{g1*}' + \sigma_{11g} I \right) X_g$$
$$= \left(X_g L_1 \Delta_{11*} L_1' X_g' + \sigma_{11g} I \right) X_g$$
$$= X_g \left[L_1 \Delta_{11*} L_1' X_g' X_g + \sigma_{11g} I \right]$$
$$= X_g \left[L_1 \Delta_{11*} L_1' + \sigma_{11g} \left(X_g' X_g \right)^{-1} \right] X_g' X_g$$

$$. A_{g11} Z_{g1} = \left(Z_{g1} L_{1*} \Delta_{11*} L_1' Z_{g1}' + \sigma_{11g} I \right) Z_{g1}$$
$$= Z_{g1} \left[L_{1*} \Delta_{11*} L_{1*}' + \sigma_{11g} \left(Z_{g1}' Z_{g1} \right)^{-1} \right] Z_{g1}' Z_{g1}$$

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Both matrixes:

$$H_{g1} = L_1 \Delta_{11*} L_1' + \sigma_{11g} \left(X_g' X_g \right)^{-1} \qquad (A_1)$$

$$H_{g1*} = L_{1*} \Delta_{11*} L_{1*}' + \sigma_{11g} \left(Z_{g1}' Z_{g1} \right)^{-1} \qquad (A_2)$$

are definite positive and therefore non-singular. It follows that

$$. A_{g11}^{-1} X_g = X_g \left(X_g' X_g \right)^{-1} H_{g1}^{-1}$$

$$. X_g' A_{g11}^{-1} X_g = H_{g1}^{-1}$$

$$. A_{g11}^{-1} X_g \left(X_g' A_{g11}^{-1} X_g \right)^{-1} X_g' A_{g11}^{-1} = X_g \left(X_g' X_g \right)^{-1} H_{g11}^{-1} \left(X_g' X_g \right)^{-1} X_g' \qquad (A_3)$$

$$. X_g \left(X_g' A_g X_g \right)^{-1} X_g' = X_g \left[X_g' X_g H_{g1} X_g' X_g \right]^{-1} X_g' = X_g \left(X_g' X_g \right)^{-1} H_{g11}^{-1} \left(X_g' X_g \right)^{-1} X_g' \qquad (A_4)$$

The equality of both expressions (A3) and (A4) illustrates that both estimators $\hat{\alpha}_{1g}(IV / OLS)$ and $\hat{\alpha}_{1g}(IV / GLS)$ are equal. On the other hand.

$$. Z_{g1}' A_{g11}^{-1} X_g = H_{g1*}^{-1} \left(Z_{g1}' Z_{g1} \right)^{-1} Z_g' X_g$$

$$. \left(X_g' A_{g11}^{-1} X_g \right)^{-1} X_g' A_{g11}^{-1} = H_{g1} H_{g1}^{-1} \left(X_g' X_g \right)^{-1} X_g = \left(X_g' X_g \right)^{-1} X_g'$$

so that,

$$\hat{\alpha}_{1g}(IV / GLS) = \left[H_{g1*}^{-1} \left(Z_{g1}' Z_{g1} \right)^{-1} Z_g' X_g \left(X_g' X_g \right)^{-1} X_g' Z_{g1} \right]^{-1} . H_{g1*}^{-1} \left(Z_{g1}' Z_{g1} \right)^{-1} Z_g' X_g \left(X_g' X_g \right)^{-1} X_g' Y_{g1}$$

$$= \left[Z_g' X_g \left(X_g' X_g \right)^{-1} X_g' Z_{g1} \right]^{-1} Z_g' X_g \left(X_g' X_g \right)^{-1} X_g' Y_{g1}$$

$$= \hat{\alpha}_{1g}(IV / CL) \qquad (A_5)$$

The equality between the three estimators is then established.

