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Summary

The aim of this paper is to analyse the performance characteristics of large firms that are at the forefront of globalization of their knowledge creating activities. This we do by making a comparison with firms that are much more concentrated in terms of their knowledge creation. Our analysis is based on around 500 of the world's largest technologically active companies, with their headquarters in the EU, Japan and the US. These companies account for a large proportion of both corporate R&D spending worldwide and total EPO patenting. In particular we address the following sets of questions:

- *Are globalized firms larger than those that are non-globalized?*
- *Do globalized firms have higher volumes of innovative activity than non-globalized firms?*
- *Do globalized firms have higher innovation intensity than non-globalized firms?*
- *Do globalized have a higher level of economic performance than non-globalized firms?*

The results for the sample as a whole show that firms that are geographically dispersed in their technology creation are, on average, considerably larger, have a higher volume of innovative activities, and have superior economic performance. However in terms of innovation intensity the difference between the two sets of firms is negligible, i.e. they both devote very similar proportions of their total resources to innovation.

The analysis also shows that there are considerable differences across sectors in the degree to which these results hold. In terms of size, while firms from most sectors conform to the aggregate pattern, the more globalized companies in the *Aerospace* industry are, on average, smaller than the non-globalized firms. With regard to the volume of innovation the anomalies are the *Automobiles* firms. The pattern for innovation intensity is very different with globalized firms from 5 sectors having a lower average value than those that remain geographically more concentrated. The largest variation is in terms of economic performance, with firms in 6 sectors showing a positive relationship with globalization of technology, 3 showing a negative relationship and for a further 2 the difference is negligible.

These results suggest that any analysis of the relationship between performance and global location of technology needs to adopt a sectoral approach. They also suggest the need for a deeper understanding of the costs and benefits of globalization versus concentration within each industrial sector. Some of these issues will be addressed in WP 3.2 where detailed information has been gathered from firms active in ICT, Pharmaceuticals and Automobiles.

With regard to future work, the next step would be to improve the quality of financial data for the period since 1990. This will enable us to adopt a more dynamic approach, including the testing of causal relationship between globalization of technology creation and performance.

1. Introduction

This paper seeks to understand the relationship between international technology creation undertaken by large R&D spending corporations and their economic performance. It follows on from Deliverable 3.1 which analysed the international location of knowledge creation. The aim here is to examine the performance characteristics of firms that are at the forefront of globalizing their technology. More particularly we are interested in the question whether firms that source their technology globally have better economic performance than those that are more domestically orientated. As we show in the next section this is a surprisingly under-researched subject.

Our analysis is based on around 500 of the world's largest technologically active companies, with their headquarters in the EU, Japan and the US. These companies account for a large proportion of both corporate R&D spending worldwide and total EPO patenting.

The performance characteristics of the companies are analysed along a number of dimensions:

- industrial sector
- economic size
- innovation volume
- innovation intensity
- profitability

In each case the aim is to see whether the firms that locate their technology creation on a global scale are different from those firms that are geographically more narrowly focused. The current analysis is based on a single cross-section covering the period 2001-06. In subsequent analysis we aim to include a more detailed and rigorous econometric analysis of the causal relationship between internationalization of technology and economic performance. This requires further cleaning of the financial data used in the current analysis to include the time series perspective.

The plan of the paper is as follows. Section 2 presents a brief discussion of the literature on internationalisation of R&D, specifically on the relationship between characteristics of firms, their propensity to engage in international R&D and the impact on long term profitability and thus sets the stage. Section 3 discusses the data collected and the methodology employed. The main results are presented in Section 4 and Section 5 presents our assessment and discussion.

2. Background

A recent report from the OECD highlights three distinguishing features of the drive towards increasing internationalization of R&D and technology creation (OECD (2008)). The first is the increasing level of green-field investments undertaken by large R&D spending companies. The second is the fact that such investments are now undertaken in an increasing number of countries, including fast developing economies such as India and China. The third feature highlighted is that such investments often go beyond local adaptation of nationally produced technology. One of the main conclusions of this report is that globalization of R&D is one of the key strategic decisions that almost every large R&D spending firm has to make and increasingly such firms are implementing corporate-wide strategies for achieving this at the business unit and functional level. The underlying rationale is that firms who succeed in this process often achieve significantly better performance in terms of savings, meeting target service levels, improving relations with suppliers, etc (Lewin et al. (2009).

The early literature on globalization of R&D argued that there are a number of sound reasons why technological activities related to the introduction of a brand new product or process may be concentrated in a single location preferably close to the company headquarters (Granstrand et. al (1992); Patel and Pavitt (1991)). These were related to certain known features of the introduction of innovations which made the management of dispersed R&D difficult: the person embeddedness of multidisciplinary scientific research, the largely tacit nature of technological knowledge, the strong need for coordination in decision making in the face of uncertainty of innovation, all of which make proximity to headquarters important. These reasons for locating R&D facilities close to the headquarters also suggest that moving some R&D to foreign locations might incur substantial management costs for the firm. The spread of R&D to newer regions has also meant handling the 'costs of distance and foreignness' traditionally discussed in analyses of international expansion of production.

Another tradition of scholarship has however argued that internationalisation of R&D results in considerable efficiency gains for large firms. Drawing on the OLI paradigm which predicts that foreign investment takes place to profit from Ownership, Location and/or Internalisation (OLI) advantages, the contention is that internationalisation of R&D is the result of the interaction between the ownership advantages of MNCs and the location advantages of regions. Cantwell (1995) for example, argues that in a global world, MNCs will locate to exploit regions of differential advantage in production and in R&D. Gains from this process can arise through several channels: e.g. by the lowering the costs for routine R&D, by the rationalisation of human capital intensive activities and by tapping into new types of skills and networks in emerging regions. The managerial efficiency of multinationals then drives them to internationalise their technology through 'asset augmenting' investments rather than extend production through 'asset exploiting' investments alone.

Motivations for foreign knowledge creating activities

The literature on the internationalisation of business suggests a number of different reasons for undertaking knowledge creating activities outside the home country. The earliest contributions saw the main purpose of foreign R&D activities as offering support for foreign production and for servicing the foreign market. Thus, Vernon (1966) argued that having established a new product or a new production process in the home market, firms would subsequently export and/or locate production facilities in foreign locations. This process would inevitably involve some foreign R&D activity focussed around the adaptation of products (e.g., to account for differences in consumer tastes) and/or the modification of production processes (e.g., to account for differences in the labour market) to suit the local market conditions.

From the mid 1990s, the perceptions of what motivates foreign R&D investments have undergone numerous changes, aptly reflected in the broader literature on 'global sourcing of technology by large firms'. The decision to undertake foreign R&D is now seen as more than just a location decision that mirrors a production decision. This literature highlights different kinds of considerations. For example one contention is that in the face of rapid technological change, maintaining competitive edge requires firms to look outside their home country in order to augment their technological capabilities. Additionally firms need to master an increasing range of potentially useful technologies as products become more complex and are affected by technological convergence, for example electronics in cars (Iansiti (1998)). Thus Patel and Pavitt (2000) contend that large firms based in small countries need to look to foreign sources to acquire these diverse technological competencies. At the same time Cantwell (1995) has shown that multinational firms utilise and exploit the advantages of a globalization through locating in areas of comparative advantage. As new centres of technology emerge, there is a growing need to access location specific technological advantages in different countries.

