Inventor Location
and the Globalization of R&D

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Abstract

R&D is becoming increasingly globalized, but R&D statistics have not kept up with this development. Firm-level data capture R&D investments irrespective of location, and OECD survey data typically capture only R&D performed within national territorial boundaries. In this paper we rely on information regarding the location of a firm's inventors and develop a method of quantifying the R&D investments by country of inventive activity. For 2,157 European business group and their subsidiaries we have identified all inventors and their locations at the time of invention. In year 2000 these corporations accounted for about 90% of the overall intramural R&D at the continental level as reflected in OECD data. Analyzing the time series of the last two decades we compare the inventor count data to the consolidated R&D expenditures and find high correlations both in levels and growth rates. We calibrate R&D expenditure regressions in order to estimate the geographical distribution of a firm's inventive activities.

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1 Introduction

The growing importance of the globalisation of R&D activities is evident from a large number of case studies, statistics and analyses, both at the national and corporate level. Yet, it is still difficult to approach the phenomenon from a statistical perspective as systematic data which map the internationalization of R&D are still rare. Some progress has been made in using patterns of patent filings and inventor collaboration as evidence of R&D globalization, but a systematic picture of the R&D *inputs* used by firms has not materialized yet. Firm-level data capture R&D investments irrespective of location. The usually employed data sources such as CompuStat or others do not contain any information on the geographic distribution of a firm's R&D activities. Conversely, most of the national R&D statistics (which are then summarized by the OECD and published via, inter alia, OECD STAN) capture all R&D activities within national territorial boundaries, but not the R&D performed abroad. In some cases the agencies collecting these data have extended their questionnaires to develop a notion of the extent of international R&D activities, but there has not been any systematic measurement over time.[1]

This paper develops a methodology that allows us to estimate the international distribution of firms' inventive activities. Towards this objective we utilize inventor location data from patent applications. From inventor addresses, we extract information on the regions in which the firm has developed inventive activities. We consolidate the inventor names in our database such as to avoid any double-counting of the personnel dedicated into the inventive activities. In this paper, we describe our methodology and the data used. We also present descriptive statistics which allow us to document the large shifts that have occurred in R&D localization. In our multivariate analysis, we employ a simple accounting approach which relates total R&D to the number of inventors in different locations. Estimating linear and non-linear versions of this R&D expenditure equation provides us with highly plausible results – inventor counts have strong explanatory power, and the overall equation explain at least 60 percent of the overall variation in R&D expenditures, and in some cases up to 80 percent.

The remainder of the paper proceeds in six sections. We first describe our conceptual approach (section 2) and the data used in our study (section 3). Section 4 gives details on a number of descriptive statistics characterizing the development of international R&D

[1] For example, Wissenschaftsstatistik GmbH in Germany estimates R&D expdenditures of German firms in foreign countries. The most recent data (Wissenschaftsstatistik 2008) show that corporations in German ownership expended 38.3 billion Euro on R&D, 11.4 billion in foreign countries. Thus the share of foreign-conducted R&D was 29.7 percent. Unfortunately, these data have not been available for further studies at the firm level.

activities and patterns of internationalization, such as the share of non-domestic inventors by country and over time. Multivariate evidence on the relationship between inventor counts and R&D expenditures is presented in section 6. Section 7 concludes and gives an outlook to future research.

2 Methods

Frequently, researchers have no data available which would inform them about the geographical distribution of a firm's innovation activities. We suggest that approximations of this geographic distribution can be obtained from inventor data as recorded in patent applications. We use R&D expenditure data for a sample of companies, calibrate a regression equation and then use the estimated coefficients to predict R&D expenditures by country of R&D execution. The approach can be applied to firms for which we observe no R&D expenditures at all. It can also be applied at the regional or the country level. The key assumption that we use is that the number of researchers generating inventions which lead to patent applications is (at the firm level or at the sector level) in fixed proportion to the overall number of R&D employees.

The first step in our approach is to identify the inventors working for a particular applicant in a given year, and to determine the overall international distribution of the inventor workforce of a particular corporation or firm. We start by defining *domestic inventors* as those inventors whose country location is the same as the country location of the applicant (respectively, its headquarters). Conversely, *foreign inventors* are defined as inventors located in a country different to that of the applicant. Note that this definition would place nationals working at the foreign R&D location among the foreign inventors, even if they are nationals from the country of the applicant. Our definition of inventors is not related to nationality, but simply to the geographic location of R&D execution.[2]

We first turn our attention to the definition of "inventor counts". For the purposes of this paper, the annual inventor counts for a given firm are based on all EPO patent applications with a particular priority year by the respective applicant. An inventor is recorded as active for the applicant in that year if she is named on a patent application whose priority filing was submitted in the respective year. Consider the following example: in year 1, a firm has filed

[2] To be precise, our allocation simply rests on the country information contained in the patent document. We assumet that at the country level, this corresponds to the country of R&D execution. For smaller countries and regions close to national borders (e.g., between Belgium and the Netherlands), this assumption will have to be checked later on.

some number of priority applications, invented jointly or individually by three inventors A, B, and C. The inventor count variable for the firm in year 1 takes the value of three. Similarly in year 2, the inventor count variable is four when we have four distinct inventors A, D, E, F, irrespective of the number of patents that have been produced by them. In year 3, the inventor count variable is five if there are five distinct inventors B, E, F, G, H who have generated patented inventions for the applicant. We expect that moving average estimates will provide a better measure of the inventive workforce, since R&D projects may frequently be considerable longer than just one year.

The above measure does not correctly reflect the number of employees in invention processes if these processes take longer than one year. Therefore, we compute as alternative measures central moving average counts with a window of three and five years to account for potential lags and delays in the invention process. For instance, applying a three-year time window in the above example we obtain an inventor count variable of 8 in year 2, since there are 8 distinct inventors A,B,C,D,E,F,G,H that have produced patents in periods 1, 2, or 3.

3 Data

Our analysis will use two related datasets in which we have identified inventors and computed inventor counts. First, we apply the above approach to the overall EPO patent data as contained in the 2007 PATSTAT database. This is the population of patent filings. Second, we use a more refined dataset containing information on 2,157 European listed companies that have disclosed R&D data. Although in many European countries firms are not required to disclose R&D information, these companies perform large part of the overall domestic R&D activities in the respective countries according to the STAN OECD database. Table 1 reports the geographical distribution of the R&D performers in our sample and the relative share of the invested R&D to overall business sector R&D expenditure (BERD). Only the countries with more 50 firms are shown and the coverage with respect to STAN-OECD has been inquired for year 2000.

Table 1 Coverage of the Sample: Top R&D Performers in Europe

Country	Firms with R&D data	R&D performed by sample firms relative to national R&D conducted by the business sector (about 2000 #)
CH - Switzerland	107	199.2%
DE – Germany	304	98.0%
DK – Germany	53	47.3%
FR – France	249	99.5%
FI – Finland	94	117.7%
GB – United Kingdom	762	101.8%
GR – Greece	85	39.8%
NL – Netherland	71	192.5%
SE – Switzerland	159	92.0%
Other EU	273	NA
Overall	2,157	88.9%

Notes: Based on Hall, Thoma and Torrisi (2007). Only countries with more 50 firms are shown. # based on STAN OECD data.

Comparisons with national data have to be taken with a grain of salt, since strictly speaking, the R&D data at the firm level and the national (territorial) data attempt to measure different variables and are not comparable. However, to make the scope of our sample somewhat transparent, our sample of R&D performers considered is equal in R&D expenditures to 88.9% of the overall business R&D at the European level. In some countries (CH, FI, GB, and NL) the total R&D in our sample is even higher than the R&D expenditures reported by OECD STAN. The reason for this discrepancy is that our firm data include the R&D expenditures performed by subsidiaries in countries other than the home country. Conversely, the country statistics are based on a territorial definition of R&D which includes the R&D undertaken by subsidiaries of corporations headquartered in other countries.

