The Location of Innovative Activity in Europe

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Abstract: In this paper we use new data to describe how firms from 15 European countries organise their innovative activities. The data matches firm level accounting data with information on the patents that those firms and their subsidiaries have applied for at the European Patents Office. We describe the data in detail.

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JEL classification: F21; F23; O3; H3

Executive Summary

Innovation by firms is an important driver not only of their own business success, but also of national productivity, welfare and growth. Innovative activity has traditionally been thought of as relatively immobile, but firms are increasingly locating innovative activity away from their home country, and in multiple locations. We see indications of an increase in the internationalisation of innovative activity in a number of statistics. For example, while in 1990 10% of all patent applications filed at the EPO listed at least one inventor based in a different country to that of the applicant, this figure had risen to 18% by 2004. As a result of firms locating innovative activity offshore, productivity and growth in a country increasingly depends not only on what firms do within the national boundaries of that country, but also on what they do abroad. A wide range of government policies are aimed at encouraging and facilitating firms' ability to innovate and to exploit innovation by others. Understanding firm behaviour is important to inform these policies.

One of the main problems facing researchers in this area has been a lack of suitable micro-level data on the location of innovative activity across firms from a range of countries. This paper describes new data that matches firm level accounting data with information on the patents that those firms and their subsidiaries have applied for at the European Patents Office (EPO). These data combine information on productive activity and firm performance for firms located across fifteen countries with detailed administrative data on individual patents. We match firms which apply for patents and which are based in one of the following fifteen European countries; Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Norway, Poland, Portugal , Spain Sweden and UK. The match between the two datasets is based on a match between company names in the accounts data and the names of firms applying for a patent in the patents data. We report that the success of matching varies across countries but is generally good. The match rate is over 80% for applicants from both the UK and Germany for example, and for most countries the match success improves greatly over time.

The benefit of the matched dataset is that it allows us to distinguish between activity based within the geographical boundaries of a country, where this can be undertaken by domestic and foreign subsidiaries, and the activity of firms which are resident in a country, where such activity could be located in a number of foreign locations as well as at home. It is this latter aspect of behaviour that we are particularly interested in understanding: where firms are choosing to locate their innovative activities. As is emphasised in the new trade theory, it is firms that take decisions over where to locate and how much activity to undertake in each chosen location. This paper maps out the innovative activities of European firms.

1 Introduction

This paper describes new data that matches firm level accounting data with information on the patents that those firms and their subsidiaries have applied for at the European Patents Office (EPO). These data combine information on productive activity and firm performance for firms located across fifteen countries with detailed administrative data on individual patents. We match firms which apply for patents and which are based in one of the following fifteen European countries; Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Norway, Poland, Portugal , Spain Sweden and UK. These data allows us to distinguish between activity based within the geographical boundaries of a country, where this can be undertaken by domestic and foreign subsidiaries, and the activity of firms which are resident in a country, where such activity could be located in a number of foreign locations as well as at home

Innovation by firms is an important driver not only of their own business success, but also of national productivity, welfare and growth. Innovative activity has traditionally been thought of as relatively immobile, but firms are increasingly locating innovative activity away from their home country, and in multiple locations.[1] These changes could be in response to a number of factors. Traditional models of the multinational firm focus on firms seeking to access foreign markets, and adapting technologies to local conditions. The public finance literature emphasises the importance of R&D tax credits. Changes in technology, for example the rapid increase in the use of Information and Communication Technology (ICT), may have led to a reduction in the costs of moving innovative activity abroad. The availability and cost of skilled workers are likely also to play a role in firms' decisions to move R&D activities offshore. The management literature and the knowledge spillover literature in economics have emphasized the importance of international technology sourcing in productivity growth.

These changes mean that productivity and growth in a country increasingly depends not only on what firms do within the national boundaries of that country, but also on

[1] UNCTAD (2005), *World Investment Report. Transnational Corporations and the Internationalization of R&D*. United Nations.

what they do abroad. A wide range of government policies are aimed at encouraging and facilitating firms' ability to innovate and to exploit innovation by others. Understanding firm behaviour is important to inform these policies.

We see indications of an increase in the internationalisation of innovative activity in a number of statistics. In 1990 10% of all patent applications filed at the EPO listed at least one inventor based in a different country to that of the applicant. This figure had risen to 18% by 2004. This change in behaviour is also illustrated by the sharp decline in the share of patents taken out in the US Patent Office by UK-owned firms where the inventors are based in the UK. This fell from almost 50% in 1975 to around 25% in 1995.[2] It has also been the case that the proportion of R&D undertaken in the UK, but financed from abroad, has risen from under 10% in 1981 to nearly 25% in 2001.[3]

One of the main problems facing researchers in this area has been a lack of suitable micro-level data on the location of innovative activity across firms from a range of countries. The existing empirical evidence on where inventive activity is locating and the determinants of these location choices are based mainly on data from the US Patent Office (the NBER Patents database), from a number of national databases, such as data on Swedish multinationals, or based on cross-section databases such as the EU Community Innovation Survey.

One source of data that is commonly used in empirical work is the OECD's Business Expenditure on R&D (BERD) data. This comes from micro data collected by national statistical agencies and captures R&D activity that takes place within the geographic boundaries of each country. In many countries the micro data underlying these aggregate data sets are available for researchers to work with though generally under very restrictive conditions, so it is not possible to compare across countries. In addition, these data do not generally contain information on the activities of firms in other countries.

In some countries firms report total expenditure on R&D in their annual accounts. However, the definition of what constitutes R&D is often different across countries, and is rarely disaggregated to the location where it is carried out.

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[2] This is the proportion of patents that UK stock market listed firms took out at the US Patent and Trademark Office.

[3] This can be observed in the OECD MSTI data.

Innovation undertaken within a country will be associated not only with firms from that country but also with foreign firms that have subsidiaries based there or who are collaborating with domestic firms. Over the last decade and a half, most countries have seen a greater share of their domestic innovative activities accounted for by foreign firms. The corollary of this is that many firms resident in a given country have activities based offshore. It is this aspect of behaviour that we are particularly interested in understanding: where firms are choosing to locate their R&D activities. As is emphasised in the new trade theory, it is firms that take decisions over where to locate and how much activity to undertake in each chosen location. [4]

The data we describe in this paper give rich detail on where firms locate their innovation activity based on information coming from two sources: patent data on the location on each inventor listed on a patent and firm ownership data. Similar data have been used extensively in the US, especially the NBER patents data matched to firm data.[5] Patent documents contain a mapping between the location of patent applicants (often firms) and that of inventors, many of which are located in a different country to the applicant firm. This provides a measure of the activities which firms undertake outside of the domestic market. However, the firms that apply for patents may themselves be subsidiaries of larger, often multinational, firms.

To make this idea concrete consider the following example. A UK multinational has subsidiaries in both the UK and Sweden. Both are engaged in innovative activities and employ inventors in their domestic markets. The Swedish subsidiary also employs inventors based in the US. Taking only the information contained in the patents data, we would record that there are inventors based in the UK, Sweden and the US, and that those based in the US could be attributable to the Swedish subsidiary (which would be the applicant on the patent). However, the patents data alone do not provide the link between the inventors employed in Sweden and the US and the UK multinational. This link is important since it represents the (international) activity of the UK multinational firm.

The data described here use patents as a measure of innovative activity and use data from firm level accounts to identify the ownership structure of firms. We find that the

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[4] See, for example, the survey in Behrens et al (2007)

[5] see http://www.nber.org/patents/ and http://elsa.berkeley.edu/~bhhall/patents.html

distinction between applicants and parent firms is not a trivial one; for example, around 25% of applicants which are associated with UK parent firms are based outside of the UK. This has become more important over time as the activities of multinationals including production and innovation have been increasingly mobile.

These data are similar to the NBER patents data, with a few notable exceptions. We match EPO patents to European firms (rather than USPTO data to US firms) and as a result capture the worldwide activities of European firms, including those activities which are carried out at the subsidiary level. The EPO data include all patent applications, including both those that were and were not granted. In comparison, the US data includes only granted patents.[6] In addition, the data developed here include more recent years than the US data (though they do not go back as far in time).

The remainder of the paper is structured as follows. The next section describes the patents data and the EPO patenting process. Section 3 describes the firm level data. Section 4 describes the data which results from matching the patents data to the accounts data and discusses the quality of the match across countries. Section 5 discusses industry classification, where in particular we have matched in data from the Derwent Innovations Index, resulting in an industry definition based on the of *use* of each patent. Section 6 describes some of the main patterns we see in the data regarding the location of activity. These data allows us to distinguish between activity based within the geographical boundaries of a country, where this can be undertaken by domestic and foreign subsidiaries, and the activity of firms which are resident in a country, where such activity could be located in a number of foreign locations as well as at home. A final section summarises.

[6] The United States Patent and Trademark Office (USPTO) started to publish patent applications as well as granted patents in 2001. See http://www.uspto.gov/main/patents.htm for more details

2 Patents data

The patents data comes from the European Patents Office's (EPO) Worldwide Patent Statistical Database (PATSTAT).[7] This database, designed to be the European patent research community's strategic source of patent and citation information, is based on the EPO's search dataset: the database used when searching for related innovations as part of the patent approval process.

These data contain information on all patent applications to the EPO, including information about the applicant, the inventors, the technology, granted status and the citations made by these patents, dating back to 1978. The most current version at the time of writing, and the one used in this paper, is October 2007. PATSTAT also contains information on patent applications to the USPTO and all other major national patent offices.[8] As will be discussed below, this information is particularly useful for indentifying equivalent applications filed outside of the EPO at an earlier time (priority applications).

The PATSTAT dataset is related to other patent data sources. EPO patent applications can also be found on the EPO Espace Bulletin CD-ROM[9]. This contains all bibliographic and legal status data on all European patent applications and granted patents, although no information on citations. Despite being a very useful look-up tool, this data source is not as conducive to large sample manipulation as PATSTAT, which was designed for this purpose. Another related dataset is the OECD's Triadic database on the sub-sample of patents that are registered in all three main patents offices: the EPO, the Japanese Patent Office (JPO) and the USPTO.[10] Prior to the creation of PATSTAT the best available source for citations data on EPO patents was the OECD's citations database.[11]

This section describes the process of filing a patent at the European Patent Office (EPO). We highlight some of the practical issues to be considered when using patents

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[7] Described in EPO (2006)

[8] PATSTAT data on patents registered in other offices is not of the same quality as for patents registered at the EPO. They do not contain as much information on the inventors listed on applications.

[9] For a description of the dataset see the brochure at www.european-patent- office.org.

[10] For triadic patents it is possible to match in detailed information on the underlying USPTO patents and companies from the Hall, Jaffe and Tratjenberg (2001) dataset and on the underlying EPO patents and companies from our AMAPAT dataset, described below.

[11] For the OECD Triadic and Citations databases see www.oecd.org.

data (specifically PATSTAT) for economic research. These include: the use of priority application dates, the presence of international applications, using granted patents and counting inventors.

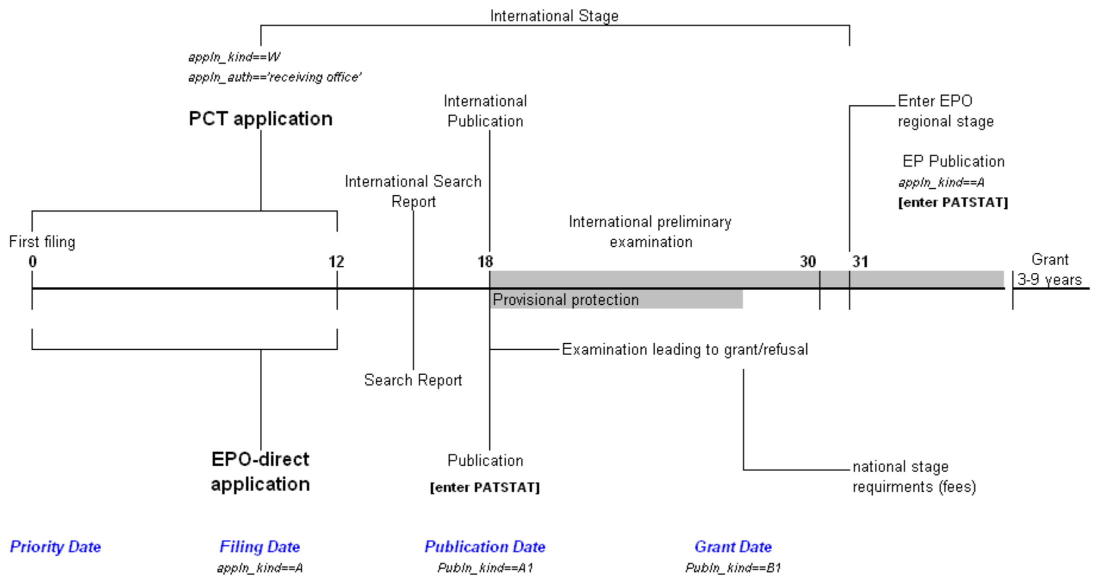
2.1 EPO Patent application process

Firms seeking patent protection in a number of European states may file an application directly at the EPO and designate the relevant national offices, among those covered by the EPO, in which protection is sought. The EPO is not a body of the European Union and as a result the states which form part of the European Patent Convention (the legal basis for the EPO) are distinct from those in the European Union.[12] A patent granted by the EPO does not lead to a single Europe-wide patent which is enforceable before one single court, but rather to independent national patents enforceable by national courts. In making an application to the EPO, rather than filing an application directly to each national patent office, a firm is able to make a single application which, as well as often being cheaper than filing separately in each national office, allows the firm to delay the decision over which national states to further the application in. Broadly speaking, an application can be filed at the EPO either directly or via an international route. Once an application to the EPO has been registered it will be examined for novelty and published before a decision is made over whether it is granted. A patent that is granted at the EPO will be effective in each of the countries designated by the applicant.

The timeline of patent applications is provided in Figure 1. International applications (PCT applications) are followed above and direct applications (EPO-direct applications) below the timeline. This will be elaborated on in the following sections.

[12] http://www.epo.org/about-us/epo/member-states.html

Figure 1: Timeline for patent applications to the EPO



Notes: Applications filed internationally, under the Patent Cooperation Treaty (PCT), are followed above the timeline while applications which are filed directly are followed below the timeline. The numbers running along the timeline represent months since the first filing of a patent application. First filing includes equivalent documents that have been previously filed, usually outside the EPO, no longer than 12 months before the current application (priority applications). The words in italics are variable names from the PATSTAT dataset.