More recent literature argues that the latest trends in foreign R&D reflect a further underlying interaction between ownership and location advantages that is not restricted to the acquisition of technology alone. The contention here is that as the world has become progressively more globalized, maintaining ownership advantages often requires MNCs to tap into location advantages of a different kind. Thus for example the second half of the 1990s saw major concerns emerging over the scarce availability of scientific talent in Western economies, resulting from increased pace of technological change. This induced many US firms in the Electronics sector moving their R&D operations to newer locations in developing regions where such talent was abundant. These investments can be viewed as simply resource seeking, where the resource that is being sought is scientific talent.

Costs and benefits from Internationalisation of Knowledge creation

Past research has shown that there are both costs and benefits associated with the internationalisation of R&D and technology creation. Firms engaged in such activity benefit from enhanced market development, sourcing of high quality human capital, and from directly tapping into foreign pockets of excellence. At the same time they incur higher transaction costs and face a potential deterioration of their existing traditional nationally based networks (Elder (2007)). These considerations are prominent in the recent research on the globalization of innovation of US firms, which suggests that the two key strategic drivers for off-shoring innovation projects are the speed to market and the domestic shortage of science and engineering talent. At the same time the loss of managerial control and employee turnover are the most important risks associated with such globalization (Lewin et al. (2009)).

The costs and benefits from R&D internationalisation depend on the host location, on different motives of the firm in undertaking such activity and on the kind of R&D

being internationalised. The increasing attractiveness of emerging economies such as China and India as excellent foreign R&D destinations has been attributed to the low cost of conducting research. China and India offer dramatic cost advantages (of between 30% and 60 %) even after accounting for training and coordination costs (Khurana (2006)). However, there are some signs that this is changing and that cost advantage is not the most critical factor driving firms to locate R&D in these countries. Rather such decisions are increasingly based on supply related motives (access to scientific and technological skills). Nevertheless while current cost advantages are expected to diminish over time, substantial labour arbitrage will exist for the next l0-15 years (Khurana (2006)). These considerations are also highlighted in a recent influential survey of international R&D activities of US and EU MNCs (Thursby and Thursby (2006)). Their results show that the most important drivers in locating in emerging economies are the growth potential in the market followed by the quality of R&D personnel. At the same time, for these economies, the quality of intellectual property protection was a detractor.

Foreign knowledge creation and corporate performance

We begin with the observation that the relationship between foreign technological activities and performance of firms has been surprisingly neglected in the literature on international business. This is partly a reflection of the difficulties in being precise about the magnitude of the economic value of all technological activities (foreign or home-based) because of the long time period over which returns may be observed. The little evidence on the positive association between R&D internationalisation and innovation performance has stressed that large firms are able to appropriate considerable efficiency gains as a result of such internationalisation, mainly arising from the interaction between the ownership advantages of MNCs and the location advantages of regions. For example Cantwell (1995) argues that MNCs will locate in different countries and regions to exploit differential advantages in production and in R&D. The contention is that managerial efficiency of multinationals drives them to internationalize their technology through 'asset augmenting' investments rather than extend production through 'asset exploiting' investments alone.

Empirical evidence shows that overseas R&D geared toward technology sourcing can have a positive impact on parent operations and productivity (Griffith et al. (2006)). Whether this occurs depends firstly on successful intra-firm reverse technology transfers from the subsidiary to the parent. Efficient transfer and integration of knowledge within MNCs are affected by organizational and technological distance and also by the existence of organizational inertia (Criscuolo and Narula (2007)). Further positive impact is also more likely to be realized if the MNC becomes embedded in the host country's productive and innovative networks (Iwasa & Odagir, (2004)). Thus local embeddedness is shown to have a positive impact on foreign subsidiary performance and innovation (Andersson et al. (2002)).

Anecdotal evidence also suggests that advancements in communications infrastructures further facilitate management of dispersed R&D. Many firms now seek to move some of the more routine work to cheaper locations, which can then be monitored by the parent company on an almost continuous basis. Zhu (2004) formalises these arguments by using a theoretical model to show that firms attempt to reap economies of scale and scope with R&D centres located in cheap labour countries.

The general literature on the relationship between intangible R&D assets and economic value of the firm has not considered separately the international dimension of R&D. Studies such as Hall and Trachtenberg (2001) show that the quality of the knowledge created (as measured by citation weighted patents) has a positive influence on the market value of US firms. This builds on the early work of Grliches (1981) which showed a positive relationship between R&D expenditures of a firm its economic value. More recently Hall et. al. (2005) show that three complimentary aspects of knowledge stocks, i.e., R&D intensity, patents to R&D ratio, and average citations received by these patents, significantly raise the market value of a firm. Similarly, Bloom and Van Reenan (2002), using a sample of UK firms found that patent stocks did have a positive and statistically significant impact on firm-level productivity and market value for UK firms. These studies underline the fact that technological change yields improvements in productivity over a long period of time but also suggest the relative scale of R&D relative to physical investment and the size of the total patent stock to be important variables capable of influencing market value directly. Moreover Nesta and Saviotti (2006) show that the stock market values the coherence of the knowledge base of biotechnology firms, i.e. the extent to which the different technological capabilities of biotech firms are related to each other.

One of the few studies examining the impact of internationalisation of knowledge creation on the market value of firms is that by Criscuolo and Autio (2008). They analyse the geographic distribution of pharmaceutical and chemical MNC's scientific publications and relate them to their market value. Their main conclusion is that adoption of a geographically dispersed network of research units is conducive to higher market valuation. A small number of studies report superior innovative performance as a result of foreign R&D. For example Penner-Hahn & Shaver (2005) show that Japanese Pharmaceutical MNEs with foreign R&D have a higher level of patenting compared to purely domestic counterparts. More recently, Bernhard et al., (2008) compared the innovative performance of foreign-owned and domestically owned firms in five European countries and finds that foreign ownership is not related to differences in innovation input, but yields higher innovation output and labour productivity. However the study by Singh (2006) shows that simply dispersing R&D in a number of locations does not contribute to firm's patents quality. But when innovative teams subsequently build on knowledge from different locations, this is likely to result in patents with higher value (Singh (2006)).

3. Data, Construction of the Sample and Indicators

As discussed in a previous deliverable for this project, past research on international location innovative activities of large firms has been based on three sets of measures: *Official national R&D Surveys*, *Patent Statistics* and *Other ad-hoc firm-level surveys*.[1] In general each of these measures has some strengths and some weaknesses. For example R&D is only one input into the innovation process and its relative importance differs according to industrial sector and size of firm. The propensity to use patents to protect technological leads varies according to the area of technology (and size of firm). Ad-hoc surveys are not easily replicable and are difficult to compare over time.

