SPRU
Science and Technology Policy Research

SPRU Electronic Working Paper Number 190

Location of Innovative Activities of EU Large Firms

Parimal Patel

SPRU University of Sussex

May 2011

University of Sussex
SPRU – Science & Technology Policy Research

SPRU – Science and Technology Policy Research
The Freeman Centre
University of Sussex
Falmer, Brighton, BN1 9QE
http://www.sussex.ac.uk/spru

GlobInn

Location of Innovative Activities of EU Large Firms

Parimal Patel

SPRU, University of Sussex

The underlying research for this working paper was funded by European Community's Seventh Framework Programme under grant agreement number 217296 (GlobInn: *The changing nature of Internationalization of Innovation in Europe: impact on firms and the implications for innovation policy in the EU)*.

Summary

This paper focuses on the main stylized facts emerging from a systematic analysis of the geographic location of knowledge-creating activities of the world's largest technologically active firms. Together these firms accounted for more than 85% of all corporate R&D in 2006 and 70% of all EPO patent applications in the period 2001-06. Thus the decisions made by these firms in terms of location of their technology facilities have important implications for both their home countries and for the host countries. In particular it addresses the following questions:

- What are the main trends in the volume and spread of innovative activities of European firms since the 1990s?
- What have been the main changes in location of such activities over time? Has the balance between the intra-EU and extra-EU dimension changed?
- Which are the industries in which EU companies are increasingly engaging with non-EU sources of knowledge?
- To what extent are EU firms engaged in this process in the areas of highest technological opportunities?

Our results show that a very high share of European firms are technologically active outside their home countries. However in terms of volume, foreign sources account for a small share of overall technology creation amongst the EU firms. The main implication of this result is that although a large number of EU companies have technology centres outside their home countries, many of these centres are relatively small. This in turn means that such centres may be involved in adapting products developed elsewhere within the company for the local market, or may be 'listening posts' aimed at monitoring developments in science and technology in foreign locations.

The results also show that the degree of internationalisation of technology varies greatly according to the nationality of EU firms and according to their main industry of activity. In relation to the first there is some evidence that this is a reflection of country-size, as companies based in some of the smaller countries, such as Belgium, Sweden, Austria, Finland and Switzerland have the highest share of technological activity in foreign countries. At the same time firms with their headquarters in large countries like Germany and Italy have much smaller shares outside the home country. The implication of this result is that some of the companies from the smaller EU countries may have gone beyond adaptation and monitoring to developing new products and processes for global markets in foreign locations. In the case of the small countries this reflects the fact that some of the technologies and skills related to new products and new processes may be in scarce supply in the home country.

There is a considerable variance across industries in terms of foreign sourcing of technological knowledge. EU firms in 4 industries appear to be amongst the most globalized when we consider the geographic spread of their knowledge creation: *Mining & Petroleum*, *Chemicals*, *ICT*, and *Pharmaceuticals.* In these industries more than 90% of EU firms have some technical facilities in at least one location in the major regions of the world. However in terms of volume, even in these industries, a much smaller proportion of the total knowledge is created in foreign countries.

The analysis in this paper shows that for large European firms the most important foreign locations are within the EU-15. These locations account for more than half of their total volume of foreign inventions. Moreover two-thirds of our sample of EU firms are active in at least one other EU-15 country, and this proportion has risen from just over one-half in the early 1990s. This result implies that an important element of the explanation for increased globalization of EU firms is the increasing integration of their research across the large R&D spending countries within the EU.

In general the most preferred location of EU firms outside the EU is the US, with more than half our sample maintaining some facilities there. This is especially the case for *Chemicals*, *Pharmaceuticals* and *ICT* firms. As for the Asian countries, around 15% of EU companies source some technology from Japan, 8% from China and less than 4% in India. Together the Asian countries account for less than 2% of the total inventions generated by our sample of EU firms. However the relative importance of India and China has risen rapidly since the 1990s when only negligible share of EU firms had any activity there.

Our results are consistent with those obtained from the latest firm-level survey undertaken by IPTS. They are also consistent with the notion that companies are increasingly involved in different foreign locations in order to tap into the local S&T resources, rather than simply adapt their products for the local markets. Such resources include access to a large pool of highly qualified personnel and other specialized R&D inputs which may not be readily available especially in the smaller EU countries. They are also consistent with the notion that firms maintain a presence in foreign locations in order to learn about the innovative activities of other firms. All of these have been cited as important reasons for increasing globalization of R&D and innovation. However the results reported here are not consistent with the view that EU large firms are in a position to introduce an entirely new range of products and processes outside the EU.

1. Introduction and Aims

Globalization of innovative activities in general, and R&D in particular, has increasingly become the centre of attention amongst policy makers and academics. It is not a new phenomenon as the first major academic studies on the subject began appearing more than 20 years ago (for a summary of this early work see Granstrand et. al. (1992)). The main conclusion of this early work was that the world's largest R&D spending firms tend to locate a vast proportion of their innovative activities at home, close to the location of their headquarters (Patel & Pavitt 1991). Two major features related to the launching of major innovations were highlighted as the main reasons for this geographic concentration: the key role played by 'person-embodied' knowledge inputs and the high degree of uncertainty surrounding outputs. Both of these are best handled through intense and frequent personal communications which enable rapid decision making. While some of these communications may be undertaken electronically, this is no substitute for geographic concentration of key units and personnel within the firm.