2.2 Priority date

For patents filed directly at the EPO the point at which a patent application first enters the EPO is the *application filing date*. However, this may not be the first time that a patent application on that technology has been filed. An equivalent or related application may have previously been filed at another office and in such cases the earlier filing is deemed to be a *priority application*. The Paris Convention provides a right of priority.[13] This means that once an application has been filed in a contracting state applications based on the same or closely related technology made to other states within 12 months will be processed as if they had been filed at the time of original application and receive priority over any applications which may have been filed since. The original date of filing becomes the *application priority date* for the same application to all other states. PATSTAT records information on the relevant priority applications, with this information often coming from national patent office data. As

[13] See WIPO, Paris Convention for the Protection of Industrial Property (1983)

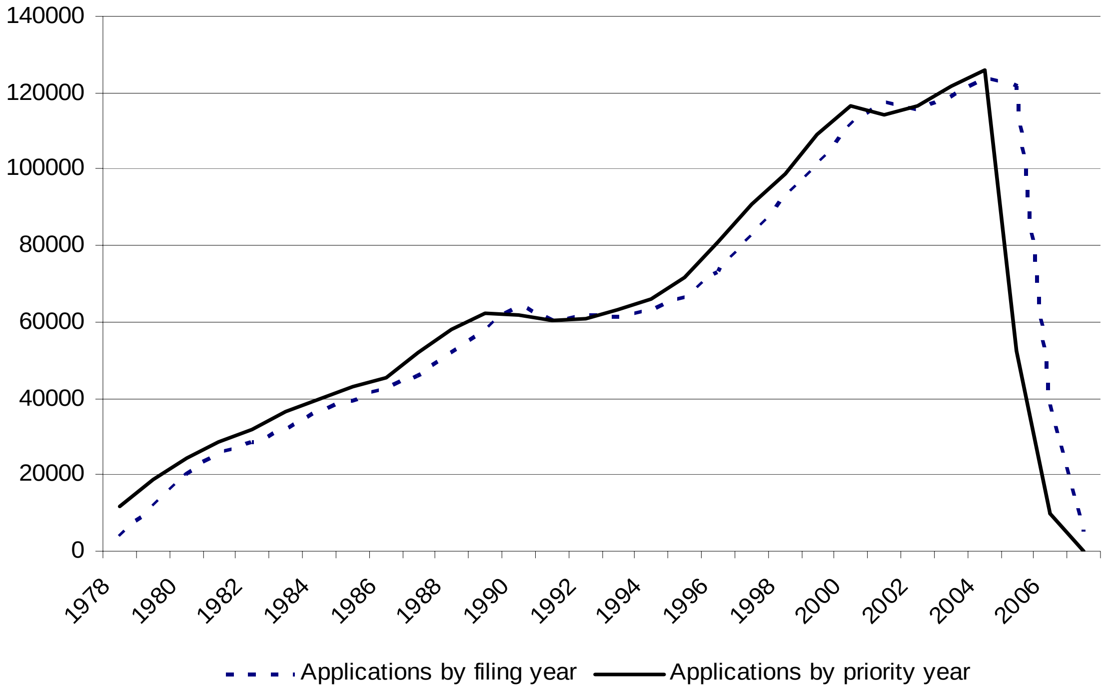
a result each application is associated with a *priority date* which can be thought of as the first date of filing of a patent application, anywhere in the world.

Later applications need not be identical to the original in order to claim priority. The application may vary if improvements have been made to the original invention or if differing national laws require the form of the application to be modified. For example, one national authority may treat a product and a process under a single application whereas another may separate this into two applications. When the original filing country requires more than one application for an invention, which is later considered to be a single application by another authority, multiple priorities can occur. Multiple priorities are also possible if improvements are made and filed in the original country. In this case the dates of both applications will become priority dates when an application is filed in another state. In cases where an application to the EPO is the first filing or where the 12 month period for claiming priority has expired, the application date is the relevant priority date.

From the priority date, the EPO has 18 months in which to produce a search report, which assesses the novelty of the patent claim, and to publish the application. It is at the point of publication that an application receives provisional protection and enters into the PATSTAT database. Thus, for direct EPO applications, there is a lag of up to 18 months between the *application priority date* and an application entering into PATSTAT. The maximum lag between the *application filing date* and entry into PATSTAT will also be 18 months since for some patents the application filing date is also the date of priority. However, many patents have a priority date before the application filing date and in these cases there will to be a shorter lag between application filing date and publication. As will be discussed in the next section, the lag for applications following an international route (a PCT application in the timeline above) may be longer than 18 months.

When using the October 2007 data the result of the lag is that the data from 2006 onwards will be incomplete: not all of the patents which sought patent protection at the EPO in this period will have been published. This can be observed in Figure 2 which plots the number of patent applications filed at the EPO, assigning patents to years using both the filing year and the priority year. As expected, the timeliness of the data is reduced more when using the priority year. The figure also shows that there has been a significant increase in patent applications at the EPO since it was created in 1978. This is in line with the well documented general increase in patenting.[14]

Figure 2: Applications to the EPO



Source: Authors' calculations using PATSTAT, October 2007 version

2.3 International patent applications

Applicants have the option of filing an international application under the Patent Cooperation Treaty (PCT) and designating to seek protection in the EPO. The PCT, which entered into force in 1978 and is administered by the International Bureau of the World Intellectual Property Organization (WIPO), allows applicants to obtain patent protection in any or all of the national and regional offices covered by the PCT.[15]

It should be noted that there is no such thing as an 'international' patent. Applications filed under the PCT may be viewed as "options for future filings, which can be

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[14] See, www.epo.org/topics/news/2007/20070810.html.

[15] http://www.wipo.int/treaties

eventually exercised (transferred to regional or national offices such as the EPO), and become then actual patent applications".[16] International applications must still pass through the application processes of each designated nations or regions. However, this method of filing an application provides a number of benefits to applicants and may help facilitate completion of the relevant national and regional phases.

If an applicant seeks protection in a number of countries the PCT route can save both time and effort and help the applicant to make decisions regarding whether to process the application at various national patent offices. The PCT route allows an applicant to file one initial application, with a single language and set of fees. Since only one form of the application is expected in the first instance this removes the need to deal with many different formal requirements.

The initial international application is filed at the International Bureau of WIPO or at a 'receiving office', of which the EPO is one. Following this an international search report is produced and the applicant receives written opinion from one of the 'International Searching Authorities'. Up to 18 months after the application's priority date the international application and international search report are published. At this point the application receives provisional protection. Applicants may then opt to have an international preliminary examination and resulting international preliminary report on patentability which assess the general aspects of patentability. This allows the applicant to obtain detailed advice from the International Searching Authority which provides a preliminary and nonbinding opinion "on whether the claimed invention appears to be novel, to involve inventive step and to be industrially applicable", providing a better basis for deciding whether and in what countries to further pursue the application. Undertaking an international preliminary examination also allows the applicant to delay entry into the regional phase for up to 31 months after priority. The International Bureau of WIPO communicates all relevant information to the national or regional offices (designated offices).

After a maximum of 31 months from priority, the international application must enter the regional or national phases, for example the EPO. At this point the application will be published at the relevant office. This requires paying national fees, providing relevant translations and in some cases appointing a representative. The applicant can

[16] OECD (1999)

decide which national phases to enter and when, within the period between the international publication and the 31 month deadline, to do this. As a result, the same patent can be in both the international and national/regional phases at the same time with respect to different offices. Since an application can spend up to 31 months in the international phase, the applicant can delay the decision to enter the regional or national phase, which entails further fees and modified versions of the application.

Importantly, applications which have taken the international route and designated the EPO may not enter PATSTAT until they have been published at the EPO in the regional stage. A subset of international patent applications will enter PATSTAT if the EPO was the receiving office but this will not represent all international applications to the EPO since there will be a significant number which file with another receiving office or with the International Bureau of WIPO. Moreover, it can be the case that not all of the international applications which designate the EPO go on to enter the EPO regional phase. Indeed, many PCT applications are not transferred from the receiving office to the regional phases and do not therefore become actual EPO applications. [17]

Since there is a 31 month lag between the priority date and an application entering the EPO regional stage there can be a lag of up to 3 years between priority and publication of a transfer.[18] International filings may therefore lead to extra lags in the data with applicants across countries experiencing differing lags as a result of their differing propensity to file international applications.

Since coming into force 1978 Euro-PCT applications have become more prevalent. This can be seen in Table 1 which shows all patent applications to the EPO and, in column 3, records how many of those were filed internationally (and went on to enter the EPO regional phase.)

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[17] In order to produce information of recent patent counts the OECD ‘nowcasts’ transfers before they are actually performed based on estimates of the transfer rate of internationally filed patents. See OECD (2007)

[18] See OECD(1999)

Table 1: Patent applications to the EPO

	Patent applications			Proportion	
[1]	[2]	[3]	[4]	[5]	[6]
Priority Year	All	International	Granted	International [3]/[2]	Granted [4]/[2]
1978	11557	2	8307	0.02	71.88
1979	18920	7	13411	0.04	70.88
1980	24376	7	17001	0.03	69.74
1981	28525	10	19815	0.04	69.47
1982	31692	13	21890	0.04	69.07
1983	36348	36	24782	0.10	68.18
1984	39705	112	26947	0.28	67.87
1985	43034	201	28773	0.47	66.86
1986	45640	440	30314	0.96	66.42
1987	52156	1344	34254	2.58	65.68
1988	57860	2821	36676	4.88	63.39
1989	62201	5907	40624	9.50	65.31
1990	61676	9255	41029	15.01	66.52
1991	60628	12543	40301	20.69	66.47
1992	61058	17290	41280	28.32	67.61
1993	63080	20556	42564	32.59	67.48
1994	65996	24375	43066	36.93	65.26
1995	71847	29936	45097	41.67	62.77
1996	80859	35516	47352	43.92	58.56
1997	90665	41606	48302	45.89	53.28
1998	98967	47693	47722	48.19	48.22
1999	109035	54069	47270	49.59	43.35
2000	116450	59415	40520	51.02	34.80
2001	114240	61421	31473	53.76	27.55
2002	116746	64797	23448	55.50	20.08
2003	121951	69694	14330	57.15	11.75
2004	125979	70708	5116	56.13	4.06
2005	52270	1199	558	2.29	1.07
2006	9707	10	4	0.10	0.04

Notes: (2) All patents filed to the EPO and published before October 2007. (3) All patents which entered the EPO, via the international (PCT) route, before October 2007. (3) Patents which have been granted before October 2007. In all cases, there are lags in the data near the end of the period, see sections 2.2-2.4.
Source: Authors' calculations using PATSTAT, October 2007 version.

Not only have there been more PCT applications but they have also represented an increased share of all applications filed at the EPO, as shown in column 6 of Table 1. It should also be noted that applicants in different countries started using the PCT route at different times and continue to use PCT route to varying degrees. This can be seen in the first two columns of Table 2. The proportion of patent applications which are filed internationally is particularly high for the UK and the Scandinavian countries and for all countries except Denmark, the proportion of applications filed internationally increased between the two periods.

Table 2: Proportion of international and granted patent applications across countries

	Proportion International		Proportion Granted	
Country of applicant firm	1991/1995	1996/2000	1991/1995	1996/2000
Belgium	27.0	41.3	69.9	48.9
Denmark	73.8	71.9	68.8	52.4
Finland	59.5	65.0	74.0	45.7
France	23.6	41.8	73.5	56.6
Germany	27.0	43.2	73.0	59.9
Italy	15.0	25.6	63.1	54.4
Netherlands	35.8	63.2	70.0	46.7
Norway	73.5	82.5	71.6	52.6
Spain	25.1	40.1	48.9	48.5
Sweden	73.7	81.9	73.2	50.7
UK	53.3	65.9	63.8	46.3

Notes: The proportions in this table are the number of international (or granted) patents that were filed by applicants in the given country and period as a proportion of all patents filed by the same applicants in the same period.
Source: Authors' calculations using PATSTAT, October 2007 version

2.4 Granted patents

Once an application has been published at the EPO, having taken either the direct or international route, a substantive examination begins and between 3-5 years later an application is granted or refused. If granted, the applicant has three months in which to produce translations in the official language of each country in which protection is sought. A granted EPO patent will be effective in each of the countries designated by the applicant.

The time it takes for a patent to be granted may depend on administrative procedure and the workloads of the relevant offices. There can be a significant lag between the publication of an application and the grant of a patent. The OECD reports that the average lag between priority and grant is 5 years, and ranges between 3 and 9 years.[19] Not all patents applications are granted. It can be seen in column 4 of Table 1 that the number of patents granted begins to fall steeply from around 2001 onwards.

The proportion of patent applications granted varies across time and country of applicants. This can be observed in Table 2.

2.5 Information contained in patents applications

Patent applications contain a large amount of standardised information. As well as a detailed account of the invention being patented and the applicant(s) filing the

[19] See OECD (2008) Patent compendium

application, there is detailed information regarding how and when the application was filed, the inventors which worked on the patent and all citations made to both patents and other relevant literature.

2.5.1 Location of inventors

Each application in PATSTAT contains a list of the inventors filed on that patent, including their names and addresses. This can be seen in the following example of an EPO patent taken out by US based Colgate-Palmolive Company.

Figure 3: Extract from an EPO patent; 'Novel handles for toothbrushes'

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 097 655 A3**

(12) **EUROPEAN PATENT APPLICATION**

(88) Date of publication A3:
12.02.2003 Bulletin 2003/07

(51) Int Cl.7: **A46B 9/04**

(43) Date of publication A2:
09.05.2001 Bulletin 2001/19

(21) Application number: **00125873.0**

(22) Date of filing: **09.08.1996**

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI NL PT SE

(30) Priority: **22.08.1995 US 2026 P**
27.02.1996 US 5184 P

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
96931374.1 / 0 957 707

(71) Applicant: **Colgate-Palmolive Company**
New York, N.Y. 10022 (US)

(72) Inventors:
- **Brady, Joan**
  Upmlers, MU 10701 (US)
- **Benedict, Helen**
  Wimbledon Common, London SW19 (GB)
- **Waguespack, Kenneth**
  North Brunswick, New Jersey 08902 (US)
- **Oxseth, Geir**
  1392 Vettre (NO)
- **Vestheim, Nils Terje**
  0953 Oslo (NO)
- **Sletbak, Helge**
  1410 Kolbotn (NO)
- **Angelfoss, Hilde**
  1392 Vettre (NO)

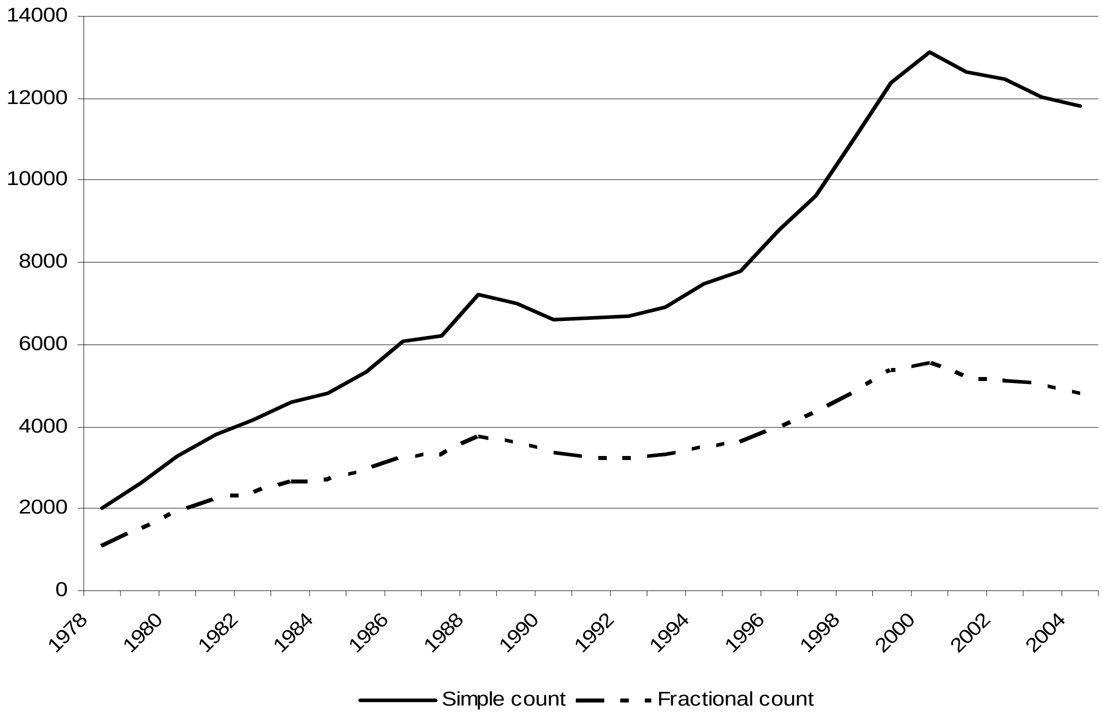
(74) Representative:
Kearney, Kevin David Nicholas et al
KILBURN & STRODE
20 Red Lion Street
London, WC1R 4PJ (GB)

Source:www.epo.org/patents/patent-information/european-patent-documents.html

 It can be seen that this patent application, filed at the EPO in 1996, registered seven inventors, two based in the US, one based in the UK and four based Norway.