We focus on consolidated R&D expenditures at the level of the ultimate parent company because this indicator gives a more appropriate picture of the inventive activities within a business group which is the typical form of organization of large-firm industrial activities in the EU context. Consolidated data is preferable to non-consolidated data since within business groups, considerable contracting of R&D services takes place. We have linked patents to the parent company level directly and indirectly through its subsidiaries firms. In particular, we have retrieved the overall list of subsidiaries using the Amadeus database during the years 1998-2006. This task has generated a list of about 150,000 subsidiaries which we relate to our 2,157 corporate groups. The consolidation of patents at the parent has relied on three levels of the hierarchy of the business group.

We have also extracted other firm's variables from Amadeus database such as founding date and age, sector activity codes, sales, sales growth, labor costs as well as the financial structure of the firm, including short and long term debt. EPO patent data and inventor counts over the period since the inception of the EPO to the end of 2006 have been obtained from the PATSTAT database as released in October 2007. Given the 18 months publication lag at the EPO, there is a potential right end truncation problem in our sample affecting the priority years 2005 and 2006.

To compute the inventor counts we first implemented a cleaning of the names as obtained from the PATSTAT database as of October 2007. A full description of this task is given in Thoma et al (2007). Most importantly, the name of each inventor were transformed to the ASCII standard codepage using the 26 letters of the English alphabet. Then each inventor name was tokenized and an index was created for their identification based on the following information: the two longest tokens of their name, the country given in the inventor address, the name of the applicant, and the priority year of the patent. This information was then used to identify identical inventors in order to avoid double counting of individuals active in inventive activities at the respective (consolidated) firm in a given years.[3]

4 Descriptive Evidence

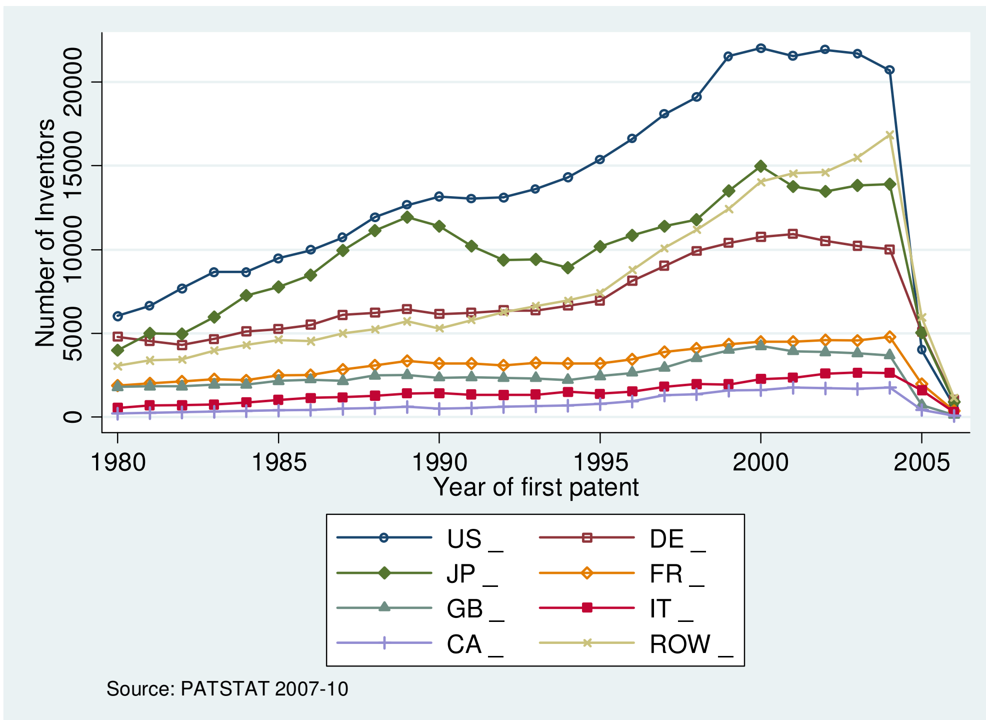
4.1 Inventor Entry Data

We start our empirical analysis by considering the entry of new inventors. The purpose of this statistic is to detect major changes in the inventor populations and to relate those to technical and economic developments. Figure 1 depicts the inventor frequency by priority year of first patent filing at the EPO, yielding a statistic of entry (rather than the stock of inventors). Only the trends of the main countries of inventor location are shown: Canada (CA), France (FR), Germany (DE), Italy (IT), Japan (JP), United Kingdom (UK), United States (US), and a residual group of countries labelled "rest of world" (ROW). We can notice two general trends during the two decades depicted. During the 1980s the entry of new inventors in the EPO dataset has grown in all the countries with an almost constant rate. On the one hand this can be associated with the increasing adoption by the business applicant of the EPO system to

[3] Obviously, this approach invokes several caveats. For example, we assume implicitly that there is no migration of inventors within a given priority year from one applicant to another. We will address potential concerns in a more detailed description in the course of this research project.

obtain protection for their inventions in Europe. On the other hand, we can see from more detailed tabulations that the overall growing trend has followed evenly the national industrial specializations with no specific technological areas prevailing over the others.

Figure 1. Inventor Entry Counts by Country of Location and Priority Year of First Recorded Application - Overall EPO Dataset (Business Applicants)



Notes: Only data for the main countries of inventor location are shown: Canada (CA), France (FR), Germany (DE), Italy (IT), Japan (JP), United Kingdom (UK), United States (US), and a residual group (ROW).

An exception to this trend during the decade is Japan which shows an acceleration of entry of new inventors in the mid-1980s. The fast growth of inventors could be associated with the so-called the "Japanese Miracle" after the oil crisis in the 1970s when many Japanese firms outperformed the US companies in the manufacturing industry. Moreover, the 1980s witnessed the fast diffusion of robotics for cost reduction in manufacturing as a response to the energy crisis. Indeed, in this technological area the Japanese firms played a leading role at the worldwide level.[4]

[4] This interpretation requires further validation. Previous studies have shown that the name translation from the Japanese language has been affected by errors. These could generate modifications in the names of identical inventors and thus lead to over-counting of inventors.

Secondly, after 1995 we can notice clearly an acceleration of inventor entry in all countries, and in particular in the US. This fast growth may be directly associated with the increase of patenting following several pro-patent reforms in many developed and developing economies during the 1990s. Some these reforms include: the introduction of the CAFC in the US; the extension of patenting to new subject areas such as biotechnology, software, business methods at the USPTO which in turn influenced directly or indirectly filings at the EPO and the introduction of the TRIPS agreements.

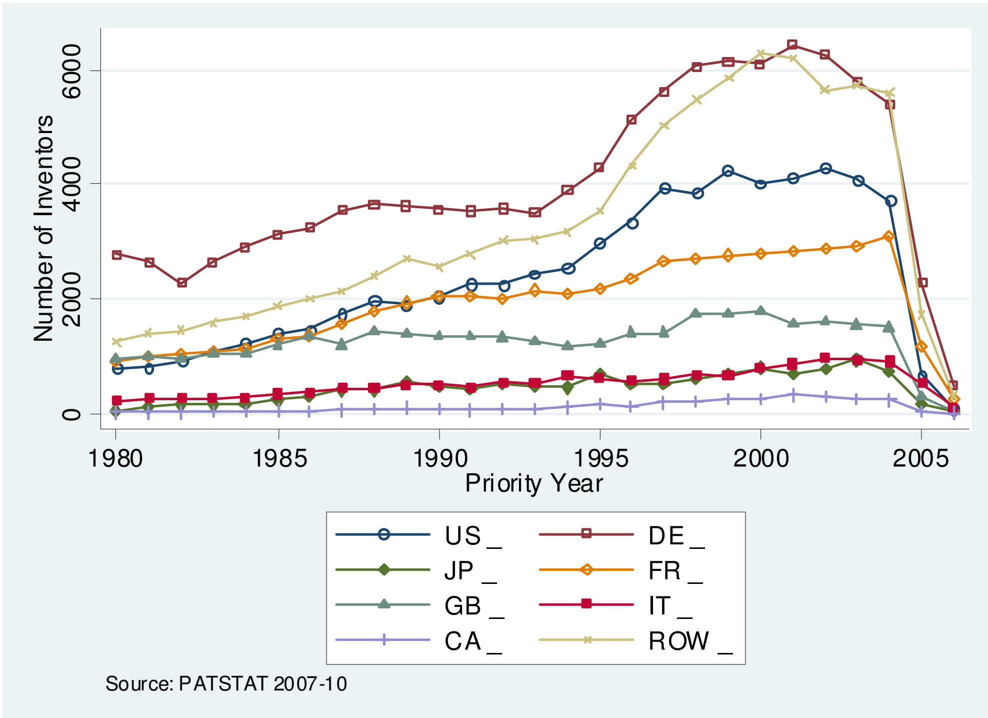
While some of these effects may simply have added to patent filings, the rise in inventors suggests that more individuals participated in the production of patents. This is in line with evidence that the national R&D expenditures grew strongly in some countries after the mid-1990s, again most notably in the USA. Another positive factor influencing the entry of new inventors after 1995 has been the advent and fast growth of the so-called internet economy that required significant inventive effort both on the hardware and software technologies – including computing, memories, telecommunication, remote management, and new business models conveyed through the Internet. This phenomenon has been particular marked in the US context and may have reinforced the effects from the mentioned pro-patenting reforms.[5]