In this paper we use patent statistics as they offer the level of detail required map the geographic distribution of knowledge creation at the firm level. The aim is to make the best available use of patent data while, at the same time, minimizing their main shortcomings. We use the country address of the inventor as a proxy measure for the location of international technological activity underlying that patent. This is not necessarily the country from which the patent application was filed. In the case where more than one country address appears on the same patent, we attribute the patent to each country.[2] This is of course an underestimation of the extent of foreign technology creating activities, as some of these activities may result in no patents at all. However, given the homogeneous nature of the sample, one would expect the propensity to patent across firms to be very similar. Moreover, the measure used in our analysis is the *share* of total patents accounted for by foreign locations, which accounts for some of the variations in the propensity to patent across firms.

The data set has been compiled from PATSTAT (October 2009), supplied by the European Patent Office. For each patent application at the EPO we have extracted information on the *name of the company* making the application, the *priority year*, the *IPC class*, and *country of origin of the inventor*. The main difficulty with the primary data is that many patents are granted under the names of subsidiaries and divisions that are different from those of the parent companies, and are therefore listed

[1] See *Deliverable 3.1.1: Location of Innovative Activities of EU Large Firms*
[2] In other words we use the 'whole' count approach as opposed to 'fractional' counts.

separately. In addition the names of companies are not unified, in the sense that the same company may appear several times in the data, with a slightly different name in each case. Consolidating patenting under the names of parent companies can only be done manually on the basis of publications such as '*Who Owns Whom*'. In the present study we have consolidated companies on the basis of the on-line version of *Hoovers*. Also from this source we obtain information on the *country address of the headquarters* and the *principal product group* of the firm.

Construction of the Sample

Here we outline the sampling procedure used in the construction of the sample, the treatment of missing values, procedure to unify the data and on handling of outliers. The dataset used in this paper consists of 483 large firms headquartered in Europe, USA & and Japan.[3] These firms are classified into 11 different sectors according to their principal product group. The dataset is constructed by matching two databases, i.e., that based on patent data available from the EPO and on financial data available from Compustat over the period 1991-2006. The creation of matched dataset of financial and patent data involved several stages.

The first stage involved the selection of the top patenting firms at the EPO. We began with a long list of some 3000 firms with patent applications in the priority years 1991-2006 which were checked against the on-line version of the *Hoovers* database to check for company affiliations. The identified firms were then compared to the 2000 companies included in the EU R&D Scoreboard for 2007.[4] This process resulted in 970 firms which can be regarded as the most technologically active firms in the world as together they account for more than 85% of corporate R&D (as reported in the EU Scoreboard of 2007) and more than 70% of all EPO patents in the period 1991-2006.

In the second stage these firms were matched to the data from *Standard and Poor's Compustat* database. This resulted in 656 firms in the three regions of USA+, EU and Japan for the period 1991-2006, which had some financial data which could be matched to the patent data. For a substantial proportion of these firms financial data supplied by *Compustat* were incomplete. Particularly, there were missing values for

[3] This includes 15 Swiss firms and 2 Norwegian firms classified as European, and 3 Canadian firms which are classified as American.
[4] See http://iri.jrc.ec.europa.eu/research/scoreboard_2007.htm

R&D expenditures (R&D), *capital expenditures, market value* and *sales* for some years. An exercise was undertaken to fill in the gaps in the data. In the first instance all observation that had *market value* and/or *sales* values missing for the entire period 1991-2006 were omitted from the final sample. In cases where *sales* were missing for only for one or two years, the average values were computed. Missing values for R&D expenditures were estimating using all publicly available information: UK and EU Company R&D Scoreboards, Annual financial reports from Company websites, etc.

Another major task undertaken was to convert all data to common currency, the euro, as the data provided by *S&P* were in national currency. The conversion to euros prior to 1999 was achieved by using the average annual exchange rate given by the European Central Bank. For companies based in non-Eurozone countries (US, Japan, UK, Sweden, Denmark, Switzerland and Norway) the average annual exchange rates provided by EURSTAT were used post 1999.[5]

Construction of Indicators

In order to analyse the extent of the international technological activities in large firms, we distinguish between two aspects of foreign technology creation, the volume and spread of such activities:

i.) The volume of international knowledge creation is measured by the *share of total patents* of a company with inventor addresses in a location outside the home country (*FORSH*).

ii.) The number of foreign locations from which patents are drawn is the proxy for the spread of international knowledge creation (*FORLOC*). In order to achieve this we only include locations with 5 patents or more over a 5 year period. This is a measure of the dispersion of technological activity and shows whether for a specific firm such activities of are concentrated in one particular country or located in multiple countries.

These two indicators are used in the following section to distinguish between firms

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5 http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tec00033, Description by Eurostat: “Exchange rates are the price or value of one country's currency in relation to another. Here the exchange rates are those for the euro published by the European Central Bank. Before 1999 the exchange rates are those of the ECU, as published by the European Commission”.

that are internationalized and those that are non-internationalized in terms of their knowledge creating activities.

In order to distinguish the performance characteristics of these two sets of firms we use a number of well-known indicators of firm level economic performance. One such indicator that has often been used in previous studies that have analysed the effect of technology on firm performance is *Tobin's Q*. This is simply the market value of a firm divided by the book value of its capital assets. Here market value is defined as the sum of (a) the common equity (share price multiplied by the number of outstanding shares), (b) long term debt (at market value) and (c) value of other securities such as preference shares. The underlying rationale is that if the firm has some intangible assets such as knowledge capital then this ratio will be above one, reflecting the long term innovation potential of a firm.[6] The advantage of using this indicator as a measure of performance is that it takes into account all available information about the firm over a span of time. Since we are dealing with large firms this is likely to be a better measure than the average of short-term profits and to reflect more fully the effect of the knowledge capital of the firm, including knowledge drawn from foreign locations.

We use the perpetual inventory method for calculating the capital stock of a company (the denominator in Tobin's Q (see for example Hall et al (2001)). We use the annual capital investment data provided by *Compustat*, which in turn are based on company annual financial reports. The rate of depreciation used is 15% and the initial year is 1991 (this is the first year for which we have investment data).

In addition we also use a number of measures of short term profitability based on data from company accounts:

- *Operating margin*, which is simply the ratio of *operating income* to sales. *Operating income* is sales less operating expenses and depreciation. This is a measure of the profitability of a company.

[6] However in the long run we would expect the market value of a firm is equal to the book value of its assets.

- *Return on Sales*, which is *net income* as a percentage of sales. *Net income* includes all income (operating and non-operating) with taxes and interest charges deducted. This is another measure of profitability of a company.
- *Return on Assets*, which is *net income* as a percentage of total assets of a company. Total assets are the capital assets of a company. This measure the profitability of a company relative to its fixed assets.

