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by

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June 2008

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Abstract

The average firm size of the top R&D investors among US-based companies is smaller than that of the EU-based firms. Does this help to explain why the US has a greater R&D intensity, or is the higher firm size in the EU, just as its lower R&D intensity, determined by the sectors in which the top R&D investors are operating? Using data on the top-R&D investors from the *2006 EU Industrial R&D Investment Scoreboard*, the size differential between R&D performers in the EU and US is more closely examined. A first observation is that, despite great differences between sectors, the overall distribution of companies' R&D investments in both economies is remarkably similar, as opposed to the distribution of the R&D/sales ratios of the same two sets of companies. The notion that size plays a role, independent of the sectoral composition of R&D, is then confirmed by regression analysis. In the US as well as in the EU, smaller sized Scoreboard companies tend to spend a larger proportion of their income from sales on R&D.

JEL-classification: L11, 030

Keywords: R&D intensity, firm size, panel data#

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Introduction

The Schumpeterian hypothesis that large firms have an advantage of size in undertaking R&D has been tested extensively in empirical work and until recently has remained largely unchallenged. Schumpeter believed that small firms were "incapable" of making "optimal" expenditures on R&D and that all technological change came from large firms. The notion of optimality would imply that the firms competing within the same sector on the basis of their own R&D would all be of a similar size. Differences in the size of the R&D performers between countries would be a consequence of the sectors in which they are operating and the numbers of R&D performers within the country in each sector. Acs and Audretsch (2005) have questioned this view, arguing that changes in the research and business environment have taken place which make it easier for smaller companies to succeed (Acs and Audretsch, 2005).

In this paper, we use data from the *EU Industrial R&D Investment Scoreboard* to throw some new light on the role of company size in R&D. We are looking within the group of top R&D investors to investigate whether size matters for R&D. The group consists of companies with established records of sales and R&D. There is considerable variation in the presence and ranking of companies over the years. We investigate whether size has an effect on the R&D intensity of the companies, i.e. whether R&D is proportional to sales, independent of the size of the company.

We are interested in the size distribution of companies operating in the same sector of economic activity and in the profile of the corresponding R&D intensity distributions. Companies in the same sector are likely to show more homogeneity if competition is strong. If that is the case, the differences in the overall R&D intensity of world regions may be largely attributed to differences in the sectoral composition of GDP in the regions. Otherwise, the R&D intensity is not typical for the sector and differences in the size distribution of the Scoreboard companies may explain a significant part of the differences in the overall R&D intensities.

The approach we adopt in this paper is not new. It combines inspection of size and R&D distributions with regressions of R&D intensity on company size, as first undertaken by

Cohen, Levin and Mowery (1987). The seminal work of Cohen and Klepper (1992) shows that a probabilistic process in which firm size conditions the returns to R&D and in which the decision to invest in R&D is affected by unobserved random variables can produce regularities in the R&D intensity distributions within industries. However, a crucial assumption of their analysis is that returns to R&D are conditioned by firm size. This paper is a first investigation of possible EU-US differences in this relation, using data on R&D for the companies with R&D investment surpassing a given threshold.

This paper first introduces the reader to the theoretical background and previous empirical evidence on the subject. It then presents a descriptive analysis of the R&D distribution across firms within different sectors. The results of the regression analysis are presented in the one but last section, before some tentative conclusions and possible policy implications are drawn at the end of the paper.

The relationship between firm size and innovation: theoretical background

R&D is used as a proxy for investment in knowledge assets in the literature on the relation between the size of the firm and its innovative performance. Schumpeter, who explicitly focussed on innovation as an economic activity with distinct economic causes and effects, put forward two models for analysing firm growth (Cohen and Klepper, 1996).

In the first model, technological change is a process of creative destruction. The typical innovators are expected to be small and newly established firms (Schumpeter, 1934). Small firms can be more innovative because they are less likely to be bound by tacit agreements deterring non-price competition such as product innovation. They also have greater incentives to follow a strategy of innovation in order to remain viable (Acs and Audretsch, 1988; Phillips, 1966; Van Dijk *et al*, 1997).

The second model emphasises that technological change is a process of creative accumulation (Schumpeter, 1942). The role of new innovators is limited, and a small number of firms divide the market in a stable oligopoly. Larger firms with market power are in a better position to innovate than small firms are. In Schumpeter's (1942) analysis, market power is a necessary condition for innovation. Firms should expect some form of ex-post market power, preventing imitation of the new products and processes and thereby allowing them to recoup

their R&D expenses. Large firms are in a better position to ensure legal protection which would provide enough short-run market power to create an incentive to invest in R&D. Without any protection, large firms would not be as likely to invest in innovative activities and there would be no technological change. Ex-ante market power will favour innovation, because it reduces the uncertainty undermining incentives to invest in R&D. Schumpeter believed that only large firms could induce technological change because it would be too hazardous for small firms to spend resources on R&D in such a competitive environment.

In addition, Galbraith (1952) and Kraft (1989) have argued that larger firms have a greater capacity to spread risks over a large number of R&D projects. If the probabilities of success for the different projects are uncorrelated, the risk from research and development projects decreases with the number of projects, and therefore with the *size* of the firm. It could be that small competitive firms tend to be more risk adverse, have greater difficulties in financing their projects and are unable to fully exploit the return to innovative activities.

Previous empirical evidence

Empirical studies using company data have focussed both on the relationship between size and R&D and on the relation between size and other indicators of innovativeness. Scherer (1980); Kamien and Schwartz (1982); Baldwin and Scott (1987) are useful references in this literature. There is sufficient *prima facie* evidence of the coexistence of firms of different size in the same sector, but the distributions of firm size arranged by sector show very diverse profiles. The size distributions may reflect characteristics of the market situation in which the firm are operating, but also more structural and institutional differences between the countries in which the companies are based. On the whole, the empirical evidence on the innovativeness of small companies appears to be stronger than that on their strengths rooted in R&D.