It is worth to mention the presence of a significant truncation lag after year 2004. This censoring problem is directly generated by the 18 months publication rule in the EPO. Indeed, our source of patent data is PATSTAT published in October 2007 which includes only patents published by the end of 2006.

Figure 2 reports inventor entry counts by entry year for the 2,157 top EU R&D performers in our sample. Again, the two general time-related trends discussed in the above can be documented for this subgroup of applicants and inventors. Moreover, a comparison of Figure 2 with the Figure 1 implies that the top EU firms are responsible for about 25 % of inventor entry in the USA. Note that this statistic takes into the account both the direct employment of the US-located inventors by the top EU R&D performers as well as the indirect involvement of US-located inventors via US subsidiaries of EU firms. Figure 2 shows that R&D location choices by EU firms are important, and that these decisions have favoured the USA in the past. Clearly, this result requires further investigation in order to understand which countries and which technological areas are mostly involved in these movements.

[5] We will explore these issues in more detail at a later stage of the project.

Figure 2. Inventor Entry Counts by Country of Location and Priority Year of First Recorded Application - Top EU R&D Performers



4.2 Regional Concentration

Figure 3 depicts the total number of patents and inventors by country for one particular year (1995). Overall, the country with the highest number of inventors named on EPO patent filings is the USA. The USA has hosted about 31% of the inventors named in the EPO system during the period 1991-1996, but less than 29% after year 2000. Only in the time period 1986-1990 was the US second in rank, with Japan assuming the first position. In turn, Japan has been second to the USA in the other periods. These two countries are followed by Germany, France, and the United Kingdom.

The geographical concentration of the inventors by country of residence is depicted in Figure 4. In particular we have analyzed the geographical concentration of the location of inventors being active in four distinct periods of five years starting in 1986. For simplicity only the top 20 location countries are considered. We can notice that the geographical concentration has decreased over time, indicating that second-tier locations have gained in importance. This is an interesting result in its own right. During the period from 1986 to 1990 the top 5 countries hosted more than 85% of the inventors named in EP filings, whereas after year 2000 the same share had decreased to less that 80%.

Figure 3 - Distribution of inventors and application by country (priority year 1995; countries with more than 100 EPO applications)

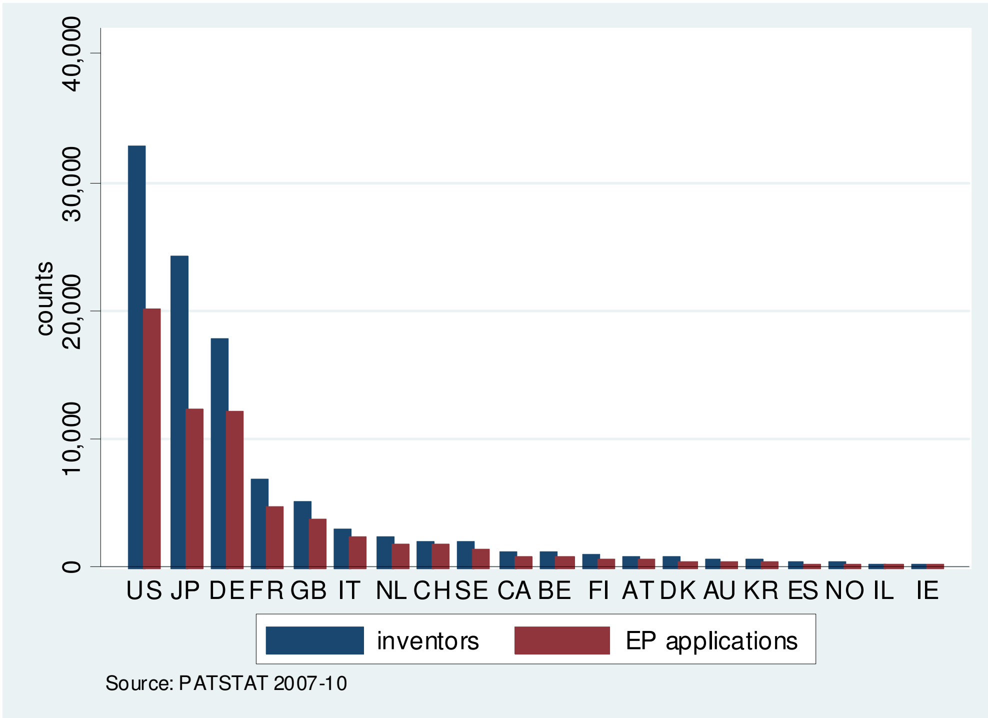


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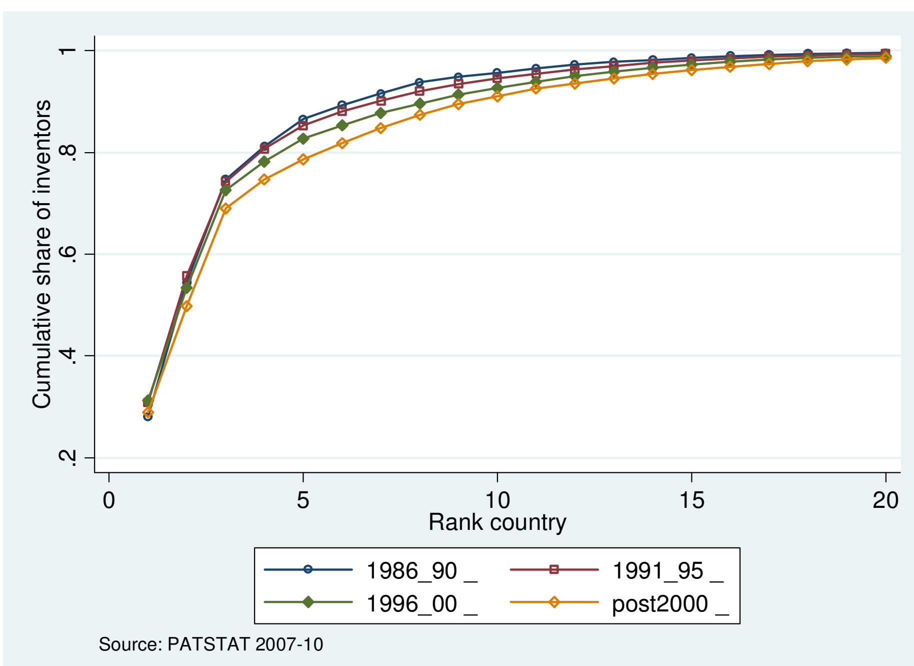
Figure 4. Geographical Concentration of Inventor Locations by Time Period



4.3 Country and Technology Trends in the Process of R&D Globalization

In this section we explore how the distribution of inventor locations has evolved over time in the overall EPO application data and in our sample of applicant firms whose ownership structures we have codified. **Table 2** shows the geographical distribution of inventor locations by country of applicant as it is recorded in the application data filed at the EPO. The applicant data used here are therefore not consolidated, and the ultimate parent of the applicant and its country may not have been identified. For example, if the German subsidiary of a US firm (e.g., IBM) files European patents, this applicant would be coded as German.