Since then many studies have argued that firms have become more globalized in terms of creation of new knowledge (i.e. knowledge related to the generation of new products and processes) and that this process has been driven by two factors.[1] First is the emergence of significant centres of technology creation outside the Triad (i.e. US, EU and Japan). Second is the greater complexity of new products and processes requiring a wider array of knowledge inputs. Both of these factors require firms be present in an increasing number of geographic locations in terms their knowledge creating activities.

One of the key overall aims of the GlobInn project is to analyse the extent to which EU firms are participating in this process and whether this leads to increasing levels of competitiveness, both in terms of technology and profitability. More precisely this paper focuses on the main stylized facts emerging from a systematic analysis of the locations of knowledge-creating activities of EU firms. It compares them to their major counterparts in the US and Japan and addresses the following questions:

[1] See OECD (2008).

- What are the main trends in the volume and spread of innovative activities of European firms since the 1990s?
- What have been the main changes in location of such activities over time? Has the balance between the intra-EU and extra-EU dimension changed?
- Which are the industries in which EU companies are increasingly engaging with non-EU sources of knowledge?
- To what extent are EU firms engaged in this process in the areas of highest technological opportunities?

The analysis is based on 963 worldwide companies which are technologically active. These companies account for a large proportion of corporate R&D and EPO patenting. The results feed directly into the analysis of the impact of global R&D and technology creation on the market value of firms (see SEWP 191). They also form the background to the in depth case studies of the management challenges and nature of international innovative activities undertaken in EU and non –EU locations: the how and why of technology internationalisation (SWEP 192).

The paper is organized as follows. Section 2 discusses the main measures that have been used in previous literature on the internationalisation of innovative activities of large firms. In Section 3 we discuss data and methods employed in our analysis. The main results related to the above questions are presented in Section 4, followed by our assessment and discussion in Section 5.

2. Measuring location of knowledge creating activities of Large Firms

Large multinational companies play a dominant role in the innovation activities of their home country and control a vast proportion of world's stock of advanced technologies. Their decisions in terms of the mode, location and exploitation of their R&D results greatly influence the home country's technological potential and competitiveness (Patel and Pavitt, 1999). The growing significance of the internationalisation of knowledge creating activities of large firms over the past two decades has therefore been cause of some concerns among innovation policy makers. In Europe this has resulted in a concern that the increasing levels of knowledge creation of EU firms from foreign locations is resulting in a 'hollowing out' of national R&D. This is regarded as indicative of a weakening of the national innovation system and an erosion of technological competitiveness. In the United States the internationalisation of industrial R&D has brought with it worries about a possible impoverishment of the national technology base due to the increasing local R&D activities of foreign firms.

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*. 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. At the same time there are a number of issues specific the use of these 3 measures as indicators of globalization of technology that need to be discussed.

Official R&D Surveys

The OECD collates all the national surveys based on the Frascati definition of R&D and regularly publishes analyses of globalization based on these data (see for example OECD (2008)). The main focus of these surveys is R&D undertaken by companies

within a given country and hence the resulting statistics are useful for analysing the involvement of foreign firms in national R&D. However there are a number of practical difficulties in making international comparisons at a sufficient level of detail. For example very few countries publish data on the share of R&D undertaken by foreign firms by industry and according to the nationality of the firm.[2]

Most OECD countries do not regularly collect statistics on R&D undertaken by national firms outside the home country. So for example OECD (2008) includes data for 8 countries which monitor this activity.[3] However, even for most of these 8 countries the data are not regularly published by the national statistical offices. The main exception is the US, which has conducted a regular survey over a long period of time and published the results by industry and country of destination (but not both at the same time). The final point to note in relation to the use of official R&D surveys is that there is very little scope for using the data for firm level analyses due to confidentiality concerns.

Patents Statistics

There is a long history of analysing the nature and extent of the geographic spread of technological activities within large firms using data on patenting (Etemad and Seguin-Delude, 1987; Cantwell, 1992; Le Bas and Sierra, 2002, Patel and Pavitt, 1991; Patel, 1995 and 1996; Patel and Vega, 1997 and 1998). This research is based on two underlying assumptions. First is that patents are a good reflection of incremental knowledge created by a company. The second is that the address of the inventor contained on the front page of a patent is a good proxy for where this knowledge was created. Our previous research has shown that the patterns revealed by patenting statistics are consistent with those revealed by the R & D statistics that are available (see Patel and Pavitt (2000) and Patel (1995 and 1996)).

Very briefly patent statistics can be used at the level of the firm to analyse:

- The relative importance of different locations

[2] A notable exception is the US where data on the involvement of foreign firms by nationality and industry are regularly published in the *National Science and Engineering Indicators*. See *http://www.nsf.gov/statistics/seind10/*

[3] Belgium, Germany, Italy, Finland, Sweden, Switzerland, Japan and the US

- Differences according to technical fields and industries
- Importance of foreign firms in national technological activities.

This paper is focused on the first of these two and the approach taken is discussed further in the next section.