Cohen and Klepper (1996) derive some stylised facts on the relationship between firm R&D effort and firm size within industries in US-based firms.¹ First, the likelihood of reporting a positive R&D effort increases with firm size and in the largest size ranges approaches one. Second, within industries, among R&D performers, the volume of R&D rises monotonically with firm size across all firm size ranges, with firm size typically explaining well over half the intra-industry variation in R&D activity. Third, there is little evidence of economies of scale

in the use of R&D. For most industries it has not been possible to reject the null hypothesis that R&D varies proportionately with size across the entire firm size distribution.

Dosi (1988) observes some regularities in the sectoral components of R&D. There appears to be a roughly log-linear relation within industries between firm size and R&D expenditures. However, this seems to apply primarily to R&D and, subject to industry differences and different measures of innovativeness, quadratic and cubic relationships between size and innovativeness produce a better fit. The size distribution of innovating firms within sectors depends on the technological characteristics of the sector and, irrespective of the selected proxy for innovativeness – in particular, irrespective of the choice between an investment measure or an output measure –, there remains a substantial unexplained inter-firm, intra-sectoral variance, in terms of both R&D investments and innovative output after the effects of size have been accounted for.

Some authors found differences in the signs of the effects of firm size on R&D intensity between large and small firms (Scherer, 1965; Soete, 1979). The statistically significant effect of the size on business unit R&D intensity is not strong when either fixed industry effects or measured industry characteristics are taken into account (Cohen *et al.*, 1987; Sterlacchini, 1994). In some cases, a significant negative effect of the firm size was found after controlling for industry and foreign ownership. Using Canadian data, Holbrook and Squires (1996) observe that the R&D-to-sales intensity declines with increases in firm size.

Many samples contain a large number of non-R&D performers. It should not come as a surprise that business unit size does not have seemed to have any effect on R&D intensity in studies using such sample. Pavitt, Robson and Townsend (1987), found an ambiguous effect of size in some sectors, using a sample of innovative firms. They conclude that in sectors with high technological opportunities or belonging to the "science-based" group (chemicals, electrical/electronics) the innovating firms "can be found heavily represented among those that are very large and those that are small". Others even conclude that small businesses are the only source of innovation in certain industries (Acs and Audretsch, 1988, 1990; Pavitt, Robson and Townsend, 1987; Rothwell and Zegveld, 1982).

Comparisons between world regions

Dosi, Llerena and Sylos Labini (2005) have challenged the view that the difference between the innovation performance between the United States and the European Union is merely a function of R&D intensity.. They argue that Europe has structural lags in top level science and innovative performance vis-à-vis the US, together with some points of strength in physical sciences and engineering. At the same time, notwithstanding some major success stories, they see ample evidence of a widespread corporate weakness in Europe.

Aled and Iorwerth (2005) analyse the differences between Canada and the US. They conclude that the lower R&D intensity of Canada is a reflection of the differences between the regions in firm size, foreign ownership presence and industry composition.

Van Reenen (1997) explains that the slower R&D growth of Britain in comparison to other countries is due to the difference in the influence of science and knowledge intensive industries (pharmaceuticals and computer software) in the aggregate production of these economies. He also finds indications that fiscal incentives have influenced the long-run R&D growth in these countries.

On the whole, the literature suggests that the relation between size and R&D intensity is sector specific but that it may also have country-specific features.

Data sources and method of analysis

The *EU Industrial R&D Investment Scoreboard*² provides an attractive panel of recent data useful for this type of studies. The 2006 Scoreboard collects the data from the latest audited company reports and accounts that have been published up to 1 August 2005. It also encompasses data for the previous three reporting years. The 2006 Scoreboard lists 1000 companies whose registered offices are located within the EU region and the same number with registration offices outside the EU. These companies are considered to be the top R&D investors for each of their respective EU and non-EU groups³. The companies are selected from the ones listed on official stock exchanges; private and state-owned companies are included, subsidiaries of any other company are excluded to avoid double counting. Out of the 1338 companies with the largest R&D investments included in “*The 2006 R&D Investment*

Scoreboard' dataset, 587 are US companies and 338 EU companies. Table 1 presents a description of the main variables for the companies with R&D above a common threshold. We have used data on the full set of 2000 companies for running the regressions.

Between the variables used for the study, the variable of interest is the firm R&D intensity defined as the ratio of R&D³ effort over the sales of the firm. This is a widely used indicator of the innovative performance of firms, industries and regions. Sterlacchini (1994) points out that with respect to the determinants of R&D intensity a variety of economic factors can be identified but, among these factors, firm size and market concentration have played a dominant role.

In order to reflect the R&D effort, we use the firm R&D investment of the firm in the year under analysis. Additionally, a series of growth rates with respect to the preceding years have been used. The Scoreboard's calculations of R&D investment included: the R&D charged to the profit and loss account (i.e. "R&D costs") plus any capitalised R&D intangibles (i.e. "R&D investments") minus any amortisation of capitalised R&D charged to the profit and loss account.

The variable used to measure the size of the firm is the total number of employees, rather than total sales, which, as Pagano and Schivardi (2003), pointed out critically depends on the intensity of intermediate inputs. In the regressions the inclusion of this variable among the regressors introduces a measure of average productivity per firm into the equation. The definition of size classes, such as SMEs, typically relates to the same variable⁴.

In order to control how belonging to a given sector of activity affects the relationship between R&D investment and firm size, we classify the sectors in four groups: lower, medium-low, medium-high and high R&D intensive sector⁵. Alternatively, the sector dummies of the 2-digit ICB sectoral classification are included to analyse the sectoral effects⁶.

The results of the analysis are presented in two parts: the descriptive analysis and the econometric analysis. The descriptive analysis follows the approach taken by Cohen and Klepper (1992).