b) Case of one Structural Equation for all Groups

It is clear that the equality between A3 and A4 implies that $\hat{\alpha}_{1g}(IV / OLS)$ and $\hat{\alpha}_{1g}(IV / GLS)$ are necessarily equal. On the contrary, the simplification used in A5 is no longer valid if one happens to sum up all the groups. Indeed, the expression

$$\left[\sum_g H_{g1*}^{-1} \left(Z_{g1}' Z_{g1} \right)^{-1} Z_{g1}' X_g \left(X_g' X_g \right)^{-1} X_g' Z_{g1} \right]^{-1} \sum_g H_{g1*}^{-1} \left(Z_{g1}' Z_{g1} \right)^{-1} Z_{g1}' X_g \left(X_g' X_g \right)^{-1} X_g' Y_{g1}$$

is different from

$$\left[\sum_g Z'_{g1} X_g \left(X'_g X_g\right)^{-1} X'_g Z_{g1}\right]^{-1} \cdot \sum_g Z'_{g1} X_g \left(X'_g X_g\right)^{-1} X'_g Y_{g1}.$$

c) *Case of the Complete System for the Group g*

Applying the instrumental variable method to the model (17) of the text for the three relevant variants gives respectively:

$$\hat{\alpha}_g (IV/CL) = \left[\widetilde{Z}'_g \left(\Sigma_g^{-1} \otimes X_g \left(X'_g X_g\right)^{-1} X'_g\right)\widetilde{Z}_g\right]^{-1} \cdot \widetilde{Z}'_g \left(\Sigma_g^{-1} \otimes X_g \left(X'_g X_g\right)^{-1} X'_g\right)\widetilde{Y}_g \qquad (A_6)$$

$$\hat{\alpha}_g (IV/OLS) = \left[\widetilde{Z}_g \widetilde{X}_g \left(\widetilde{X}'_g A_g \widetilde{X}_g\right)^{-1} \widetilde{X}'_g \widetilde{Z}_g\right]^{-1} \cdot \widetilde{Z}_g \widetilde{X}_g \left(\widetilde{X}'_g A_g \widetilde{X}_g\right)^{-1} \widetilde{X}'_g \widetilde{Y}_g \qquad (A_7)$$

$$\hat{\alpha}_g (IV/GLS) = \left[\widetilde{Z}_g A_g^{-1} \widetilde{X}_g \left(\widetilde{X}'_g A_g^{-1} \widetilde{X}_g\right)^{-1} \widetilde{X}'_g A_g^{-1} \widetilde{Z}_g\right]^{-1} \cdot \widetilde{Z}_g A_g^{-1} \widetilde{X}_g \left(\widetilde{X}'_g A_g^{-1} \widetilde{X}_g\right)^{-1} \widetilde{X}'_g A_g^{-1} \widetilde{Y}_g \quad (A_8)$$

Contrary to the case of a single equation, the three estimators are not identical. Needless to say, the last two estimators are equal (and more efficient than the first). The equality of both expressions in A7 and A8 is easy to demonstrate.

Let us note the matrix of selection L:

$$L = \begin{bmatrix} L_1 & & \\ & 0 & \\ & & L_N \end{bmatrix} \text{ so that: } \widetilde{X}_{g*} = \widetilde{X}_g L, \text{ where } \widetilde{X}_g = I_N \otimes X_g.$$

The following results are successively attained:

$$\begin{aligned}
. A_g \widetilde{X}_g &= \left[\widetilde{X}_g L\Delta_* L' \widetilde{X}'_g + \Sigma_g \otimes I\right]\widetilde{X}_g \\
&= \left[L\Delta_* L' \widetilde{X}'_g \widetilde{X}_g + \left(\Sigma_g \otimes I\right)\right] \quad because \text{ we have } \left(\Sigma_g \otimes I\right)\widetilde{X}_g = \widetilde{X}_g \left(\Sigma_g \otimes I\right) \\
&= \widetilde{X}_g \left[L\Delta_* L' + \Sigma_g \otimes \left(\widetilde{X}'_g \widetilde{X}_g\right)^{-1}\right]\left(\widetilde{X}'_g \widetilde{X}_g\right) \\
&= \widetilde{X}_g H_g \left(\widetilde{X}'_g \widetilde{X}_g\right)
\end{aligned}$$

with

$H_g = \left[L\Delta_* L' + \Sigma_g \otimes \left(X'_g X_g\right)^{-1}\right]$ is definite positive, $A_g^{-1} \widetilde{X}_g = \widetilde{X}_g \left(\widetilde{X}'_g \widetilde{X}_g\right)^{-1} H_g^{-1}$ and $\widetilde{X}'_g A_g^{-1} \widetilde{X}_g = H_g^{-1}$.