Recent ad-hoc Firm level surveys

There is a long tradition of surveys of selected companies, industries, or countries, concerned with understanding the nature and motivation for firms locating technological activities in foreign locations. The results from the latest generation of these surveys, undertaken in the last 5 years, have become influential in the discussion of the type of activities undertaken by MNCs outside their home countries and the reasons why. The most prominent of these are:

- UNCTAD (2005)[4]: A survey of 69 large MNCs
- Booz Allen Hamilton and INSEAD (2006)[5]: A survey of 186 global firms
- Thursby and Thursby (2006)[6]: A Survey of 203 US and EU firms
- IPTS-EU (2005, 2006, 2007, 2008)[7]: A Survey of 130 EU firms

These surveys have provided much needed empirical evidence gathered directly from firms on globalization of their R&D. Their main strengths are firstly that they elucidate the relative importance of factors that affect the location decisions of firms. They also provide some idea about the future plans of firms in terms of the location of their R&D.

As an illustration of the type of information that can be obtained from these surveys, the latest IPTS-EU survey highlights the following results. Two-thirds of the sample

[4] UNCTAD (2005), *UNCTAD survey on the internationalization of R&D: Current patterns and prospects on the internationalization of R&D* UN, New York. http://www.unctad.org/en/docs/webiteiia200512_en.pdf

[5] Booz Allen Hamilton and INSEAD (2006), Innovation: Is Global the Way Forward? <www.boozallen.com/media/file/Innovation_Is_Global_The_Way_Forward_v2.pdf>.

[6] Thursby, J and Thursby, M (2006) , Here or There: A Survey of Factors in Multinational R&D Location, Washington, D.C.: National Academy of Sciences. <http://www.nap.edu/openbook.php?record_id=11675&page=1>

[7] IPTS (2005-8), *The EU Surveys on R&D Investment Business Trends (2005-2008)*, IPTS, Seville <http://iri.jrc.ec.europa.eu/research/docs/survey/2008/JRC51800.pdf>

of EU companies regard the home country as the most attractive location for their R&D. This proportion has changed little since 2005. On average these companies undertake around 20% of their R&D outside the EU. The most important non-EU locations are the US and Canada, and within the EU, Germany. India and China account for around 3% each of EU companies' R&D. The latest survey (2008) shows that there are some early indications that within-EU locations are becoming relatively more favourable.

While these surveys form an important part of our assessment of globalization of R&D, they need to be treated with some caution. Firstly their focus is R&D, hence neglecting other knowledge creating activities from outside the R&D laboratory. Secondly it is difficult to compare the different surveys as there are big differences in the composition of the samples. Their third important shortcoming is that they cannot be analysed by country of origin of the firm or the industrial sector.

3. Data Sources and Methods

The above discussion has highlighted the three main measures employed in the literature concerned with analysing the location of innovative activities of firms, together with their main strengths and weaknesses. This paper is based on patent statistics. The aim is to make the best available use of patent data while, at the same time, minimizing their main shortcomings.

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 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*. We also obtain information on the *country address of the headquarters* and the *principal product group* of the firm from this source.

Construction of the Sample

Our sample of 963 firms consists of the most technologically active companies in the world. We began the process of sample selection by constructing a list of the top patenting firms at the EPO. For this we considered patent applications with priority years between 1991 and 2006. We began with a long list of some 3000 firms which were checked against the on-line version of Hoovers. The identified firms were then compared to the 2000 companies included in the EU R&D Scoreboard for 2007.[8] Thus our sample comprises firms that are R&D active but includes others that are

[8] See http://iri.jrc.ec.europa.eu/research/scoreboard_2007.htm

large patentees but do not appear in the R&D Scoreboard. We regard the resulting 970 firms as the most technologically active 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

Table 1 shows the numbers of large firms in our sample according to their principal product group and region of origin (based on the country of the HQ).[9] Overall more than two-thirds of these firms are R&D active. In terms of nationalities more than 40% are of European origin, just under one-third are American and around a quarter are Japanese. The product groups most represented in our sample are *Medical and other specialized equipment* (including *Instruments*), *Chemicals* and *Electronics*. These three industries together with *General Machinery and Equipment* comprise more than 50% of the sample.

Table 1. Distribution of Large firms by Industry and Region.

Industry	Japan*	EU	USA**	Total
Aerospace & Defence		12	12	24
Automobiles & Parts	28	47	19	94
Chemicals & Chemical Products	48	45	44	137
Electronics (inc Electrical)	48	50	34	132
Food, Drink & Tobacco	8	15	10	33
ICT	11	22	51	84
Machinery & Equipment	29	56	19	104
Medical & Other Specialized Equipment	22	67	56	145
Metals & Metal Products	20	49	10	79
Mining & Petroleum	6	10	8	24
Other Manufacturing	5	4	7	16
Pharmaceuticals	14	43	33	90
Whole Sample	240	420	303	963

* Includes 9 Korean firms and 2 from Taiwan.
** Includes 9 Canadian firms.

[9] There are a number of bi-national firms included in our analysis (such as Shell and Unilever). They have been assigned a region arbitrarily in Table 1 but they have been treated as bi-national in the following analysis. In other words for Shell both the UK and the Netherlands are considered to be home countries.

Construction of Patent Indicators

We use the *country address* of the inventor as a proxy measure for where the technological activity related to the invention occurred. 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.[10]

Our analysis of changes over time compares company patenting for two time periods: 1991-96 and 2001-2006. One of the main reasons for using this method is to avoid the annual fluctuations that occur in patent data due to administrative reasons.