4. Performance characteristics of Globalized Firms

The main aim of this paper is to analyse the performance characteristics of firms who are at the forefront of globalizing their knowledge creation activities. This we do by making a distinction between firms according to the level of their technology creation outside the home country. The subsequent analysis focuses on examining the differences according to these two groups of firms according the following dimensions:

+ Economic size as measured by *sales* and *market value*.
+ Volume of knowledge creation as measured by their level of *patenting* and *R&D expenditures*.
+ Intensity of knowledge creation (*R&D* and *patent intensity*).
+ Profitability as measured by *Tobin's Q, Operating Margin, Return on Sales* and *Return on assets*.

A classification of Globalized and Non-Globalized firms

We use the two dimensions of location of technology discussed above to classify the firms in our sample: their *foreign share* and the *number of foreign locations*. In particular we consider firms to be globalized in terms of their knowledge creation (*Glob*) if, in the period 2001-06, they have more than 15% of their patents invented from foreign locations and these patents are sourced from more than 1 foreign location. The remaining firms are classified as non-globalized (*NonGlob*).[7] The latter are largely either active in only one country other than the country where their headquarters is located or have less than 15% of their patents with foreign inventor addresses.

Table 1 reports the number of firms in each category and the mean values of their foreign share and the number of locations. The differences between the *Glob* and *NonGlob* firms are stark. For the sample as a whole average share of patents invented from foreign countries in 2001-06 is nearly 40% for the former and only 7% for the latter. Additionally, on average, globalized firms are technologically active in 6 foreign locations compared to 1 location for the non-globalized firms. These patterns largely hold across the 12 sectors reported in Table 1. The only other point to emerge

[7] We have only considered firms with some foreign invented patents in this analysis. In other words those that are only active in their home country have not been included in our final sample.

from this table is that there are a number of industries where we have too few firms to make a meaningful comparison: *Aerospace, Food, Drink and Tobacco, Metals, Mining & Petroleum* and *Other Manufacturing*. This needs to be borne in mind when interpreting the results regarding the differences in the characteristics of firms below.

Table 1. Sample of Firms Classified according to their level of Globalization

Principal Industry	**Number of Firms**		**Foreign Share** (Mean values)		**Foreign Locations** (Mean values)	
	Glob	*NonGlob*	*Glob*	*NonGlob*	*Glob*	*NonGlob*
Aerospace & Defence	9	5	28.7	5.4	5	2
Automobiles & Parts	21	24	44.4	6.7	5	2
Chemicals & Chemical Products	39	42	35.7	6.2	7	1
Electronics (inc Electrical)	25	37	31.9	6.8	7	1
Food, Drink & Tobacco	9	6	50.9	9.3	6	1
ICT	25	23	41.8	7.9	9	2
Machinery & Equipment	19	20	33.6	8.4	4	1
Medical & Oth Specialized Equipment	33	27	47.5	9.6	5	1
Metals & Metal Products	9	8	38.3	3.9	6	1
Mining & Petroleum	8	5	43.8	7.6	6	1
Other Manufacturing	4	7	37.6	5.8	5	1
Pharmaceuticals	24	10	49.5	16.3	8	2
All Firms	225	214	39.5	7.3	6	1

Differences according to economic size

The question addressed in this subsection is whether there are differences between globalized and non globalized firms in terms of their economic size. We use two measures of size: average *volume of sales* and *market value*, both averaged for the period 2001-2006 (Figures 1 and 2). The results show that in general the firms that are geographically more spread in terms of their technology creation are larger than those that are more narrowly based. Figure 1 shows, for the sample of 439 firms as a whole, the average *NonGlob* has around 60% of the sales of the average *Glob* firm. There are considerable differences according to sectors in this pattern. For example in the *Aerospace* industry the globalized firms are much smaller than those that are relatively non-globalized. At the other end of the spectrum, firms at the forefront of spreading their knowledge creation on a global scale in the *Pharmaceutical*, *Machinery, Chemicals,* and *Electronics* industries are more than twice as large as firms that are non-globalized. The differences between the two types of firms are much narrower in two other industries: *Automobiles* and *ICT*.

Figure 1 Comparing firms according to their volume of Sales (2001-06)

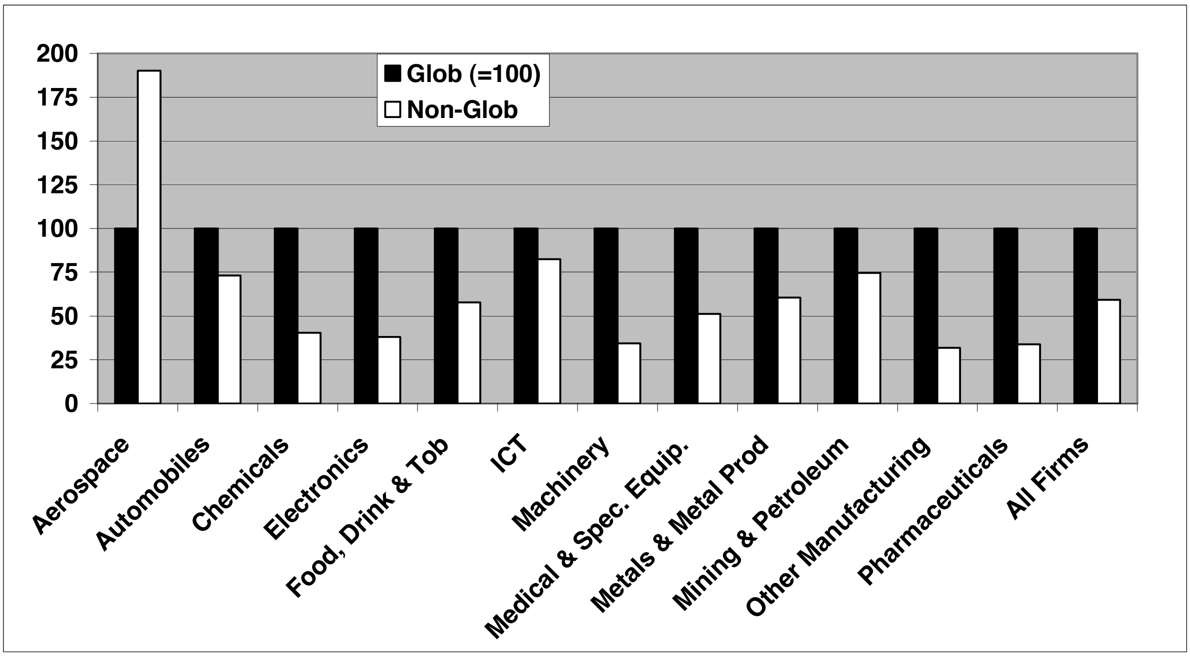
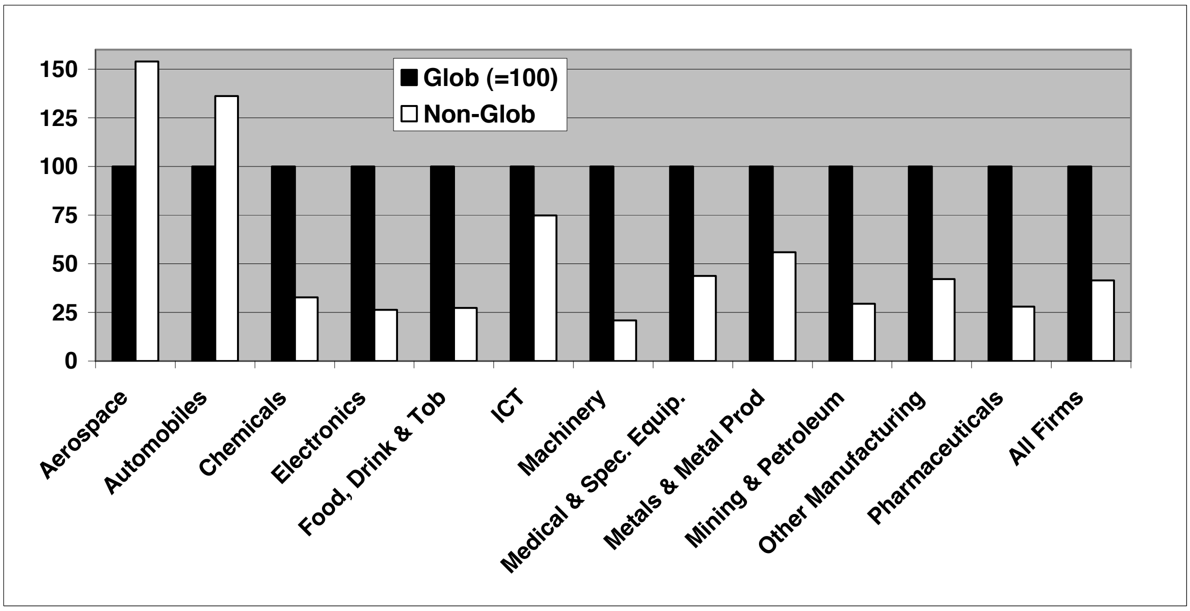