One issue that arises when using data on inventors is how to count them. We consider two basic approaches - one is to count an inventor once every time they appear on a patent application (we will refer to this as a simple count), the other is to count an inventor according to the proportion of all inventors on an application which they represent (fractional counting). Take the above patent as an example. Using a simple count we would count the number of inventors based in the UK as '1'. Using a fractional count we would attribute '1/7' of an inventor to the UK since the UK based inventor represents a seventh of all inventors listed on the patent. The result of using simple counts is that patents are counted multiple times according to the number of inventors. Under a fraction count the sum of the weighted inventors would be one, and therefore each patent is only counted once. While neither method if necessarily better, the chosen method will affect the resulting count of inventors. Figure 3 plots the number of inventors based in the UK using both a simple and fractional count in order to illustrate the difference in the count of inventors which results from the choice of counting method.

Figure 4: Number of inventors based in UK by priority year



Source: Authors' calculations using PATSTAT version October 2007.

2.5.2 Citations

Patents data contains information on citations both to and from a patent. Citations can be to other patents or to non-patent literature, for example to academic articles. In both cases it is possible to distinguish whether the citations were added by the applicant or the patent examiner. When the citation is to another patent, PATSTAT includes the relevant patent application identifier. All the citations made by a patent are held against the latest version of the patent application.

All of the information on citations comes from citations made by a patent. As a result, the citations received by a patent are held against all of the relevant citing patents. This means that in order to capture the citations received by a patent filed in time *t* one must consider all other patents which were filed since *t*, including the citations made by equivalent applications held in other offices.[20]

2.6 Are patents a good measure of innovative activity?

Patents have been used as indicators of the location of inventive activity in a large number of papers.[21] Patents data provides a rich source of information which, since patent applications are legal documents, is standardised and therefore consistently measured at the micro level (the level of the research project) both across countries and over time. Griliches (1990) notes that patent statistics "…are available; …are by definition related to inventiveness, and … are based on what appears to be an objective and only slowly changing standard."

Another widely used measure of innovation is R&D expenditure. R&D data generally come either from micro data collected by national statistics agencies, or from firm accounts. National statistics bodies tend to report R&D expenditure at the aggregate industry level, or make firm level data available under restrictive conditions. These data are usually based on activity within geographic the boundaries of a country and do not generally contain information on the activities of firms in other countries.

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[20] A discussion of using citations received can be found in Hall, Traff & Trajenberg (2001)

[21] For discussions of the advantages and disadvantages of patents statistics in general see Griliches (1990). For discussions of the use of patents statistics as indicators of the location of inventive activity see Verspagen and Schoenmakers (2004), Acs et al (2000) and Griffith Harrison and Van Reenen (2006).

Patents data allow us to map the location of the firm applying for a patent and the location of the inventor(s) listed in that application, where inventors can be used as a proxy for innovative activity and its location. As a result patents data allow a consideration of firms' activities in a number of countries. This level of detail regarding the location of innovative activity is not found in other data.

One reason that we may be particularly interested in the number of inventors as a measure of innovative activity is if this is where we think the externalities arise. It may be that the highest spillovers from innovative activity result from the interactions between people, to the extent that knowledge is tacit, and that innovators are the people who have most tacit knowledge.

Despite the benefits of using patents there are a number of issues to be aware of. The propensity to patent varies both across industries and across time and this needs to be accounted for in any analysis. Many productivity enhancing innovations do not require patenting and certain industrial sectors traditionally rely on secrecy [or lead times] as a way of protecting their intellectual property. Moreover, patenting may be used by firms to deter entry rather than to protect real innovations. The illegal strategy of repeatedly patenting the same technology has been observed.

The value of patents can be heterogeneous and its distribution very highly skewed.[22] While some patents have little or no industrial application and therefore low economic value, others are of substantial value.[23]

[22] See, Schankerman and Pakes 1986, Scherer 1998 and Graeventiz, Wagner and Harhoff (2008)

[23] This can be partially controlled for by using subsequent citations as an indicator of quality. This assumes that valuable patents are cited more frequently by other patents than lower-value patents. See, for example, Jaffe (1986).

3 Firm Data

This section describes the firm level data, and in particular how we capture ownership structure.

Our primary source of data is European company accounts information collected by Bureau van Dijk in the Amadeus database.[24] We use Amadeus data for the years 1996, 1997, 1999, 2000, 2001, 2004 and 2006.[25] The data contains accounting information going back up to ten years for firms both ‘active’ and ‘inactive’ in these years. For each year active firms are those that have filed accounts in that year, whereas inactive firms are those that have not, but *have* filed accounts in at least one of the four preceding years. If a firm does not file accounts for five years that firm is dropped from Amadeus on the fifth year. The data contain both unconsolidated accounts for subsidiaries, and consolidated accounts at the parent level. Each firm in Amadeus is identified using a unique identifier called a BVD number.[26]

One advantage of these data is that they cover a large number of firms across many countries, and they are reasonably consistently measured (based on accounting rules) across countries.

As well as accounting data, information is held on ownership structure and industrial sector. Name changes are not recorded in Amadeus, but are available for UK firms from the Financial Analysis Made Easy (FAME) database.[27] Table 3 shows the total number of firms for each country. Column 2 gives the number which have an ultimate owner recorded by Amadeus, column 3 the number that are recorded as inactive in the most recent Amadeus version and column 4 the number that appeared in earlier versions of Amadeus but were subsequently dropped due to a lack of account filings for a period longer than four years.

[24] Budd et al (2005), Budina et al (2000) and Konings et al (2001) are examples of econometric studies that have used the Amadeus dataset in other contexts.

[25] The Amadeus accounts information was downloaded and organised by Nick Bloom and Sharon Belenzon at the Centre for Economic Performance. Sharon Belenzon wrote an algorithm that greatly improved the ownership information in Amadeus. For more information see Belenzon (2007).

[26] Although broadly true it seems to be the case that this number is not always a unique identifier of firms.

[27] Like Amadeus this is a Bureau van Dijk product, see www.bvdep.com.

Table 3: Firms in Amadeus

Country	Firms in Amadeus (1)	With Ultimate Owner (2)	Inactive (3)	Dropped (4)
United Kingdom	1,989,345	154,077	577,615	21,333
Germany	893,245	39,970	0	109,810
Netherlands	351,906	131,933	22,198	19,658
Finland	90,203	7,095	0	8,940
Sweden	255,428	45,399	11,328	4,110
Belgium	343,439	28,490	11,356	16,263
Norway	174,884	18,755	34,280	1,609
Spain	818,928	37,200	51,580	11,375
Denmark	158,654	27,700	25,298	1,018
Italy	545,281	11,518	21,057	11,561
France	957,429	59,024	29,931	24,289
Czech Republic	49,788	1,246	1,536	1,491
Poland	35,924	2,719	2,025	8,218
Portugal	82,421	4,089	4,758	0
Greece	28,969	1,145	2	2,150

Notes: (1) The number of firms present in at least one of the versions of Amadeus from 1996, 1997, 1999, 2000, 2001, 2004, 2006.
(2) Those in column (1) with an Amadeus ultimate owner.
(3) Those in column (1) that are inactive- have not filed accounts for the last four years.
(4) Those in column (1) that have been dropped from more recent versions of Amadeus.

The sample of firms increases over time. There are two reasons for this. Firstly, firms that have died prior to 1992 are not included as this is earlier than the earliest edition of Amadeus that we have (1996, minus the four year retention period for inactive firm accounts). Secondly, the coverage for Amadeus increases over the sample period, with a large increase in the 2004 edition. This will affect the success of matching.

Amadeus provides information on European firms. We also want to capture European subsidiaries operating in the US. A large amount of the activity of European firms is known to be based in the US. Looking at patent applicants to the EPO, we see that a large number of the inventors they employ are based in the US. It is therefore expected that a large number of firms have established subsidiaries in the US. In order to capture this possibility we use the Icarus database, also collected by Bureau van Dijk, which records accounts data for the top 1.4 million US firms and allows us to identify which of these have European parent firms.

In the accounting data we capture both firms that are independent and firms which are subsidiaries, ultimately owned by a parent firms. A company A is ultimately owned by a parent firm B if B is an independent company, (no single firm owns more than 24.99% of the shares), and has a recorded share of over 24.99% in A. This definition is based on firms and not individuals. The parent firm is the highest firm in the ownership chain for which the above conditions hold. The country of the parent firm is the one in which the firm is registered.

The accounting data records ownership at a single point in time. Using the version of Amadeus outlined above we capture the ownership structure prevailing in 2004. As a result of this we do not account for any mergers or acquisitions that take place either before or after 2004. As an example; if a firm, A, operates independently until 2002 and is taken over by a parent firm, B, in 2003 then the definition of ownership we use will show firm A as a subsidiary of firm B for the whole period.

4 The matched data

In this section we describe how the patents and firm accounts data are combined to produce a mapping between European firms from 15 countries and the location of their innovative activities. We describe both the matching process and resulting data.

We attempt to match each corporate patent applicant in the EPO to a firm in the accounting system Amadeus. The match is undertaken using company name. The difficulties that arise include: i) the matching can only be performed by comparing names, which have been keyed in to each system by hand; ii) company names, corporate extensions and characters sets are very different across countries; and iii) there are a large number of entities listed in both datasets (1.7 million UK firms in Amadeus, for example). We have written re-usable software that includes a name standardization algorithm to clean names and converts permutations of corporate legal extensions into standard formats. The match was performed at different levels of accuracy, such as exact match and stem name match, and the level of accuracy of each match is recorded for the researcher. Where possible the Derwent (2000) industrial standard for converting corporate extensions to standard formats for many different countries was followed. Multiple matches are resolved using supplementary information, such as applicant/firm address, where available

4.1 Matching process

Our target population for matching consists of patent applications to the EPO filed between 1978 and 2004 by corporate applicants from fifteen countries. Corporate patent applicants are the focus of analysis since non-corporate applicants will not be present in the firm accounts.

Column 1 of Table 4 shows the number of patent applications for each selected country and column 2 shows the number of those which we have identified as having at least one corporate applicant.

Table 4: Patents filed at the EPO, 1978-2005

Country of applicant	Number of patent applications [1]	Number of patent applications with at least one corporate applicant [2]
Belgium	16792	13849
Czech republic	612	430
Denmark	12258	10821
Finland	18194	17039
France	131074	112619
Germany	348426	312320
Greece	718	228
Italy	57825	49798
Netherlands	60854	57127
Norway	5317	4271
Poland	669	468
Portugal	490	340
Spain	8857	6265
Sweden	37265	32710
UK	88004	75686

Note: Patents are assigned to countries fractionally in cases where there is more than one applicant in order that each patent is counted only once. Years refer to the application filing year.
Source: Authors' calculations using PATSTAT.

Corporate applicants are identified by the matching process as those names which either i) contain a well known corporate identifier or ii) do not contain a university or government identifier and is not written in the standard format in PATSTAT for an individual (usually an inventor).[28] This process also identifies institutions, such as universities, and individuals. Corporations account for by far the largest share of patenting. Our aim is to match each corporate patent applicant uniquely to a firm in Amadeus.

We do not try to match on year of activity as well as name, the matching is performed on name alone, so that if a firm is observed in the accounts data from 1999 onwards, say, but observed filing a patent in 1990 then this firm would be successfully matched to that patent, the assumption being that the firm is active even though we do not observe its accounts.

The first step of the matching process is to create lists of standardised patent applicant names and standardised firm account names. The standardised names are then matched together, in the first instance using the full string and in the second instance a

[28] A random sample was checked manually.

"stem" name which has had the corporate legal identifier removed. Where this leads to multiple matches, we attempt to resolve this using ownership and address information. We checked manually that all very large patenters are matched successfully and known big R&D spenders are accounted for (global companies that spend a lot on R&D are listed in the UK government's R&D scoreboard).[29]

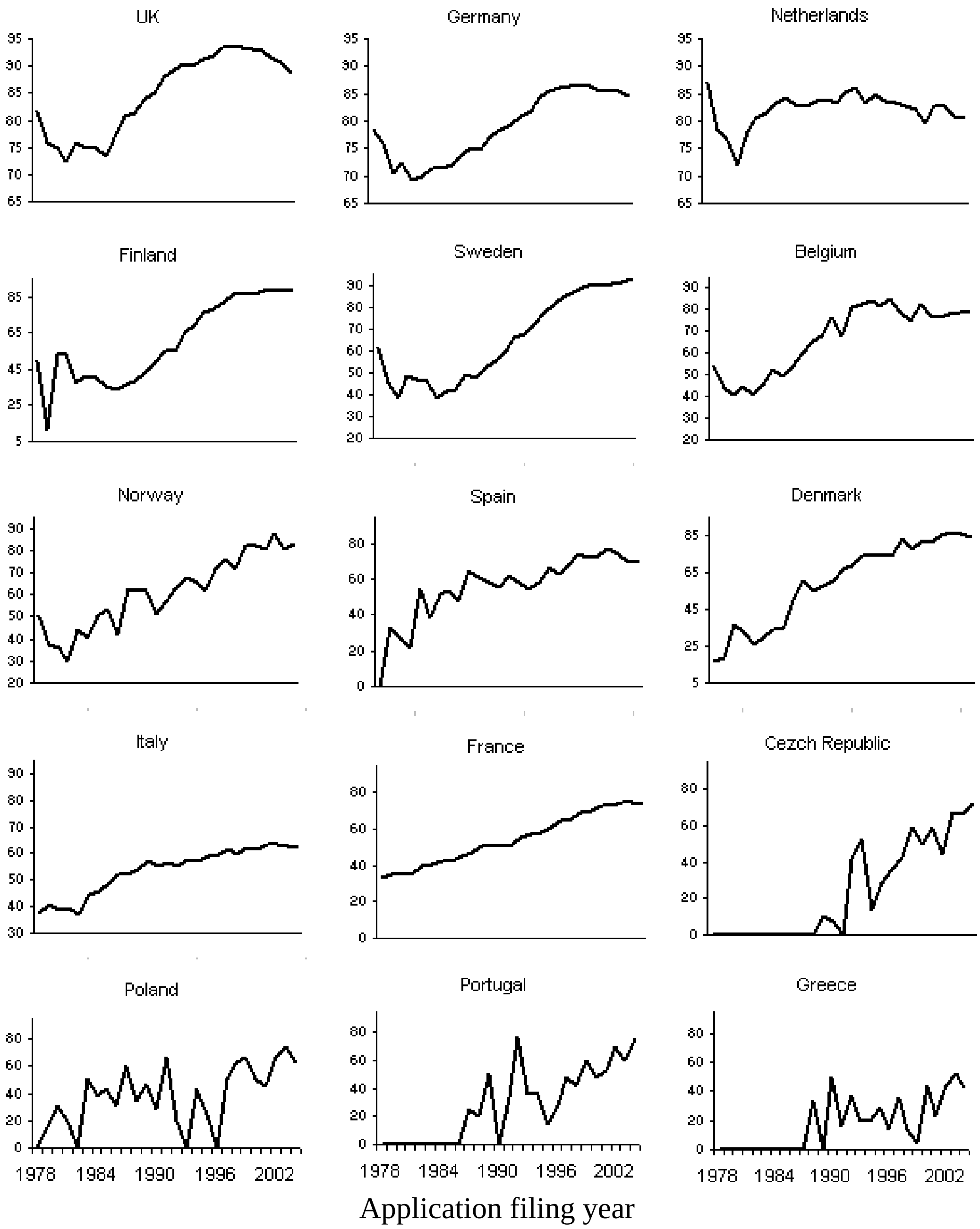
Figure 5 shows the matching success, measured as the percentage of corporate patents that have at least one applicant matched uniquely to an Amadeus firm, broken down by application filing year and country of the applicant firm. The year of application runs from the opening of the EPO in 1978 to 2004 (the years 2005 and 2006 have been excluded from this graph as patent applications are truncated after 2004, as discussed in section 2.2. The applicant countries are ordered by average success, with the most successfully matched country coming first and the least successfully matched country coming last.