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$$.A_g^{-1}\tilde{X}_g\left(\tilde{X}'_g A_g^{-1}\tilde{X}_g\right)^{-1}\tilde{X}_g^{-1}A_g^{-1}$$

$$= \tilde{X}_g\left(\tilde{X}'_g\tilde{X}_g\right)^{-1}H_g^{-1}H_gH_g^{-1}\left(\tilde{X}'_g\tilde{X}_g\right)^{-1}\tilde{X}'_g$$

$$= X_g\left(\tilde{X}'_g\tilde{X}_g\right)^{-1}H_g^{-1}\left(\tilde{X}'_g\tilde{X}_g\right)^{-1}\tilde{X}'_g \qquad (A9)$$

$$.\tilde{X}_g\left(\tilde{X}'_g A_g\tilde{X}_g\right)^{-1}\tilde{X}'_g = \tilde{X}_g\left[\left(\tilde{X}'_g\tilde{X}_g\right)H_g\left(\tilde{X}'_g\tilde{X}_g\right)\right]^{-1}\tilde{X}'_g$$

$$= \tilde{X}_g\left(\tilde{X}'_g\tilde{X}_g\right)^{-1}H_g^{-1}\left(\tilde{X}'_g\tilde{X}_g\right)^{-1}\tilde{X}'_g \qquad (A10)$$

The last two results show the equality of $\hat{\alpha}_g(IV/OLS)$ and $\hat{\alpha}_g(IV/GLS)$.

APPENDIX 2

Table II. Random Coefficients Models-Three-Stage Least Squares (RCM3SLS) and Fixed effect (Between)

END.VAR EXOG.VAR ESTIMATION METHODS	Lny Production		LnInno Innovation		Lnspillext Spillovers		Lnrd R&D	
	Between	RCM-3SLS	Between	RCM-3SLS	Between	RCM-3SLS	Between	RCM-3SLS
Intercept	-	1.7806 (1.051)	-	0.9741 (1.831)	-	0.8509 (0.779)	-	-1.013 (0.819)
Lnk: the stock of physical capital	**0.2743 (3.185)**	**0.2962 (4.821)**						
Lnl:remuneration of non research activity	**0.3005 (2.091)**	**0.4222 (3.181)**						
Lnrd: the stock of internal R&D at the firm level (R&D employees)	**0.1478 (3.150)**	**0.2598 (4.012)**	**0.2759 (2.112)**	**0.3543 (4.309)**	**0.3601 (3.737)**	**0.5376 (4.211)**		
Lnh: Human capital (qualified employees not R&D employees)			**0.2873 (3.284)**	**0.2628 (4.129)**				
Lmrd: Indicator of migration of scientists, only new R&D employees coming from others enterprises are used to compute this variable, with two periods lag	0.1123 (1.021)	**0.0860 (5.319)**	**0.0698 (2.573)**	**0.0984 (4.003)**	0.0310 (0.341)	**0.0621 (3.422)**		
Lnspillext: external R&D technology sourcing (national spillovers)	**0.1080 (2.477)**	**0.2009 (2.979)**	0.0974 (1.674)	**0.1274 (3.097)**			-0.1948 (1.230)	**0.2039 (4.001)**
Lninno: part of the turnover due to innovating products of firm i					**0.1023 (2.033)**	**0.1847 (3.348)**	**0.092 (4.324)**	**0.1087 (3.273)**
Lnspillm:Spillovers from imported machines tools	0.1384 (1.822)	**0.1084 (3.081)**	**0.0683 (3.710)**	**0.1137 (4.461)**				