Figure 2 Comparing firms according to their Market Value (2001-06)



The results in terms of market capitalization (Figure 2) largely confirm those based on sales. For example for the sample as a whole the most globalized firms are on average 2.5 times bigger in terms of market capitalization than those that are the least globalized. Some of the contrasts between industries mentioned above in terms of sales also appear here. For example firms in the *Machinery* sector that spread their technology creation on a global scale are on average 5 times larger than those that are more narrowly focused. The same differences between the two categories of firms can be observed in the *Pharmaceuticals Mining and Petroleum* and *Food, Drink and Tobacco* industries, albeit on a smaller scale. In contrast *Non-glob* firms in *Aerospace* and *Automobiles* and are between 50% and 40% larger than *Glob* firms in terms of market capitalization.

Differences according to volume of Technological Activities

Here we use two measures of the size of technological activities to compare globalized and non-globalized firms: *R&D expenditures* (Figure 3) and *Number of patent applications* at the EPO (Figure 4).

Figure 3 Comparing firms according to the volume of R&D Expenditures (2001-06)

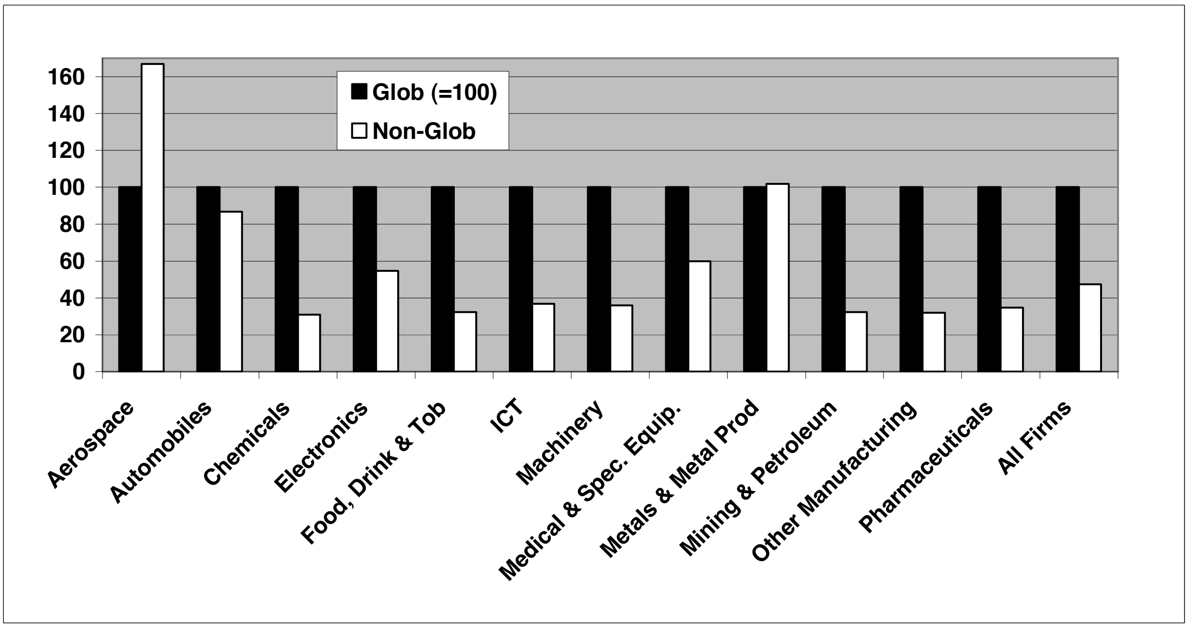
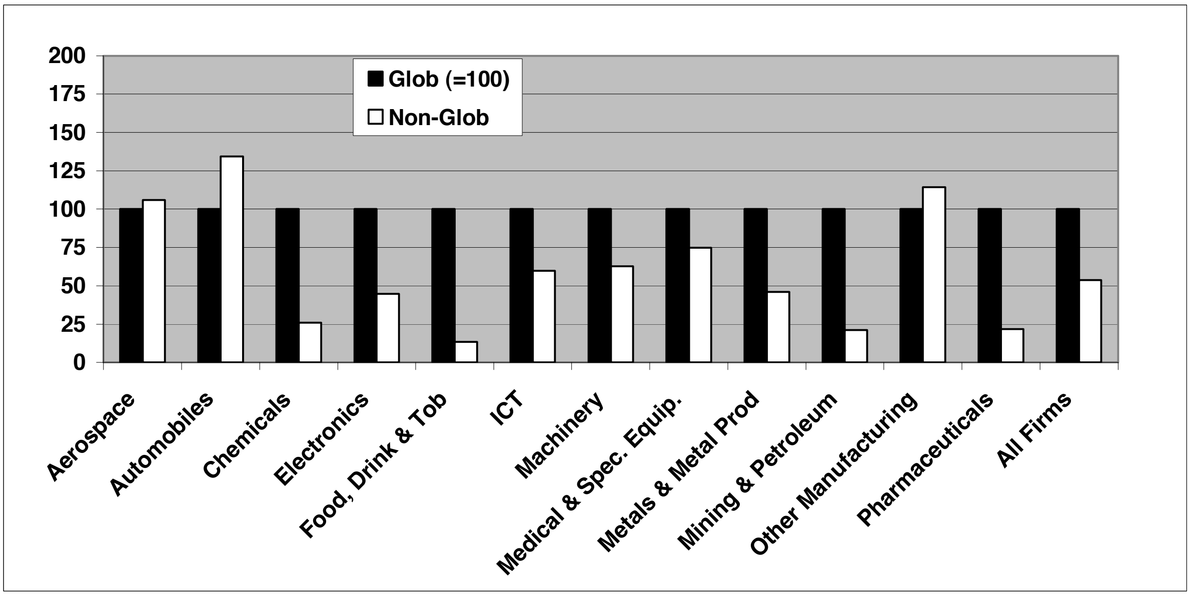