The most successfully matched country is the UK, the one that the researchers know most about. The ordering of success reflects another bias; countries with a large volume of patenting were given priority over those with low patenting activity. The four least successfully matched countries are also the four lowest patenting countries (Czech Republic, Poland, Portugal and Greece, see table 2 for patenting activity), and their matching success rate shows great volatility over time, suggesting that it may be difficult to use the within country variation of these countries in research applications.

The matching success rate increases with time, in part because the coverage for Amadeus increases over the sample period

[29] www.innovation.gov.uk/rd_scoreboard/downloads/2006_rd_scoreboard_analysis.pdf

Figure 5: Percentage of patents by corporations matched



Note: Each graph plots the proportion of patents taken out by corporations that have been matched to the accounting data. Years refer to the application filing year.
Source: Authors' calculations using PATSTAT matched to accounts data.

This attenuated success rate in early years is due mainly to firms that have filed patent applications and subsequently gone out of business, and are therefore not alive in our period of observation for firms, which is 1995 to 2006. It is also related to firms changing their names over time.

Table 5 shows the match results across countries for the entire time period, 1978-2007, with countries ordered by decreasing overall matching success (ordered by column 9).

Table 5: Applicants of EPO patents filed between 1978 and 2007 matched to Amadeus firms

Country	No. of Applicants	No. of Corporate Applicants	No. Matched	% Matched (4)/(3)	No. Matched Uniquely	% Matched Uniquely (6)/(3)	Weighted % Matched *w**(4)/(3)	Weighted % Matched Uniquely *w**(6)/(3)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
GB	23570	15542	10920	0.70	10809	0.70	0.88	0.87
DE	51792	28804	15939	0.55	15199	0.53	0.88	0.85
NL	8320	5868	2648	0.45	2599	0.44	0.83	0.82
FI	3341	2168	1262	0.58	1113	0.51	0.85	0.80
SE	9825	5610	2751	0.49	2730	0.49	0.78	0.77
DK	3947	2579	1406	0.55	1389	0.54	0.77	0.75
BE	4036	2323	1210	0.52	1135	0.49	0.74	0.72
NO	2424	1421	882	0.62	844	0.59	0.73	0.71
ES	5022	2868	1485	0.52	1473	0.51	0.69	0.68
FR	28014	15990	5991	0.37	5436	0.34	0.65	0.62
IT	20804	13822	7248	0.52	6280	0.45	0.64	0.59
CZ	452	232	105	0.45	103	0.44	0.56	0.56
PL	588	298	93	0.31	90	0.30	0.48	0.48
PT	357	198	70	0.35	69	0.35	0.48	0.47
GR	721	168	39	0.23	37	0.22	0.29	0.27

(1) GB: Great Britain, NL: Netherlands, SE: Sweden, ES: Spain, DE: Germany, FI: Finland, DK: Denmark, NO: Norway, IT: Italy, FR: France, BE: Belgium, CZ: Czech Republic, GR: Greece, PL: Poland, PT - Portugal.
(2) The number of unique standardised applicant/proprietor names
(3) The number of applicant/proprietors that we have identified as corporate (not university, individual or government department)
(4) Number of corporate applicants which we have matched to one or more entries in Amadeus
(5) The percentage of corporate applicants which we have matched to one or more entries in Amadeus
(6) Number of corporate applicants which we have matched to only one entry in Amadeus
(7) The percentage of corporate applicants which we have matched to only one entry in Amadeus
(8) The percentage of corporate applicants which we have matched to one or more entries in Amadeus, weighted by the applicant's total number of patents
(9) The percentage of corporate applicants which we have matched to only one entry in Amadeus, weighted by the applicant's total number of patents

Column 2 of Table 5 shows the number of unique applicants responsible for the patent applications observed for each country (where a unique applicant is one with a unique ***standard name***). Column 3 shows the number of these applicants that are corporate and column 4 shows the number of these corporate applicants that have been matched to firm accounts for each country. Column 5 shows this as a percentage, so for the United Kingdom we can see that we have matched 70 percent of corporate applicants by all matching methods at our disposal. This success rate is considerably lower for other countries. Column 6 shows the numbers of these matched applicants that have been matched to a unique company account in Amadeus (or have been matched to multiple accounts in the first instance but resolved by one of the methods described in Section 2.2.3) and column 7 shows the percentage of corporate applicants that have been matched uniquely. Column 8 shows the percentage of corporate applicants matched weighted by their patent applications and column 9 shows the same figure for unique matches and constitutes our key measure of success. The higher weighted success rates indicates that the matching process in disproportionately more successful at matching large patenting firms than small ones. This is in part likely due to higher survival rates for large firms that file patents in early years and is in part likely due to a deliberate effort in the manual matching phase of the process to ensure that large patenting firms are matched. The weighted unique success rate is over 50 percent for 12 of the 15 countries in the sample, and over 70 percent for 7 of the countries. Our most successfully matched country is the one we know most about: the United Kingdom with a weighted unique success rate of 88 percent. This number compares favourably with the results in Figure 19 of Hall, Jaffe and Trajtenberg (2001), which shows the percentage of patents matched to Compustat in the NBER data by grant year.[30] Given that Compustat contains US firms the equivalent success rate is for US-assigned patents. This is less than 70 percent for all grant years, peaking in the late 1980s and declining below 50% by 1999 (since the Compustat firms are those existing in 1989). Our success rates are higher as we have a larger target population of firms, as Amadeus contains accounts for both listed and unlisted firms, whereas Compustat contains accounts for only listed firms.

The match between patent applicants and firms has been achieved by a number of methods, each of which indicates a varying degree of exactness. Unresolved multiple matches and matches of identified ***non-corporate*** applicants are excluded from the final output. Those matches which remain are based on ***standardised name, stem name, previous name or a manual match.***

[30] Hall, B., Jaffe, A. and Trajtenberg, M. (2001). 'The NBER Patent Citations Data File: Lessons, Insights and Methodological Tools'

Table 6 breaks down uniquely matched corporate applicants (seen in column 6 of Table 5) into the method by which they have been matched, weighted by the applicant's proportion of patents held out of *matched* patents. For example, for the UK, 87 percent (column 4) of those matched did so on standard name, 5 percent (column 6) did so on stem name, 8 percent (column 8) on old name (only available for the UK), and a very small percentage were manually matched, 13 firms (column 9). Column 11 shows the number of applicants, from all methods, that matched to dropped or inactive firms, and we can see that this is a large proportion, 18 percent weighted by patents for the UK, which illustrate the importance of the use of old versions of Amadeus. The pattern is similar for nearly all countries in that the majority of matches are achieved using ***standard name***, although Belgium is a noted exception, with most matches there achieved using ***stem name***. The proportion of applicants that match to dead or inactive firms varies significantly across countries and is surprisingly high in some countries, 75 percent in Germany for example. It is hard to believe that such a large proportion of German patenting was carried out by firms that subsequently died, and noting that firms become "inactive" in Amadeus if they fail to file accounts for the most recent year, it calls into question the usefulness of this indicator in Amadeus. It is not used in the matching process and should probably not be used in research applications.[31]

[31] It is likely used in Germany to distinguish duplicate records in Amadeus, as discussed in section 2.2.3.

Table 6: Relative importance of each match method for *uniquely matched corporate applicants*

	All	Standard Name		Stem Name		Previous Name		Manual match		Of which dead or inactive	
Country	No. Matched Uniquely	No. by this method	As weighted % of matches w*(3)/(2)	No. by this method	As weighted % of matches w*(5)/(2)	No. by this method	As weighted % of matches w*(7)/(2)	No. by this method	As weighted % of matches w*(9)/(2)	No. of applicants that matched to dead firms	As weighted % of matches w*(11)/(2)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
GB	10809	9552	0.87	529	0.05	826	0.08	13	0.00	2306	0.21
DE	15199	14602	0.92	1322	0.08	0	0.00	15	0.00	7484	0.47
NL	2599	2531	0.96	94	0.04	0	0.00	23	0.01	480	0.18
FI	1113	1087	0.86	173	0.14	0	0.00	2	0.00	444	0.35
SE	2730	2658	0.97	80	0.03	0	0.00	13	0.00	185	0.07
DK	1389	1256	0.89	139	0.10	0	0.00	11	0.01	191	0.14
BE	1135	326	0.27	881	0.73	0	0.00	3	0.00	512	0.42
NO	844	802	0.91	77	0.09	0	0.00	3	0.00	142	0.16
ES	1473	1408	0.95	62	0.04	0	0.00	15	0.01	146	0.10
FR	5436	4482	0.75	1473	0.25	0	0.00	36	0.01	1006	0.17
IT	6280	5558	0.77	1670	0.23	0	0.00	20	0.00	840	0.12
CZ	103	99	0.94	6	0.06	0	0.00	0	0.00	8	0.08
PL	90	85	0.91	2	0.02	0	0.00	6	0.06	2	0.02
PT	69	60	0.86	7	0.10	0	0.00	3	0.04	3	0.04
GR	37	34	0.87	5	0.13	0	0.00	0	0.00	2	0.05

Notes: (1) UK: United Kingdom, NL: Netherlands, SE: Sweden, ES: Spain, DE: Germany, FI: Finland, DK: Denmark, NO: Norway, IT: Italy, FR: France, BE: Belgium, CZ: Czech Republic, GR: Greece, PL: Poland, BG: Bulgaria, PT-Portugal.
(2) Number of applicants matched to only one entry in Amadeus (as in column (6) of Table 1)
(3) The number of applicants matched using a standardised version of the name
(4) The percentage of all matches that matched using a standardised version of the name, weighted by applicant's patents relative to matched patents
(5) The number of applicants matched using a stem version of the name
(6) The percentage of all matches that matched using a stem version of the name, weighted by applicant's patents relative to matched patents
(7) The number of applicants matched using a previous version of the firms' name (from FAME)
(8) The percentage of all matches that matched using a previous version of the firm's name, weighted by applicant's patents relative to matched patents
(9) The number of applicants matched by hand
(10) The percentage of all matches that matched by hand, weighted by applicant's patents relative to matched patents
(11) The number of applicants matched, by any method, to a dead or inactive firm

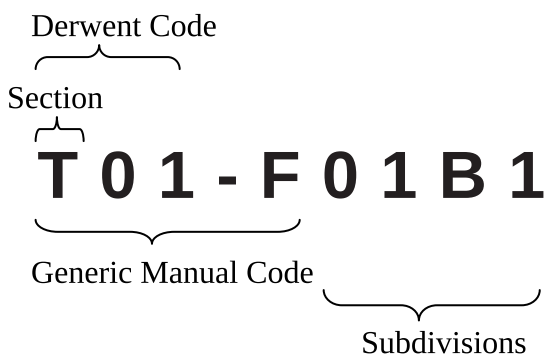
5 Industry Classification

In many applications researchers want to classify patents or firms by industry. We add a novel definition of industry based on the Derwent Innovations Index (DII) which is compiled by Thomson for commercial purposes.[32] The DII classifies individual patents according to the industry in which the patent has an application. In what follows, we describe this data and how it compares to nace codes and International Patent Classifications (IPC). The literature involving R&D and innovation has tended to use either IPC or nace codes as the basis for defining industries.

5.1 Derwent Innovation Index (DII)

The DII provides a hierarchical code which can be used to identify industries at a number of levels of accuracy. Take the following example, shown in figure 6, of a full manual code, **T01-F01B1'.** This is the most detailed level of the industry classification available. In what follows we explain the components of this code and the information that each part reveals.

Figure 6: Derwent Innovation Index Manual Code



Note: this is an example of a full manual code identifying 'Firmware microprogramming' within the computing and control section.

The DII contains three main technology groupings, Chemical, Engineering and Electrical and Electronics which are sub divided into the 20 sections; A-M (Chemical); P-Q (Engineering); and S-X (Electrical and Electronic). These *Sections* are listed in Table 7. In the above example, section 'T' identifies 'Computing and Control'

[32] see http://scientific.thomson.com/products/dii/furtherinfo/

Table 7: Derwent Innovation Index Sections

Chemical; A_M		*Engineering; P-Q*	
A	Polymers and Plastics	**P**	General
B	Pharmaceuticals	**Q**	Mechanical
C	Agricultural Chemicals		
D	Food, Detergents, Water Treatment and Biotechnology		*Electrical and Electronic; S-X*
E	General Chemicals	**S**	Instrumentation, Measuring and Testing
F	Textiles and Paper-Making	**T**	Computing and Control
G	Printing, Coating, Photographic	**U**	Semiconductors and Electronic Circuitry
H	Petroleum	**V**	Electronic Components
J	Chemical Engineering	**W**	Communications
K	Nucleonics, Explosives and Protection	**X**	Electric Power Engineering
L	Refractories, Ceramics, Cement and Electro(in)organics		
M	M Metallurgy		
N	Catalysts[33]		

Note: Broad Industry classifications contained in Derwent innovations Index.
Source: Derwent innovation Index; see http://scientific.thomson.com/products/dii/furtherinfo/

The *Sections* are further subdivided into Derwent classes where each class consists of the section letter, followed by two digits. For example, 'T01' is the class for 'Digital Computers'. The Derwent classes give a more precise industry definition than the sections alone.

Thomson considers all aspects of the patent document when producing Derwent codes including references to technological areas that may not be the main subject matter of the application. In many cases, an application will be assigned to a number of Derwent classes in a number of sections. All patents have a full Derwent code, see Figure 6.

Most patents are also associated with a series of manual codes which provide finer categories according to various aspects of the invention. Manual Codes are intended to highlight the novel aspects of an invention and are therefore normally assigned according to the claimed novelty. In addition, codes are applied to indicate the use of an invention. A patent can be assigned a number of manual codes.