Variable								
Lnspillh: Spillovers based on foreign patent acquisition, licensing agreements, and hiring foreign labor	**0.1109** **(2.271)**	**0.1276** **(3.007)**	**0.0590** **(3.532)**	**0.0941** **(4.013)**				
Lnspillinter: Intrenational spillovers or inward foreign direct investment	0.071 (1.981)	**0.0112** **(2.297)**	0.0203 (1.146)	**0.0170** **(5.493)**				
Lnspillcoop: budget for international R&D cooperation	0.1708 (1.410)	0.0745 (1.944)	0.0980 (0.319)	**0.0371** **(2.716)**	0.1030 (1.411)	0.1203 (1.904)	**-0.1900** **(2.191)**	**- 0.1320** **(2.619)**
Lnfinpub:Amount of subsidies of French government for research			0.0321 (1.833)	**0.0841** **(2.217)**	**0.1040** **(3.097)**	**0.1236** **(4.833)**	**0.1705** **(2.818)**	**0.1809** **(4.956)**
Lnroicee:Amount of subsidies a firm has received from the EU			0.0103 (0.134)	**0.0643** **(3.307)**	0.0410 (1.903)	**0.0690** **(2.327)**	**0.1111** **(2.703)**	**0.1230** **(3. 011)**
LnSh:Market share of the firm in its sector g with one period lag			**0.2091** **(3.319)**	**0.1971** **(2.642)**			**0.3231** **(2.383)**	**0.2243** **(2.090)**
Cots: degree of concentration of the industry g in the principal sector of activity of the firm i					-0.1552 (1.801)	**-01898.** **(2.111)**	-0.1007 (1.270)	**-0.1203** **(2.831)**
Lnbrv: number of patents of the enterprise			**0.0960** **(2.901)**	**0.1108** **(3.204)**	0.0630 (1.231)	**0.0514** **(2.890)**	**0.1591** **(3.019)**	**0.1990** **(3.990)**
$\overline{R}^2$	0.7121	0.7978	0.7830	0.7990	0.6580	0.6986	0.7441	0.7654

The variables in lowercase denote logarithms. In parenthesis t of Student. Sign and significance of the coefficients are analyzed at 5%. Heavy character significant at 5%.

Table III. Within Method

END.VAR EXOG.VAR	**Lny** Production	**Lnspillext** Spilllovers	**Lnrd** R&D	**Lninno** Innovation
Intercept	1.1379 (0.6398)	-1.780 (0.981)	1.986 (1.793)	0.3709 (1.742)
Lnk: the stock of physical capital	**0.1712** **(2.008)**			
Lnl:remuneration of non research activity	**0. 3014** **(3.201)**			
Lnrd: the stock of internal R&D at the firm level (R&D employees)	**0.1670** **(2.098)**	**0.4678** **(2.941)**		**0.3931** **(2.127)**
Lnh: Human capital				**0.2279** **(2.986)**

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Lmrd: Indicator of migration of scientists, only new R&D employees coming from others enterprises are used to compute this variable, with two periods lag				0.0667 (1.314)
Lnspillext:external R&D technology sourcing (national spillovers)	0.1490 (0.674)		0.1021 (1.186)	0.1037 (1.845)
Lninno: part of the turnover due to innovating products of firm i		0.0210 (0.980)	**0.0578** **(2.371)**	
Lnspillm:Spillovers from imported machines tools	0.1090 (1.789)	**0.1983** **(2.819)**		0.0498 (1.919)
Lnspillh: Spillovers based on foreign patent acquisition, licensing agreements, and hiring foreign labor	0.0790 (1.180)			**0.0896** **(5.708)**
Lnspillinter: Intrenational spillovers or inward foreign direct investment	0.0493 (0.679)			0.0926 (1.903)
Lnspillcoop:budget fo international R&D cooperation	0.1029 (1.890)	0.0710 (1.040)	0.0131 (0.110)	0.0180 (1.930)
Lnfinpub:Amount of subsidies of French government for research		**0.0945** **(3.458)**	0.1681 (1.713)	**0.0300** **(2.084)**
Lnroicee:Amount of subsidies a firm has received from the EU		**0.0325** **(2.011)**	0.0743 (1.993)	
LnSh:Market share of the firm in its sector g with one period lag			**0.2537** **(3.194)**	0.4094 (1.309)
Cots: degree of concentration of the industry g in the principal sector of activity of the firm i		0.1407 (1.906)	**0.1085** **(2.799)**	
Lnbrv: number of patents			**0.1221** **(2.091)**	**0.0660** **(2.747)**
$\overline{R}^2$	0.6167	0.6303	0.6804	0.7029