Figure 3 shows that on average firms with a globalized structure of knowledge creation spend twice as much on R&D as those with a more narrow geographic spread. The differences between the two sets of firms are the largest for the *Chemicals*, *Mining & Petroleum*, and *Food, Drink & Tobacco* industries. Here firms at the forefront of global technology creation have R&D expenditures that are more than 3 times those of non-globalized firms. Similar differences can be found in *Pharmaceuticals, Machinery* and *ICT* industries, albeit at a lower level. The one industry where the opposite pattern applies is *Aerospace*, where the *NonGlob* firms spend 60% more on R&D than the *Glob* firms.

In Figure 4 we analyse the differences according to the volume of patenting. Overall this confirms the results above in terms of R&D spend. In aggregate firms with a non-globalized structure of knowledge creation have half the number of patent applications compared to their globalized counterparts.

Figure 4 Comparing firms according to Total number of Patent Applications (2001-06)

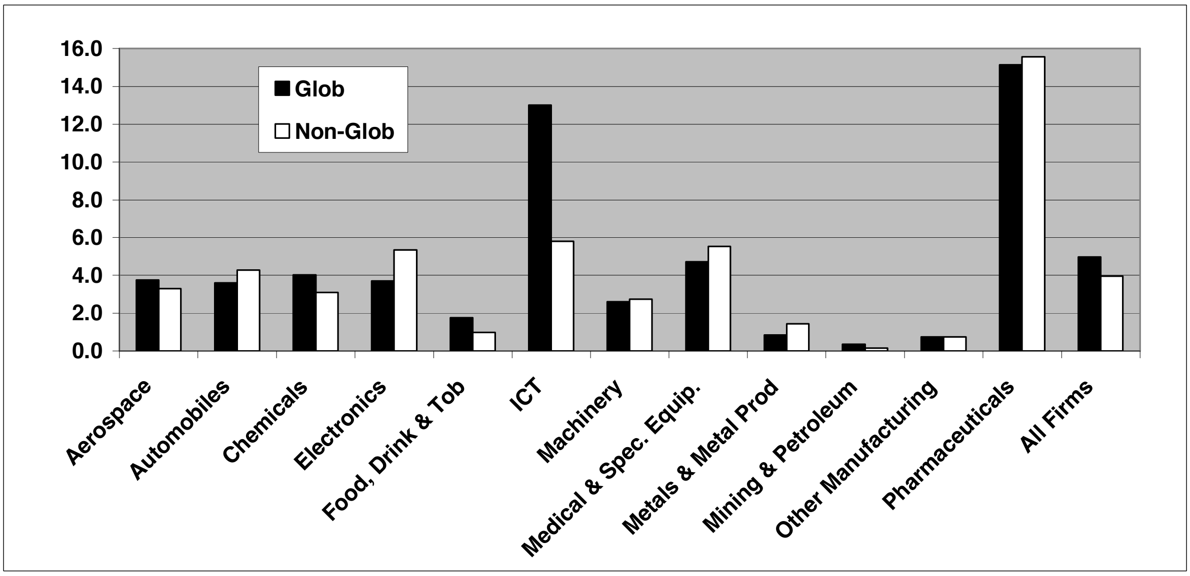


Again the industries with the largest differences between these two categories of firms are those linked to *Chemicals*: *Food, Drink and Tobacco, Pharmaceuticals, Mining & Petroleum*, and *Chemicals*. In each of these sectors firms that create knowledge in a relatively large number of countries have more than 4 times the number of patent applications compared to those that are more narrowly focused. The other point to emerge from Figure 4 is that the *Non-Glob* firms in *Automobiles*, *Other manufacturing,* and to a lesser extent *Aerospace* have a higher volume of patenting than those in the *Glob* category.

Differences according to Technology Intensity

The above analysis has outlined the differences according to the volume of activity, we now turn to an analysis based on measures of technology intensity: *R&D intensity* (R&D as a % of sales) and *Patent Intensity* (Patents per billion euros of sales).

Figure 5. Differences according to R&D Intensity: (2001-06)

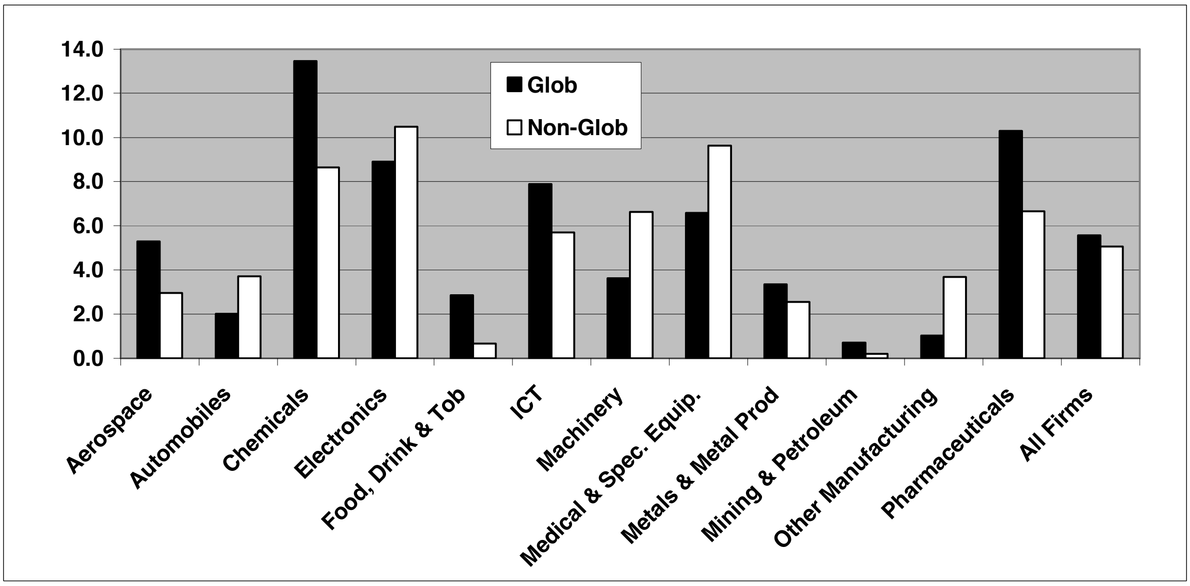


The main point to emerge from Figure 5 is that many of the differences observed in terms of economic and technological size between globalized and non-globalized firms largely disappear when we consider R&D intensity. Taking the sample as a whole, firms that create technology in a large number of locations have an R&D intensity of 5% compared to 4% in the case of firms which are active in a small number of locations. While this difference is statistically significant, it is rather small. In another sector highlighted above as having large differences, *Pharmaceuticals*, the disparity between the two sets of firms is negligible (15.1% for *Glob* and 15.6% for *Non-Glob*).