For the analysis of fast-growing technologies we begin with the list of all the IPC classes at 4 digit level that our firms are active in.[11] For each of these 5700 classes we compute the growth in the volume of patenting between 1991-96 and 2001-2006. For each industry group in Table 1 we then identify the fastest growing IPC classes. The result is a total of 250 classes (across all 12 industries) which increased their share of total patents from around 5% in 1991-96 to more than 15% in 2001-2006. These classes we regard as being areas of greatest technological opportunity for the firms in a particular industry.

[10] In other words we use the 'whole' count approach as opposed to 'fractional' counts.
[11] International Patent Classification version 8

4. Main Results

The core aim of this paper is to present the main stylized facts regarding the location of knowledge creating activities of technologically active EU firms. The results will be used in subsequent analysis to test the relationship between international location of technology and market value of the firm. They will also form the background for the analysis of the difficulties involved in managing internationally dispersed R&D.

The analysis below focuses on the following issues:

- balance between intra-EU and extra-EU locations
- main changes since 1991
- emergence of new locations
- comparisons of EU firms with those from US and Japan
- differences across industries
- internationalisation of technology in the fastest growing areas of opportunity.

We use two types of indicators to measure internationalisation of technology for each firm:

(i) the *share of total patents* of a company with inventor addresses in a location (based on whole-counts rather than fractional counts). This measures the volume of activity in a location.

(ii) *number of foreign locations*, where the aim is to capture locations with activity above a certain threshold. In order to achieve this we only include locations with 5 patents or more in each of the two time periods under consideration: 1991-96 and 2001-06. This is a measure of the dispersion of technological activity of the firm. The assumption is that firms have some on-going R&D and/or other technology creating activity in the identified locations.

Volume of international technology creation of EU firms

In Table 2 we report the share of EPO patents originating from home country locations, foreign research facilities and extra-EU facilities, according to the nationality of the parent company in the period 2001-2006. The degree of

internationalisation measured by this indicator varies substantially among European countries. Companies based in some of the 'smaller' countries, such as Switzerland, Belgium, Sweden, Austria and Finland have among the highest shares of technological activity abroad, while firms from some large countries, such as Germany and Italy, concentrate their efforts in the home country. Two other large R&D spending countries have large firms that are highly internationalized, namely the UK and France.

Table 2. Internationalisation of Technology among EU firms

Nationality	% share of EPO patents in 2001-2006		% share outside the EU
	Home	Abroad	
Austria	50.0	50.0	16.3
Belgium	44.8	55.2	12.2
Denmark	65.7	34.3	16.3
Finland	51.7	48.3	15.6
France	58.4	41.6	18.7
Germany	79.8	20.2	10.5
Italy	84.2	15.8	6.8
Netherlands	58.2	41.8	16.8
Sweden	45.0	55.0	14.5
Switzerland	31.2	68.8	19.5
UK	48.8	51.2	29.8

The data in Table 2 also show that a large proportion of the knowledge creating activities of the European companies are within the EU. This is especially the case with many of the most highly internationalized firms from the smaller countries mentioned above. For example, although more than 55% of all technology creation of Belgian companies occurs outside Belgium, much of it is within the EU, with only 12% outside the EU. The share of extra-EU activity ranges from nearly 30% of the total in the case of UK-based firms to less than 7% in the case of Italian firms.

Table 3 reports the changes in the share of patenting outside the home country since 1991. The largest changes have been for firms based in Finland and Belgium. Both sets of firms have substantially increased the proportion of their knowledge that is created outside the home country. But in both cases the increase in the extra-EU share

has been lower than that within the EU. For example, Finnish firms have increased their foreign share by 15% form 1991 to 2006 but the share accounted for by non-EU locations has only gone up by 5%. In other words the larger increase (around 10%) has been for locations within the EU. Comparing columns 2 and 3 shows that this increase in the relative importance of intra-EU locations also applies to firms based in Germany, Netherlands, Sweden, Switzerland and the UK.

Table 3. Changes in Internationalisation of technology: 1991-96 too 2001-06

Nationality	Total Foreign % Share	Extra-EU % Share
Austria	-3.3	2.8
Belgium	7.7	2.0
Denmark	-3.3	-2.3
Finland	15.2	4.8
France	0.9	3.8
Germany	2.3	0.1
Italy	-9.0	-4.3
Netherlands	2.0	0.7
Sweden	1.5	-7.9
Switzerland	1.5	0.3
UK	0.9	-4.6

EU Firms' presence in different locations

The aim in this sub-section is to explore in some more detail the location of technology creating activities of EU firms by comparing them with their counterparts from the US and Japan. This we do firstly by analysing the number of firms that create some knowledge outside their home countries. Table 4 shows that a large proportion of EU firms (just under 80%) created some knowledge in foreign locations in the period 2001 to 2006. This is very similar to the share of American companies undertaking such activities outside the US. However in the case of Japanese firms this proportion is much lower, under 45%.

According to this measure all technologically active firms have become much more globalized since the early 1990s. For example in the case of both EU and US large firms the proportion creating some knowledge in foreign locations has gone up from around 60% to nearly 80%. Even in the case of Japanese firms this share has increased from 31% in 1991-96 to 44% in 2001-06.