We will proceed to look at the differences between the sectoral contributions to the total average R&D intensity in both regions, following the finding by Van Reenen (1997) in which the changes in aggregate R&D intensity is mainly due to changes in industries' shares of national output given their differences in technological intensities. The procedure for the econometric work is a standard one. First, we develop a model where the dependent variable is R&D intensity measured by the R&D expenditures over the sales in the same year. The included explanatory variables follow the line of our hypothesis; we include the size (controlling for the size effect), the sector (inter-industry differences, technological accumulation or technological variety differences), the region (inter-regional differences) and the year dummies (controlling for time effects). Trying to capture as much information as possible, the first step in our analysis will be to include the size and sector in grouped terms (size categories and sectors groups based on the R&D intensity level). To capture the regional specificities the analysis has been run in parallel in both regions. Finally, attempts of capturing the lag effects of the innovation variables have been done by changing the dependent variable the R&D investment in year t over the sales in the year before.

Descriptive analysis

This section, as a first step of our analysis, contains a comparison of the distribution of R&D volumes, company sizes and R&D intensities of the firms in the sample. Table 1 shows that the means of the variables show some differences when we compare the different macro-regions under analysis. Our analysis will focus on the EU-US gap. The R&D expenditures, sales, number of employees and capital expenditures tend to be lower for the US-based firm comparing to the EU ones. With regards to the R&D intensity variables, measured by R&D over sales and R&D over employees, the average in the US is higher than the average R&D intensity in the EU. We investigate whether these differences are due to the size effect or the sectoral composition of output in the two macro-regions.

| Variables | ALL FIRMS | | BY REGION | | | | | | | |
|-----------|-----------|----------|-----------|----------|----------|----------|-------------|----------|---------------------|----------|
| | | | EU firms | | US firms | | JAPAN firms | | "REST of the WORLD" | |
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| R&D | 256.65 | 666.99 | 318.41 | 760.04 | 233.24 | 658.81 | 289.63 | 655.70 | 177.44 | 489.88 |
| Sales | 6816.52 | 17176.58 | 9927.25 | 22113.68 | 5068.99 | 16530.76 | 7561.22 | 13430.03 | 5700.12 | 10780.91 |
| Employees | 26459 | 52839 | 38749 | 64354 | 17498 | 39059 | 29141 | 49023 | 30827 | 69493 |
| Cap Exp | 432.59 | 1258.37 | 651.31 | 1583.18 | 237.93 | 901.18 | 497.62 | 1300.51 | 609.07 | 1461.63 |
| R&D/Sales | 0.31 | 2.27 | 0.17 | 1.51 | 0.53 | 3.14 | 0.05 | 0.04 | 0.15 | 0.81 |
| R&D/Size | 0.03 | 0.05 | 0.02 | 0.03 | 0.04 | 0.06 | 0.01 | 0.01 | 0.02 | 0.03 |
| Firms | 1338 | | 338 | | 587 | | 237 | | 176 | |
| Observs | 5162 | | 1254 | | 2322 | | 914 | | 672 | |

Table 1. Descriptive statistics⁷

We take a closer look at the distributions of the variables before performing any econometric analysis. First, we look at the distribution of total R&D investments. Figure 1 shows the distribution of R&D expenditures. It reveals a similar distribution for the whole sample and for the sub-samples of the macro-regions. The profiles illustrate the familiar pattern of a concentration of R&D investors around the median and a relatively small number of large investors.

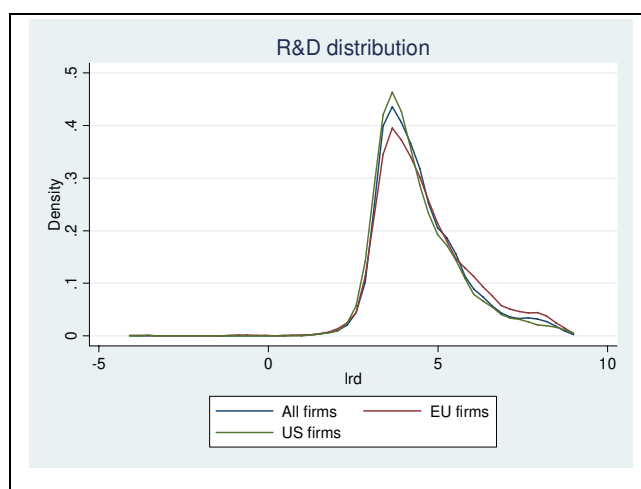
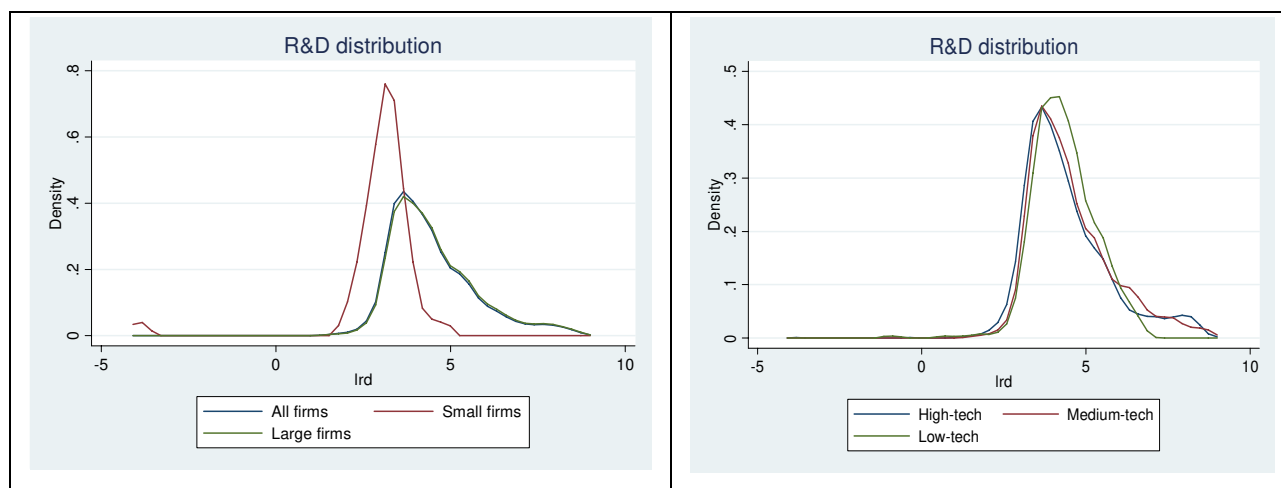