While most *sections* have a complete set of manual codes classification for different sections did start at different times, some as recently as 2006, and manual codes for

[33] Section N is not a true Derwent section. However, in some cases there are N manual codes which have been applied to sections E, H and J from Derwent Week 197701. These codes can be derived from any of the sections A through M. For more details see, Derwent World Patents Index, CPI Manual Codes (2007).

section Q have not yet been created. In cases where manual codes have not been assigned, the Derwent code is the most disaggregated level of information. In most cases the manual code is a direct subdivision of the Derwent code.[34]

In figure 6 the generic manual code, *'T01-F'*, identifies *'software Program control'*. Manual codes can have subdivisions, up to 5 digits long, which classify the industry into finer groups. In the example *'T01-F01'* identifies *'Microprogramming'* and 'T01-*F01B1'* identifies '*Firmware microprogramming'*.

The usefulness of the DII is that the definition of industry is directly related to the technology embodied in a patent and reflects the use of the technology.

5.2 Comparisons between industry definitions

5.2.1 IPC codes

Patents are classified using International Patent Classification (IPC); an internationally-recognised classification system controlled by the World Intellectual Property Organisation (WIPO). The IPC codes are assigned to patent documents by Patent Offices.[35] The IPC classifies patent documents according to the technical fields that the patent relates to. The system is hierarchical with the highest level containing eight sections corresponding to very broad technical fields. In the 2006 edition of the IPC these sections are further divided into 120 classes with further subclasses.

In some cases there is a direct correspondence between the IPC code and the Derwent section.[36] However, in most cases, since the Derwent codes expands on the novelty of a patent and its application, there is no strict correspondence between Derwent classes IPC codes.[37]

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[34] In sections H-X, the manual code is a direct subdivision of the Derwent code. However, for sections A through G the manual and Derwent codes were developed independently and while the *sections* are common to both, the manual codes are not a direct subdivision of the Derwent code. Despite this, there sections A-G still have 3 digit Derwent codes and manual codes of at least 4 digits. More information can be found in Derwent World Patents Index, CPI Manual Codes (2007).

[35] http://classifications.wipo.int/.

[36] This is the case for Sections P and Q (Engineering)

[37] More information can be found in the appendix of Derwent World Patents Index; EPI manual codes (2008)

Table 8 shows patents with a priority date between 1990 and 2004 which have been matched to the accounting data and classifies them according to both IPC and Derwent codes. A patent can be assigned to multiple IPC and Derwent codes. In cases where more than one code is relevant, patents are weighed by the inverse of the number of codes in order that the sum of the weights is one for each patent. Comparable industries in both definitions are not matched together.

5.2.2 NACE codes

Accounting data in Amadeus includes nace codes which classify firms into industries. The classification of firms according to nace codes is unrelated to patenting. The code is based on the main industry in which a firm operates. *"Data on those organisations which work with or produce the same product or service is gathered together under the same industry heading."* Nace codes include four digits with the first two digits identifying the broad industry group.

Table 9 shows the mapping between Derwent and nace codes. Again, patents can be in multiple industries, are weighted accordingly and no attempt is made to match comparable industries.

Table 8: **Derwent Innovation Index and International Patent Classification (IPC)**

Derwent Industry	Main IPC classes								
	Chemistry	Electricity	Fixed constructions	Human necessity	Mechanical engineering	Transporting	Physics	Textiles	Total
Catalysts	59.9	1.0	0.0	2.3	6.7	29.0	0.8	0.3	100
Chemical	59.2	1.7	0.1	17.6	2.7	11.7	4.6	2.3	100
Chemical Engineering	25.1	1.8	0.4	3.5	12.1	40.4	15.8	1.0	100
Communications	0.4	66.5	0.5	1.5	1.7	3.5	25.9	0.1	100
Computing	1.4	25.7	0.5	3.7	3.1	9.7	55.5	0.5	100
Disinfectants and Detergents	50.9	0.3	0.2	31.0	0.5	7.3	7.9	1.9	100
Electric power	4.0	29.1	2.7	5.9	19.6	22.7	13.9	2.1	100
Electronic	5.9	53.7	1.0	2.4	5.9	7.8	22.9	0.4	100
Explosives	17.7	3.5	0.5	8.9	15.9	9.0	44.4	0.1	100
Food	21.4	0.1	0.1	66.7	1.7	7.2	2.5	0.3	100
General Engineering	7.9	6.1	1.6	27.6	4.4	32.6	18.2	1.6	100
Glass	40.2	30.6	1.3	1.4	3.2	10.6	11.6	1.1	100
Instruments and measuring	5.4	9.3	0.6	13.0	4.3	10.9	56.1	0.4	100
Mechanical Engineering	2.8	3.5	13.7	3.6	38.8	32.1	4.4	1.2	100
Metallurgy	42.3	5.4	0.5	1.3	6.9	39.8	3.3	0.5	100
Paper and Wood	26.0	0.2	0.2	5.9	2.9	15.6	2.1	47.1	100
Petroleum	43.2	1.3	11.7	1.9	15.8	20.3	5.5	0.4	100
Pharmaceuticals	43.0	0.2	0.0	43.1	0.3	4.8	8.5	0.1	100
Plastics	42.0	4.3	2.2	13.0	4.0	24.5	5.6	4.5	100
Printing	62.7	2.0	0.6	3.9	0.9	14.9	11.8	3.2	100
Semiconductors and Circuitry	5.7	61.2	0.2	0.7	1.6	3.6	26.9	0.1	100
Textiles	23.2	0.9	0.9	12.4	1.8	11.4	1.5	47.8	100
Unclassified	18.6	18.5	3.3	15.4	9.1	18.9	14.4	2.0	100
Vehicles	1.2	4.6	2.4	1.4	14.2	69.7	6.2	0.3	100
Total	17.8	17.0	2.9	12.2	10.1	20.8	17.0	2.2	100

Note: This table contains all patents with a priority date between 1990 and 2004 which have been matched to the accounting data and classifies them according to both IPC and Derwent codes. Each row represents all of the patents classified according to the given Derwent industry. Patents may appear in more than one Derwent and IPC category and have therefore been weighted such that each patent is counted only once.
Source: Authors' calculations using PATSTAT matched to accounts data and Derwent innovations index.

Table 9: Derwent Innovation Index and NACE codes

Derwent Industry	**Primary NACE code of parent firm**																			
	Agriculture / Mining	Computers	Construct	Electric/Gas/ Water	Financial	Basic	Chemical	Food	Fuel	Machinery	Other manuf.	Textiles	Vehicles	Pharmaceuticals	R&D	Services	Trade	Transport	Unclassified	Total
Catalysts	10.1	0.1	0.1	0.2	3.8	1.7	29.7	0.6	3.1	2.6	0.0	0.1	5.6	11.5	2.2	14.8	4.3	0.0	9.4	100
Chemical	4.2	0.1	0.2	0.2	4.1	1.3	28.4	2.5	1.2	3.6	0.1	0.4	1.8	16.4	3.6	17.8	5.9	0.0	8.5	100
Chemical Engineering	4.4	0.1	0.8	0.5	4.7	3.4	12.8	0.5	0.9	14.6	0.1	1.0	7.4	6.9	6.9	21.3	4.6	0.1	9.1	100
Communications	0.1	1.9	0.4	0.1	1.8	1.0	0.6	0.0	0.0	42.7	0.3	0.4	4.9	0.2	1.1	38.6	1.7	0.1	4.2	100
Computing	0.2	5.2	0.4	0.1	2.0	1.3	1.8	0.1	0.0	43.1	1.5	0.8	5.8	0.8	1.7	27.8	2.2	0.1	5.3	100
Disinfectants and Detergents	1.1	0.1	0.5	0.2	4.6	0.8	15.5	5.3	0.1	5.3	0.1	0.8	0.1	14.5	11.0	26.3	6.1	0.0	7.6	100
Electric power	0.5	0.4	0.5	0.2	3.0	4.7	1.5	0.2	0.1	31.4	0.1	0.7	21.5	0.6	2.5	22.2	3.4	0.1	6.5	100
Electronic	0.2	0.4	0.4	0.1	2.4	3.4	2.1	0.0	0.0	38.0	0.4	0.4	8.7	1.1	4.1	28.5	2.4	0.0	7.4	100
Explosives	0.6	0.1	0.5	0.4	2.7	8.9	6.5	0.1	0.2	20.3	0.0	0.3	0.6	4.8	24.0	19.7	1.2	0.0	9.2	100
Food	1.2	0.1	0.2	0.1	6.1	1.4	16.0	15.0	0.0	10.9	0.0	0.5	0.4	4.4	3.4	22.6	7.9	0.0	9.8	100
General Engineering	0.6	0.7	0.5	0.1	3.7	5.9	5.6	0.5	0.1	28.4	0.7	3.7	4.5	3.5	2.9	23.9	5.3	0.1	9.2	100
Glass	1.1	0.1	0.9	0.2	3.3	5.9	7.8	0.2	0.2	26.1	0.2	0.6	3.7	3.3	6.9	24.6	3.2	0.1	11.7	100
Instrument and measuring	0.7	0.8	0.5	0.2	2.7	2.5	3.0	0.4	0.1	36.1	0.3	0.6	9.7	4.4	6.7	21.0	3.5	0.1	6.9	100
Mechanical Engineering	1.2	0.3	1.3	0.2	3.0	10.1	2.1	0.4	0.1	21.2	0.3	2.1	16.1	0.9	1.2	25.8	4.8	0.2	8.9	100
Metallurgy	2.0	0.2	0.5	0.1	1.9	12.0	7.8	0.4	0.3	18.1	0.1	0.6	4.3	2.4	3.6	31.2	3.8	0.1	10.6	100
Paper/Wood	1.7	0.0	0.1	0.0	6.5	1.7	15.0	0.6	0.1	16.8	0.8	5.2	0.3	11.5	1.2	18.0	3.5	0.0	17.0	100
Petroleum	20.4	0.1	1.7	0.6	2.5	3.1	13.9	0.3	3.7	5.8	0.0	0.3	9.3	5.0	2.2	19.8	3.4	0.0	7.9	100
Pharmaceuticals	0.3	0.2	0.2	0.0	3.5	0.8	6.8	3.4	0.0	3.4	0.2	0.2	0.1	29.3	12.5	28.6	3.9	0.0	6.8	100
Plastics	2.2	0.1	0.4	0.1	5.5	5.6	21.3	1.5	0.7	8.4	0.3	2.1	2.2	11.2	3.0	21.0	5.9	0.0	8.4	100
Printing	1.7	0.0	0.3	0.0	7.0	2.0	38.1	0.4	0.4	4.9	0.6	1.1	0.6	12.7	1.6	15.6	4.7	0.0	8.1	100
Semiconductors and Circuitry	0.2	0.5	0.4	0.1	1.6	1.1	1.4	0.0	0.0	53.1	0.3	0.2	5.0	0.6	4.6	20.9	2.0	0.0	8.1	100
Textiles	0.7	0.2	0.3	0.0	7.8	3.5	15.6	0.8	0.1	18.3	0.1	5.2	2.2	7.4	1.2	20.5	6.8	0.0	9.4	100
Unclassified	1.1	1.0	0.5	0.2	3.7	4.5	6.5	1.3	0.2	24.0	0.2	1.5	6.0	7.9	3.4	25.5	4.1	0.1	8.3	100
Vehicles	0.2	0.1	0.2	0.0	2.9	6.2	0.8	0.1	0.0	12.0	0.0	0.9	38.3	0.3	1.3	25.8	3.2	0.2	7.5	100
Total	1.3	0.8	0.6	0.1	3.4	4.4	7.6	1.0	0.3	24.1	0.4	1.4	8.5	5.6	3.7	25.0	4.1	0.1	7.8	100

Note: This table contains all patents with a priority date between 1990 and 2004 which have been matched to the accounting data and classifies them according to both the NACE code of the parent firm and the Derwent codes associated with the patent. Each row represents all of the patents classified according to the given Derwent industry. Patents may appear in more than one Derwent category and have therefore been weighted such that each patent is counted only once.
Source: Authors' calculations using PATSTAT matched to accounts data and Derwent innovations index.

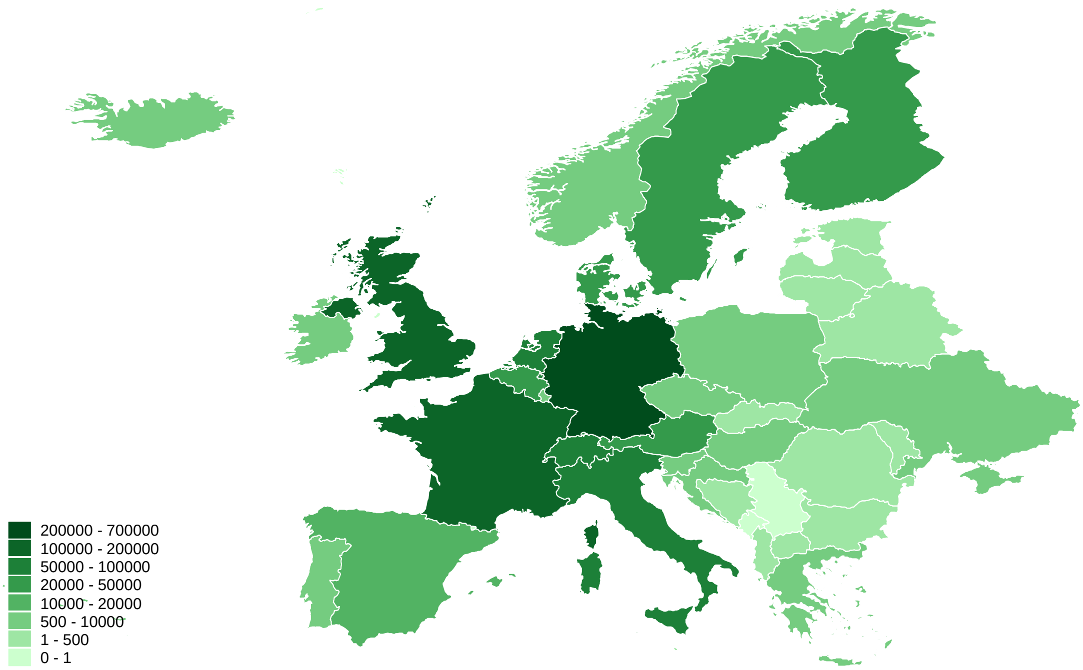
6 The geography of innovation activity

Having outlined the data, this section looks at the location of innovative activities. We draw a distinction between activity based in a country, which can include the activity of both domestic and foreign firms, and the activity of firms resident in a country, which can be conducted both at home and abroad.