Table 4. Share of firms with some Foreign technological activity in different World regions, by nationality: 1991- 2006

% of All Firms	*Location*								% active	
	EU-15		US or Canada		Asia		Other European			
Nationality	*1991-96*	*2001-06*	*1991-96*	*2001-06*	*1991-96*	*2001-06*	*1991-96*	*2001-06*	*1991-96*	*2001-06*
EU	52.6	68.3	38.1	51.7	11.7	20.2	15.7	28.1	63.1	79.0
US	61.7	78.2			13.5	25.1	8.9	19.8	64.7	81.5
Japan	16.5	30.0	22.6	33.7	6.6	5.3	1.6	4.9	31.3	44.4

Table 4 also shows that more than two-thirds of our sample of EU-headquartered companies has some technology creating facilities in other EU-15 countries (i.e. other than their home countries) and just over a half in the US and Canada. Relatively few EU companies are active in Asia, but this proportion has risen quite steeply since the early 1990s. Other important set of foreign locations for EU companies are the other European country (which includes the New Member States and Norway and Switzerland) and their relative importance has also increased: with around 16% of EU firms active therein rising to 28% by 2001-06.

The other point to note from Table 4 is that almost all the US firms with some foreign activity are active in the EU-15 and around one-fifth in the other European countries. Compared to their EU counterparts relatively more US companies source some technology from Asia.

Table 5 provides more detail in terms of the relative importance of different countries as locations of technology creation. For both EU and Japanese large firms, the US is the most important country and increasingly so since the early 1990s. Within the EU, Germany is the favoured foreign location for firms from all countries. More than half of all US firms had some technology creating facilities in Germany in 2001-06, and 48% were active in the UK, and 31% in France.

Table 5. Share of firms with some foreign technological activity in Different countries, by Nationality: 1991 to 2006

% of All Firms		*Nationality*					
		EU		**USA**		**Japan**	
		1991-96	***2001-06***	***1991-96***	***2001-06***	***1991-96***	***2001-06***
Location Country	**USA**	38.1	51.7			21.8	33.7
	Germany	27.9	35.7	41.6	51.2	8.2	15.2
	France	19.3	30.0	24.1	31.4	2.9	8.2
	UK	16.9	23.6	33.7	47.9	7.0	14.0
	Japan	11.0	15.5	13.2	16.8		
	China	0.2	8.3	0.0	6.3	0.0	1.6
	India	0.7	3.6	0.3	5.9	0.4	0.8

As for the Asian countries, around 15% of EU companies undertake some knowledge creation in Japan, 8% in China and less than 4% in India. However the relative importance of China has risen rapidly since the 1990s when only a very small share of EU firms had any activity there to a position in 2001-06 where 8% of EU firms are active therein.

Table 5 also shows that there is a contrast between American and European firms with regard to the relative importance of India and China as sources of technology. A higher proportion of US companies are active in India (6%) compared to their EU counterparts (3.6%). On the other hand 8.3% of EU firms have facilities in China compared to 6.3% of US firms.

In Table 6 we turn to the analysis in terms of the volume of patenting in the same world regions as reported in Table 4. The main point to emerge from this is that while a large proportion of companies are active in foreign locations, these locations account for a relatively small proportion of the total volume of patenting. Taking the EU companies as an example, while around 68% have some foreign facilities in EU-15 countries (Table 4), these countries account for only 20% of their overall technology creation in 2001-06.

Table 6 also shows that around 10% of all patenting of technologically active EU firms is sourced from the US, and around 2% each from Asia and other European

countries. For the US companies the most important locations are in the EU-15 countries, which together account for just under a quarter of all patents. The table also shows that throughout the period since 1990 US companies have sourced a relatively higher proportion of their technology from Asia than the EU firms. However the share of EU firms' activity in Asia has risen rapidly as has their share in Other European countries.

Table 6. Distribution total technological activity in different World regions, by Nationality: 1991 to 2006

% of total Patents	*Location*							
	EU-15		**US or Canada**		**Asia**		**Other European**	
Nationality	*1991-96*	*2001-06*	*1991-96*	*2001-06*	*1991-96*	*2001-06*	*1991-96*	*2001-06*
EU	18.9	19.8	11.7	10.0	1.2	1.9	1.2	2.0
US	20.7	23.4			2.3	2.3	1.0	1.4
Japan	2.2	3.8	2.5	3.1	0.1	0.3	0.1	0.2

Differences according to Industries

Thus far we have considered all EU firms together. However previous research has shown that there are large differences across industries in terms of globalization of technology (Patel 1995). This sub-section examines the differences according to 11 industries in the foreign activities of EU firms (Tables 7 and 8).[12]

Table 7 confirms that there is a considerable variance across industries in terms of foreign sourcing of technological knowledge. This ranges from *Mining and Petroleum* where all EU firms are active in at least one foreign location to *Aerospace* firms, where only just over one-half are active outside the home country.

The data presented in this table show that EU firms in 5 industries are amongst the most globalized in terms of their knowledge creation: *Mining and Petroleum*, *Chemicals*, *ICT*, *Pharmaceuticals* and *Automobiles*. In these industries a large proportion of EU firms have some technical facilities in at least one location in the

[12] Here industry refers to the principal product group of the firm.

major regions of the world. Taking *Chemicals* as an example, more than 95% of EU firms source some technological knowledge outside the home country, more than 90% do so in at least one other EU-15 country, 70% in the US & Canada, more than 50% in Asia and around 44% in other European countries (which includes New Member States, Switzerland and Norway).

