An Analysis of the Innovative Activity of Entrepreneurial and Young Firms in the UK*

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ABSTRACT

This paper provides an overview of a new database that uses intellectual property data to track the innovative activity of firms in the UK. The paper looks at the extent and nature of patenting activity, focusing on micro firms and SMEs. Over the period 2000 to 2007, SME patenting has increased whereas large firm patenting has fallen and micro firm patenting has been roughly constant. Most micro and SMEs patent while relatively young (aged ten or less) and this tendency is becoming more pronounced over time. The paper provides some preliminary analysis on micro firms and SMEs that become high growth firms (defined as having greater than 20% growth per annum). Overall, 28.0% of young micro and SMEs achieve high growth (over 2002 to 2007). In comparison, 29.4% of young micro or SMEs that patent achieve high growth. This difference is much greater for firms in the high-tech industries.

KEYWORDS: Firm growth, intellectual property.

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1 Introduction

One of the most important aspects of modern economies is the generation of new, entrepreneurial firms, especially those that are pursing innovative activities. The ability to generate and grow such firms is thought to be a major factor in raising productivity levels and ensuring a sustainable future. While the importance of such firms is widely accepted the evidence base on such firms is sparse. If measurement and quantification are the prerequisites to analysis and understanding, the lack of data on such firms suggests weak analysis and poor understanding. In particular, while survey and small sample data do exist there is a paucity of large sample data. This paper reports on a database containing the population of UK firms, as well as their intellectual property in form of patents and trade marks, for the 2000 to 2007 period. This paper provides some preliminary analysis of the data. The construction of such databases is part of an OECD project entitled *Analysis of the Innovative Activity of Entrepreneurial and Young Firms* that intends to foster database development across OECD member countries.

The basic components necessary for the construction of such an integrated database are twofold. First, data on the creation of new firms must be available. In the UK, Companies House contains details of all new (registered) companies, as well as all existing and active companies. For example, in 2001 around 162,000 new firms were incorporated and there were around 2 million existing firms. Second, there needs to be an indicator(s) of which firms are innovative and entrepreneurial.[1] There is an argument that all new firms are innovative and/or entrepreneurial: the fact that they are new suggests they are offering a new product or service, or offering an existing product or service to a new market. However, new firms contain a large number of firms that offer standard, existing products and services in different markets (e.g. 'cafes and restaurants' and 'business services' such as web designers and consultants). Analysis might want to distinguish these firms from those that offer more innovative products and services. How should one define 'more innovative'? A useful categorisation of innovation is: new-to-firm, new-to-economy, and new-to-world. There is an interest in using intellectual property registrations as indicators of these categories. This paper focuses on patenting activity of firms. A new or young firm that makes a patent application considers it has a new to the world innovation.[2] Another possibility is to use trade mark data. A firm with a trade mark might be considered to have created a new-to-the-economy innovation. These issues, along with a consideration of the benefits and drawbacks of intellectual property (IP) data, are discussed in more detail below.

[1] Schumpter (1942, p.13) stated 'The function of entrepreneurs is to reform or revolutionize the pattern of production by exploiting an invention, or more generally, an untried technological possibility for producing a new commodity or producing an old one in a new way.' This quote is taken from Audretsch et al (2006, p.4) who discuss in more detail the issues of entrepreneurial and innovative firms. Greenhalgh and Rogers (2009) also discuss the distinction between entrepreneurship and innovation.

[2] To be specific: The firm files the patent application since it believes the invention to be new-to-world. The patent application relates to an invention, which may then be developed into an innovation. The firm hopes that obtaining a patent will assist appropriability of the innovation. This new-to-the-world belief is confirmed if the patent is subsequently granted.

The end point of such database construction is to allow further insight into the characteristics and efficiency of the entire innovation process in modern economies. Although much is known about innovation in large and medium sized firms, there are many gaps in our knowledge about smaller and newer firms. In the UK and elsewhere there is strong interest in understanding why innovative firms are formed and how such firms prosper. A closely linked issue is the creation of so-called high growth firms (sometimes classified into 'gazelles' or 'gorillas', see BERR (2008)). Quantification of such innovative and high growth firms, including the analysis of trends at the economy level, is an important step in understanding the economy. This paper provides an overview of new and young UK firms and their patent activity.

Section 2 describes the database creation and the nature of the IP data. Section 3 contains an overview of patenting in the UK with a specific focus on the differences between micro, SME and large firms. Section 4 provides a preliminary discussion of performance and patenting, with a focus on growth rates.

2 The Oxford Firm-level Intellectual Property Database

The data used for the analysis come from the Oxford Firm Level IP (OFLIP) database. The database draws on the Financial Analysis Made Easy (FAME) data that cover the entire population of registered UK firms (FAME downloads data from Companies House records).[3] In this paper we use 'firms' to mean registered firms. Hence a firm refers to the legal entity that organizes production, in contrast to census-type data that often uses the plant or production unit. In addition, OFLIP contains data on the IP activity of firms in the form of patents and trade marks. OFLIP has been constructed by matching the FAME database and a number of IP datasets.

The FAME database is a commercial database provided by Bureau van Dijk.[4] To construct the data base, two versions of the FAME database have been used: FAME October 2005 and March 2009. The main motivation for using two different versions of FAME is that FAME keeps details of 'inactive' firms (see below) for a period of four years. If we used only the 2009 version of FAME, we would be unable to allocate IP to any firm that has exited the market before 2005, which could bias our matching results.

FAME contains basic information on all firms, such as name, registered address, firm type and industry code. Availability of financial information varies substantially across firms. In the UK, the smallest firms are legally required to report only very basic balance sheet information (shareholders' funds and total assets). The largest firms provide a much broader range of profit and loss information, as well as detailed balance sheet data. In terms of numbers of firms, FAME October 2005 contains information on around 3.1 million firms (of which 0.9 million are inactive). The FAME March 2009 data contain 3.8 million firms (of which 1 million are inactive). Inactive firms are those that have exited the market and belong to one of the following categories: dissolved,

[3] See also data appendix B.

[4] http://www.bvdep.com/en/FAME.html

liquidated, entered receivership or declared non-trading.

In the analysis below firms are divided into size categories: micro, small and medium-sized enterprises (SMEs) and large firms. The European Union defines firm size categories using three criteria: employment, turnover and assets. Since total assets are the most common financial variable in the FAME database, we primarily define firm size according to assets. According to the EU, a SME must have total assets greater than Euro 2 million and less than or equal to Euro 43 million. A firm with assets below Euro 2 million is classified as a micro firm, above Euro 43 million is classified as a large firm. While this is the basic method of assigning firm size, we make adjustments when employment data is available and, importantly, we also consider firms' ownership structure (for example, if a micro firm is owned by a large firm, it is reclassified as large).[5]

For this updated version of OFLIP, the IP data used for the construction of the database comes from two different sources: the European Patent Office (EPO) PATSTAT database and Marquesa Ltd.[6] Data on patent publications at the EPO, World Intellectual Property Organization (WIPO) and UK IP Office was downloaded from PATSTAT version October 2008.[7] OFLIP also contains trade mark data in the form of UK as well as Community trade marks, which are obtained from Marquesa Ltd., although these data are not used in this paper.