Figure 5 also shows that a sector where globalized firms have a much higher intensity than their non-globalized counterparts is *ICT*, where the former spend 13.0% of their sales on R&D and the latter 5.8%. Another such sector albeit at a lower scale is *Chemicals* (*Glob* firms with 4% and *Non-glob* firms with 3.1%). However in a number of other sectors such as *Electronics* and *Automobiles*, firms which have a high level of geographic concentration in terms of knowledge creation have a higher level of R&D intensity than those that are much more globalized in their structure.

The data presented in Figure 6 on differences according to patent intensity confirm the results highlighted above in terms of R&D intensity. For example, in the *ICT* sector the globalized firms have a much higher patent intensity than non-globalized firms, and the reverse applies in *Electronics*.

Figure 6. Differences according to Patent Intensity: (2001-06)



Differences in Profitability

The analysis of the differences in profitability is based on 4 different measures: *Tobin's Q, Operating Margin, Return on Sales* and *Return on assets*. The results for the first two of these are reported in Figures 7 (*Tobin's Q*) and 8 (*Operating Margin*) and those for the other two performance measures are reported in the Appendix.

There are certain similarities between the results for the reported in Figures 7 and 8. For example in the case of the *Food Drink and Tobacco* and *Pharmaceuticals* industry firms with relatively more globalized structure of knowledge creation have a higher level performance compared to those that are less globalized, whichever measure of performance is used. However in the case of *ICT* and *Chemicals* firms the two measures show different results. If we take *Tobin's Q*, then globalized firms perform much better then their non-globalized counterparts. However the opposite applies when the measure of performance is *Operating Margin*.

Figure 7. Differences according to Tobin's Q : (2001-06)

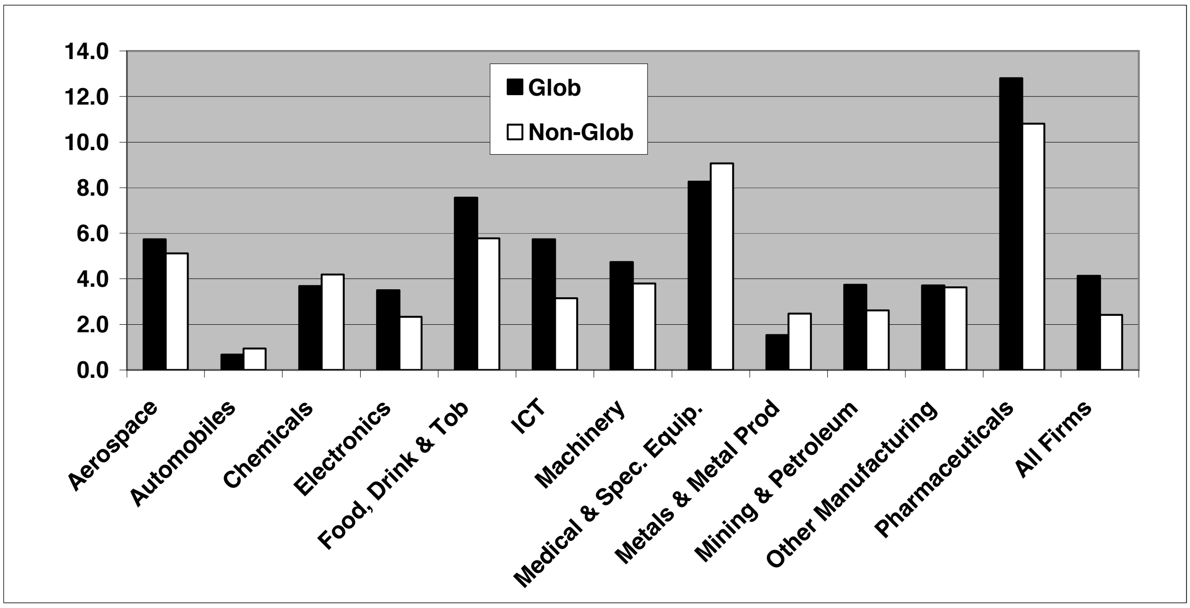
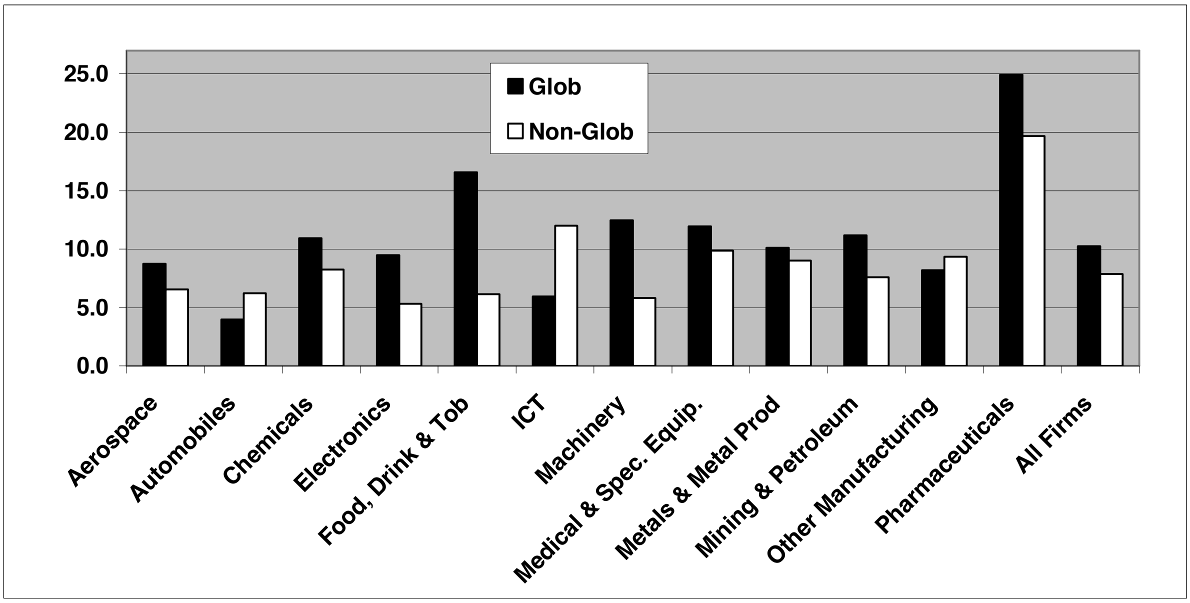


Figure 8. Differences according to Operating Margin : (2001-06)



On the basis of the results reported in Figures 7 and 8 and A1 and A2 (in the appendix) the main conclusions to emerge is that there is a great deal of heterogeneity amongst industries in the relationship between globalization and economic performance. Thus firms that source their technology from a number of different countries have a much higher level of profitability in *Electronics, Machinery, Pharmaceuticals, Aerospace* and *Mining & Petroleum*. On the other hand in the case of *Automobiles* and *ICT* industries, the firms that are much more geographically concentrated in their knowledge sources have a relatively higher level of performance. There is a further group of industries where it is difficult to draw firm conclusions as the different measures show different results: *Chemicals* and *Medical equipment*.