6.1 Innovative activities based in a country

The number of inventors based in a country provides a measure of the amount of innovative activity which is taking place in that location. This is the basis upon which most aggregate statistics on innovative activity are reported. Figure 7 provides an overview of the number of inventors located in European countries between 1990 and 2004. Here, and it what follows, inventors have been counted once each time they appear in a patent.[38]

Figure 7: Innovative activity in Europe using all PATSTAT data, 1990-2004



Notes: the legend refers to the number of inventors based in a country. The inventors are those associated with all patents, including those filed by firms, institutions and individuals

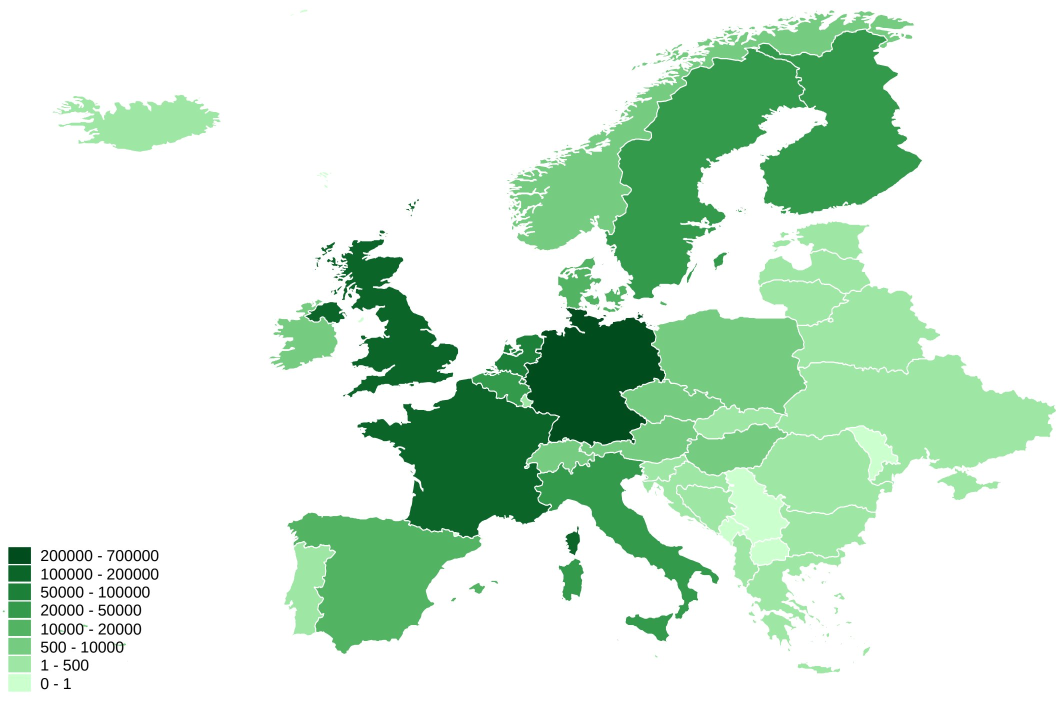
[38] This is a ‘simple’ count. The relationships between countries and trends shown here do not change significantly if fractionally counting is used.

We see that Germany, France and the UK are associated with the greatest number of inventors, Eastern Europe have the lowest. This is, in part, related to the relative size of the countries; Germany has the largest number of patents and the largest population. The map in figure 7, exploits all of the PATSTAT patents data; it includes inventors associated all firms, institutions and individuals.

In what follows we use only the matched data. That is, we use the patents of firms which we are able to match to the accounting data. This allows us to map those inventors based in a country to the location of the relevant patent firm. As a result, the number of patents and inventors will not represent all patents and inventors. When considering inventors based in a country we will not capture those inventors that file patents as individuals, that work for institutions or that work for a firm that could not be matched to Amadeus.

Figure 8 redraws the map of Europe using matched data. For those countries which we do not match we expect the count of inventors to be much lower since, in these cases, we will only capture inventors employed by foreign firms. This is the case. However, as the map illustrates, using the matched dataset leaves the relative levels of innovation in Europe virtually unchanged.

Figure 8: Innovative activity in Europe using all Matched data

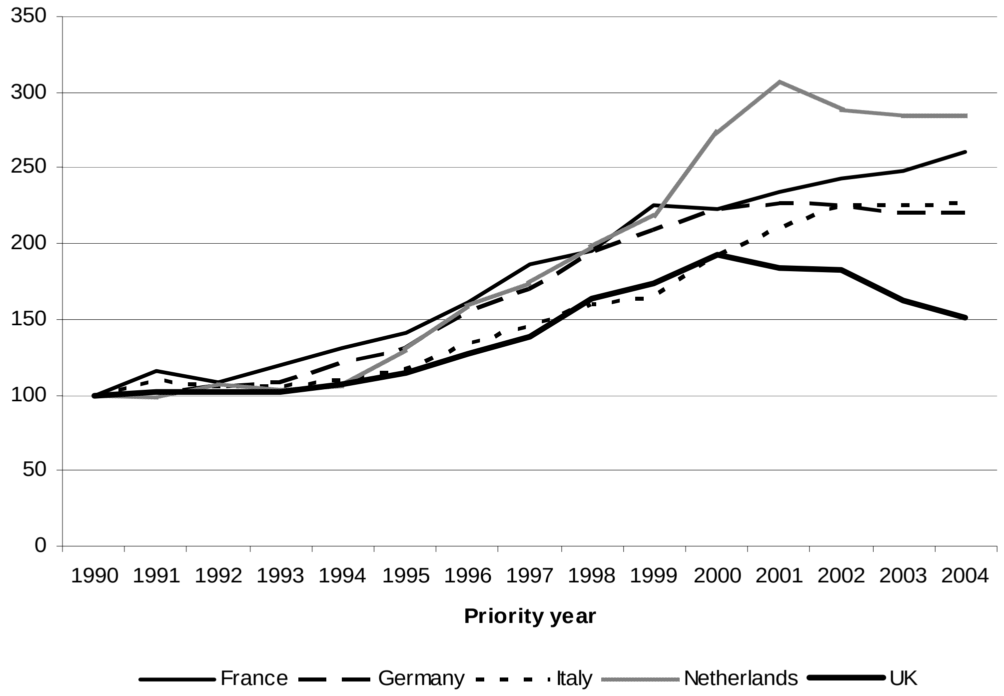


Notes: the legend refers to the number of inventors based in a country. The inventors are those associated matched firms from 15 European countries.

Table 10 provides a break down of the activities based in a country according to a definition of industry based on the Derwent innovations Index. Each column represents 100% of all the inventors based in a country, with each cell representing the proportion of those inventors associated with a given industry. The numbers in bold indicate the two industries which represent the largest proportion of activity. It can be seen that the combination of general and mechanical engineering represents 30% of the activity in Germany. *Pharmaceuticals* is important for the UK, Denmark and Spain and *Communications* is important for Finland, the Netherlands and Sweden

Taking the 5 most innovative countries Figure 9 plots an index of the innovative activity undertaken within a country. The number of inventors based in a country has been indexed to equal 100 in 1990. In each year, the index shows the level of activity relative to 1990; a number greater than 100 indicates that innovative activity is higher in that year than it was in 1990. It can be seen that innovative activity in these countries has been increasingly over time. Although not shown here, the innovative activity of all European countries has increased over time.

Figure 9: Trends in innovation within a country; index 1990=1000



Notes: This graph plots the number of inventors based in a country, counted using a simple count (see section 2.5.1), relative to the number of inventors based in the country in 1990.

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Table 10: Inventors in a country, by Industry

	Country of residence of inventor										
Industry	Belgium	Germany	Denmark	Spain	Finland	France	UK	Italy	Netherlands	Norway	Sweden
Catalysts	1.3	1.5	1.0	1.0	0.5	1.0	1.0	1.3	1.4	1.1	0.3
Chemical	8.5	7.3	4.8	6.3	3.0	5.5	6.3	5.3	5.1	6.5	2.0
Chemical Engineering	1.5	2.3	2.0	1.5	1.7	1.6	2.4	1.8	1.5	3.9	1.8
Communications	5.3	4.4	4.8	6.6	26.7	9.0	6.9	4.1	**10.9**	5.3	**13.2**
Computing	4.7	4.4	3.3	3.9	**11.7**	6.2	6.4	3.7	11.0	5.4	6.8
Disinfectants/Detergents	6.5	4.4	**12.9**	8.3	3.7	6.5	7.1	3.4	4.7	4.9	5.1
Electric power	2.9	9.1	3.8	7.2	3.8	6.6	4.9	9.2	5.4	4.9	6.9
Electronic	2.1	3.7	2.4	2.7	2.2	4.2	3.2	3.4	4.1	1.7	2.9
Explosives	0.5	0.2	0.1	0.2	0.2	0.8	0.5	0.1	0.2	0.7	0.4
Food	1.0	0.6	4.3	2.0	1.2	0.7	1.0	1.0	2.1	2.2	0.6
General Engineering	**14.7**	**11.2**	11.1	9.5	9.4	**10.8**	**12.4**	**14.6**	**14.4**	**11.9**	**15.9**
Glass	2.4	2.7	1.7	1.2	1.2	3.1	2.3	1.8	3.1	1.4	2.2
Instrument/measuring	4.4	4.6	4.2	3.0	4.0	4.2	5.4	3.5	4.8	5.9	5.5
Mechanical Engineering	5.6	**13.0**	9.5	**11.5**	**8.2**	**10.6**	8.9	**15.4**	5.9	**13.6**	10.3
Metallurgy	1.7	1.8	0.7	0.9	0.9	1.6	1.1	1.9	0.8	2.9	2.2
Paper/Wood	0.4	0.8	1.2	0.4	5.0	0.4	0.4	0.3	0.3	0.2	1.7
Petroleum	0.9	1.0	1.3	0.6	0.6	1.2	1.8	1.3	1.8	7.7	0.6
Pharmaceuticals	7.5	5.1	**18.8**	**16.1**	4.7	7.6	**12.7**	8.9	4.0	8.0	7.7
Plastics	**14.0**	9.0	5.9	7.8	4.4	7.9	7.1	9.3	6.7	6.7	4.2
Printing	7.2	2.4	0.6	0.6	0.7	1.1	1.5	1.0	1.7	0.9	0.5
Circuitry	1.9	3.0	1.4	1.6	3.3	4.1	3.2	1.8	7.8	1.3	3.3
Textiles	1.9	1.5	2.3	1.6	0.6	0.8	0.9	2.6	0.6	0.5	1.7
Unclassified	1.6	1.3	1.8	1.6	1.9	1.3	1.5	1.5	1.3	1.6	1.6
Vehicles	1.6	4.8	0.4	4.3	0.5	3.5	1.4	2.9	0.7	0.8	2.5
Total	100	100	100	100	100	100	100	100	100	100	100

Note: Each column represents the inventors based in the given country, broken down according to Industry. Industry refers to the classification assigned to patents and is constructed from the Derwent innovations index. These numbers refer to patents with an application priority year between 1990 and 2004.
Source: Authors' calculations using PATSTAT matched to Derwent innovations index

A proportion of innovative activities based within a country will be attributable to foreign firms. That is, some of the inventors will have worked on patents which are filed by a foreign firm. We are able to observe the proportion of inventors based in a country that are attributable to a foreign applicant firm. That is, where the firm that holds the property rights imparted by a patent on which the inventors are working is resident in a different location to the inventor(s).

However, as earlier discussions have highlighted, applicants can be subsidiaries of other firms; a share of both the foreign and domestic applicants will be owned by another firm which may be resident in a different country. Using the link to parent firms we are able to distinguish between those inventors that are employed by a domestic firm, a foreign firm or a domestic firm that is itself a subsidiary of a foreign firm.

Figure 10 decomposes the innovative activity in a country over the period 2000-2004, according to whether it is associated with a 'home' or foreign firm. That is, inventors based in a country according to those which are ultimately owned by a domestic parent firm in the same country and those which are owned by a foreign parent firm. The domestic firms are further split into those which only operate in the national market and those which are 'multinational', where a firm is deemed to be a multinational if it has a productive subsidiary outside of the home country[39]

It can be seen the composition of firms, that is foreign domestic and multinational, varies across countries. Foreign firms represent over 40 % of the activity in Belgium, Spain and the UK. This proportion is much lower for Germany, Denmark and Finland. It is also notable that in the case of France and the Netherlands, domestic firms represent only a small share of all activity with home multinationals accounting for most inventors.

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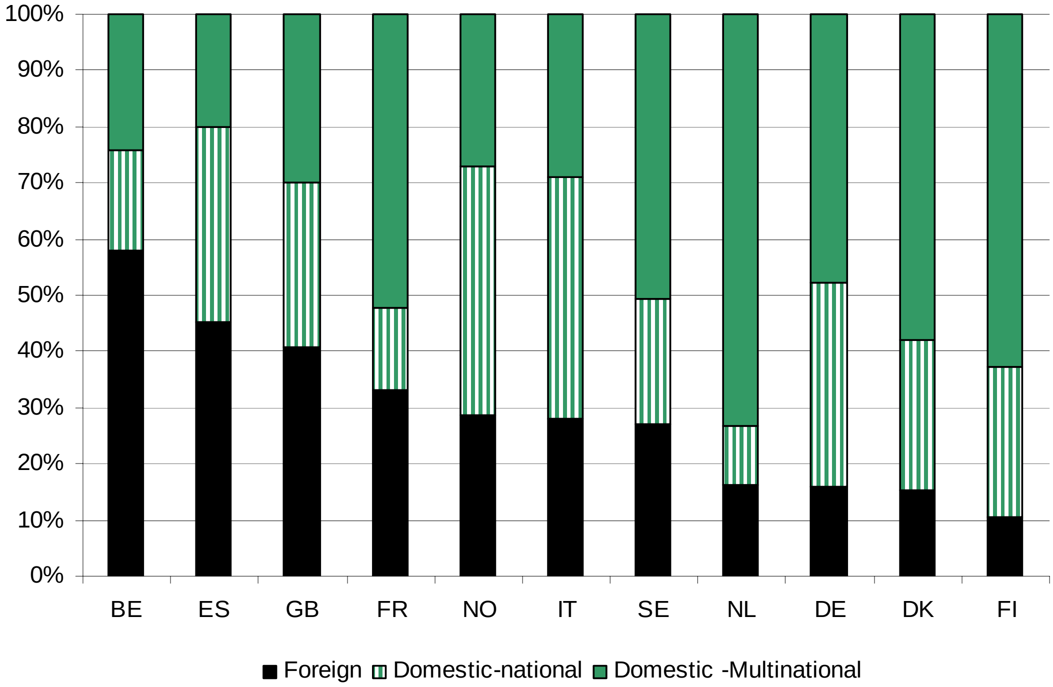
[39] A firm's foreign subsidiary is classed as productive if its assets, turnover and employment meet a set of criteria based on the European Union's definition of a small company. This information comes from the accounts data, Amadeus.

Figure 10: Inventors based in a country, 2000-2004



Notes: Each bar represents all inventors based in a country (100%) in the period 2000-2004 and decomposed into those which are associated with a foreign parent firm (bottom bar), those with a domestic parent firm that has no productive activity outside the domestic market (middle bar) and those with a domestic parent firm that has multinational productive activity (top bar)

6.2 Innovative activities of firms

We showed above that foreign firms account for a significant proportion of the activity within a country. The corollary of this is that firms locate their activities in foreign locations. This section considers the worldwide innovative activities of European multinational parent firms. [40] Using the matched dataset developed above, we are able to capture that part of a firm's activity which takes place via European and US subsidiaries. [41]

R&D is traditionally considered to be one of the least mobile aspects of firms' activity. Recently, however, we have seen that innovative activities are increasingly mobile. Table 11 provides the proportion of innovative activity conducted outside the resident country of the multinational firms. Firstly, note that the extent to which multinationals conduct their activity offshore varies across counties. Looking down

[40] Note that we could equally include domestic firms that collaborate abroad.