This paper focuses on patenting by UK firms over the period 2000 to 2007. The three different types of patent publication are used since UK firms have a choice of how to approach seeking patent protection. One method is to file an application at the UK IP office, which is relatively cheap and would, if ultimately successful, provide protection in the UK. Another option is to apply for the patent at the EPO. This is more expensive, but the advantage is that it provides a clear route to seek subsequent protection in member countries of the European Patent Convention (EPC) (currently 35). Another option is to ask WIPO to provide an initial examination and then publish the patent, after which there is a procedure to ask for full examination in the (current) 139 countries that are members of the Patent Cooperation Treaty (PCT). Patents published through WIPO are referred to as PCTs.[8] It can be argued that the choice of the UK, EPC and PCT routes depends on the firm's expected value of the invention, since the associated costs differ dramatically. However, there is relatively little empirical evidence on this issue.

Which ever the route chosen, the initial stage of the patent system involves an application by a firm. At this stage the firm believes it has a new invention which may be novel enough to be granted a patent. To be specific, in order to be granted a patent

[5]See data appendix E for a full discussion.

[6]See Rogers, Helmers, and Greenhalgh (2007) for a description of the components of the previous version of OFLIP.

[7]See also data appendix C.

[8]It is also possible that some UK firms may apply directly to the US PTO or other countries' IP offices. The OFLIP data currently does not contain such data.

three main criteria must be met: novelty (in the worldwide domain); it has to be a significant inventive step (so must be non-obvious, even to experts in the field); and it must be capable of industrial application. After an initial examination, the patent is 'published' after approximately 18 months, which means it is made public.[9]

Only patent applications that have been published are visible and available to researchers (and others), hence these data can be used in studies such as this. Some of these publications will be granted. The time to grant varies, but the can take a number of years. This delay is one reason why publication data are used, especially for the analysis of smaller and start-up firms. Using the year in which the patent is granted provides a lagging indicator of the innovative activities of the firm. It is the case, however, that many publications will not be granted. Does this represent a drawback of using patent publication data? In our view, for the analysis of smaller firms, it does not: the use of patent publications is as an indicator of innovative activities. If the patent is subsequently not granted, this may still imply that the invention was either new-to-the-firm or new-to-the-market, hence it is still a potential indicator that the firm is engaged in research and innovative activities.[10]

3 Overview of patenting in the UK

3.1 Summary statistics

Table 1 contains information on the numbers of patenting firms, the total number of patents, and the average number of patents per firm for the entire 2000 and 2007 period. The columns of the table show the results for UK, EPC and PCT patent publications, while the rows indicate firm size. The top panel shows that around 4,150 large firms published UK and EPC patents in the period (in fact 1,719 large firms had both UK and EPC publications). Fewer large firms (3,292) published patents via the PCT system, something which is true for all firm sizes. While the number of SMEs that published patents is lower than for large firms, the numbers of micro firms is higher (e.g. 5,724 micro firms had a UK patent published). The second panel shows the total numbers of patent publications. Note that the total for large firms is much greater than SMEs or micro firms separately, but that the combined SME and micro patents roughly equals large firm activity. The final panel shows patents published per firm (i.e., the total divided by number of firms). As might be expected, large firms have more patents with averages above three, while SMEs and micro firms have averages below two.

[9]This is the situation in the UK and EPO systems. The US system is different if the patent application only requests protection in the USA. The PCT system is similar to UK and EPC, although publication occurs after 31 months. Also note that there is a possibility to request advanced publication (less than 18 months since the filing of the application) which is often used as a way of creating a defensive publication.

[10]This simplified discussion abstracts from more complex patent filing strategies driven by strategic motives. Strategic patenting activity may be more likely in larger firms, especially those in certain industries. For example, see Hall and Ziedonis (2001) for large firms in the semi-conductor industry. See also Guellec and Pottelsberghe (2007) and Granstrand (1999).

Table 1: Patenting activity

	UK	EPC	PCT
Size	Number of Patentees		
Large	4,151	4,153	3,292
SME	3,718	3,329	2,852
Micro	5,724	5,311	4,854
	Number of Patents		
Large	12,964	18,983	14,153
SME	6,370	8,748	5,786
Micro	8,100	9,652	8,567
	Number of Patents per firm		
Large	3.12	4.57	4.30
SME	1.71	2.63	2.03
Micro	1.42	1.82	1.76

Another general feature of patent data is that they are highly skewed (i.e., most patenting firms have only one or two patents and a few have much larger numbers). The data for the UK are no exception. For example, of the 14,149 firms that had one or more UK patents published over 2000 to 2007, only 154 (1.1%) had 15 or more patents published in a year. In contrast, in 71% of cases when a firm patents in a given year it only has one patent publication. This skewed distribution is also present for EPC and PCT publications, and also within firm size categories.

The above table shows patenting broken down by firm size. In some cases it was not possible to allocate a firm to a firm size due to missing asset data. In particular in many of these cases the patent was published after the firm had become *inactive* (an inactive firm is dissolved, liquidated, in receivership or declared non-trading). Such firms account for around 2,500 patents (out of a total of around 96,000) over the 2000 to 2007 period. Possible reasons for this include: the firm is non-trading but owns IPRs for tax or other reasons, failure by firms to update patent offices of dissolution, or failure to notify patent offices of takeovers or assignments. Further analysis would be needed to understand the reasons for such cases; in particular, taking into account of mergers and acquisitions among firms.

3.2 Trends

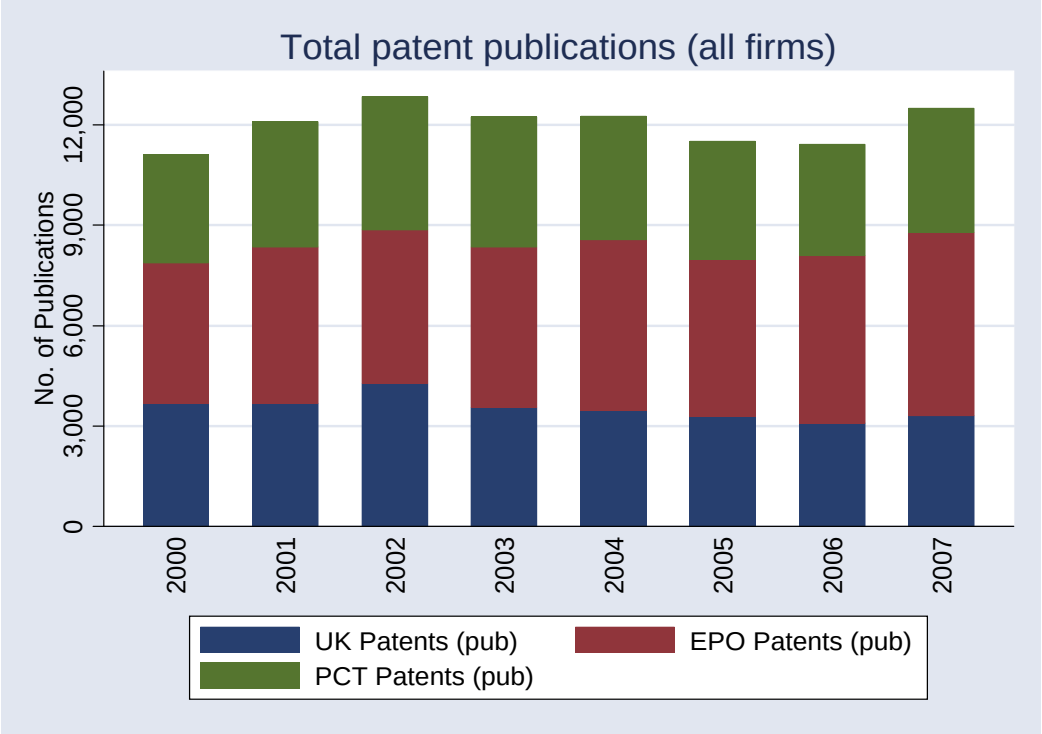
For any economy, the trend in patenting activity is a closely watched indicator. The rapid recent growth in patenting by China and South Korea, has attracted considerable interest.[11] In the cases of these and other countries, the rapid growth of patenting is seen as an indicator of innovation, technological sophistication and a leading indicator of GDP growth and export success. In contrast, the rapid growth in patenting over