Figure 1. R&D distribution comparison between macro-regions

Figure 2 shows the comparison between the two size groups of the distribution of the R&D investment. Not surprisingly, the data show some differences between size groups. However, not only the mean but also the standard deviations of R&D investment by firm are smaller for the group of smaller firms. It is interesting to note that the distribution of the variable for the whole sample is similar to the distribution of this variable for the large firms, which reflects the limited number of small firms and their low weight in the sample small firms in the

sample. Comparing R&D intensity groups, in figure 3 we find that the R&D investment distributions of the three groups are quite similar. Only for the case of the low-tech firms, we find a greater dispersion.



Figures 2 and 3. Densities of log R&D investment between size and R&D intensity groups

Whereas R&D volumes appear to have similar distributions, there are striking differences between the size of the firms in R&D intensity groups, both in terms of number of employees and in terms of sales. Figure 4 shows that in particular high R&D intensity firms tend to be much smaller than medium to high intensity firms. The monotony is even more apparent in Figure 5, which shows the distribution of sales in the three R&D intensity groups.

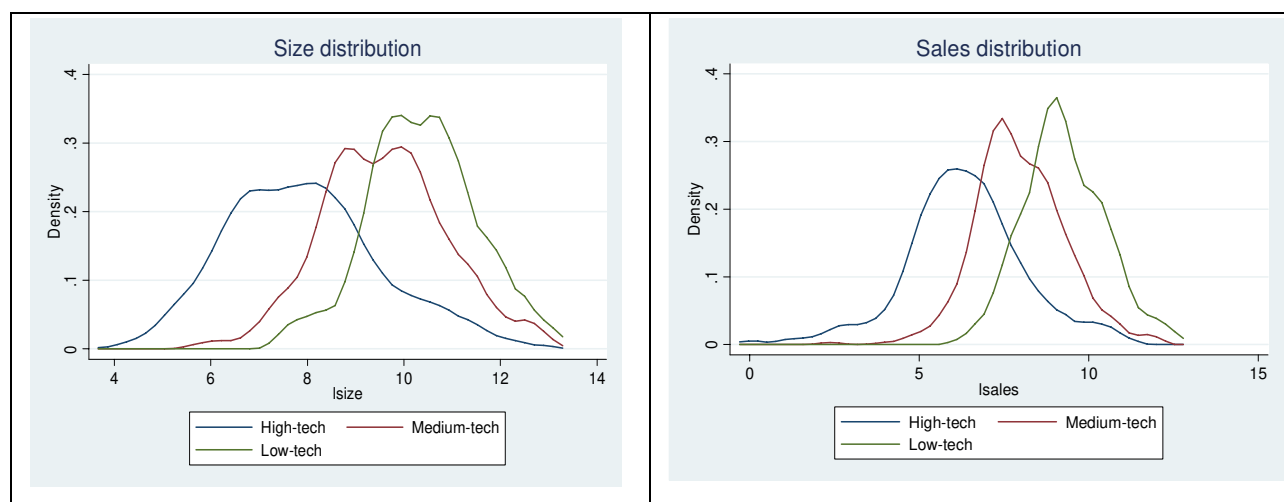


Figure 4 and 5. Size and Sales distributions comparison between R&D intensity sectoral groups

Following the work by Cohen and Klepper (1992) we now look in detail at the R&D intensity distributions. To identify regularities, we plot frequency distributions of the R&D intensities

for the aggregate sample, the 1338 firms, and for the sub-samples regarding the size of the firm. As Figure 6 illustrates, there is a much wider variation in R&D intensity among the smaller firm. They also have a larger mean, which contrasts with the (bi-modal) shape of the distribution of R&D intensity average for the large firms. Again, the similarity between the sub-sample of large firms and the whole sample reflects the over-bearing presence of large firms in the sample.

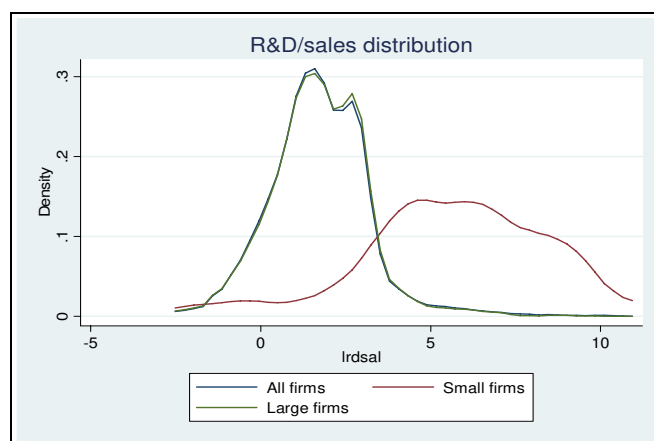


Figure 6. R&D intensity distributions between size groups

Looking at the stratification of the groups by R&D intensity, the three groups are tightly concentrated around the mean (Figure 7).