[41] Note that while this section again exploits the relationship between parent firms and inventors, one may also consider the intermediate relationship between inventors and applicant firms where applicants can be located in a different country to both the parent firm and the inventors..

the columns in table 11 reveal that while multinationals from countries such as Belgium, the Netherlands and the UK locate around half of their activity abroad, the proportion is much smaller for the multinationals from other countries such as Italy and Germany. A more common trend emerges across time: in most cases, the proportion of activity located offshore has increased.

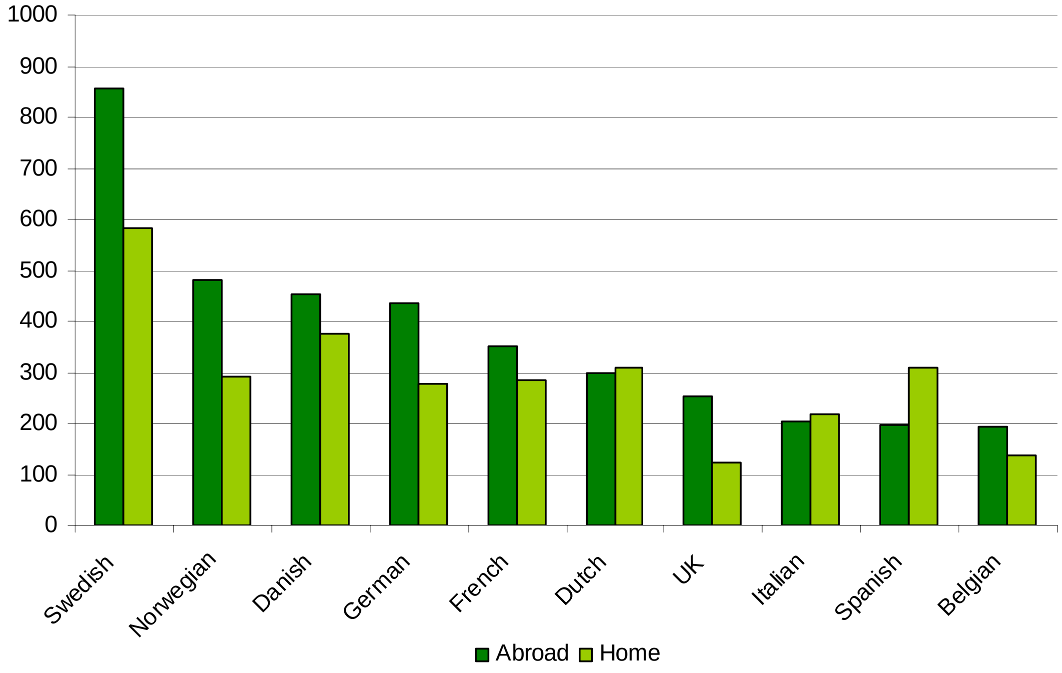
Table 11: Proportion of innovative activity based offshore (%), ranked by proportion in 2000/2004

Multinational nationality	1990/ 1994	1995/ 1999	2000/ 2004
Belgian	45.7	62.0	63.8
Dutch	50.7	49.4	48.5
UK	35.1	48.4	46.6
Swedish	27.9	32.4	42.3
French	33.8	37.0	38.6
Danish	29.4	38.7	38.5
Norwegian	25.0	39.5	36.6
Finnish	14.0	22.1	29.5
Spanish	29.6	28.8	18.9
Italian	20.0	20.2	15.7
German	11.7	14.0	13.9

Note: Each figure represents all inventors based offshore as a proportion of all the inventors listed on the patents owned by the relevant country's multinational firms, between the priority years 2000 and 2004.
Source: Authors' calculations using PATSTAT and Amadeus databases.

The increasing proportion of activity located offshore has tended to be the result of activity abroad growing more quickly than activity at home. This can be seen in Figure 11. The darker (lighter) bar represents the average level of innovative activity conducted offshore (at home) between 2000-2004 relative to the amount that was located abroad (at home) in 1990. A number greater than 100 indicates an increase in innovative activity. For most countries, the growth of multinationals' foreign activity was greater than the growth of activity based at home. This resulted in an increasing proportion of activity being located offshore.

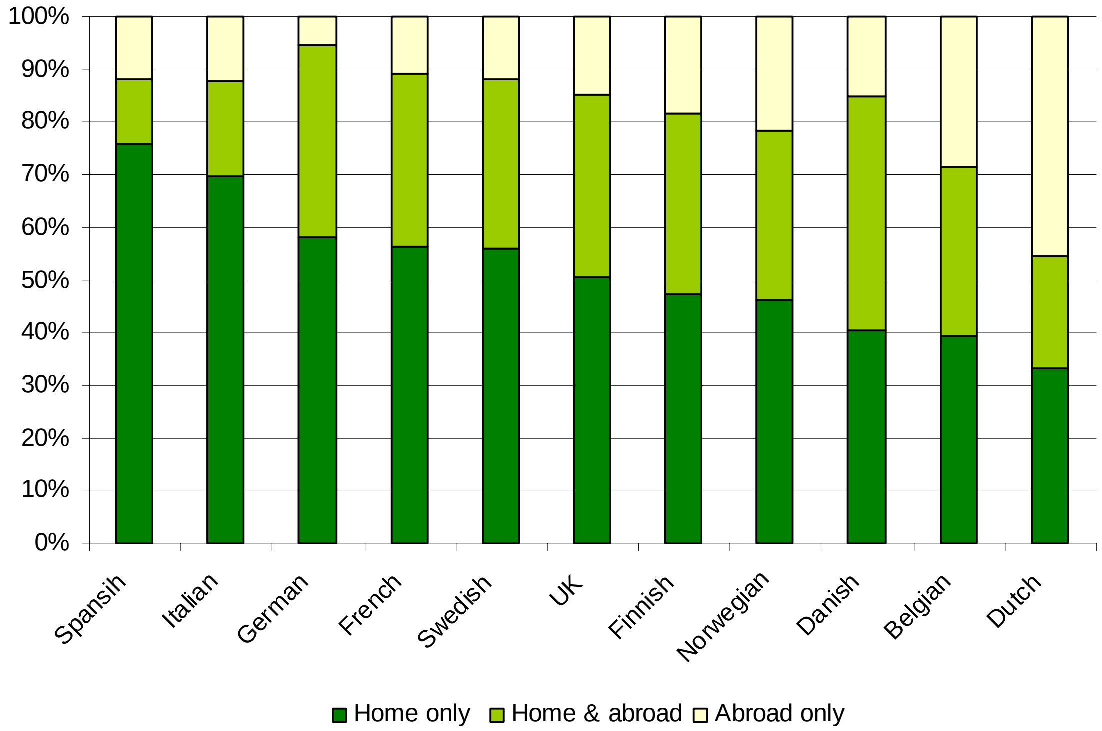
Figure 11: Innovative activity of multinational firms, by location. Average level of activity 2000-2004 relative to 1990, 1990=100



Note: Each bar plots the average level of innovative activity, as measured by the number of inventors listed in the patents owned by these multinational firms, between 2000 and 2004, relative to the level in 1990. The first bar (abroad) shows this measure for inventors based outside the country of the multinational while the second bar (Home) uses inventors based in the domestic market of the multinational. All years refers to the priority year.
Source: Authors' calculations using PATSTAT matched to accounting data.

It is important to note that not all multinationals have located their activities offshore. There is substantial heterogeneity across firms in the way they organise their innovative activities. While many firms locate all of their innovative activity in the domestic market, some locate all activity offshore. Figure 12 shows, for the multinational from each country, the proportion of multinational firms in the period 2000/2004 that locate their activity either all at home, all abroad or a mix of both. This break down varies across countries with those countries associated with higher proportions of activity located offshore (such as the Netherlands or the UK) also tending to have fewer multinationals that operate only in the home market.

Figure 12: MNEs by location of innovative activity; 2000/2004



Note: The bar s represent all (100%) of multinationals firms resident in a given country between 2000 and 2004. This is broken down into i) those that only employ inventors based in the same country, home, ii) those that employ inventors based both at home and abroad and iii) those that employ only inventors based offshore.
Source: Authors' calculations using PATSTAT matched to accounting data.

The proportion of multinationals that locate activity at home, abroad or both has changed over time. This is considered for the 3 largest European countries, France, Germany and the UK, in table 12.

Table 12: MNEs by location of innovative activity across time

Nationality of MNE	Proportion of MNEs operating in given location: Home only	Home& Abroad	Abroad only
French			
1990/1994	58.7	29.9	11.4
1995/1999	55.5	35.5	9.0
2000/2004	56.4	33.0	10.7
German			
1990/1994	64.2	29.3	6.5
1995/1999	62.4	32.4	5.2
2000/2004	58.3	36.4	5.3
UK			
1990/1994	57.1	32.8	10.0
1995/1999	46.0	38.9	15.1
2000/2004	50.4	35.0	14.7

Note: Each row represents all (100%) of the multinational firms resident in a given country in a given period. This is broken down into i) those that only employ inventors based in the same country, home, ii) those that employ inventors based both at home and abroad and iii) those that employ only inventors based offshore. The '2000/2004' rows correspond to figure 12.
Source: Authors' calculations using PATSTAT matched to accounting data.

The ‘2000/2004’ rows in table 12 correspond to the relevant bar in figure 12. In all three cases the proportion of multinationals that locate all of their activity at home has fallen over time while the proportion of firms that operate both at home and abroad has increased. Although not shown here, all countries in figure 10 show an increase in the proportion of firms that locate activity both at home and abroad over time. It is notable that German multinationals have a low proportion of firms with all activity located offshore and that this has fallen since the early 1990s.

The preceding discussion suggests that changes in the growth of innovative activity abroad is driven by both changes in whether firms choose to locate their innovative activity abroad or not (the extensive margin) and, given firms’ choices over the location of their activities, how much firms do in each location (the intensive margin).

Having seen that multinationals locate a significant share of their activity outside of their home economy, we further consider where such activity is located.

Table 11 provides a mapping between the country of the multinational firm and that of the innovative activity. Again, we consider French, German and British multinationals. Each row includes multinationals from the indicated country, each column the location of innovative activity. The rows sum to 100, so each cell represents the proportion of activity of the multinationals from that home country that are located in the indicated location. The numbers in bold represent firms innovative activity in home countries (and are the counterparts to the figures in table 9).

It has been well documented that the US is a major recipient of investment in R&D activity from European firms[42] and we are able to observe this in Table 13. The US has been a particularly important location for UK multinationals with a fifth of activity being located there between 2000 and 2004. This is higher than for French Multinationals and much higher than for German Multinationals. For French multinationals, Germany has been a significant host of activity.

[42] See, for example, von Zedtwitz and Gassman (2002).

Table 13: Location of multinationals' innovative activity

	Location of Innovative activity (%)						
	France	Germany	UK	Rest EU15	US	Others	Total
1990/1994							
French MNEs	**66.19**	8.98	4.15	6.66	12.46	1.56	100
German MNEs	1.47	**88.34**	1.26	2.25	5.42	1.26	100
UK MNEs	1.73	3.29	**64.9**	6.36	21.55	2.17	100
1995/1999							
French MNEs	**63.02**	12.13	2.62	6.07	14.01	2.15	100
German MNEs	1.4	**86.04**	1.11	2.99	6.64	1.82	100
UK MNEs	2.68	5.56	**51.62**	9.76	27.53	2.85	100
2000/2004							
French MNEs	**61.42**	12.39	1.79	6.63	13.98	3.8	100
German MNEs	1.43	**86.08**	0.85	3.85	5.17	2.61	100
UK MNEs	2.98	7.05	**53.43**	12.62	19.46	4.46	100

Note: The level of innovative activity is measured by the number of inventors listed in the patents owned by these multinational firms, filed at the European Patent Office. The year refers to the priority year of the patent application. Rest EU15 is composed of the remaining 12 EU countries, namely Belgium, Czech Republic, Denmark, Finland, Greece, Italy, Netherlands, Norway, Poland, Portugal , Spain and Sweden.
Source: Authors' calculations using PATSTAT matched to accounting data.

The data allows us to comprehensively map out the location of innovative activity. For French, German and UK owned multinationals this has been done in figures 14-16. The shading on each of the world maps represents the proportion of all the inventors associated with multinationals from the given country, between the period 2000 to 2004, based in each location. Darker shading indicates a higher proportion of inventors based in the country.[43] As table 13 showed, the multinationals of each country have the largest number of inventors based at home with the US also being a significant location. A large proportion of the activity of firms from all three countries has also been based in Europe. Figures 17-19 use the data in the world maps and provide a closer look at the location of innovative activity in Europe. As before, the shading represents the proportion of all the inventors associated with multinationals from the given country, between the period 2000 to 2004, based in each European location.

[43] Note that the small, darkly shaded, region at the top of South America refers to French Guiana which in fact registers no inventors but is wrongly attributed the inventors associated with France under the current mapping software.