[Table 2 about here]

First, we can notice that there is considerable variation in terms of the extent to which inventive activity is located in a foreign country. For example, even as early as between 1986 and 1990, applicants in Switzerland and Netherlands had located more than 40% of their inventors in foreign countries. Conversely, even after 2000 Japanese applicants had concentrated more than 95 % of their inventors in their home country .

Second, there is a clear tendency towards internationalization of R&D activities over time. For example within two decades the share of domestic inventors has decreased from 89.6 to 82.9 for US firms, 89.8 to 85.5 in Germany, 81.5 to 76.9 in United Kingdom, and 88.0 to 78.6 in France. The evidence documented in Table 1 is therefore consistent with the view that the globalisation of R&D activities is increasing over time.

Third, we can notice that the USA has gained most strongly in this process, followed by Germany and the United Kingdom. Comparing the period 1996-2000 to the first time period (1986-1990), the countries that have directed more inventors toward the USA are Canada (17.7% vs. 9.9%), Switzerland (14.1% vs. 11.1%), Netherlands (11.1% vs. 8.6%) and the United Kingdom (10.1% vs. 7.4%).

For a number of reasons, these estimates are likely to underreport the true extent of globalization. Much larger measures of R&D internationalization can be expected once the identity of the parent companies is taken into account. To do so, we have followed the principle of allocating firms in our applicant sample to the country where the owner with the dominant ownership share resides. **Table 3** reports the geographical distribution of inventors by the country of the top R&D performing applicants in the EU. The results confirm many of the previous findings. First, the Swiss and Dutch firms are the most globalized in terms of the location of their inventors. A more differentiated picture emerges for the time trend – the share of non-domestic inventors has been almost stable for applicants from CH, DE and FR, while inventive activities have become more global over time for UK applicants. This finding is somewhat surprising and suggests that raw patent data can lead to overly pronounced globalization patterns which are confounded by ownership issues. Third, the USA has attracted large part of the inventive activities in our sample, followed distantly by Germany and France. Unfortunately, as of yet we cannot identify in our data if this is due to acquisitions, mergers or the establishment of new subsidiary activities.

[Table 3 about here]

Table 4 attempts to provide a dynamic view of the development in various technological areas. For simplicity, we have reported the one digit aggregated technological areas (see OST (2006) for more details).

[Table 4 about here]

For (1) Electrical and Electronic technologies we can notice a very fast process of locating inventive activities outside the domestic borders of Germany, France, Sweden, Switzerland, the UK and US. In the same countries a similar trend, though less marked can be encountered also for (2) Instruments and (5) Process Engineering. In (3) Chemicals and (4) Pharmaceuticals the share of foreign inventors has been relatively high compared to the other technological areas. Moreover, this share has been increasing visibly in France, Sweden, Switzerland, UK, and US. It also appears that areas in which the respective countries may have some comparative advantage (e.g., mechanical engineering in Germany and Japan) show relatively low tendencies to locate inventors in other countries.

5 Econometric Analysis

In this section we discuss the results of the multivariate econometric model. We start by showing the descriptive statistics of the variables used in the econometric analysis (see Table 5). We then present estimates from various econometric specifications.

5.1 Accounting for R&D and Inventors

In the following we propose a simple accounting model linking the R&D investments of the firms and domestic and foreign R&D employment of the firm. In line with the Frascati Manual definitions, we assume that R&D expenditures R_{it} of a firm i in year t can consist of labor costs L_{it}, expenditures for materials M_{it} and capital investment C_{it}. From the survey data collected in OECD countries, it is well know that R&D labor costs account for roughly 60 percent of overall R&D budgets. Materials make up roughly 30 percent, and capital goods approximately one tenth of R&D expenditures.[6] The exact composition differs by industry, technology and possibly other factors, but appears to be relatively stable over time.

Hence our initial accounting equation is given by:

$$R_{it} = L_{it} + M_{it} + C_{it} \quad (1)$$

We proceed by setting labor expenditures equal to the wages incurred in the various countries in which the firm is active. We assume that there are k countries in which firms are actively pursuing inventions:

$$L_{it} = \left(\sum_{k=1}^{K} W_{ikt} I_{ikt} \right) \quad (2)$$

We model total R&D expenditures R_{it} of firm i in year t then in the following simple accounting manner:

$$R_{it} = \left(\sum_{k=1}^{K} W_{ikt} I_{ikt} \right) \cdot m_{it} \cdot c_{it} \quad (3)$$

where the materials and capital components are modelled as time- and firm-specific mark-ups m_{it} and c_{it}. Taking the logarithm of equation (3) we have the expression:

$$\log R_{it} = r_{it} = \log\left(\sum_{k=1}^{K} W_{ikt} I_{ikt} \right) + \log m_{it} + \log c_{it} \quad (4)$$

We do not observe inventor wages in our data, but (4) can in principle be estimated as a nonlinear equation in which wages are treated as unknown coefficients. To simplify (4) further, we assume that the time trends are homogeneous across countries and that wage levels are the same across firms within a given country. Let $W_{ikt}=W_{0k}*f(t)$ where $f(t)$ is a time-

[6] In Germany, the 2007 data indicate a composition of 61%, 31% and 8% for labor, materials and capital investments respectively. Cf. http://www.stifterverband.org/statistik_und_analysen/publikationen/fue_datenreport/fue_datenreport_2008.pdf (last download May 16, 2009).

dependent markup describing the wage behaviour across countries. Then we can estimate for each country a base wage W_{0k} while the time development would be subsumed in time dummy variables. The base wage may also be industry-specific if we assume a multiplicative form as for the time impact.

Our nonlinear regression equation is then given by

$$\log R_{it} = \alpha + \log\left(\sum_{k=1}^{K} \beta_k I_{ikt}\right) + \sum_{j=1}^{J} \delta_j D_j + \sum_{t=1}^{T} \gamma_t D_t + \gamma \log P_{jt} + \lambda \log A_{it} + \varepsilon_{it} \qquad (5)$$

where the D_j dummies reflect industries, and the time effects are contained in the D_t variables. The error term is supposed to satisfy the usual i.i.d. assumptions. As an instrument for diverging personnel intensities across industries, we also include the total number of patents P_{jt} at the three-digit level and the firm's age A_{it} in the regression. It is important to note that equation (5) would not be identified if we treat the β parameters in the logarithmic function as coefficients of the regression. One of the coefficients needs to be set to an arbitrary level in order to identify the other coefficients up to scale.

An approximation to equation (5) would be to estimate the linear equation

$$\log R_{it} = \alpha + \beta_0 \log I_{it} + \sum_{k=1}^{K} \beta_k \left(\frac{I_{ikt}}{I_{it}}\right) + \sum_{j=1}^{J} \delta_j D_j + \sum_{t=1}^{T} \gamma_t D_t + \gamma \log P_{jt} + \lambda \log A_{it} + \varepsilon_{it} \qquad (6)$$

using the logarithm of the total number of inventors and country shares as a approximation to the non-linear term in equation (5). A particularly simple variant of (6) would be to aggregate all non-domestic inventors in one pooled share variable.

If we can estimate the above equations with reasonable precision, then the estimated coefficients would allow us to derive the total R&D expenditures of a firm (or country) from inventor count data. More importantly, we can estimate the R&D expenditures in the respective countries in which a firm is active and thus generate information about the extent to which the firm (or country) has internationalized its R&D activities and about the distribution of those R&D activities.

5.2 Descriptive Statistics

The firm sample is constituted by 957 firms and allows us to use an unbalanced panel with 5514 observations (from 1 to 15 years per firm over the period 1991-2005). For these firms we have complete information contemporaneously regarding annual sales, R&D expenditures, inventor counts and year of founding.

As we can notice from **Table 5** the firms in the sample are large and relatively old, with median sales of 630.5 million euro and median year of incorporation equal to 1971. The median ratio of R&D expenditure to sales is about 3.6%, whereas the mean is about 200%. This strong skewness of the R&D to sales ratio is caused by a few observations of younger firms having very low sales.