Table 7. EU firms active in Foreign locations by Principal Product Group: 2001-06

Industry	*Total No. of Firms*	% of EU Firms Active in				
		Any Foreign Location	*EU15*	*US or Canada*	*Asia*	*Other European*
Aerospace & Defence	12	58.3	58.3	50.0		25.0
Automobiles & Parts	47	78.7	70.2	53.2	23.4	25.5
Chemicals & Chemical Products	45	95.6	91.1	75.6	53.3	44.4
Electronics (inc Electrical)	50	76.0	62.0	46.0	18.0	28.0
Food, Drink & Tobacco	15	66.7	66.7	53.3	13.3	13.3
ICT	22	90.9	77.3	68.2	45.5	31.8
Machinery & Equipment	56	75.0	67.9	42.9	8.9	17.9
Medical & Other Specialized Equip.	67	67.2	53.7	46.3	4.5	20.9
Metals & Metal Products	49	75.5	65.3	32.7	6.1	22.4
Mining & Petroleum	10	100.0	100.0	60.0	40.0	30.0
Pharmaceuticals	43	90.7	67.4	62.8	30.2	48.8
Whole Sample	420	79.0	68.3	51.7	20.2	28.1

The other point to emerge from Table 7 is that a relatively large proportion of EU firms from most industries are active in at least one location within the EU-15 and in the US. There are much bigger variations across industry in the relative importance of the Asian countries and the Other European countries. In the case of Asia this ranges from 4.5% of EU *Medical Equipment* firms having some facilities there to more than 50% in the case of *Chemicals*. The other industries with a low share of active firms in Asia are *Metals* and *Machinery*.

According to this measure the most highly integrated industries in terms of the EU are *Chemicals* and *Pharmaceuticals*. Both have a large proportion of firms (more than 90%) with technology creating facilities within at least one other EU-15 country. They also have a high proportion active in at least one other European country: 49% in the case of *Pharmaceuticals* and 44% in *Chemicals*.

The data reported in Table 8 confirm one of the main results discussed above, namely

the considerable variance across industry in the globalization of technology amongst EU firms. For example considering the relative importance of the volume of foreign sources as a whole, the table shows that this varies from 14% of all knowledge creation for *Aerospace* firms to 53% in the case of *Pharmaceuticals*.

Table 8. Distribution of the volume of technological activity of European firms by Principal Product Group and Location: 2001-06

Industry	% of Total patents Invented in				
	All Foreign Locations	***EU15***	***US & Canada***	***Asia***	***Other European***
Aerospace & Defence	13.7	8.3	5.1		0.3
Automobiles & Parts	16.4	10.1	3.8	1.3	1.0
Chemicals & Chemical Products	34.8	19.9	9.8	2.4	2.1
Electronics (inc Electrical)	35.0	20.1	9.8	1.7	3.1
Food, Drink & Tobacco	46.5	16.7	23.3	4.6	0.2
ICT	43.5	27.4	11.0	2.8	1.4
Machinery & Equipment	26.1	19.1	4.2	0.7	1.5
Medical & Other Specialized Equip.	33.5	21.3	8.4	0.4	3.3
Metals & Metal Products	30.4	20.1	7.5	0.6	1.9
Mining & Petroleum	45.3	22.6	16.3	2.4	3.0
Pharmaceuticals	53.2	27.7	20.2	2.6	2.3
Whole Sample	35.6	19.8	10.0	1.9	2.0

Table 8 also confirms one of the other major results reported above at the aggregate level, i.e. that while globalization appears to be very prevalent when considering the numbers of large firms that some foreign technological activity in the major regions of the world, it appears to be less so in terms of the total volume of such activity located in those regions. Taking EU *Automobile* firms as an example, Table 7 shows that 79% have some activity in at least one foreign location, more than half are active in the US or Canada and around a quarter in Asia and the other European countries. In contrast the data in Table 8 show that only 16% of these firms' total knowledge creation occurs in foreign locations, 10% of which is within the EU-15, 4% in the US and only around 1% in Asia and other European countries.

EU firms in the following 4 industries are amongst the most internationalised in terms of the relative importance of foreign sources in the volume of total technology creation: *Pharmaceuticals, Food, Drink and Tobacco, Mining & Petroleum,* and *ICT*.

For these industries the percentage of all patents invented in foreign locations ranges from 43% to 53%. These are also firms with a high share of foreign activities in the EU-15 and in the US. On the other hand firms in *Aerospace*, *Automobiles* and, to a lesser extent, *Machinery* are amongst the least internationalised, with the share of foreign invented patents ranging from 14% to 26%.

Table 8 also shows that in 10 out of the 11 industries EU firms locate a relatively share of foreign technological activity in EU-15 countries compared to their share in the US and Canada. The exception is the *Food, Drink and Tobacco* industry where nearly a quarter of all patents are invented in the US compared to 17% in the EU-15. In terms of locations Asia and other European countries account for a very small share of EU firms' total knowledge creation across all industries.

Finally we examine the extent to which EU firms are locating their technology in the fastest growing areas of opportunity outside the home country by analysing the share of firms active in different locations (Table 9).