5. Assessment and Discussion

The aim of this paper is to analyse the performance characteristics of large firms that are at the forefront of globalization of their knowledge creating activities. This we do by making a comparison with firms that are much more concentrated in terms of their knowledge creation. Our analysis is based on around 500 of the world's largest technologically active companies, with their headquarters in the EU, Japan and the US. These companies account for a large proportion of both corporate R&D spending worldwide and total EPO patenting. In particular we address the following sets of questions:

- *Are globalized firms larger than those that are non-globalized?*
- *Do globalized firms have higher volumes of innovative activity than non-globalized firms?*
- *Do globalized firms have higher innovation intensity than non-globalized firms?*
- *Do globalized have a higher level of economic performance than non-globalized firms?*

The main conclusion to emerge from the results reported in section 4 is that the answer to these questions depends on the sector to which a particular firm belongs. At the aggregate level firms with geographically dispersed technology creation are on average considerably larger, have a higher volume of innovative activities, and perform much better economically. In terms of innovation intensity the differences between the two sets of firms for the sample as a whole are small. However there are considerable variations across sectors in this aggregate pattern as shown in Table 2, which gives our assessment of the answers to each one of the above questions on the basis of the foregoing analysis.

In terms of size, while firms from most sectors conform to the aggregate pattern, the more globalized companies in the *Aerospace* industry are, on average, smaller than the non-globalized firms. In terms of the volume of innovation the anomalies are the *Automobiles* firms. The pattern for innovation intensity is very different with globalized firms from 5 sectors having a lower average value than those that remain geographically more concentrated. The largest variation is in terms of economic performance, with firms in 6 out of the 11 sectors reported in Table 2 showing a positive relationship with globalization of technology, 3 showing a negative relationship and a further 2 the results are unclear.

Table 2 Are there Differences in the characteristics of globalized and non-globalized firms?

	Economic Size	*Innovation Volume*	*Innovation Intensity*	*Economic performance*
Aerospace	N	N	Y	Y
Automobiles	??	??	N	N
Chemicals	Y	Y	Y	??
Electronics	Y	Y	N	Y
Food, Drink & Tobacco	Y	Y	Y	Y
ICT	??	Y	Y	N
Machinery	Y	Y	N	Y
Medical & Specialized Equip.	Y	Y	N	??
Metals & Metal Prod	Y	Y	??	N
Mining & Petroleum	Y	Y	N	Y
Pharmaceuticals	Y	Y	??	Y
All Firms	Y	Y	??	Y

Y indicates that the Glob firms perform better in that measure; ***N*** indicates the opposite and ***??*** indicates very little difference

The differences between sectors can be illustrated by comparing *Pharmaceuticals* and *Automobiles* firms, which according to the EU R&D scoreboard appear amongst the top 20 R&D spenders. In the case of *Pharmaceuticals*, the most global technology creating firms are larger, spend more on innovation and perform better in terms of profitability measures compared to those that remain geographically concentrated. In terms of innovation intensity the difference between the two groups of firms is negligible. For *Automobile* firms there is virtually no difference between the global and the non-global firms in terms of either size or innovation volume. But firms in this sector that are geographically concentrated in terms of technology creation have higher innovation intensity and perform much better in terms of profitability than those that create new technology in multiple locations.

These results suggest that any analysis of the relationship between performance and global location of technology needs to adopt a sectoral approach. They also suggest the need for a deeper understanding of the costs and benefits of globalization versus concentration within each industrial sector.

However one of the shortcomings of the current analysis is the lack of a dynamic element, without which it is difficult to analyse any causal relationships. The main reason this was not undertaken in the current paper is the poor quality of the financial data as we go further back in time. This issue is currently being addressed and once this is resolved we will be able to undertake a more sophisticated econometric analysis of the relationship between economic performance and global creation of technology.

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Appendix

Figure A1. Differences according to Return on Sales : (2001-06)

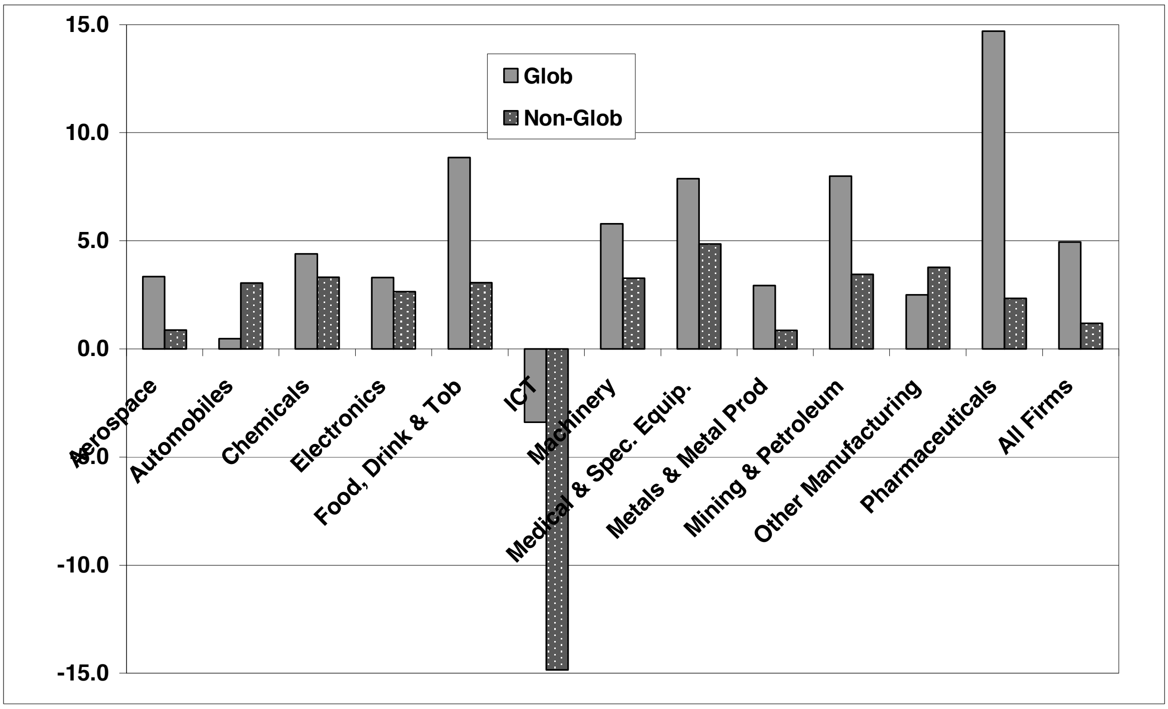

Figure A2. Differences according to Return on Assets : (2001-06)