[Table 5 about here]

The patent counts at the three digits sector level are based on the work of Thoma et al. (2008). They have elaborated these counts by matching about 70% of European patent holders at the EPO to business information directories. The average number of EPO patents at the sectoral level is about 766.5 and the median about 459 patents.

Table 5 also reports some statistics on the inventor annual count and stocks according to their geographical location that is the home country vis-à-vis other foreign countries. We can notice that the average firms has employed about 36 inventors in the home country, whereas there a few more on average in the foreign countries. Indeed, the ratio of the number of inventors abroad to domestic inventors is about two.

A first analysis of the relationship between R&D expenditures and the number of inventors is contained in **Table 6** which lists Pearson product-moment correlations for levels and growth rates.

[Table 6 about here]

The correlation coefficients in levels range between 0.570 and 0.722 in levels of uncorrected annual inventor counts. Using three-year or five-year moving averages leads to a substantial increase in the correlation – for five-year moving averages, the correlation between inventor counts and R&D ranges between 0.660 and 0.757. Growth rates are also correlated rather strongly, but as expected less so than levels. Here the correlation coefficients range between 0.191 and 0.607 for uncorrected annual inventor counts, and between 0.408 and 0.707 for the five-year moving averages. These results are promising – they suggest that there is a strong bivariate relationship between the number of active inventors and overall R&D expenditures.

In the following sections we explore if the information on inventor location can be utilized to gain further insights into this relationship.

5.3 Basic Estimates

We first present estimates of equation (6) with the logarithm of the total number of inventors and the regional shares of inventors as the main variables. **Table 7** reports the results from these regressions. The LHS variable is R&D expenditures in deflated prices with price levels of year 2000. Other variables are annual patents at the 3 digit sector level and various controls such as year of incorporation, and sector and time dummies. All non-binary variables are in logs.

As we can notice inventor counts have considerable explanatory power in these regressions. When we experiment with different count measures, we find that the moving averages perform much better than the simple inventor count variable computed on an annual basis.[7] Moreover, patents at the sector level are positively associated with R&D investments after controlling for the number of inventors. The overall goodness of the model as measured by the adjusted R-squared is between 0.54 for the simple counts and 0.59 for the five-year moving averages.

[Table 7 about here]

The coefficients of the share variables suggest that inventive activities in the Far East and in the US and Canada are particularly "expensive" to the firms in our sample. This is an expected result. In terms of the elasticity of R&D w.r.t. the number of inventors, doubling the total number of inventors leads to a 75 percent increase in total R&D expenditures.

5.4 Non-linear Estimation

We used the TSP International Econometric Toolbox (TSP, 2005) in order to estimate equation (5) directly. The estimation of equation (5) requires the assumption of at least one restriction on the wage coefficients, since its specification is in absolute terms. In particular we set one coefficient equal to unity. The results are reported in **Table 8**. for a set of aggregated inventor locations and in **Table 9** for a more detailed one.

[7] We also computed inventor stock variables with different forms of "depreciation".It is worth to mention that the size of the domestic inventor counts coefficients and of R-squared ratio are larger for the stocks than the flows. This finding is not surprising and typically it might suggest some lags in the inventive process by an inventor since his employment in a firm. We need to investigate this effect further.

[Table 8 about here]

As we can notice, Table 8 confirms the findings documented in Table 7. Indeed the sign and the relative size of the coefficients across the geographical contexts, their statistical significance, and the adjusted R-squared are very similar across Table 7 and Table 8. Moreover, the relatively high R-squared values attests to the high correlation of inventor counts to the (consolidated) R&D expenditures at the firm level.

Moreover, Table 8 support the previous finding that activities in the US and Canada are particularly "expensive" to the firms in our sample, but not that in the Far East, though the coefficients of the latter countries are close to the unity. Model 5 and 6 suggest that the average labour cost per inventor in not EU15 countries and excluding Norway, Switzerland and Island is about half of the costs in EU15 countries, which is consistent with the distribution of the income pro-capita.

We can notice large coefficients for residual group of countries which represent only about 3% of the overall inventor workforce of the firms in our sample. A potential speculation is that the choice of a firm to locate their R&D activities in the residual group of countries could be corresponded by idiosyncratic economic rationales not associated with lower unitary labour costs. However, this speculation requires further investigation.

[Table 9 about here]

The estimation of the equation (5) for a more disaggregated set countries shows a high variability if the size of the coefficients across the three different inventor counts. While coefficients of yearly inventor counts are below the unity, those of five years moving average counts are mostly bigger than one. [discussion to be concluded].

6 Concluding Remarks

In this paper, we have reported first results of a new measurement approach seeking to relate total R&D expenditures to inventor count variables. Our ultimate objective is to obtain robust relationships between the number of inventors and R&D expenditures. While some previous studies have used inventor location data in order to measure regional spillovers or even the distribution of inventor for narrowly defined technical fields, we are not aware of any systematic and large-scale attempt to generate estimates of the distribution and size of the inventive workforce of corporations or countries. We hope that further steps towards this objective may help to trace the globalization of R&D systematically, and that the estimates described here will be helpful in analyzing the impact of globalization, for example on the impact of R&D on profitability and productivity.

Given the limitations of our data – we only observe highly selected patents at the EPO – the results are definitely encouraging. We find that there is a strong relationship between our inventor measures and R&D expenditures. Moreover, the time trends that we find using our measure of R&D globalization allow us to derive interesting implications for R&D and innovation policies. The relationship between R&D and inventors is stable. However, our exercise would profit considerably from having access to reliable wage data for inventors. The regional distribution of inventors matters, with some locations (Far East, US, Canada) adding considerably to R&D expenditures. This effect is expected since firms presumably undertake sourcing of R&D in foreign locations in order to tap into valuable knowledge pools which are not available at the home location.

Future work will use a more comprehensive set of patents and inventors, including filings in the USPTO and PCT systems, to detect changes in the international distribution of inventive activity within and across firms. Moreover, we hope that our data will allow us to cast more light on the extent of international knowledge flows within MNEs. Since these have not been measured satisfactorily in the past, there is an open question how estimates of international R&D spillovers will fare once the within-MNE flows are accounted for.

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Table 2 - Distribution of Inventors by Applicant and Inventor Country

Overall EPO Dataset - Business Applicants - Row Percent

Priority Years 1986-1990

Applicant country	*CA*	*CH*	*DE*	*ES*	*FR*	*GB*	*IT*	*JP*	*KR*	*NL*	*ROW*	*SE*	*US*
CA	78.4	0.1	0.4	.	0.6	8.3	0.1	0.6	.	0.1	1.3	0.1	9.9
CH	0.3	59.8	12.2	0.1	3.4	3.3	1.6	0.9	0.0	0.9	4.9	1.4	11.1
DE	0.1	0.9	89.8	0.1	0.7	0.8	0.2	0.5	0.0	0.5	3.0	0.2	3.1
ES	.	0.1	4.1	87.9	1.7	3.4	0.7	0.5	.	0.3	0.5	.	0.8
FR	0.1	0.3	2.1	0.1	88.0	1.4	0.5	1.4	.	0.2	1.2	0.1	4.5
GB	0.5	0.3	3.0	0.1	1.2	81.5	0.4	1.0	0.0	2.2	2.3	0.2	7.4
IT	0.0	0.7	0.8	0.1	0.8	0.5	94.5	0.1	.	0.5	0.6	0.1	1.3
JP	0.0	0.1	0.2	0.0	0.1	0.2	0.0	98.4	0.0	0.0	0.2	0.0	0.8
KR	.	.	.	.	.	1.0	.	0.7	85.8	.	1.7	.	10.8
NL	0.3	0.6	11.9	0.2	6.6	9.9	0.8	1.1	.	56.3	3.4	0.4	8.6
ROW	0.1	0.7	3.9	0.1	2.5	2.0	0.2	33.2	0.0	9.2	38.7	0.6	8.9
SE	0.1	0.5	1.4	0.0	0.7	2.0	0.3	0.7	.	0.7	4.4	84.7	4.4
US	0.9	0.4	1.7	0.1	1.0	2.3	0.3	1.5	0.0	0.7	1.6	0.1	89.6