The variables in lowercase denote logarithms. In parenthesis t of Student. Sign and significance of the coefficients are analyzed at 5%. Heavy character significant at 5%.

ACKNOWLEDGMENTS

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Appendix 3

We have the following information concerning the innovation and the co-operation activity of the firms. All these variables are in flows without inflation and in thousands of French francs **(1Euros=6.59 FRF)**.

Table IV. Budgets spent for co-operation, MEAN (1990-1996)

Variables	Total	Not innovators	Innovators
FREQ	4801.00	2038.00	2763.00
DEORG	**1.6×10^6**	**0.002548×10^6**	**1.597452×10^6**
DETRG	**1.66×10^6**	**0.027112×10^6**	**1.632888×10^6**
DETRA	**1.075×10^6**	**0.009702×10^6**	**1.06529×10^6**

DEORG : expenditures in the case of international collaboration; **DETRG**: expenditures in the case of cooperation with firms in the same group; **DETRA**: : expenditures in the case of cooperation with foreign firms.

Table V. R&D expenditures, MEAN (1990-1996)

Variables	Total	Not innovators	Innovators
FREQ	4801.00	2038.00	2763.00
DERD	**15.85×10^6**	**0.51×10^6**	**15.34×10^6**
DIRD	**61.70×10^6**	**1.61×10^6**	**60.09×10^6**

DERD: external R&D expenditures; **DIRD**: internal R&D expenditures.

Table VI. Public subsidies MEAN (1990-1996)

Variables	Total	not innovators	Innovators
FREQ	4801.00	2038.00	2763.00
FINPUB	**13.40×10^6**	**0.0268×10^6**	**13.3732×10^6**
ROICEE	**5.64×10^6**	**$0.OO2328 \times 10^6$**	**5.637672×10^6**

FINPUB: Public subsidies for innovation; **ROICEE**: EC subsidies for research.

Table VII. Total of turnovers for each type of innovation

Variables	Total	not innovators	Innovators
FREQ	4801.00	2038.00	2763.00
TURNOVER1	244220566.66	0.00	244220566.66
TURNONER2	305496949.56	0.00	305496949.56
TURNOVER3	549717516.21	0.00	549717516.21
TURNOVER4	1431309059.46	264814704.67	1166494354.79
TURNOVER5	211537872.67	0.00	211537872.67
TURNOVER	1981026575.67	264814704.67	1716211871.00
EMPLOYEES	1599937.00	267198.00	1332739.00

Sources : SESSI (French Ministry of industry)

turnover 1 : part of turnover due to products significantly changed from technological
viewpoint or newly introduced products in 1994-1996

turnover 2 : part of turnover due to products with minor improvements in present markets

turnover 3 : part of turnover due to products subject to incremental technological changes

turnover 4 : part of turnover due to products technologically unchanged

turnover 5 : part of turnover due to new products in new markets

Table VIII. Investment received by firms, MEAN (1990-1996)

Variables	Total	not innovators	innovators
FREQ	4801.00	2038.00	2763.00
RETRG	1.37×10^6	0.1365×10^6	1.2335×10^6
RETR	8.58×10^6	0.1602×10^6	8.4198×10^6
RETRA	1.51×10^6	0.0181×10^6	1.4919×10^6

RETRG: Investment received from firms in the same group; **RETRA**: Investment received from foreign firms.