Figure 14: Location of French multinationals' innovative activity, 2000/2004

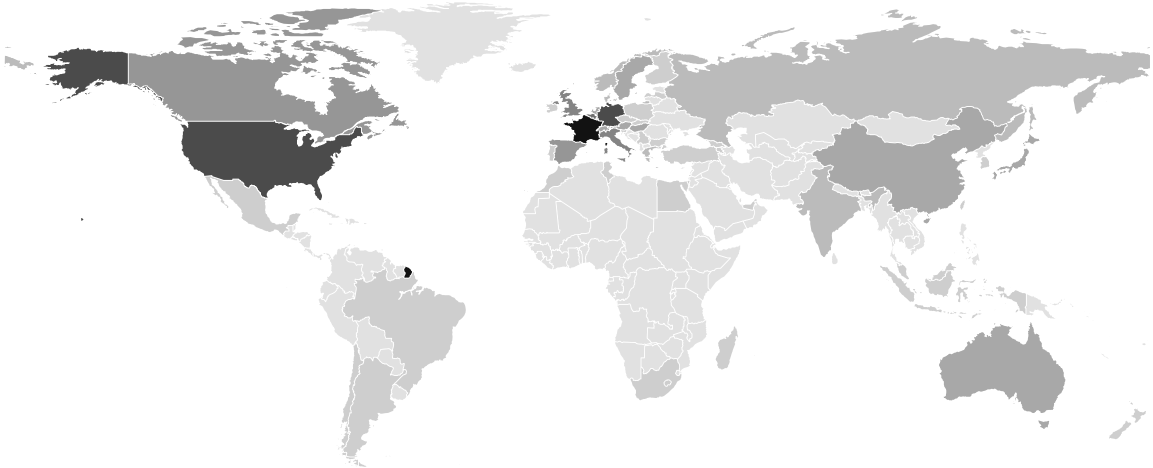


Figure 15: Location of German multinationals' innovative activity, 2000/2004

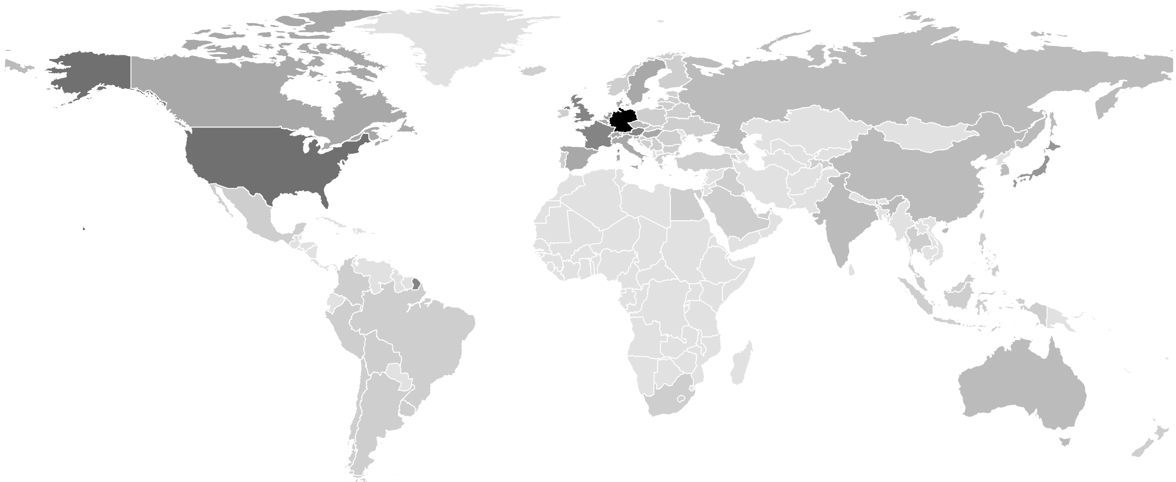
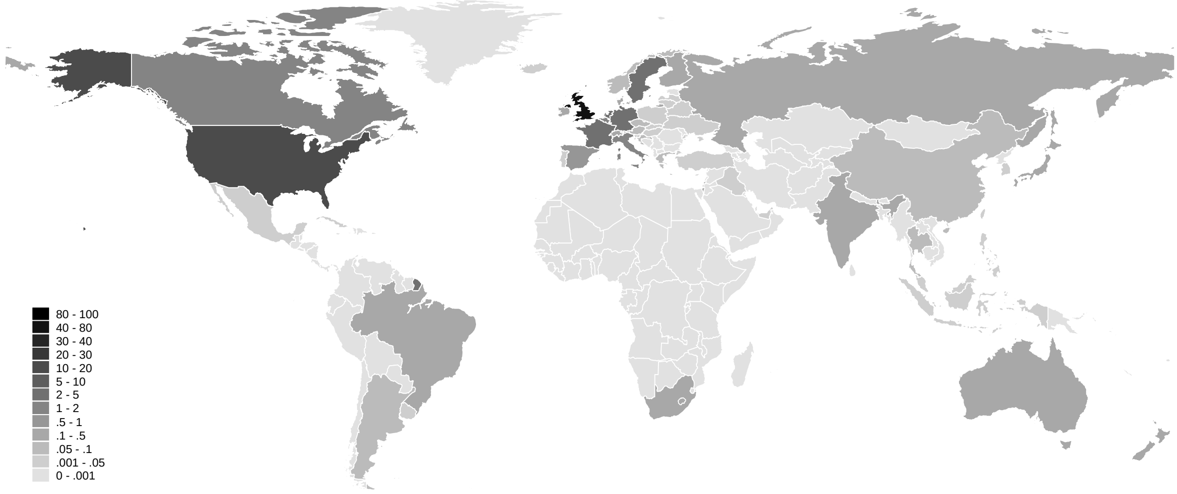


Figure 16: Location of UK multinationals' innovative activity, 2000/2004



Note: Innovative activity is measured by the number of inventors listed in the EPO patents owned by these multinational firms. Year refers to the priority year. Legend represents the proportion if inventors in each location

Source: Authors' calculations using PATSTAT matched to accounting data.

Figure 17: European locations of French multinationals' innovative activity, 2000/2004

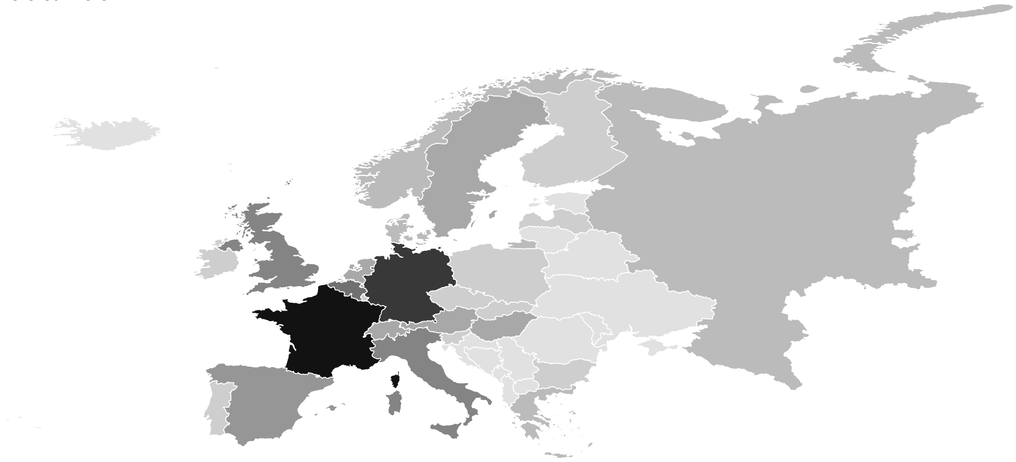


Figure 18: European locations of German multinationals' innovative activity, 2000/2004

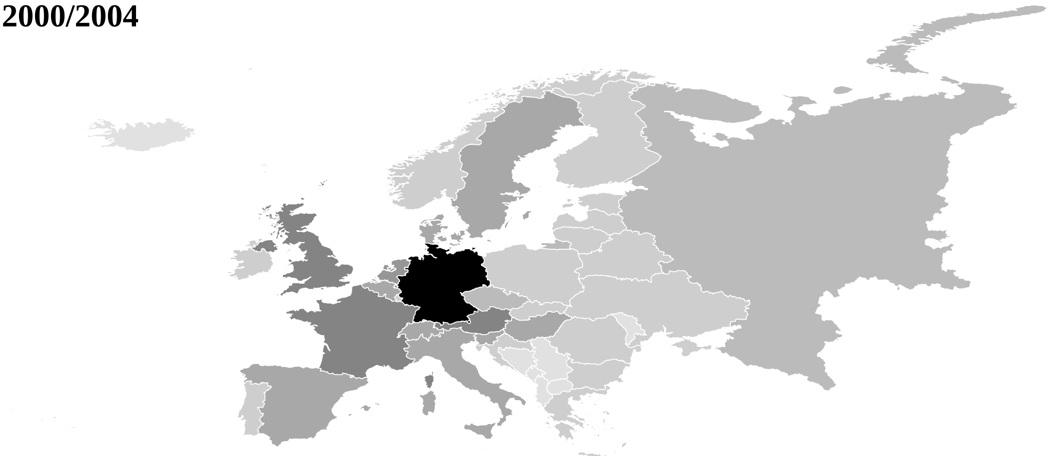
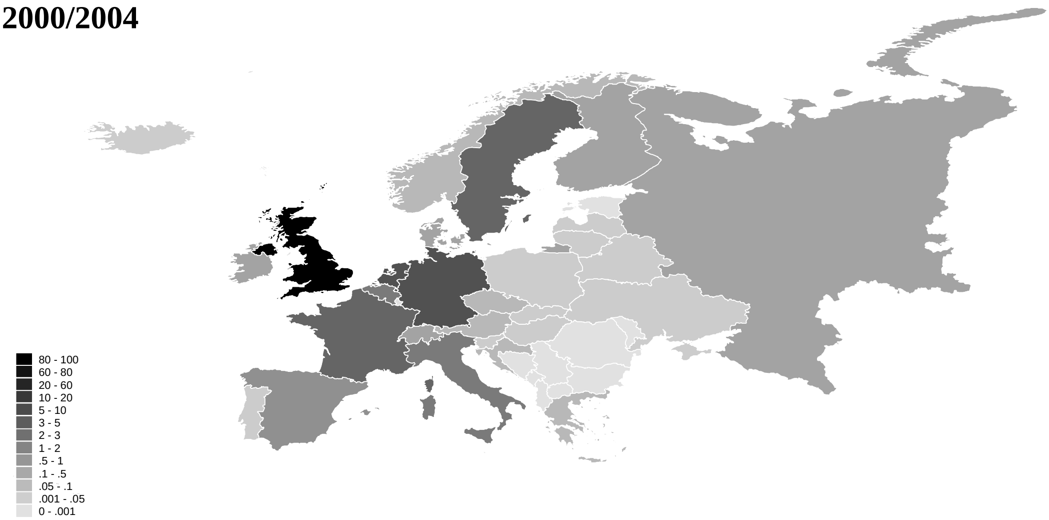


Figure 19: European locations of UK multinationals' innovative activity, 2000/2004



Note: Innovative activity is measured by the number of inventors listed in the EPO patents owned by these multinational firms. Year refers to the priority year. Legend represents the proportion if inventors in each location

Source: Authors' calculations using PATSTAT matched to accounting data.

Although not shown here, the relative importance of foreign locations has changed over time. During the period 2000 to 2004 the US hosted a reduced share of the activity of UK multinationals while a higher proportion has been located in other European countries. The Netherlands and Sweden are significant hosts of activity. Over time Italy and Spain, despite attracting only a fairly small proportion of activity, have grown in importance. The growing importance of other European countries in hosting innovative activity of UK Multinationals is a result of a faster growth in the level of activity in these countries relative to the US since the mid 1990s.

The trends in the foreign locations of innovative activity are in part related to specific industries. This can be seen in table 14 which gives a break down of the innovative activities of French, German and UK multinationals' innovative activities by location and industry. The 'total' rows give the same figures as those presented in the relevant section of table 13 above and represent activity of all industries combined. Activity is then broken down into the largest 10 industries (by patenting). Each row shows the proportion of all activity in the given industry, located in each location.

Table 14 allows the comparison between the locations of activity across industry. For French multinationals it can be seen that a lower proportion of the activity in Communications and Computing is based in France than is the case for the other industries. In the case of Computing, 17% of activity is based in Germany and a further 17% in the US. Turing to German multinationals it can be seen that the both Pharmaceuticals and Semiconductors and Circuitry are associated with higher proportions of activity located offshore. In the case of Pharmaceuticals, almost 14% of activity is based in the US. For Semiconductors and Circuitry, almost 9% of activity is based in each of the rest of the EU and the US. UK multinationals also locate a significant proportion of their pharmaceuticals activity offshore with almost 30% in the US and a further 15% in the rest of the EU15. The Disinfectants and Detergents industry stands out for UK multinationals since a much lower proportion of activity is based in the UK than is the cases for other industries. While 38% of activity is based in the domestic market, 20% is located in the rest of the EU15 and 30% in the US.

Table 14: Location of Multinationals' innovative activity, by industry

	Location of inventive activity (%)						
2000/2004	France	Germany	Rest EU	UK	US	Others	Total
French Multinationals							
Total	***61.4***	***12.4***	***6.6***	***1.8***	***14.0***	***3.8***	***100***
Chemical	68.8	5.7	6.9	3.1	13.8	1.9	100
Communications	50.8	13.3	9.3	1.4	19.5	5.8	100
Computing	50.6	17.0	7.5	1.4	17.4	6.0	100
Disinfectants and Detergents	75.1	7.0	3.8	3.5	9.0	1.6	100
Electric power	71.3	14.5	5.0	1.8	5.6	1.8	100
Electronics	54.0	13.2	6.0	1.8	21.1	3.9	100
Mechanical Engineering	67.7	14.5	6.0	2.0	8.7	1.2	100
Pharmaceuticals	67.0	9.8	3.3	2.4	7.9	9.5	100
Plastics	60.4	7.1	12.2	1.5	16.4	2.4	100
Semiconductors and Circuitry	56.9	15.0	7.4	1.5	15.5	3.7	100
All other industries	67.3	10.9	4.6	1.8	12.8	2.5	100
German Multinationals							
Total	***1.4***	***86.1***	***3.9***	***0.9***	***5.2***	***2.6***	***100***
Chemical	2.7	87.2	1.9	0.7	5.1	2.5	100
Communications	0.7	83.7	8.4	2.0	3.4	1.8	100
Computing	1.2	84.4	4.0	1.1	6.8	2.5	100
Disinfectants and Detergents	1.3	81.7	4.3	0.8	8.3	3.6	100
Electric power	0.6	91.4	3.0	0.6	2.7	1.7	100
Electronic	0.5	88.0	4.9	0.6	2.8	3.2	100
Mechanical Engineering	1.6	90.0	4.0	1.0	2.3	1.2	100
Pharmaceuticals	0.9	70.5	4.7	1.3	13.9	8.7	100
Plastics	1.4	86.9	2.7	0.5	6.1	2.4	100
Semiconductors and Circuitry	1.2	77.3	8.7	0.6	8.9	3.5	100
All other industries	1.7	87.8	2.9	0.6	4.6	2.3	100
UK Multinationals							
Total	***3.0***	***7.1***	***12.6***	***53.4***	***19.5***	***4.5***	***100***
Chemical	2.8	6.2	12.4	55.5	19.9	3.3	100
Communications	3.4	12.9	12.4	56.8	8.0	6.5	100
Computing	3.7	5.9	3.9	68.2	13.8	4.5	100
Disinfectants and Detergents	1.2	3.5	20.8	38.4	31.3	4.8	100
Electric power	4.0	14.5	5.8	63.7	10.3	1.7	100
Electronic	0.9	16.5	4.8	67.0	9.1	1.6	100
Mechanical Engineering	5.5	16.4	7.8	57.4	11.1	1.8	100
Pharmaceuticals	2.3	1.0	15.7	45.4	29.3	6.2	100
Plastics	2.8	6.8	14.1	53.4	19.5	3.4	100
Semiconductors and Circuitry	1.5	20.9	8.6	48.5	15.3	5.1	100
All other industries	3.2	8.2	12.2	59.2	13.8	3.4	100

Note: The level of innovative activity is measured by the number of inventors listed in the patents owned by these multinational firms, filed at the European Patent Office. Inventors have been weighted such that they are only counted once. The year refers to the priority year of the patent application. Rest EU15 is composed of the remaining 12 EU countries, namely Belgium, Czech Republic, Denmark, Finland, Greece, Italy, Netherlands, Norway, Poland, Portugal , Spain and Sweden. Industries are based on the Derwent Innovations Index.
Source: Authors’ calculations using PATSTAT and Amadeus databases.

7 Summary

This paper has described the development of a dataset which combines firm level accounting data with information on the patents that those firms and their subsidiaries filed at the European Patent Office (EPO). The matching of these data is carried out for Belgium, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Greece, Italy, Netherlands, Norway, Poland, Portugal , Spain and Sweden. The match between the two datasets is based on a match between company names in the accounts data and the names of firms applying for a patent in the patents data.

The benefit of the matched dataset is that it allows consideration of the innovative activities of firms, including that part which is undertaken, either at home or abroad, via a subsidiary. Specifically, the dataset maps out the global locations of innovative activity.

We report that the success of matching varies across countries but is generally good. The match rate is over 80% for applicants from both the UK and Germany for example, and for most countries the match success improves greatly over time.

To this we add a novel industry classification based on the Derwent Innovations Index. Importantly the Derwent classification indicates both the novel technical aspects of a patent and the areas in which the technology is used.

In the final part of the paper we explore the innovative activities based within the geographical boundaries of a country. We then map out the global locations of the innovative activities associated with European firms, including that part which is conducted in subsidiaries.

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