Priority Years 1991-1995

Applicant country	*CA*	*CH*	*DE*	*ES*	*FR*	*GB*	*IT*	*JP*	*KR*	*NL*	*ROW*	*SE*	*US*
CA	74.3	0.1	0.6	0.1	1.2	6.5	0.1	0.5	0.0	0.3	2.1	0.3	13.8
CH	0.3	54.7	12.8	0.2	4.2	2.7	2.1	1.8	0.0	1.2	5.3	1.9	12.7
DE	0.1	0.9	88.8	0.3	1.0	1.0	0.4	0.8	0.0	0.6	2.6	0.2	3.2
ES	0.1	0.1	2.4	86.4	1.7	3.8	0.5	0.7	.	0.3	1.9	0.1	2.0
FR	0.1	0.6	3.2	0.5	84.1	1.3	0.8	1.7	0.0	0.3	2.1	0.1	5.1
GB	0.4	0.4	2.8	0.1	1.4	77.0	0.5	0.5	0.1	2.8	3.4	0.5	10.3
IT	0.0	0.5	1.5	0.1	0.8	0.5	92.7	0.3	0.0	0.1	1.1	0.2	2.1
JP	0.1	0.0	0.3	0.0	0.1	0.3	0.0	97.1	0.0	0.0	0.4	0.0	1.7
KR	0.2	.	0.2	.	.	0.2	.	0.5	92.0	0.2	1.7	.	5.1
NL	0.2	0.5	10.3	0.3	4.5	8.4	2.4	1.5	0.0	54.6	5.5	0.5	11.1
ROW	0.2	1.0	4.0	0.1	2.1	2.3	0.6	28.3	0.1	6.2	42.9	0.5	11.7
SE	0.6	0.3	3.0	0.2	0.9	4.0	0.5	0.2	0.1	2.7	5.5	77.3	4.8
US	0.9	0.4	2.0	0.1	1.1	2.8	0.5	1.9	0.1	0.6	2.5	0.2	86.9

Priority Years 1996-2000

Applicant country	*CA*	*CH*	*DE*	*ES*	*FR*	*GB*	*IT*	*JP*	*KR*	*NL*	*ROW*	*SE*	*US*
CA	69.6	0.3	1.5	0.0	1.7	5.1	0.2	0.6	0.0	0.6	2.5	0.2	17.7
CH	0.8	47.6	15.0	0.4	5.4	3.1	2.4	1.8	0.0	1.0	6.2	2.2	14.1
DE	0.2	1.0	86.1	0.3	1.3	1.2	0.5	0.7	0.0	1.0	3.6	0.4	3.8
ES	0.1	.	1.0	91.4	2.0	0.6	0.5	0.4	.	0.6	2.2	0.1	1.1
FR	0.3	0.6	4.3	0.6	81.6	1.4	1.1	0.8	0.1	0.5	3.3	0.2	5.3
GB	0.6	0.5	2.7	0.3	1.8	75.1	0.8	0.7	0.1	2.3	4.5	0.6	10.1
IT	0.1	0.6	2.0	0.3	1.4	0.6	90.9	0.2	.	0.2	1.4	0.1	2.2
JP	0.1	0.0	0.4	0.0	0.2	0.4	0.1	96.1	0.1	0.1	0.4	0.0	2.2
KR	0.2	0.0	0.6	0.4	0.3	0.5	0.1	1.7	87.5	0.0	3.7	.	5.0
NL	0.2	0.9	8.3	0.2	4.0	6.2	1.2	1.0	0.0	60.9	4.6	1.3	11.1
ROW	0.4	0.9	4.9	0.2	2.7	2.7	0.7	15.2	0.1	10.0	52.0	1.0	9.1
SE	1.2	0.4	4.4	0.4	1.5	5.3	0.7	0.6	0.0	2.7	6.6	70.4	5.9
US	1.1	0.4	2.7	0.2	1.4	3.4	0.7	1.5	0.1	0.7	3.5	0.3	83.9

Priority Years 2001-2006

Applicant country	*CA*	*CH*	*DE*	*ES*	*FR*	*GB*	*IT*	*JP*	*KR*	*NL*	*ROW*	*SE*	*US*
CA	78.2	0.5	1.3	0.1	1.6	2.6	0.1	0.3	0.0	0.3	2.3	0.1	12.6
CH	0.6	43.8	14.8	0.3	6.9	3.6	2.1	1.3	0.0	1.1	6.5	1.8	17.2
DE	0.3	1.0	85.5	0.5	1.5	1.0	0.6	0.8	0.1	1.0	3.9	0.3	3.7
ES	0.1	0.1	1.3	92.0	1.7	0.6	0.9	0.1	0.0	0.5	1.1	0.1	1.5
FR	1.1	0.5	4.2	0.6	78.6	1.2	1.4	1.0	0.0	0.5	4.5	0.1	6.4
GB	0.5	0.8	2.2	0.6	1.6	76.9	1.2	1.0	0.1	2.5	5.1	0.4	7.2
IT	0.0	0.4	1.4	0.3	1.1	0.5	92.8	0.2	0.0	0.2	1.3	0.0	1.7
JP	0.1	0.0	0.6	0.0	0.2	0.4	0.1	95.9	0.1	0.1	0.5	0.0	2.1
KR	0.1	0.0	0.4	0.0	0.2	0.3	0.2	1.6	92.3	0.0	2.6	0.0	2.2
NL	0.2	0.7	10.1	0.2	5.8	7.6	0.8	1.4	0.0	54.7	5.6	0.9	11.9
ROW	0.5	1.0	5.9	0.2	3.2	3.2	1.0	4.2	0.1	9.0	61.1	1.0	9.7
SE	1.3	0.6	6.1	0.7	2.0	5.6	1.8	0.7	0.3	1.8	5.6	66.6	7.0
US	1.3	0.4	3.0	0.2	1.6	3.0	0.8	1.2	0.2	0.7	4.4	0.4	82.9