Table IX. Number of innovator firms in each sector

Code Nace2	Manufacturing Sector	Number of Firms
15-16	Foods products; beverages and tobacco	239
17-19	Textiles and leather	250
20-22	Wood; pulp and paper; publishing	293
23-24	Cook and refined petroleum products and chemicals	211
25-26	Rubber and plastic; other non-metallic mineral pro	278
27-28	Basic metals and fabricated metal products	481
29	Machinery and equipment NEC	245
30-33	Electrical and optical equipment	310
34-35	Transport equipment	242
36-37	Manufacturing NEC	214

Table X. Mean of current expenditures on innovation in 1996 by the 2763 French firms

Description	% of innovating firms Which spent for this activity	In thousands of French Francs

	%	In thousands of French Francs
Mean capital expenditures spent:		
- for internal R&D activities	73.5	72321.2
- for external R&D activities	28.3	7921.7
- on investment, machinery		
and linked to new product innovation	41.6	7575.0
- Acquisition of patents and licenses	9.5	591.5
- Product design	27.2	6814.3
- Trial. Production, training and tooling-up	25.3	971.9
- Commercialization of new products	30.6	4081.5
Total		**100 277.1**

Table XI. Mean of current expenditures on innovation in 1996 by the 1174 plants owned by European firms

Description	% of innovating firms Which spent for this activity	In thousands of French Francs
Mean capital expenditures spent:		
- for internal R&D activities	67.6	12874.9
- for external R&D activities	31.3	2506.6
- on investment, machinery.		
And linked to new product innovation	45.5	3699.5
- Acquisition of patents and licenses	8.4	254.4
- Product design	26.4	1626.2
- Trial. Production, training and tooling-up	26.2	383.7
- Commercialization of new products	32.9	759.2
Total		**22 104.1**

Table XII. Mean of current expenditures on innovation in 1996 by the 491 plants owned by USA firms

Description	% of innovating firms Which spent for this activity	In thousands of French Francs
Mean capital expenditures spent:		
- for internal R&D activities	75.1	6334.2
- for external R&D activities	28.6	2340.5
- on investment, machinery.		
And linked to new product innovation	45.9	1516.1
- Acquisition of patents and licenses	9.1	201.0
- Product design	33.7	561.1
- Trial. Production, training and tooling-up	26.1	111.8
- Commercialization of new products	35.2	473.5
Total		**11 538.2**

Table XIII. Mean of current expenditures on innovation in 1996 by the 54 plants owned by Japanese firms

Description	% of innovating firms Which spent for this activity	In thousands of French Francs
Mean capital expenditures spent:		
- for internal R&D activities	52.6	324.0
- for external R&D activities	25.2	33.9
- on investment, machinery.		
And linked to new product innovation	44.9	118.9
- Acquisition of patents and licenses	3.9	5.0
- Product design	21.6	20.7
- Trial. Production. training and tooling-up	16.8	14.9
- Commercialization of new products	33.6	17.7
Total		**535.1**

Table XIV. Innovation and collaboration between 1994 and 1996 of the 2763 French firms

Technologically changed products	Number of firms	% of the total
Development of the product is assured by :		
- external services[*]	191	6.9

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	Number of firms	% of the total
-collaboration(national and/or international)	959	34.7
- mainly the enterprise	1881	68.1
-exclusively the enterprise	1462	52.9
Technologically changed processes		
Development of the processes is assured by :		
- external services[*]	398	14.1
- collaboration(national and/or international)	1232	44.6
-mainly the enterprise	1658	60.0
-exclusively the enterprises	1210	43.8

*external services means that an enterprise can paid another enterprise to develop innovative processes.