[11]The trends in patenting can relate to domestic or PCT applications, and also the numbers of patents filed at the US PTO. The basic data can be found in WIPO Patent Reports (e.g. 2007). Reuters (2008), for example, predicted that China will overtake Japan in number of patents by 2012.

the last twenty years in the US has attracted much debate. Some commentators argue that the rapid growth does not simply reflect innovation, but also strategic behaviour by firms, which may in fact inhibit innovation. Jaffe and Lerner (2004) and Bessen and Meurer (2008) argue strongly that the US patent system is 'broken' and reforms are needed.[12] In the UK, there is concern that firms do not patent as much as firms in other countries (see, for example, DTI, 2003) – and low patenting is interpreted as an indicator of relatively poor innovation.

Figure 1 shows the overall trend in patenting by summing the UK, EPC and PCT patent publications to form a bar chart. Between 2000 and 2002, the chart shows an increase in the total number of patent publications, but there is a subsequent dip in 2003 to 2006. The higher numbers in 2007 break with this trend, although the 2007 total is still just below 2002. Hence, these firm-level based patent data suggest little change in corporate patenting activity in the UK.

Figure 1: Number of patent publications, by year and type



A further, and related, issue concerns the trend in patenting for smaller firms. One of the issues mentioned in critiques of the patent system is that it does not allow smaller firms to protect their inventions effectively. The argument is that larger firms may be

[12] For a concise review see Greenhalgh and Rogers (2009).

much better able to afford the high costs (including litigation costs), as well using the patent system strategically.[13]

The debate on these issues is on-going, but a key element missing in discussions is the actual trends of large firm versus small firm patenting. The OFLIP data allows an analysis of the differences across firm size. Figure 2 shows the total patenting activity by year and across three different firm sizes: micro, SME and large. These size categories are defined according to European Union definitions as discussed above. The figure shows that total patent publications for SMEs have shown an increase over the years 2000 to 2007, with most of this growth coming from EPC and PCT publications. In contrast, large firm patenting increases to 2002, then dipped, with the most recent year 2007 showing a recovery (again due to EPC and PCT publications). The trend for the micro firms, in contrast, is roughly static.

Figure 2: Number of patent publications, by year and firm size

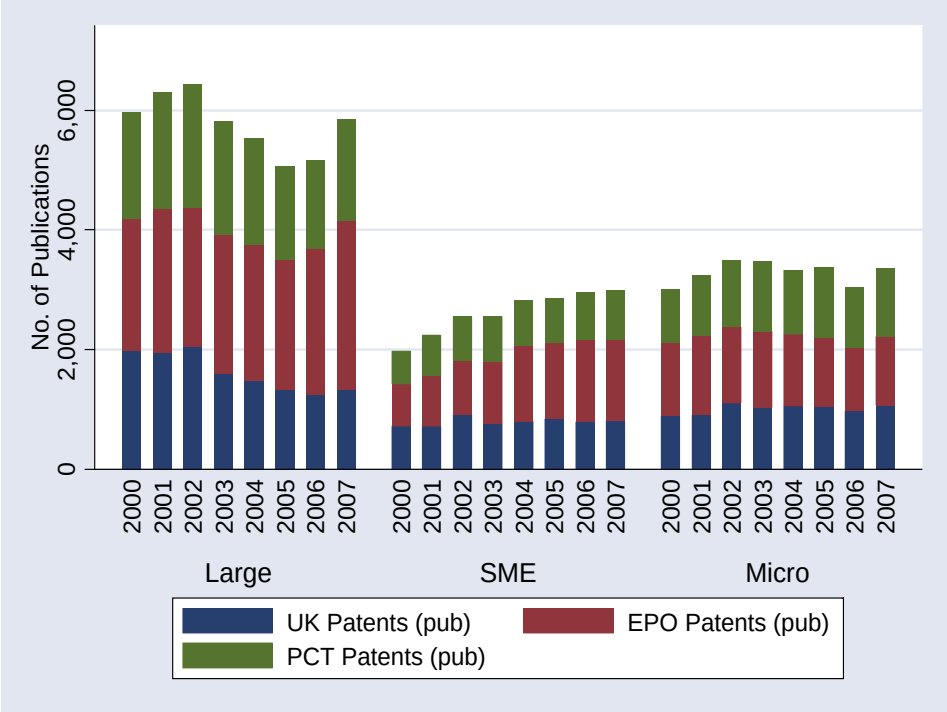


Table 2 breaks down the patenting by micro and SMEs into different sectors (although it reports only the total number of patents, whether through the UK, EPC or

[13]Weatherall, Webster and Bently (2009) review the available information on patent litigation costs and conclude that the UK is significantly more expensive than any other European country.

PCT routes). In 2000, the highest levels of patenting by far were in manufacturing – the sum of high-tech, medium-tech and other manufacturing is 1,374 in 2000.[14] By 2007, business services have 1,307 patent publications compared to the total of 1,445 in all manufacturing. If we compare the average patenting in 2000 and 2001, with the average for 2006 and 2007, the table shows a growth of 35.7%. Over the same period, patenting in R&D services grew most rapidly (86%), compared to a 19% growth in high-tech and 10% growth in medium-tech. In general, it is not clear from these figures whether the growth in patenting in R&D services reflects an outsourcing of R&D from manufacturing as opposed to other sectors. In fact, if R&D is being contracted out to specialist small firms it is not clear why patenting is increasing (as one might expect the funding firm to own any IP created).

Table 2: Micro and SME patenting activity, by sector

sector	2000	2001	2002	2003	2004	2005	2006	2007
Agric./ Mining	30	29	55	41	45	33	38	44
High-tech	286	280	378	320	365	390	354	321
Medium-tech	334	310	378	341	320	379	354	355
Other Manufacturing	754	820	745	715	775	809	801	769
EGW, Constr.	64	55	99	101	93	94	107	108
Whole, Retail, Hotel	415	461	462	517	583	671	699	672
Transport, Telecom	50	38	99	63	73	52	51	61
Finance, Real Estate	39	27	49	37	44	58	52	45
Computer	167	345	443	499	479	457	328	411
R&D Services	568	535	610	768	784	984	962	1,090
Business Services	760	933	995	1,080	1,111	1,077	1,091	1,307
Health, Educ., Cult.	227	246	255	261	278	252	272	259
Total	3,694	4,079	4,568	4,743	4,950	5,256	5,109	5,442

3.3 When do new firms patent?

The question of when do firms use patents during their life time is not one that has attracted much attention. For larger firms the assumption is that innovative firms use patenting continuously, although there is a literature on how persistently large firms innovate (see Geroski, Van Reenen and Walters, 1997). For smaller firms, and also for new firms, it is interesting to understand when patenting occurred. Early application implies an organised and strategic choice and that the patent is integral to the creation of the firm itself. It may even be that the patent is first filed (the priority date) before

[14] High- and medium-tech are defined using OECD guidelines. High-tech industries are: pharmaceuticals SIC 2423; aircraft & spacecraft SIC 353; medical, precision & optimal instruments SIC 33; radio, television & communication equipment SIC 32; and office, accounting & computing machinery SIC 30. Medium-tech industries are: electrical machinery & apparatus SIC 31; motor vehicles, trailers & semi-trailers SIC 34; railroad & transport equipment SICs 352&359; chemical & chemical products SIC 24 (excluding 2423); and machinery & equipment SIC 29.

the incorporation date of the company.[15] In such cases, any IP policies, such as free consultancy on IP, need to be targeted at scientists and entrepreneurs, rather than existing firms.