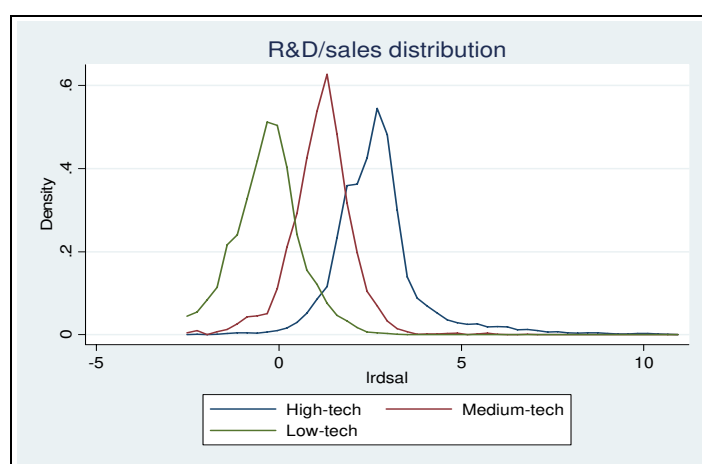
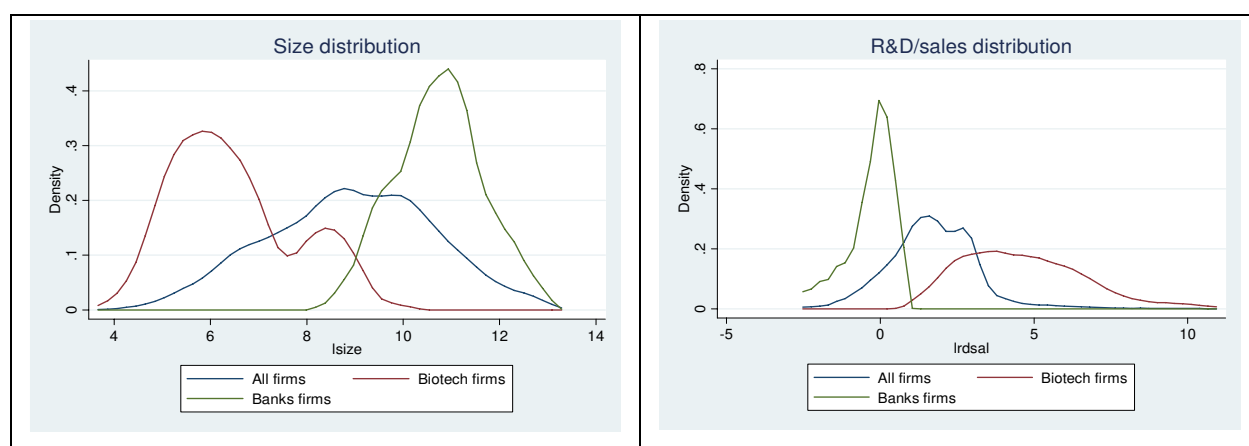


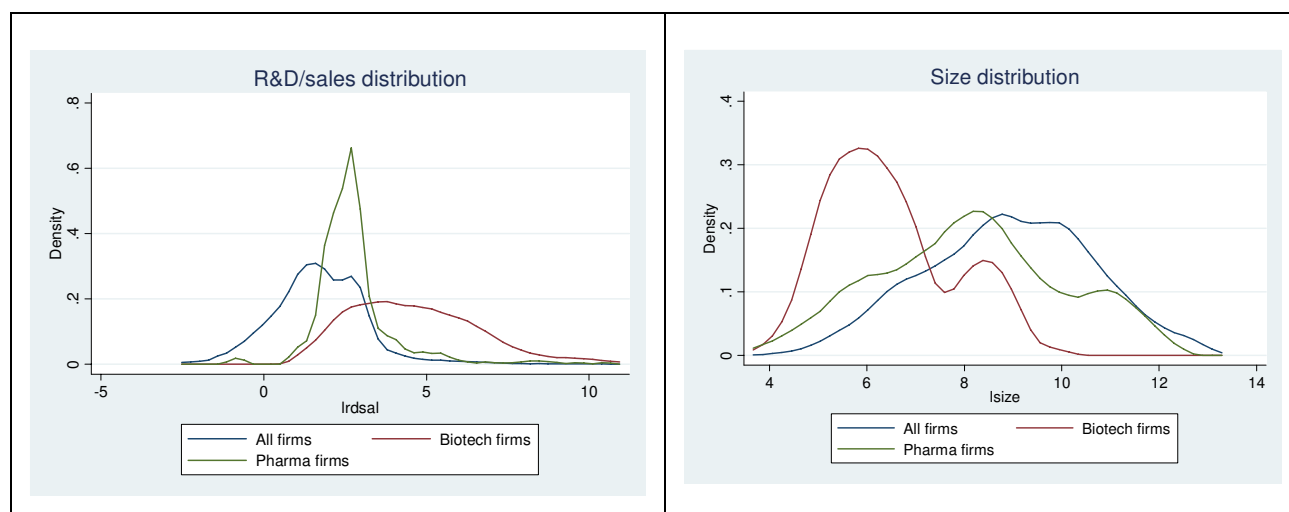
Figure 7. R&D intensity distributions between sectors

Two specific types of firms – banks belonging to the low-tech sector and biotech firms belonging to the high-tech sector group – are presented separately, for illustration. Figure 8 shows the inter-sectoral variance in terms of size (see also Dosi and others, 1988).



Figures 8 and 9. Size and R&D intensity distributions between bank and biotech industries

As we can see in the figures 8 and 9, there are significant differences among industries in the dispersion (*biotech* and *banks*) of firm R&D intensity. In particular, industries with higher mean R&D intensities (*biotech* firms) are also characterized by higher standard deviations and coefficients of variation. By consequence, there is no evidence that in the more research-intensive industries there is a greater conformity of firm behavior (Sterlacchini, 1994). In general terms Mansfield (1991), using a random sample of US firms, finds that the more R&D intensive firms are closely linked to academic research and this linkage is particularly strong for firms belonging to pharmaceuticals, optical instruments and information processing industries. We can even find differences within the same R&D intensity category. Figures 10 and 11 illustrate the differences within the high R&D intensity group sectors.



Figures 10 and 11. R&D intensity and size distributions between Pharma and Biotech firms

Size effects may explain partly the differences between R&D intensities. Both sectors present a huge dispersion in their size distributions. Biotech firms are typically operating at a smaller scale than pharmaceuticals. However, pharmaceuticals seem to have a more concentrated distribution of R&D intensities.