Table 9. EU firms active in Foreign locations in Fast-growing areas of technology by Industry: 2001-06

Industry	% Active in				
	Any Foreign Locations	***EU15***	***US & Canada***	***Asia***	***Other European***
Aerospace & Defence	33.3	25.0	16.7		
Automobiles & Parts	48.9	31.9	36.2	12.8	8.5
Chemicals & Chemical Products	51.1	28.9	33.3	17.8	11.1
Electronics (inc Electrical)	34.0	32.0	20.0	8.0	8.0
Food, Drink & Tobacco	26.7	20.0	20.0	6.7	
ICT	81.8	72.7	45.5	27.3	18.2
Machinery & Equipment	37.5	30.4	16.1	3.6	3.6
Medical & Other Specialized Equip.	29.9	19.4	17.9	1.5	6.0
Metals & Metal Products	26.5	20.4	12.2	2.0	10.2
Mining & Petroleum	50.0	30.0	40.0	10.0	10.0
Pharmaceuticals	53.5	39.5	39.5	14.0	16.3
Whole Sample	41.9	29.9	24.7	8.7	8.7

The first point to note is that around 42% of all EU firms have some technology facilities outside the home country in the fastest growing technical fields, with 30% of firms active in EU-15, 25% in the US and around 9% each in Asia and other European

countries. European ICT firms are amongst the most internationalized according to this measure: around 82% are active in at least one foreign location, 73% in EU-15 countries, 45% in the US and 27% in locations in Asia. A relatively high proportion of EU firms in *Pharmaceuticals*, *Mining & Petroleum*, and *Automobiles* create some knowledge related to fast changing areas of technology opportunity in both the USA and in other EU-15 countries. However, in the *Metals industry*, *Food, Drink and Tobacco* and *Medical equipment*, a smaller share of firms are active in foreign locations.

5. Assessment and Discussion

This paper has focused on the main stylized facts emerging from a systematic analysis of the geographic location of knowledge-creating activities of the world's largest technologically active firms. Together these firms accounted for more than 85% of all corporate R&D in 2006 and 70% of all EPO patent applications in the period 2001-06. Thus the decisions made by these firms in terms of location of their technology facilities have important implications for both their home countries and for the host countries.

Here we proxy the geographic location of innovative activities of firms on the basis of the inventor addresses named on their patent applications. There are a number of difficulties associated with the use of patent statistics as indicators of technology. For example the propensity to protect innovative leads varies by field of technology and size of firm. In the present analysis we mitigate the effect of such biases by comparing 'like with like', i.e. by considering large firms only and by comparing firms within industries. The assumption is that large firms within the same industry are likely to have similar propensity to patent. In any case our review of the main measures of location of innovation used in past studies showed that for any systematic analysis (i.e. across countries, industries and locations) at the firm-level there is very little choice other than using patent data. The only alternative is to collect primary data through a survey of technologically active companies.

In the paper we analyse two dimensions of globalization of technology: volume and dispersion. The volume of activity of a firm in a location is measured by the share of total patents with inventor addresses in that location. The dispersion measure is based on the countries in which a firm has patents above a certain threshold. The assumption being that in such a country the firm has some on-going R&D or other technology creating activity.

Spread vs Volume

At a general level our results show that a very high share of European firms are technologically active outside their home countries. However in terms of volume,

foreign sources account for a small share of overall technology creation amongst the EU firms. Thus in 2001-06 nearly 80% of the 420 technologically active EU companies in our sample had knowledge creating facilities in at least one foreign country. In the same period the share of total inventions originating from foreign locations for these firms was around 35%. The main implication of this result is that although a large number of EU companies have technology centres outside their home countries, many of these centres are relatively small. This in turn means that such centres may be involved in adapting products developed elsewhere within the company for the local market, or may be 'listening posts' aimed at monitoring developments in science and technology in foreign locations. It also implies that very few European companies are in a position to develop completely new product and processes for the global market in foreign locations. The types of activities undertaken in foreign locations will be elaborated further on the basis of the detailed case studies that are currently being undertaken in workpackage 3.3.

Differences according to Nationality

Our results also show that the degree of internationalisation of technology varies greatly according to the nationality of EU firms and according to their main industry of activity. In relation to the first there is some evidence that this is a reflection of country-size, as companies based in some of the smaller countries, such as Belgium, Sweden, Austria, Finland and Switzerland have the highest share of technological activity in foreign countries. At the same time firms with their headquarters in large countries like Germany and Italy have much smaller shares outside the home country. The UK based firms are an exception: although from a large country they together source more than 50% of technology from foreign sources. The implication of this result is that some of the companies from the smaller EU countries (and the UK) may be an exception to the general rule discussed above. Such firms may have gone beyond adaptation and monitoring to developing new products and processes for global markets in foreign locations. In the case of the small countries this reflects the fact that some of the technologies and skills related to new products and new processes may be in scarce supply in the home country.

Differences according to Industries

There is a considerable variance across industries in terms of foreign sourcing of technological knowledge. This ranges from *Mining and Petroleum* where all EU firms are active in at least one foreign location to *Aerospace* firms, where only just over one-half are active outside the home country. EU firms in 4 industries appear to be amongst the most globalized when we consider the geographic spread of their knowledge creation: *Mining & Petroleum*, *Chemicals*, *ICT,* and *Pharmaceuticals.* In these industries more than 90% of EU firms have some technical facilities in at least one location in the major regions of the world. However in terms of volume, even in these industries, a much smaller proportion of the total knowledge is created in foreign countries. The biggest contrast in the two measures is in relation to the EU *Chemicals* firms. While more than 95% are active in at least one foreign location, all foreign locations together only account for 35% of total inventions. In general firms in *Pharmaceuticals*, *Food, Drink & Tobacco*, *Mining & Petroleum*, and *ICT* industries source a relatively large proportion of their new technologies in foreign locations.