Figure 3: Age of firm when patent(s) published in 2007, by firm size

Figure 3 shows three histograms of patentees (any route); one each for the large, SME and micro firm size groups. These histograms refer to patents published in 2007 and the age of the firm in that year. Note that a few patents are published when the age of the firm is '-1' – i.e. in the year prior to when the firm was incorporated. Similarly, many patents are published when the age of the firm is '0-2', and since publication is at least 18 months from application, this also indicates very early application. For large firms it is clear that the age of firms that published patents in 2007 has a peak in the 6-10 year category but is distributed across the age range. SME's show more concentration in the 3-5, 6-10 and 11-15 age ranges and, as might be expected, fewer firms in the higher age ranges. This pattern is even more exaggerated for the micro firms.

The age distributions in the Figure are calculated only for the year 2007. The data

[15]The data extracted from PATSTAT for this research does not, currently, contain priority date. There is an application date, but this may not refer to the first filing date of a patent *related to* the patent publication (i.e. the priority date).

also allow us to calculate the age distribution for each year between 2000 and 2007. Do the data suggest that the age distribution of patentees have been changing? Overall, there is some evidence that the age of patentees has become younger. This is most pronounced for micro firms. If we calculate the percentage of firms in the 0 to 10 years of age category, the average for 2000 and 2001 for micro firms was 58.2%, and this increased to 76.3% in 2006 and 2007. For SMEs the comparable percentages are 45.9% and 50.0%. While for large firms the 2000 and 2001 average is 36.5% which grew to 42.3% (average of 2006 and 2007).

3.4 Technological diversity of patent portfolios

Each patent's technology is classified according to International Patent Classification (IPC) index. The IPC is split into sections (letters A to H), then classes, sub-classes and groups. For example, H refers to 'electricity', under this there are various classes (such as H01 'basic electric elements'). Underneath each class there are subclasses and groups (for example, H01S 'devices using stimulated emission', and then H01S 3/00 is 'lasers'). Each patent can have a number of IPCs and, of course, each firm can have more than one patent. This means that analysing IPC data can be a complex and lengthy task. This paper considers two summary measures. The first one is the main IPC section on the published patent. In the case where the firm has one patent per year, this is straightforward to calculate. When the firm has multiple patents in each year, the main IPC is the most commonly used. The second one is a measure of the diversity of the IPC's in a firm's patent portfolio.

Table 3 shows the percentages for each main IPC section for EPC patents applied for over 2000 to 2007 by firm size. The table indicates that the most common IPCs are G (Physics), A (Human Necessities), B (Performing Operations; Transporting) and C (Chemistry; Metallurgy). IPC D (Textiles; Paper) has very few patents (1.4% of total) and class E (Fixed Constructions) has 6%. There are some differences between firm sizes. Large firms are less active in sections A and G, but are more active in B and F. Similar patterns exist across UK and PCT patents. Figure 5 shows how the fractions shown in the total column in Table 3 (Column 4) have changed over time (i.e. for all firms). Figure 6 shows the same fractions but this time for only micro firms and SMEs. There is relatively little change occurring over the 2000 to 2007 period. The one exception is that IPC A (Human Necessities) has been increasing its share.

The second measure provides a summary measure of the diversity of a firm's patent portfolio. The results are presented in Table 4 and Appendix F discusses the method of calculating the diversity measure. The minimum value for the index is one which indicates that a firm has indicated only a single IPC section whereas the maximum is eight, in which case a firm patents in all IPC sections equally. Table 4 suggests that the largest share of firms (around 60%) across all size categories patents only within a single IPC section. Large firms appear to be technologically more diversified, as the share of firms with patents in only a single IPC section is 50%, whereas for micro firms and SMEs the share is close to 70%. However, given that IPC sections are relatively broad technological areas, this does not necessarily imply that these firms

Table 3: IPC main category, by firm size

	Large	SME	Micro	Total
	(1)	(2)	(3)	(4)
A Human Necessities	13.73	18.14	19.34	17.2
B Performing Operations; Transporting	16.59	16.85	14.22	15.67
C Chemistry; Metallurgy	14.78	13.73	13.12	13.82
D Textiles; Paper	2.00	1.17	1.07	1.40
E Fixed Constructions	6.74	5.86	5.50	6.00
F Mechanical Engineering; Lighting; Heating	11.46	8.77	8.06	9.35
G Physics	17.48	19.8	24.61	21.04
H Electricity	17.22	15.68	14.08	15.52
Total	100	100	100	100

are not technologically diversified. A more disaggregated analysis would be required to investigate further the degree of technological diversification of these firms.

Table 4: Diversity measure, EPC in 2007, by firm size

diversity d	Large	SME	Micro	Total
d = 1	578	434	562	1,574
$1 < d < 2$	385	153	181	719
$2 < d < 3$	161	40	47	248
$3 < d < 4$	40	4	9	53
$4 < d < 5$	2	3	3	8
$5 < d < 6$			1	1
Total	1,166	634	803	2,603

3.5 Foreign ownership

The FAME database has an indicator for whether the firm is ultimately controlled by a foreign firm. The UK has experienced substantial inward foreign direct investment, and also has high levels of R&D funded from overseas, hence there is an interest in isolating patenting from foreign controlled firms. Also, since there is no information on the size of the foreign owner, some of the micro firms and SMEs reported on above will include those owned by large foreign firms. As Table 5 shows the numbers of micro and SME patents by foreign owned firm is significant. Again, in this table the patents are the sum of UK, EPC and PCT publications. In 2001/2002 the share of foreign patents was 22%, rising to 25% in 2004, but falling to 16% in 2007. Hence over the entire period there is a declining share of foreign patent activity relative to domestic firms.

Table 5: Patenting and foreign ownership, micro and SME only

	2000	2001	2002	2003	2004	2005	2006	2007
Domestic	3,051	3,306	3,735	3,869	3,956	4,333	4,408	4,680
Foreign owned	643	773	833	874	994	923	701	762
Total	3,694	4,079	4,568	4,743	4,950	5,256	5,109	5,442

4 Performance and patenting in smaller firms

The traditional rationale for awarding patents is to provide protection so as to allow a firm to appropriate the returns from innovation. At the most basic level, greater appropriability should ensure survival, as it prevents imitators stealing the firm's market. More generally, greater appropriability should allow faster growth and subsequently higher profits. There is substantial evidence that larger firms gain from patenting (e.g. Hall, 1993), however, the evidence base for smaller firms is much more limited.