Table 3 - Distribution of Inventors by Applicant and Inventor Country

Top EU R&D Performers - Row Percent

Applicant country	*CA*	*CH*	*DE*	*ES*	*FR*	*GB*	*IT*	*JP*	*KR*	*NL*	*ROW*	*SE*	*US*
							1986-1990						
CH	0.4	31.8	28.8	0.1	4.0	4.5	1.3	1.7	0.0	0.8	3.9	1.4	21.3
DE	0.2	0.8	72.0	0.2	4.4	2.3	1.1	2.6	0.0	0.9	4.0	0.5	11.1
FR	1.2	0.7	19.3	0.4	48.5	5.5	2.1	2.8	0.0	0.8	4.9	0.4	13.4
GB	0.6	0.4	12.2	0.1	6.4	44.1	0.8	4.6	0.0	4.7	2.7	0.8	22.5
IT	0.1	0.6	10.7	0.1	5.7	12.2	58.6	0.1	.	0.2	4.9	0.1	6.7
NL	0.2	0.9	42.2	0.1	6.2	7.3	2.4	3.8	0.0	25.2	2.8	1.0	7.9
other EU	0.2	1.1	9.9	0.4	9.1	5.6	2.5	1.8	.	3.8	51.4	5.0	9.3
SE	0.2	7.7	16.4	0.1	4.9	5.5	3.4	0.6	.	1.7	7.6	43.0	9.1
							1991-1995						
Applicant country	*CA*	*CH*	*DE*	*ES*	*FR*	*GB*	*IT*	*JP*	*KR*	*NL*	*ROW*	*SE*	*US*
CH	0.4	28.8	25.6	0.4	4.7	3.7	2.1	1.7	0.1	1.1	5.0	1.7	24.7
DE	0.4	1.2	64.7	0.5	4.4	2.3	1.4	3.3	0.2	1.0	5.3	0.4	14.7
FR	1.1	0.9	17.9	1.0	49.0	3.9	1.9	2.5	0.4	0.9	4.4	0.5	15.6
GB	1.0	0.7	11.9	0.2	9.0	36.4	1.3	5.4	0.0	4.2	4.5	1.0	24.4
IT	0.2	0.4	10.4	0.3	7.9	7.7	59.5	0.4	0.1	0.2	5.0	0.4	7.3
NL	0.2	1.6	40.3	0.1	6.8	7.1	3.6	2.8	0.0	21.6	3.6	1.4	10.7
other EU	0.3	1.1	11.7	0.1	9.7	5.0	2.7	1.5	0.2	2.7	50.5	3.8	10.7
SE	0.6	5.7	18.0	0.1	3.3	5.8	2.5	0.8	0.3	2.1	6.3	42.8	11.8
							1996-2000						
Applicant country	*CA*	*CH*	*DE*	*ES*	*FR*	*GB*	*IT*	*JP*	*KR*	*NL*	*ROW*	*SE*	*US*
CH	0.6	27.2	24.7	0.3	4.9	3.4	3.0	1.9	0.1	0.8	6.9	1.5	24.5
DE	0.6	1.3	67.3	0.6	3.4	2.1	1.2	2.6	0.3	1.2	4.8	0.4	14.2
FR	1.3	0.7	15.9	0.8	47.8	3.0	1.4	3.1	0.5	1.1	4.8	0.7	19.0
GB	1.4	2.0	11.4	0.4	9.9	32.1	1.2	5.0	0.1	3.5	5.0	1.0	27.0
IT	0.6	1.2	12.4	0.4	8.5	5.5	52.5	0.3	.	0.8	6.5	0.5	10.8
NL	0.3	1.2	37.7	0.3	7.2	5.1	4.2	1.4	0.0	25.0	4.7	1.4	11.4
other EU	0.5	1.1	9.8	0.4	6.6	5.2	2.4	0.9	0.2	2.5	52.9	4.0	13.6
SE	1.2	3.1	16.5	0.4	3.7	6.5	2.2	1.3	0.0	1.9	9.9	41.9	11.4
							2001-2006						
Applicant country	*CA*	*CH*	*DE*	*ES*	*FR*	*GB*	*IT*	*JP*	*KR*	*NL*	*ROW*	*SE*	*US*
CH	0.6	27.3	21.1	0.3	5.6	3.9	2.9	1.7	0.1	0.9	8.2	1.1	26.2
DE	0.6	1.1	69.2	0.9	3.3	1.5	1.6	2.6	0.2	0.9	5.0	0.4	12.8
FR	2.0	0.8	14.0	0.9	48.7	2.6	1.6	4.6	0.6	0.9	4.9	0.5	17.9
GB	1.4	2.7	11.3	0.5	11.3	27.4	1.7	5.1	0.0	3.6	6.8	0.7	27.5
IT	0.3	0.5	9.7	1.1	8.0	3.3	58.3	0.5	.	0.7	7.4	0.9	9.1
NL	0.1	1.2	35.2	0.6	8.9	5.8	5.4	1.6	0.3	24.1	6.0	0.8	9.9
other EU	0.7	0.9	9.1	0.5	5.2	4.5	3.0	1.4	0.2	2.2	55.1	3.1	14.2
SE	1.2	4.0	17.9	0.8	3.3	6.6	3.7	1.5	0.1	2.0	9.3	38.9	10.9

Table 4 - Share of Foreign Inventors by Technological Class and Applicant Country

Overall EPO Dataset - Business Applicants

year	*CA*	*CH*	*DE*	*ES*	*FR*	*GB*	*IT*	*JP*	*KR*	*NL*	*ROW*	*SE*	*US*
1 Electricity - Electronics													
1986-1990	28.4	24.7	8.2	6.2	9.2	11.0	5.2	1.6	21.8	41.0	88.9	11.0	9.4
1991-1995	30.3	31.3	8.6	1.6	17.4	13.4	6.9	3.4	11.4	43.8	82.8	24.4	12.4
1996-2000	38.0	42.1	14.0	4.0	25.0	16.2	8.6	4.9	11.7	28.9	69.1	32.0	15.1
2001-2005	22.8	47.5	15.2	4.1	32.9	18.5	7.2	5.2	7.9	45.3	54.2	39.2	16.2
2 Instruments													
1986-1990	19.6	34.6	8.3	10.7	9.6	10.6	7.7	1.0	22.2	45.0	72.3	15.8	8.1
1991-1995	26.3	39.6	9.7	8.2	12.7	14.1	9.7	1.7	9.1	41.3	63.4	17.0	10.4
1996-2000	25.0	44.0	10.7	5.8	15.8	16.6	10.9	2.7	7.7	36.7	50.9	20.0	12.4
2001-2005	16.6	52.3	11.2	8.4	16.0	13.7	6.4	2.7	7.2	43.9	43.3	20.9	13.1
3 Chemicals													
1986-1990	23.6	46.5	10.9	8.1	15.5	23.9	5.8	1.5	2.2	52.9	50.3	19.2	11.4
1991-1995	28.4	54.4	13.4	15.7	16.9	26.5	10.5	2.3	4.4	53.0	48.0	36.4	14.5
1996-2000	26.6	63.1	17.2	14.6	19.7	32.2	16.2	3.6	6.3	53.7	37.0	45.4	17.4
2001-2005	22.9	63.6	18.4	6.2	22.3	31.7	11.8	3.7	6.5	54.2	31.5	46.2	16.4
4 Pharmaceuticals - Biotech													
1986-1990	23.1	64.6	19.3	11.3	11.5	25.5	9.1	2.4	7.4	49.3	25.1	30.1	9.8
1991-1995	24.5	62.9	19.8	14.0	16.1	35.4	7.8	4.5	2.6	53.9	31.5	32.5	12.1
1996-2000	25.0	68.3	21.7	14.1	19.5	36.8	11.8	4.9	17.1	52.8	30.0	36.7	13.6
2001-2005	21.5	71.1	21.6	10.5	17.0	32.6	8.4	5.2	2.4	50.9	30.4	34.0	13.3
5 Process engineering													
1986-1990	19.7	33.9	6.8	17.9	9.4	14.5	2.9	0.9	18.8	32.4	41.6	12.1	10.6
1991-1995	20.3	41.1	8.1	20.5	12.0	16.7	4.4	1.6	3.9	32.0	38.4	18.1	12.0
1996-2000	23.1	49.9	10.4	6.4	12.1	20.9	5.4	1.9	9.7	33.6	34.0	19.6	14.4
2001-2005	15.8	54.7	10.2	8.7	13.7	19.5	4.0	1.7	2.1	32.0	25.5	19.0	15.3
6 Mechanical engineering													
1986-1990	17.0	27.6	7.5	22.4	13.8	20.4	4.6	1.0	25.0	25.9	38.0	8.3	7.5
1991-1995	27.6	32.3	7.4	19.7	14.3	26.2	4.6	1.9	4.1	31.6	36.3	12.4	9.5
1996-2000	27.4	39.9	7.6	5.0	9.7	16.2	5.8	1.5	4.0	22.7	28.7	17.2	14.2
2001-2005	21.2	43.4	9.0	8.8	10.9	11.4	5.5	1.9	2.1	20.0	23.2	30.6	20.2
7 Other													
1986-1990	12.8	31.4	6.6	1.1	10.1	10.4	3.6	1.0	0.0	30.4	36.7	10.7	10.0
1991-1995	15.4	30.4	7.2	3.3	11.6	14.2	5.2	2.4	0.0	34.5	34.6	11.9	11.6
1996-2000	25.2	31.6	6.8	4.9	13.3	15.9	4.3	1.9	0.0	30.6	30.4	20.3	15.1
2001-2005	21.9	36.8	8.1	3.5	12.6	15.7	5.1	2.2	2.3	39.5	30.9	18.0	16.5

Table 5 - Descriptive Statistics

(5514 useful observations, 957 firms, 18 countries, 1991-2005)