Table XV. Innovation and collaboration of 491 plants owned by USA firms

Technologically changed products	Number of firms	% of the total
Development of the product is assured by :		
- external services[*]	40	8.2
-collaboration(national and/or international)	165	33.6
- mainly the enterprise	343	69.8
-exclusively the enterprise	274	55.9
Technologically changed processes		
Development of the processes is assured by :		
- external services[*]	48	9.8
- collaboration(national and/or international)	228	46.5
-mainly the enterprise	312	63.6
-exclusively the enterprises	224	45.6

Table XVI. Innovation and collaboration of 1174 plants owned by European firms

Technologically changed products	Number of firms	% of the total
Development of the product is assured by :		
- external services[*]	124	10.6
-collaboration(national and/or international)	336	28.6
- mainly the enterprise	844	71.9
-exclusively the enterprise	701	59.7
Technologically changed processes		
Development of the processes is assured by :		
- external services[*]	210	17.9
- collaboration(national and/or international)	475	40.5
-mainly the enterprise	694	59.1
-exclusively the enterprises	556	47.4

Table XVII. Innovation and collaboration for 54 plants owned by Japanese firms

Technologically changed products	Number of firms	% of the total
Development of the product is assured by :		
- external services[*]	8	13.9
-collaboration(national and/or international)	25	46.7
- mainly the enterprise	29	53.0
-exclusively the enterprise	21	39.4
Technologically changed processes		
Development of the processes is assured by :		
- external services[*]	2	4.4
- collaboration(national and/or international)	36	66.2
-mainly the enterprise	30	55.6
-exclusively the enterprises	17	31.5

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Appendix 4   Table I: Variables and sources

Endogenous Variables:	**Sources**	**Comments**
y_{git} : value-added $Inno_{git}$: innovation (performance indicator e.g. the part of the turnover due to innovating products of firm i $Spillext_{git}$: external R&D technology sourcing (national spillovers)	Value-added from EAE of MEFI-SESSI[13].Inno from CIS 1 and 2 of MEFI-SESSI. CIS is the the community innovation survey. R&D is from « Enquête Annuelle sur les moyens consacrés à la Recherche et au Développement dans les Entreprises » (French Ministry of Education, Direction of Research)	We can measure innovation by quantitative data on innovation inputs (Tables IV and V) or by quantitative data on the output of the innovation processus, the sales arising from new products (Table VII). We choose the second one to ascertain the innovation performance of the firms (variable Inno). These can be decomposed into sales of incrementally changed, and of significantly changed or newly introduced products (Table VII). The first thing to notice (Tables IV and V) is the high expenditures of R&D and cooperation budgets in the innovation sample.
2 type of Exogenous Variables:		
1. Classical firm economic variables:		
RD_{git} : the stock of internal R&D at the firm level (R&D employees)	R&D is from « Enquête Annuelle sur les moyens consacrés à la Recherche et au Développement dans les Entreprises » (French Ministry of Education, Direction of Research)	
K_{git} : the stock of physical capital (fixed capital stocks calculated from the flow of investments with an obsolescence rate of 5%)	EAE ("Enquête Annuelle sur les Entreprises") of MEFI-SESSI (« Ministère de l'economie, des finances et de l'idustrie-Service des statistiques »)	
L_{git} : remuneration of non research activity without social security outlay of employees	EAE ("Enquête Annuelle sur les Entreprises") of MEFI-SESSI (« Ministère de l'economie, des finances et de l'idustrie-Service des statistiques »)	
H_{git} :Indicator of human capital[14]	ESE (Enquête des Structeres d'Empois) is from INSEE and R&D is from « Enquête Annuelle sur les moyens consacrés à la Recherche et au Développement dans les Entreprises » (French Ministry of Education, Direction of Research)	Our firms encompass a large labour force (Human capital) which consists of many long term employees (R&D employees are not included) with considerable generic as well as firm-specific human capital. At least four types of employees should be distinguished: managers; marketing personnel; engineers with their considerable high tech capabilities and specializations; and blue collar workers, many of whom also possess considerable firm-specific and system-specific skills.
2. Variables related tospilloverss:		
$MRD_{gi,t-2}$ = Indicator of migration of scientists. Only new R&D employees coming from others enterprises are used to compute this variable	The most informative information on the mobility of R&D employees between enterprises comes from the « Enquête Annuelle sur les chercheurs » (French Ministry of Education, Direction of Research).	Including a measure engineers and scientists mobility in our study is necessary to account for the skills embodied in the R&D employees coming from others firms. It has been less frequently used in the previous literature probably because these kinds of data are not always available on a sufficiently broad basis. We introduce two periods lag because we consider that when a scientist is hired, the project's development, production, and marketing take two periods. In the first period, the scientist develops the innovating idea. In second period, the enterprise produces and markets the product. The researcher database