Previous analysis using the earlier version of OFLIP has revealed a number of results. Rogers et al. (2007) provided a preliminary analysis of patenting and performance for the cohort of 130,000 SMEs active in 2001. This preliminary analysis found two main findings of relevance here. First, SME patenting appeared to increase survival, although the relationship was not statistically significant. Second, the growth rates and profitability of patentees appeared to become 'polarised' (i.e. patentees were over represented in both the lowest performing and highest performing groups). One reason why this analysis was preliminary was that the data on performance only extended to 2004 (relatively soon after the patent was published in 2001). A longer time period would be necessary to assess whether the polarisation was temporary. Another reason was that the large heterogeneity across SMEs is likely to affect results.

Responding to the second reason, Helmers and Rogers (2008, 2009) have tested the effects of patenting on new firms. Helmers and Rogers (2008) takes the cohort of all 162,000 firms incorporated in 2001 and analyses their survival over the subsequent five years. The paper uses both patent dummy variables and counts (for UK or EPC publications), as well as trade mark dummy variables and counts, to test the association between IP activity and survival. The basic statistics show that IP active firms are much more likely to survive. By 2005, around 80% of IP active firms survive compared to 60% of non-IP active. Helmers and Rogers then proceed to use a Cox proportional hazard model to assess the robustness of these associations to other factors. Their analysis controls for industry characteristics (such as growth and capital intensity), ownership (including whether foreign owned), number of directors, proximity to university, as well as geographical effects (regional development agency dummies, unemployment and house prices). Even when controlling for all these factors, the positive association of patenting with survival comes through: having one or more UK or EPC patents is associated with a reduction of hazard rate by around 40%.

The strong, positive associations between patenting and survival found by Helmers and Rogers (2008) are consistent with the view that the patent system is providing some protection against imitation. However, it is clear that uncovering any *causal* relationship is much more difficult. Patenting firms may have better ideas than non-patenting firms and it may be 'quality' of the idea that is generating the association. In addition, some industries and sectors in the economy have much lower opportunities to patent. In order to investigate these issues Helmers and Rogers (2009) focus on new firms in the high and medium technology industries. They argue that all these new firms have the potential to apply for a patent, but some choose not to for reasons of secrecy, cost or they believe that the patent system is ineffective. The analysis covers all the 7,638 high- and medium-tech firms incorporated in 2000 and their patenting activity over the period 1999 to 2001.[16] They then analyse the association between this patenting and performance over the 2001 to 2005 period. This methodology is intended to test the link between patenting and performance more closely. The results show that, as expected, there is a strong positive effect of patenting and survival. Furthermore, patenting appears to raise subsequent growth rates (where growth is measured by growth in assets 2001 to 2005). The estimates suggest that patentees grow between 6% and 17% per annum faster than non-patentees.

The next section provides an overview of the growth rates of micro and SMEs in the updated OFLIP data for 2000 to 2007. This analysis adds to our knowledge of patenting and performance as shown in Rogers et al. (2007) for two reasons. First, the previous analysis was limited to performance to 2004 whereas now the data allow analysis to 2007. Second, the finding in Rogers et al. (2007) that performance could be polarised is explored in more detail.

4.1 High growth firms

In order to analyse high growth firms we take the cohort of firms aged ten or less in 2002 and calculate their annual average growth in assets between 2002 and 2007. Using a five-year period, rather than a three-year period, is deliberate. In some previous analysis of patentees it was found that performance in the three year period after patenting was relatively weak in comparison to a control group. One possibility is that a young, small firm that publishes a patent is in the process of a setting up a new business which may take longer than three years to show results. Hence, in the analysis below we assess growth over five years (2002 to 2007). The analysis looks at patenting over the period 2000, 2001 and 2002. Note that these years correspond to the year in which the patent was published, not granted. Growth in assets is used since this is the variable that has maximum coverage in the database (since small UK firms need only report total assets and total shareholder funds).

In order to calculate growth over the period 2002 to 2007 the firm must have total asset data in each year. This means that the analysis is conditioned on surviving firms.

[16] Helmers and Rogers also take account of the fact that some firms have patents published prior to incorporation in the personal names of their directors.

There are 266,928 micro and SME firms, aged between 0 and 10, which survived over the period 2002 to 2007 and have total asset data in both years.[17] Of these, 1,158 had a patent published in the 2000 to 2002 period or 0.4%. This percentage does vary by sector and industry, for example in the high-tech industries the percentage is 5.5%. There is a concern that foreign owned micro firms or SMEs are governed by different growth dynamics, hence in the analysis below we exclude the 13,638 foreign owned firms. This leaves 253,290 domestic owned firms in our 'growth' sample. Table 6 shows the numbers of patentees by sector for the micro firms and SMEs represented in this growth sample. Overall, there are 1,033 patentees in the sample. The table shows the numbers of firms that patent via the UK, EPC and PCT routes (since firms do patent through multiple routes the first three columns do not sum to the last column).

Table 6: Numbers of micro firms and SMEs patenting, in growth sample

	UK patentees	EPC patentees	PCT patentees	Total
Agric. / Mining	10	7	10	17
High-tech	38	30	30	62
Medium-tech	49	30	27	74
Other Manufacturing	116	80	71	186
EGW, Constr.	20	8	11	30
Whole, Retail, Hotel	40	35	28	72
Transport, Telecom	5	0	4	7
Finance, Real Estate	8	5	3	12
Computer	53	35	45	87
R&D Services	53	92	89	139
Business Services	142	121	155	280
Health, Educ., Cult.	39	27	37	67
Total	573	470	510	1,033

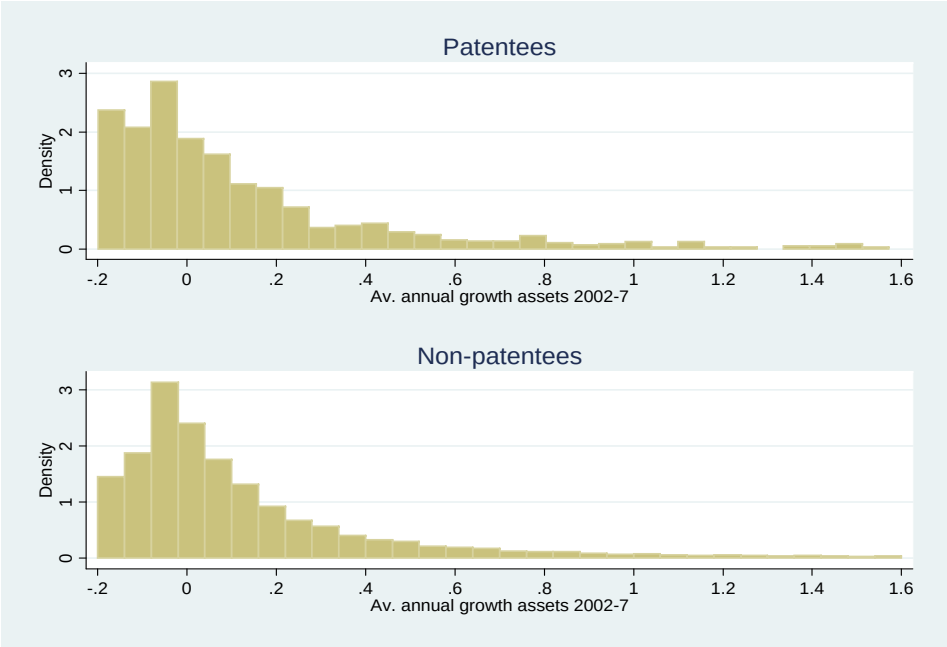
A first issue to understand is that the distribution of annual growth rates for smaller firms are highly skewed. The lowest growth rate in the cohort is -19.99 percent (i.e. assets approached zero in 2007), whereas the highest growth rate is over a billion percent. The 99th percentile of the growth distribution is 817% per annum. The massive differences in growth rates means that standard regression analysis may be misleading.[18] Figure 4 shows histograms of the growth distribution of patentees and non-patentees. The plots only show firms with average annual growth rates of below 160% (which is just below the 95th percentile of the distribution). A comparison between them indicates that more of the patentees' distribution is below zero, but it may also be that slightly more patentees have higher growth rates. Even this basic, unconditional evidence sug-