Variable	*Mean*	*S.D.*	*Min*	*Max*	*Median*
R&D expenditures (milion of current euros)	181.8	579.8	0.0	7462.6	16.6
R&D expenditures (deflated with a price index of 2000)	181.7	572.8	0.0	6954.9	16.6
Sales (milion of current euros)	5332.0	15280.0	0.0	246859.0	634.0
Sales (deflated with a price index of 2000)	5326.8	14893.6	0.0	218458.8	630.5
R&D/Sales	200.0	4682.4	0.0	270000.0	3.620
Year of Founding	1952.1	48.3	1665.0	2005.0	1971.0
Patents at 3 digit sectoral level	766.5	840.6	0.0	3555.0	459.0
Inventors at the home country	56.5	241.2	0.0	4161.0	5.00
Inventors at the home country (3 years moving average)	166.8	702.0	0.0	10757.0	16.00
Inventors at the home country (5 years moving average)	271.4	1135.5	0.0	17019.0	27.00
Inventors in the foreign countries	63.0	325.8	0.0	8572.0	5.000
Inventors in the foreign countries (3 years moving average)	186.1	954.1	0.0	24471.0	16.000
Inventors in the foreign countries (5 years moving average)	302.3	1539.5	0.0	39477.0	25.000

Table 6 - Correlation of Inventor Counts and R&D Expenditures

		log of annual counts			growth rates		
Year	N	annual	3 yrs mav	5 yrs mav	annual	3 yrs mav	5 yrs mav
1991	159	0.614	0.652	0.660	.	.	.
1992	174	0.692	0.702	0.699	0.607	0.691	0.693
1993	188	0.679	0.699	0.705	0.583	0.743	0.737
1994	217	0.722	0.745	0.757	0.551	0.632	0.684
1995	250	0.709	0.730	0.733	0.492	0.632	0.663
1996	303	0.716	0.733	0.728	0.343	0.526	0.513
1997	377	0.680	0.703	0.716	0.372	0.453	0.480
1998	426	0.690	0.718	0.727	0.319	0.432	0.453
1999	470	0.705	0.711	0.726	0.405	0.527	0.532
2000	485	0.677	0.708	0.718	0.280	0.448	0.489
2001	489	0.691	0.717	0.722	0.269	0.403	0.408
2002	540	0.703	0.715	0.723	0.396	0.542	0.584
2003	570	0.699	0.735	0.741	0.318	0.484	0.477
2004	589	0.674	0.686	0.701	0.311	0.488	0.518
2005	277	0.570	0.679	0.685	0.191	.	.
Total	**5,514**	**0.681**	**0.710**	**0.719**	**0.383**	**0.533**	**0.555**

Table 7 - Log linear Regressions - Dependent Variable: R&D
(deflated with a price index of year 2000)
(5514 useful observations, 957 firms, 18 countries, 1991-2005)

Variables	*Model 1*		*Model 2*		*Model 3*	
	yearly counts		*3 yrs moving avg*		*5 yrs moving avg*	
	coeff	*std*	*coeff*	*std*	*coeff*	*std*
Total number of inventors (log)	**0.728**	**0.012**	**0.740**	**0.011**	**0.748**	**0.011**
Share of inventors in EU 15 and Switzerland, Norway and Island	*0.521*	*0.309*	**0.868**	**0.311**	**1.021**	**0.309**
Share of inventors in Other Europe	-	-	-	-	-	-
Share of inventors in USA and Canada	**0.641**	**0.313**	**0.988**	**0.316**	**1.121**	**0.315**
Share of inventors in Far East (AU,HK,ID,JP,KR,MY,NZ,SG,TW)	**0.750**	**0.371**	**1.081**	**0.380**	**1.278**	**0.380**
Share of inventors in Other countries	0.464	0.444	**0.901**	**0.467**	**1.057**	**0.477**
Patents at 3 digit sectoral level	**0.074**	**0.016**	**0.067**	**0.016**	**0.066**	**0.016**
Year of incorporation dummies (6 periods of time)	Yes		Yes		Yes	
Sectoral dummies	Yes		Yes		Yes	
Time dummies	Yes		Yes		Yes	
Country dummies	Yes		Yes		Yes	
Constant	Yes		Yes		Yes	
Adjusted R squared	**0.543**		**0.575**		**0.588**	

Notes: All the variables are in logs; The coefficients in bold are statistically significant at 5% level, whereas those in italics at 10%

Table 8 - NLLS Regressions with Regions - Dependent Variable: R&D (deflated with a price index of year 2000)

(5514 useful observations, 957 firms, 18 countries, 1991-2005)

Variables	*Model 4*		*Model 5*		*Model 6*	
	yearly counts		*3 yrs moving avg*		*5 yrs moving avg*	
	coeff	*std*	*coeff*	*std*	*coeff*	*std*
Inventors in EU 15 and Switzerland, Norway and Island	**1.000**		**1.000**		**1.000**	
Inventors in other European countries	**0.921**	**0.402**	**0.528**	**0.184**	**0.481**	**0.175**
Inventors in USA and Canada	**1.127**	**0.101**	**1.150**	**0.104**	**1.165**	**0.108**
Inventors in Far East (AU,HK,ID,JP,KR,MY,NZ,SG,TW)	**0.900**	**0.167**	**0.852**	**0.164**	**0.885**	**0.175**
Inventors in other countries	**1.217**	**0.456**	**1.442**	**0.436**	**1.449**	**0.457**
Patents at 3 digit sectoral level	**0.042**	**0.018**	0.021	0.018	0.015	0.018
Year of incorporation dummies (6 periods of time)	Yes		Yes		Yes	
Sectoral dummies	Yes		Yes		Yes	
Time dummies	Yes		Yes		Yes	
Country dummies	Yes		Yes		Yes	
Country*Time dummies	Yes		Yes		Yes	
Constant	Yes		Yes		Yes	
Adjusted R squared	**0.561**		**0.588**		**0.596**	

Notes: All the variables are in logs; The coefficients in bold are statistically significant at 5% level, whereas those in italics at 10%

Table 9 - NLLS Regressions with Disaggregated Countries - Dependent Variable: R&D (deflated with a price index of year 2000)

(5514 useful observations, 957 firms, 18 countries, 1991-2005)

	Annual flow of R&D expenditures					
Variables	*Model 7*		*Model 8*		*Model 9*	
	yearly counts		*3 yrs moving avg*		*5 yrs moving avg*	
	coeff	*std*	*coeff*	*std*	*coeff*	*std*
Inventors in Germany	***1.000***		***1.000***		***1.000***	
Inventors in Benelux	**0.658**	**0.120**	**0.882**	**0.168**	**1.071**	**0.214**
Inventors in France	**0.461**	**0.085**	**0.672**	**0.127**	**0.797**	**0.161**
Inventors in Italy	**0.739**	**0.169**	**1.010**	**0.232**	**1.260**	**0.311**
Inventors in Nordic countries (DK,FI,IS,NO,SE)	**0.318**	**0.053**	**0.572**	**0.093**	**0.812**	**0.137**
Inventors in Switzerland and Austria	**0.383**	**0.073**	**0.430**	**0.082**	**0.536**	**0.104**
Inventors in UK and Ireland	**0.561**	**0.076**	**0.999**	**0.135**	**1.495**	**0.210**
Inventors in USA and Canada	**0.678**	**0.077**	**0.986**	**0.122**	**1.302**	**0.172**
Inventors in Other countries	**0.884**	**0.233**	**1.279**	**0.342**	**1.730**	**0.481**
Inventors in Far East (AU,HK,ID,JP,KR,MY,NZ,SG,TW)	**0.547**	**0.106**	**0.701**	**0.145**	**0.918**	**0.198**
Patents at 3 digit sectoral level	**0.050**	**0.018**	0.023	0.018	0.011	0.018
Year of incorporation dummies (6 periods of time)	Yes		Yes		Yes	
Sectoral dummies	Yes		Yes		Yes	
Time dummies	Yes		Yes		Yes	
Country dummies	Yes		Yes		Yes	
Country*Time dummies	Yes		Yes		Yes	
Constant	Yes		Yes		Yes	
Adjusted R squared	**0.562**		**0.589**		**0.598**	

Notes: All the variables are in logs; The coefficients in bold are statistically significant at 5% level, whereas those in italics at 10%