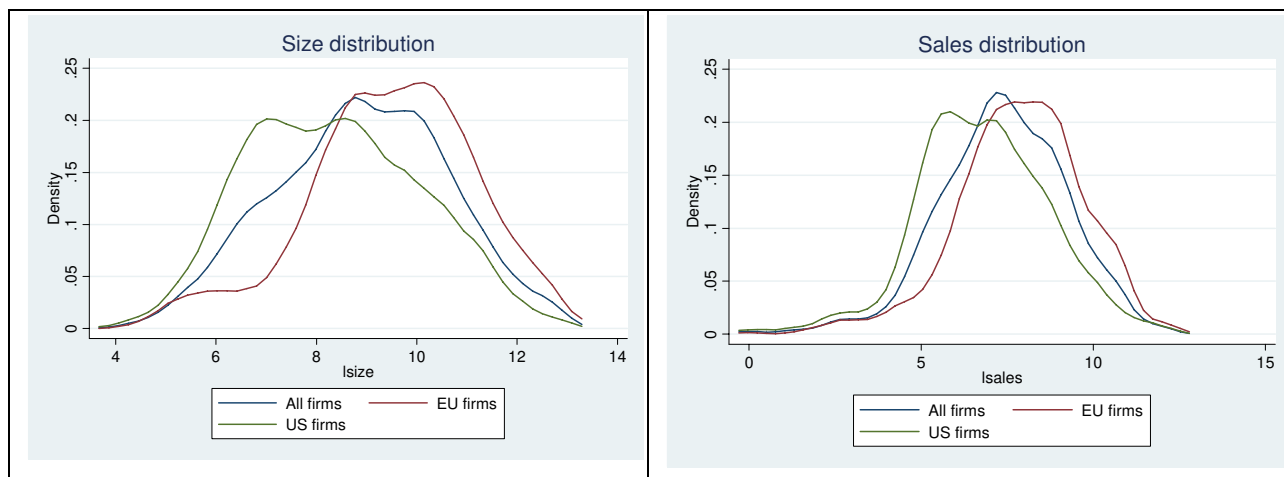


Figure 12 and 13. Size and sales distributions between macro-regions

The size distribution of the firms also differs when we compare the two macro-regions. EU companies in the Scoreboard have a larger size than US companies. The sales distributions show similar differences. Keeping in mind that the distributions of the R&D volumes are almost the same for the three sub-samples described in figure 14, it is worth noting that the average R&D intensity for the US firms is considerably higher than for the EU firms.

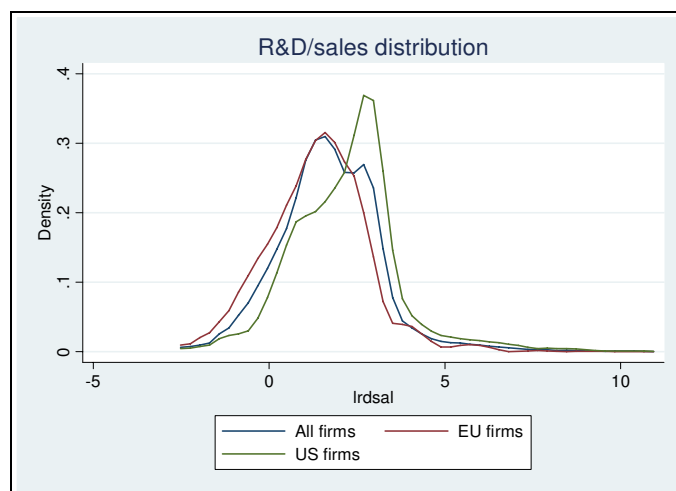


Figure 14. R&D intensity distribution between macro-regions

Empirical results

In the econometric analysis, we run a sequence of regressions to test the regularities and differences shown in the descriptive analysis. The first step of our analysis includes the results of the pooled Ordinary Least Squares estimation. The analysis was done (as the following ones) for the overall sample of firms, and in a second step for the EU and US firms. Table 2 reports the results of the pooled OLS regression results of the overall sample⁸. Sectoral effects can play a role. First, we approximate this effect by introducing sectoral dummies (we exclude the *low tech* one to avoid multicollinearity problems). The results seem to confirm that relatively high technological opportunities tend to be associated with a formalised, R&D-based mode of technological learning (Nelson, 1981a). A more satisfactory understanding of the relationship between innovation and structural and performance characteristics would require an analysis of the learning and competitive process through which an industry and firm changes⁹.

Column IV incorporates the individual sectoral effect in the model (with the inclusion of the 2-digit industry variables). As Dosi and others found, inclusion of the sectoral dummy variables leads to a noticeable increase in the global significance test statistic; the explanatory power of the first specification is greater than that of the second one. Variables such as the size and the regional dummies have the same significant coefficients as in the previous specification.

In general, the high, medium-high and medium-low R&D intensive sectors show positive and significant coefficients (some examples are biotech, pharma, software, internet, aerospace, among others). This is confirmed by the grouped effect in column II and III. In contrast, firms belonging to the "low-tech" sectors present in the majority of the cases a non-significant effect on the R&D intensity variable. The results included in this model corroborate the findings on sectoral differences referred to in our descriptive analysis and in many other studies. Dosi (1988) states that each production activity is characterized by a particular distribution of firms according to their R&D investments, innovative output, size, degrees of asymmetries in product quality, and production efficiency¹⁰.

Column III and IV show the estimation results when the regional dummies are included. We have excluded the "Rest of the World" dummy variable in order to avoid collinearity problems. As expected, the US base of companies has a positive and significant effect on R&D intensity, the same results appears in all the regressions. Belonging to an EU member state also has a positive effect on R&D intensity, although the coefficient is lower than for the US. The results show no significant effect of firms based in Japan, meaning that there is no significant difference compared to the excluded category. In order to know more about the effect of the size variables for the firms, we run the same regressions separately for the EU and the US.