[17] The derivation of this 266,928 is as follows. There are 1,313,103 firms in the database in 2002 reporting total asset data; of these 887,292 are aged between 0 and 10. Removing large firms and those with missing SIC codes reduces this number to 675,452. Removing firms with total assets equal to zero leaves 571,939 firms; and of these 266,928 survived and report total asset data in 2007 (47%). This is not an accurate survival rate since many of the firms may have missing asset data due to late, or incomplete, filing of information.

[18] See Helmers (2009) for an application of quantile regressions in this context.

gests that any association between patenting and performance may be complex.

Figure 4: Distribution of annual growth rates (2002-2007)



To provide another overview of the differences in growth rates, firms are divided into three groups: those which experienced negative growth, those with growth between 0% and 20%, and those with growth above 20% per annum. The latter category is generally considered 'high growth' (see BERR, 2008). Table 7 shows a cross tabulation of these groups and patenting. The patentees are over-represented in the negative growth group, which reflects Figure 4, but are under represented in the middle group. Both patentees and non-patentees have around 28% of firms in the high growth group.[19]

As might be expected, the pattern of results shown in Table 7 does vary between sectors. In many sectors the pattern is over-representation in the high growth group but also in the low growth group. Although this polarisation result is common in most cases the results are not statistically significant (using a Chi-squared test and 0.1 P-value). The two exceptions are 'agriculture and mining' (with only 17 patentees) and 'high-tech'. The results for high-tech are shown in Table 8. This shows that patentees perform better that non-patentees with 40% of the 62 patentees being in the high growth group. Since patents might be expected to be of most help in these high-tech industries,

[19] A Chi-squared test on whether the differences in the table are significant has a P-value of 0.004.

Table 7: Micro and SMEs asset growth 2002-2007, domestic owned, by groups

Average annual growth	Patentees	Non-patentees	Total
Negative growth	468	106,017	106,485
	45.3	42.03	42.04
0 <Growth <20	261	75,589	75,850
	25.27	29.97	29.95
> 20 Growth	304	70,651	70,955
	29.43	28.01	28.01
Total	1,033	252,257	253,290

this might be expected. However, in the medium-tech sector patentees do worse than non-patentees (only 22% are in high growth group compared to 25%). Similarly, 'other manufacturing' patentees perform slightly worse. Nevertheless, it is important to stress that these results point out only associations in the data and certainly do not imply any causal relationships.

Table 8: High-tech micro and SMEs asset growth 2002-2007, domestic owned, by groups

Average annual growth	Patentees	Non-patentees	Total
Negative Growth	22	537	559
	35.48	43.59	43.2
0 <Growth <20	15	374	389
	24.19	30.36	30.06
> 20 Growth	25	321	346
	40.32	26.06	26.74
Total	62	1,232	1,294
	100	100	100

5 Cohort analysis

A drawback of the previous analysis is that it focusses on a firm as the unit of analysis. This might appear to be entirely justified, but when studying innovation or patenting in the context of young and entrepreneurial firms, this may not be the case. Consider the dynamics of an entrepreneurial economy. Many new ideas are generated by entrepreneurs and scientists, some of these are the basis for starting firms and a (small) proportion of these firms survive until age ten. Of those that survive, some experience mediocre growth while some experience good growth. The impact on employment and GDP depends, of course, on the rate of growth. A very small number experience such rapid and sustained growth that they become very large companies; and these have a massive impact on employment and GDP. Sometimes such firms are referred to as 'gorillas'. Economists and policymakers are particularly keen to make sure that these 'gorillas' survive and prosper.

In the current context, we are interested in whether the patent system helps the creation of such firms. Let us take an example to illustrate the issue. Suppose the patent system plays a positive role in the creation of 100 innovative firms (who subsequently publish a patent). If 50 of these firms fail within five years, and if this is the same rate as non-patentees, we might (wrongly) assume the patent system has little effect.[20] However, it may be that patenting firms are attempting to dramatically change the technology frontier (i.e. undertake radical innovation) and, in such cases, many attempts fail. Of the surviving 50 firms suppose that 49 experience low growth: their (expected) radical innovation is, in fact, incremental or a failure. However, one of the patentees succeeds and ultimately becomes a very large company, creating thousands of jobs and adding significantly to GDP. What would economic analysis find in this situation? Survival analysis finds no strong results for patentees. Growth analysis would show one high growth firm, but 49 firms with low growth. Standard regression analysis in this context is problematic since it normally starts by giving every firm equal weight in the analysis. In fact, some regression models omit or give less importance to extreme values (i.e. the high growth firm). Is this '1 in a 100' scenario likely? In short we do not know, but there is an existing literature on the highly skewed value for patents (e.g. Schankerman and Pakes, 1986), which suggests there is some relevance.

One possibility to start an investigation into these issues is to use cohort analysis. In essence we are interested in the performance of the cohort of patentees vs. non-patentees. These cohorts are defined by sector and age, so as to improve comparability.[21] As above, the patentee cohort is made up of any domestic SME or micro firm that published a patent in the 2000 to 2002 period. For each cohort we also calculate the growth in total assets over the period 2002 to 2007. Using total assets of the entire cohort means that even if a single firm grows very large this is reflected in the cohort growth rate. Table 9 shows the cohort growth rates, for patentees and non-patentees, broken down by age group and sector. In only a few cases does the patentee cohort out perform the non-patentee cohort. Out of the 36 sector-age groups, in only 11 cases does the patentee cohort outperform the the non-patentee cohort. In the high-tech sector it is only the patentees aged between 3 and 5 that out perform non-patentees (14.1% per annum compared to 5.6%). For the medium-tech sector the two older age groups of patentees out perform non-patentees, but for 'other manufacturing' none of the patentee cohorts performs better than non-patentees. The only sector where patentees do better across all age bands is 'health, education, etc'.

These results suggest that, on average, the cohort of patentees do not generate significantly higher asset growth than non-patentees. The most basic conclusion from this is that patenting is not a simple way to generate high growth firms. However, it is clear that a variety of other issues and explanations may be at work. At an analytical level it would be interesting to refine the comparison cohort for the patentees, perhaps using a matching estimator to control for other characteristics of the firms. Equally, it

[20] Although our previous analysis suggests that patenting does help *new* firms to survive, there is more mixed evidence for older firms

[21] There could, of course, be further analysis to refine comparability of the cohorts, such as matching estimators; something we leave as a possibility for future work

would be interesting to look at group in turnover. Should the results remain robust to these changes, there are a number of possible explanations for such findings, such as:

- Patenting does not act as an indicator of the highest growth potential firms. Secrecy and first-mover strategies, which are often highlighted in survey findings, are more important.
- The patent system is failing to provide adequate protection against imitation, perhaps because smaller firms cannot afford to enforce their property rights.
- Related to the previous point, the high growth potential firms may be taken over by larger firms, hence they do not show up in our data.
- The patent system is also supposed to act as a signal to financiers, hence allowing high growth potential firms to obtain finance. This 'signalling' role may not be working effectively.
- The use of patent publications, rather than grants, may hide a more significant relationship.