Importance of Intra-EU locations

The analysis in this paper shows that for large European firms the most important foreign locations are within the EU-15. These locations account for more than half of their total volume of foreign inventions. Moreover two-thirds of our sample of EU firms are active in at least one other EU-15 country, and this proportion has risen from just over one-half in the early 1990s. There are some variations across industries in relative importance of intra-EU locations. For example in *Chemicals* and *ICT* these locations are of overwhelming importance but less so in *Medical* equipment. The most important country locations within the EU are Germany and France, and to a lesser extent, the UK. This result implies that an important element of the explanation for increased globalization of EU firms is the increasing integration of their research across the large R&D spending countries within the EU.

Importance of the US

In general the most preferred location of EU firms outside the EU is the US, with more than half our sample maintaining some facilities there. This is especially the case for *Chemicals*, *Pharmaceuticals* and *ICT* firms. However in terms of volume

only around 10% of EU firms' total inventions originate from the US. This implies that a large number of EU firms maintain small-scale technical facilities in the US. Our results show that only in the case of *Pharmaceuticals, Food, Drink & Tobacco* and *Mining & Petroleum* firms are such facilities likely to be of a larger scale.

Increasing importance of Asia

As for the Asian countries, around 15% of EU companies source some technology from Japan, 8% from China and less than 4% in India. Together the Asian countries account for less than 2% of the total inventions generated by our sample of EU firms. However the relative importance of India and China has risen rapidly since the 1990s when only negligible share of EU firms had any activity there.

The above results are consistent with those obtained from the latest firm-level survey undertaken by IPTS.[13] As discussed in Section 2 one of the main results of this survey is that on average EU companies undertake 20% of their R&D outside the EU. For our sample the proportion of total inventions accounted for by non-EU locations is 16%. The IPTS survey also shows that the most important non-EU locations for the European firms are the US and Canada and within the EU, Germany. India and China account for a very small share but growing share of EU firms' total R&D.

Our results are also consistent with the notion that companies are increasingly involved in different foreign locations in order to tap into the local S&T resources, rather than simply adapt their products for the local markets. Such resources include access to a large pool of highly qualified personnel and other specialized R&D inputs which may not be readily available especially in the smaller EU countries. They are also consistent with the notion that firms maintain a presence in foreign locations in order to learn about the innovative activities of other firms. All of these have been cited as important reasons for increasing globalization of R&D and innovation. However the results reported here are not consistent with the view that EU large firms are in a position to introduce an entirely new range of products and processes outside the EU.

[13] <http://iri.jrc.ec.europa.eu/research/docs/survey/2008/JRC51800.pdf>

References

Cantwell, J. (1992) "The Internationalisation of Technological Activity and its Implications of Competitiveness", in Granstrand, O., Hakanson, L. and Sjølander, S. (eds.) Technology Management and International Business, Chichester, Wiley.Cantwell, J. (1992)

Etemad, H. and L. Seguin Delude (1987) "Patenting Patterns in 25 Multinational Enterprises", Technovation, 7 (1): 1-15

Le Bas, C. and C. Sierra (2002) Location versus country advantages' in R&D activities: some further results on multinationals' locational strategies. *Research Policy*, Vol. 31, pp. 589-609.

O. Granstrand, L. Hakanson and S. Sjolander (eds) (1992), Technology Management and International Business: Internationalisation of R&D and Technology, Wiley, Chichester.

OECD (2008), *The Internationalisation of Business R&D evidence, impacts and implications*.

Patel, P and Pavitt, K. (1991) "Large Firms in the Production of the World's Technology: An Important Case of Non-Globalisation", Journal of International Business Studies, 22: 1-21.

Patel, P. and Pavitt, K. (2000), "National systems of innovation under strain: the Internationalisation of Corporate R & D", in R Barrell, G Mason and M O'Mahoney (eds.), Productivity, Innovation and Economic Performance, Cambridge University Press, 2000.

Patel, P. (1995) "The Localised Production of Global Technology", Cambridge Journal of Economics, 19: 141-153.

Patel, P. (1996) "Are Large Firms internationalizing the Generation of Technology? Some New Evidence", IEEE Transactions on Engineering Management, 43: 41-47.

Patel, P. and M. Vega (1999), "Patterns of internationalisation of corporate technology: location vs, home country advantages", Research Policy, 28, pp.145-55.

Booz Allen Hamilton and INSEAD (2006), *Innovation: Is Global the Way Forward*? <www.boozallen.com/media/file/Innovation_Is_Global_The_Way_Forward_v2.pdf>.

Thursby, J and Thursby, M (2006) , *Here or There: A Survey of Factors in Multinational R&D Location*, Washington, D.C.: National Academy of Sciences. <http://www.nap.edu/openbook.php?record_id=11675&page=1>

UNCTAD (2005), *UNCTAD survey on the internationalization of R&D: Current patterns and prospects on the internationalization of R&D* UN, New York. http://www.unctad.org/en/docs/webiteiia200512_en.pdf

IPTS (2005-8), *The EU Surveys on R&D Investment Business Trends (2005-2008)*, IPTS, Seville <http://iri.jrc.ec.europa.eu/research/docs/survey/2008/JRC51800.pdf>