Concerning the overall significance of the models, the R-squared seems to be higher for the first specification of the model, where the dependent variable is the ratio of R&D over current sales. Moreover, as far as the number of explanatory variable is increasing the overall significance of the model is higher. Based on the F-statistic, the most suitable model is the one where the R&D intensity is explained by the size, the three sectoral and the year dummies.

| ln(R&D/sales_t) | I | II | III | IV |
|--------------------------------------|-------------------|-------------------|--------------------------------|---------------------------------|
| ln (SIZE _t) | -0.572 (0.009) | -0.354 (0.009) | -0.353 (0.009) | -0.288 (0.009) |
| MED-LOW | - | 0.674 (0.069) | 0.665 (0.069) | - |
| MED-HIGH | - | 1.278 (0.051) | 1.274 (0.051) | - |
| HIGH | - | 2.253 (0.054) | 2.241 (0.055) | - |
| 2-digit sect DUM | - | - | - | YES |
| EU | - | - | 0.149 (0.048) | 0.082 (0.044) |
| JAPAN | - | - | 0.051 ^{ns} (0.053) | -0.024 ^{ns} (0.048) |
| US | - | - | 0.126 (0.046) | 0.109 (0.042) |
| Constant | 2.217 (0.084) | -1.323 (0.105) | -1.428 (0.114) | -2.360 (0.170) |
| N. observations | 4732 | 4732 | 4732 | 4732 |
| N. firms | 1338 | 1338 | 1338 | 1338 |
| F(n-1; m-1) | 3834.82 | 1920.59 | 1101.77 | 270.81 |
| (p-value) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| R-sq | 44.77% | 61.91% | 62.01% | 70.30% |
| Estimation Method | POLS | POLS | POLS | POLS |

Table 2. Determinants of R&D Intensity (OLS, overall sample) ¹¹

Table 3 presents the results of the estimation for the different macro-regions separately. The labels of the columns follow the specifications of the models in table 2 of results apart from

column V which includes the same specification of column IV without the regional dummies. The results are similar to the ones that we found for the overall sample, a negative and very significant size effect in both sub-samples and a positive and significant effect of the sectoral dummies. As can be shown in all the models, the size, measured by the logarithm of the number of employees appears to be significant with a negative parameter. However, its coefficient decreases when other variables enter the specification of the model. As to the sector effects, measured by the intensity level sector dummies (*medlow*, *medhigh* and *high*), they are significant with a positive coefficient.¹²

| Region | US | | | EU | | |
|--------------------------------------|-------------------|--------------------|-------------------|-------------------|-------------------|-------------------|
| | I | II | V | I | II | V |
| ln(R&D/sales_t) | | | | | | |
| ln (SIZE _t) | -0.615 (0.013) | -0.422 (0.014) | -0.328 (0.013) | -0.548 (0.011) | -0.322 (0.011) | -0.278 (0.011) |
| MED-LOW | - | 0.906 (0.149) | - | - | 0.247 (0.081) | - |
| MED-HIGH | - | 1.274 (0.110) | - | - | 1.114 (0.065) | - |
| HIGH | - | 2.342 (0.112) | - | - | 2.188 (0.070) | - |
| 2-digit SECT DUM | - | - | YES | - | - | YES |
| Constant | 2.717 (0.114) | -0.8031 (0.176) | -2.247 (0.285) | 1.049 (0.090) | -2.100 (0.122) | -2.935 (0.169) |
| N. observations | 2261 | 2261 | 2261 | 3508 | 3508 | 3508 |
| N. firms | 587 | 587 | 587 | 978 | 978 | 978 |
| F(n-1; m-1) | 2107.48 | 886.22 | 170.17 | 2459.00 | 1162.36 | 172.54 |
| (p-value) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| R-sq | 48.26% | 61.11% | 71.60% | 41.22% | 57.03% | 65.40% |
| Estimation Method | POLS | POLS | POLS | POLS | POLS | POLS |

Table 3. Determinants of R&D Intensity: US vs EU comparison (OLS)¹¹

In order to increase the efficiency of the estimation over conventional cross-sectional techniques we run panel data regressions. Regarding the specification of the model, some arguments have to be made. We have chosen the between and the random effects rather than the fixed effect specification. In principle, with short panels the within variability of the data is practically inexistent, this is the main reason to choose the between or the random-effects specifications rather than the fixed-effects one. Additionally, some explanations about the appropriateness of random effects specification dealing with the same sort of data can be found in Potters, Ortega-Argilés and Vivarelli (2007). Basically, the Hausman specification test corroborates the suitability of this specification. Moreover, with the random-effects it is possible to overcome problems caused by the fact that the within-firm variability of the data in short panels is much greater than the between one, showing that the time-effect in short panels does not affect the results significantly and a treatment similar to the cross-section

analysis is warranted. Finally, the global specification of the model appears to increase with the between and the random-effect specifications, because of the possibility of including time-invariant regressors (like the two-digit sector dummies).

Some of the results of the panel data analysis in both regions are presented in table 4. Our main conclusion is the high importance of the size and the sector in explaining a company's R&D intensity. As we found in previous tables, the negative effect of the number of employees over the R&D intensity is present in many of the models. The individual and global significance of the time dummy variables shows that time-related macro economic conditions are affecting the R&D intensity of the firms. The models show a high significance of the Wald test based on the chi-square test for the set of variables introduced indicating the high explanatory power of these models.