These issues, of course, also relate to the analysis in the previous section and any analysis of the performance of innovative firms.

6 Conclusion

This paper has provided an overview of the data in the latest version of the OFLIP database. In particular, the paper has focused on patenting as an indicator of innovative and entrepreneurial firms. Focusing on micro firms and SMEs the data show that patenting activity has increased over the 2000 to 2007 period, although this has primarily been driven by SME activity. Despite this growth, patenting is very rare: only around 0.4% of young micro firms and SMEs patent (although this share is much higher in some sectors, e.g. 5% in high-tech sector). The analysis also finds that patenting firms are increasingly using the EPC and PCT systems (although patenting through the domestic UK IP office is not falling for micro firms and SMEs in absolute terms).

The last sections of this paper are an analysis and discussion of the relationship between patenting and performance. Previous research has established that patenting, and also trade marking, has a strong association with survival in newly incorporated firms (i.e. start-ups). In addition, when focusing solely on start-ups in high-tech industries there is evidence that both survival and growth (in total assets) are improved. However, there is little evidence for young firms in general (i.e. not just start-ups). The previous section also outlined a number of implications and suggestions for further analysis. If the '1 in 100' story is indeed empirically relevant, a single high-growth firm may compensate for many unsuccessful firms. However, this may imply that on average, there will be little correlation between patenting and firm growth. Hence, the standard conditional mean estimators employed ubiquitously in the literature, will find little correlation between patenting and firm growth. Yet, it is important not

to confound the lack of statistical significance for correlation between patenting and growth with economic significance since a single patentee succeeding may have a huge impact on the overall economy despite the failure of a large number of other patentees. Another issue deserving more analysis is the way in which patents serve micro firms and SMEs. Our findings suggest some positive correlation between patenting and firm performance, but this leaves unclear the possible channels through which patents assist firms in succeeding relative to non-patenting firms. Future analysis should aim to investigate these channels and move beyond broad associations in the data.

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Figure 5: Fraction of IPCs, by year

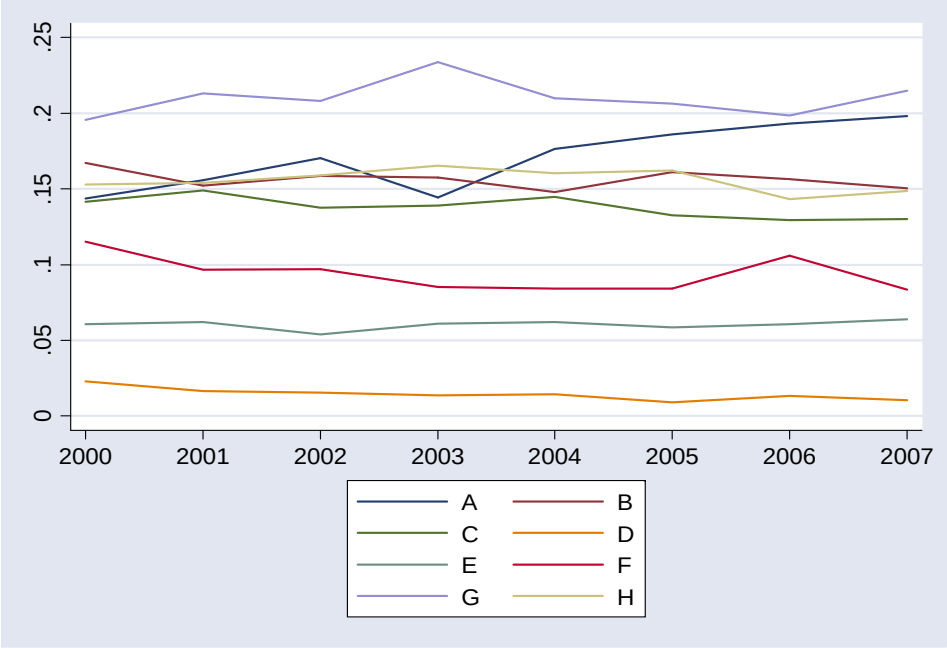
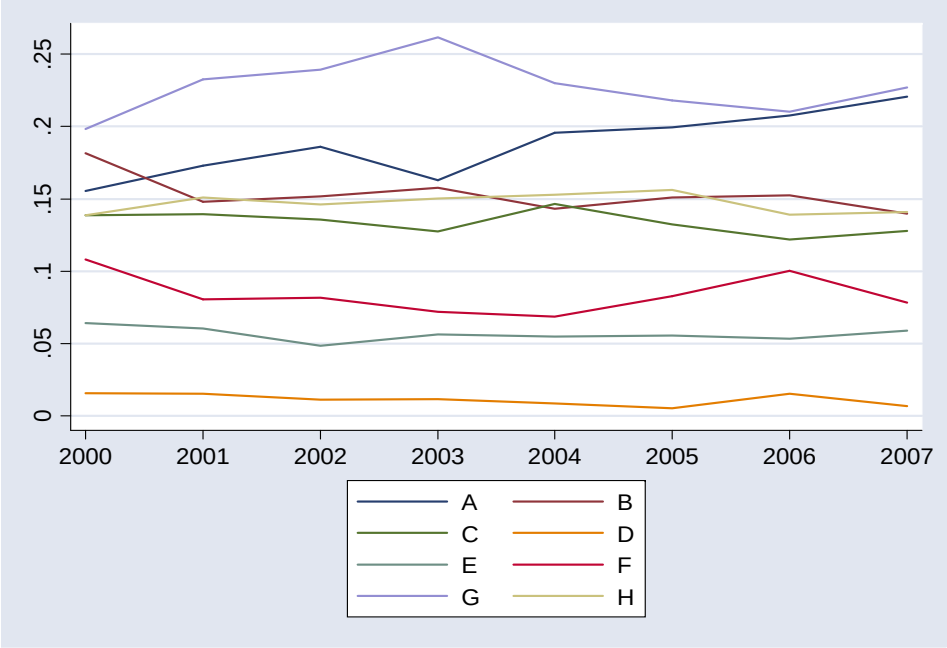


Figure 6: Fraction of IPCs, SMEs and micro firms only, by year



A Data Appendix

B FAME

Firm-level financial data as well as information on other firm characteristics, such as location and age, are obtained from the Financial Analysis Made Easy (FAME) database. We use two versions of FAME. In the October 2005 edition of FAME, there are around 2.19 million 'active' firms, or companies, in the database (the words 'firm', 'company' and 'enterprise' are used as synonyms henceforth). In the March 2009 version, there are 2.79 million 'active' firms. All of these firms have basic information, such as name, registered address, directors and registered number. For firms that have filed a set of annual accounts there is also some financial data available. The extent of this financial data varies substantially across firms, as the smallest firms legally need only report very basic balance sheet data (namely shareholders' funds and total assets). The largest firms provide a wide range of Profit and Loss information as well as detailed balance sheet data. The FAME data also lists 'inactive' limited companies (there are around 0.9 million in the October 2005 version and 1 million in the March 2009 version). 'Inactive' refers to firms that have been dissolved, liquidated, entered receivership or declared non-trading.