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[13] EAE : Enquête Annuelle d'Entreprises ; MEFI-SESSI : Ministère de l'Economie, des Finances et de l'Industrie-Service des Statistiques.

[14] H_{git} : *Indicator of Human Capital is* $\left(\dfrac{remuneration\ of\ qualified\ employees}{total\ of\ \text{Re}\ muneration} \times \dfrac{Number\ of\ qualified\ employees}{Total\ of\ employees} \right)$

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		distinguishes many categories which enter the R&D department. Our own research focuses only on engineers and scientists mobility.
$Spill\,int\,er_{git}$: The R&D activities of foreign firms or inward foreign direct investment	R&D is from « Enquête Annuelle sur les moyens consacrés à la Recherche et au Développement dans les Entreprises » (French Ministry of Education, Direction of Research)	
$Spillm_{git}$: Spillovers from imported machines tools	The annual **TTI** (Transfert Technologique International) database issued by the DREE ("Direction des Relations Economiques Exterieures").	
$Spillh_{git}$: Spillovers based on foreign patent acquisition, licensing agreements, and hiring foreign labour	R&D is from « Enquête Annuelle sur les moyens consacrés à la Recherche et au Développement dans les Entreprises » (French Ministry of Education, Direction of Research)	
$Spillocoop_{git}$: budget for international R&D collaboration (cooperation)	R&D is from « Enquête Annuelle sur les moyens consacrés à la Recherche et au Développement dans les Entreprises » (French Ministry of Education, Direction of Research)	
$Spillext_{git}$: national R&D spillover indicator	R&D is from « Enquête Annuelle sur les moyens consacrés à la Recherche et au Développement dans les Entreprises » (French Ministry of Education, Direction of Research)	
sh_{git-1} : market share of the firm in its sector g	EAE ("Enquête Annuelle sur les Entreprises")of MEFI-SESSI (« Ministère de l'economie, des finances et de l'idustrie-Service des statistiques »)	We include this variable in our model because under oligopolistic market environments, rather than competing by price changes, firms may prefer to turn to product differentiation and quality improvements in order to preserve their market share. In the French industries which are characterized with high R&D intensity, technology is a main component of the non-price competition.The market share $SH_{i,t-1}$ of the year preceding innovation or co-operation is included as an explanatory variable for many reasons: 1) high market share eases the problem of financing innovation; 2) market share may exert an important influence on the incentives to innovate as shown by many game-theoretic models; 3) firms with a high market share may be attractive partners for a co-operation project.
$COTS_g$: degree of concentration of the industry g in the principal sector of activity of the firm i	EAE ("Enquête Annuelle sur les Entreprises") of MEFI-SESSI (« Ministère de l'economie, des finances et de l'idustrie-Service des statistiques »)	
$Finpub_{git}$: amount of subsidies of French government for research	R&D is from « Enquête Annuelle sur les moyens consacrés à la Recherche et au Développement dans les Entreprises » (French Ministry of Education, Direction of Research)	
$Roice_{git}$: Amount of subsidies a firm has received from the EU	R&D is from « Enquête Annuelle sur les moyens consacrés à la Recherche et au Développement dans les Entreprises » (French Ministry of Education, Direction of Research)	
brv_{git} : number of patents	Sciences and Technics Observatory (OST) database contains information on patents for the period 1983-1995	

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