| Region | US | | EU | |
|--------------------------------|---------------------|---------------------|---------------------|---------------------|
| Ln(R&D/sales _t) | II-bis | V-bis | II-bis | V-bis |
| Ln (SIZE _t) | -0.354 (0.022) | -0.289 (0.021) | -0.277 (0.019) | -0.244 (0.018) |
| MED-LOW | 0.977 (0.285) | - | 0.276 (0.147) | - |
| MED-HIGH | 1.331 (0.209) | - | 1.163 (0.119) | - |
| HIGH | 2.5265 (0.210) | - | 2.3750 (0.125) | - |
| 2-digit SECT DUM | - | YES | - | YES |
| YEAR DUM | YES | YES | YES | YES |
| Constant | -1.474 (0.300) | -2.638 (0.513) | -2.596 (0.208) | -3.391 (0.299) |
| N. observations | 2261 | 2261 | 3508 | 3508 |
| N. individuals | 587 | 587 | 978 | 978 |
| Wald test (p-value) | 1020.93 (0.0000) | 1621.50 (0.0000) | 1387.97 (0.0000) | 2016.61 (0.0000) |
| R-sq | | | | |
| within | 2.80% | 2.99% | 0.01% | 0.01% |
| between | 62.96% | 74.07% | 59.73% | 68.59% |
| overall | 60.79% | 71.52% | 56.81% | 65.22% |
| Method | RE | RE | RE | RE |

Table 4. Determinants of R&D Intensity: US vs EU comparison (Panel Data)¹¹

Conclusion

The advantage of size in conducting R&D has been the subject of many theoretical and empirical studies, departing from Schumpeter's observation that large companies are better placed to exploit the gains to innovation. The idea has taken hold that each sector of economic activity has its own optimal R&D intensity and that the differences in overall R&D intensity between national economies are explained by the sectoral build up of GDP. Smaller companies therefore need a higher R&D intensity, at least temporarily, to compete with established firms. However, this neglects the variety in R&D intensity that is observed, not only for economies of the size of the EU and the US as a whole but also within sectors and between countries. In this paper we take a different approach. First, we show that the size distribution of the R&D volumes of the top R&D investors in the US and the EU have a similar shape. At the same time, the corresponding distributions of the company size of the top investors are different. This suggests that the variation in R&D volumes may be typical for an economy of a given size.

This paper focuses on the differences in R&D intensity between the EU and the US. We investigate whether this difference has anything to do with the size of European and American companies. For this purpose, we use the R&D Scoreboard which contains data on the top R&D investors in the world. It contains a considerable number of companies in the EU and the US. We use the total employment in the company as a proxy of the size. We also take into account the possibility that the size effect differs by industry.

We look for systematic time effects in the size-R&D relationship across industries. We carry out regressions of the R&D intensity in firms on the size of the firms, separately for EU-based and US-based firms, using sectoral-specific and year-specific dummies trying to capture the evolution of the economy, market and sector aspects. Size seems to have a significant and negative effect on R&D intensity in the US, robust against variations in sector definitions. This is also the case for the EU, with a slightly smaller negative coefficient. One explanation is that there are large companies with high R&D intensities based in the US but that smaller companies with high R&D intensities are rapidly gaining weight. In the EU, the large companies with similarly high R&D intensities as in the US are bigger and slightly more dominating in the results.

The main policy implication of this study is that it is more important to sustain a critical mass of R&D across sectors of economic activity than it is to protect the R&D activity of a given company. Policymakers should focus on a sound overall distribution of R&D volumes rather than on underinvestment by individual companies. At the level of the EU and US economy, this distribution has strikingly similar characteristics. Measures to stimulate collaboration on R&D and measures which neutralise the advantages of large companies in limiting the access to the knowledge they have generated may be more effective than measures to increase the overall volume of R&D.

Notes

¹ The early studies in the empirical literature are on the US, for which the most reliable data were available.

² Henceforth "*The Scoreboard*".

³ Majority-owned subsidiaries are consolidated in the accounts of the parent, whereas joint ventures that are 50% owned by each of two partners are included as stand alone companies.

⁴ The definition of "R&D" is that used by companies, following accepted international accounting standards (IAS 38), in accordance with the definitions used in official statistics (as defined in the OECD's Frascati Manual). The term "R&D Investment" used in the Scoreboard refers to a company's cash outlays on R&D – conducted on its own behalf and funded by the company itself.

⁵ Very few SMEs are present in the Scoreboard. We classify *large firms* as the ones with 250 employees or more.

⁶ Sector are classified according to the ICB sectoral classification. The detailed ICB sectoral classification is given on the following website: <http://icbenchmark.com>.

⁷ Although this table presents the descriptive statistics for the reduced sub-sample of European firms that has used to be compared with US-based ones. The regressions for the EU are based on the whole sample of the EU-based firms from the 2006 R&D Investment Scoreboard.

⁸ The following sectors have been classified as high R&D intensive sectors: Software, Leisure goods, Computer Hardware and Services, Biotech, Pharmaceuticals, Semiconductors, Health care equipment, Telecommunications equipment, Internet. As medium-high: Aerospace and defence, Automobiles and parts, Chemicals, Electronics and electrical equipment, General Industrials, General retailers, Household goods, Industrial engineering, Industrial transportation, Other financials, Personal goods, Support Services and Travel and Leisure. Under medium-low: Beverages, Electricity, Oil equipment serv. & distr., Fixed line telecommunications, Food producers, Electricity, Media, Non-life Insurance. Finally, as low-tech: Banks, Construction and materials, Food and drug retailers, Forestry and paper, Gas, water and multiutilities, Industrial metals, Life insurance, Mining, Mobile Telecommunications, Oil and Gas producers, Tobacco.

⁹ Time year dummies have been excluded in the POLS specification because of the global and individual null significance. Even if they are excluded, their incorporation into the model appears to increase the global significance of the model.

¹⁰ Another different specification of the model, in which the R&D intensity has been defined as the ratio of the R&D over one-year lagged sales, has also been tested. These results can be displayed upon request to the authors.

¹¹ Standard errors in brackets; all coefficients are significant at the 99% apart from those which present the superscript *ns*.

¹² We also have run same regressions in parallel for the different R&D intensity sectoral groups sub-samples. We found that the negative and significant effect of the actual size can be only found in the results for the high intensity firms' sub-sample.

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