C Patent Data

The patent data used in the research comes from the European Patent Office (EPO) Worldwide Patent Statistical Database (PATSTAT) version September 2008. We extract three types of patents, UK, EPC and PCT patents from PATSTAT. PATSTAT combines patent information from several sources: DocDB (the EPO master bibliographic database containing abstracts and citations), PRS (the patent register for legal data), EPASYS (the database for EP patent grant procedure data), and the EPO patent register as well as the USPTO patent database for names and addresses of applicants and inventors. The main advantage of PATSTAT over other data sources such as the EPO ESPACE Bulletin is its broader coverage. Importantly, it also includes information on PCT patent applications while for example the ESPACE Bulletin does not.

D Matching FAME and PATSTAT

The basic method of matching was to use the company name from FAME and the applicant name from patent data. Both a firm's current and previous name(s) were used for matching accounting for changes of the name of firms. Since patent records do not include the registered number of the company it was not possible to match on this; instead the data was matched on applicant names in the patent documents and firm names in FAME. Matching on the basis of company name requires names to be 'standardized' in both data sets prior to analysis (e.g. the removal of capitals and standardized of Limited to Ltd, etc).

To gauge the outcome of the matching procedure requires comparison of the data to external sources. This is difficult since there have been no comparable matches of patents to UK firms. Nevertheless, some insight can be gained from looking at official data on all patenting activity. Table 10 summarizes the matches and also some official sources for the year 2003. The official sources count all patents from UK residents, whether corporate or personal, hence one would expect them to be greater. The official figure for EPC patents is particularly problematic as it also contains inventors which biases the number upwards. Unfortunately no more accurate figure on patent publications could be obtained from the EPO. Equally, the FAME database only contains registered firms and there are a large number of unregistered businesses in Britain.

As can be seen from the table, the number of patent publications matched is around 62 percent for UK patents and 70 percent for EPC patents. However, due to the inflated official number for EPC patents, the relevant matching success for EPC patents is certainly higher than 60 percent. Imperfect matches should be expected also as patents may be held under the names of the company directors which is particularly relevant for smaller firms (perhaps because directors filed for a patent before registering the company). Matching firms' names as provided by FAME with applicant names in PATSTAT is complicated also because names appear to have undergone some minor transformations (possibly 'standardizations') in PATSTAT. There are, for example, terms that appear in FAME within brackets, e.g. '(uk)', which are missing in PATSTAT while all remaining parts of the names are identical in FAME and PATSTAT. If there are other such systematic differences in names between the two data bases, it is not surprising that the match for UK patents is lower than the match.

E Defining firm size categories

The European Union defines SMEs using three criteria: employment, turnover and assets. Since total assets are the most common financial variable in the FAME database, we define an initial firm size groups using this variable. According to the EU, an SME must have total assets greater than Euro 2 million and less than or equal to Euro 43 million. A firm with assets below Euro 2 million is classified as a micro firm, above Euro 43 million is classified as a large firm. Sterling is converted to Euros at the rate of 0.675, which is the average exchange rate over the 2000 to 2008 period. We then consider firms that have employment data (only around 3% of FAME firms report employment). Any firm that has employment greater than or equal to 250 is reclassified as a large firm.

Next we consider firms that are subsidiaries of other firms. The FAME data contains a variable for the 'ultimate holding company' of any subsidiary (this is based on last available accounts). If a micro or SME is wholly-owned by a 'large' firm, the firm is reclassified as a 'large' firm. Similarly, any micro firm wholly owned by an SME is reclassified as an SME. In situations where a firm is owned by two or more different sized holding firms, we reclassify it into the largest holding firm size group. Reclassifying firms according to the size of their holding company is only possible if we have the data on holding company size. For UK holding companies, FAME has this information. However, in the case of foreign owned firms there is no data on the size of the holding company. FAME provides only limited information on the nature of foreign

holding companies (for example in over 80% of cases there is no information on size of shareholding). This presents a problem since excluding foreign owned SMEs could remove many majority owned UK firms; however, in some cases - such as being owned by Ford or Toshiba - it is important to know. Given this, in the analysis we do isolate foreign-owned SME firms at certain points.

Finally, we make an adjustment for the fact that the FAME March 2009 database does not have 2007 accounting data for a small number of firms (due to delays in filing financial accounts). This means, for example, that an SME in 2006 could have missing asset and employment data in 2007, hence would be classified as a micro firm. In general, when a firm has missing asset data it is classified as a micro firm. To avoid this we classify such firms as the same category as the previous year (e.g. if the firm was an SME in 2006, and has missing accounting data in 2007, it is classified as an SME in 2007).

F Technological diversity metrics

Drawing on the work of Jaffe (1986), we can define a vector representing the technological diversity of a patent portfolio held by a firm. Note that each patent has a number of different classifications, meaning that even a firm with one patent may have a technological diversity. Define

$$F_i = (f_{i1}, f_{i2}, ..., f_{iK}) \tag{1}$$

where F_i is the percentage of firm i's patents in patent classification k. The patent classification is at the section level (e.g. A). The technological diversity of the firm's patent portfolio is now defined as

$$DIV_i = (F_i' F_i)^{-1} \tag{2}$$

For example, if a firm has one patent in only one IPC class, its $DIV = 1$. If the firm's single patent had two IPC classifications then $DIV = 2$. As the number of IPC classifications increases as a result of either more patents or more IPCs per patent, the diversification measure increases. In our analysis we use IPC's A to H, hence a firm which has maximal diversity will have a share of 0.125 in each classification. This will mean that the maximal value of the diversity measure is eight.

Table 9: Micro and SMEs growth 2002-2007, by cohorts

	Patentees			Non-patentees		
	age 0 to 2	age 3 to 5	age 6 to 10	age 0 to 2	age 3 to 5	age 6 to 10
Agric. Mining	297.2	-8.4	21.9	6836.8	13.2	8.9
High tech	24.8	13.8	4.5	26.0	4.1	14.3
Medium tech	-0.3	14.1	6.3	7.4	5.6	3.0
Other Manufacturing	17.4	1.1	5.3	23.1	6.7	11.0
EGW, constr.	-10.8	-1.6	8.8	26.4	23.7	13.5
Whole,retail,hotel	8.0	4.6	5.9	16.3	11.3	8.6
Transport, telecom	19.5	-3.0	14.5	25.6	11.6	7.5
Finance, Real estate	29.4	33.9	9.8	23.7	16.2	13.3
Computer	-5.0	9.7	2.3	20.0	15.9	36.3
R&D services	52.1	4.6	1.9	98.3	48.6	6.4
Bus. services	14.9	85.5	14.8	29.3	15.9	51.5
Health,educ,cult,nie	51.3	106.2	18.8	27.7	12.1	9.9
Total	21.6	29.2	6.4	114.8	14.5	18.2

Table 10: Benchmarking the matching outcome

	Official Data	Matched Data	Percentage (%)
UKIP - UK patents	5,708	3,555	62.3
EPC - European patents	6,786	4,793	70.6

Notes:
The number for 'Official data' for British-based applications published are from UKIP Office Facts and Figures 2004/5.
The EPC figure is obtained from PATSTAT.