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Patents, Entrepreneurship and Performance

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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 a descriptive analysis on micro firms and SMEs that become high growth firms (defined as having greater than 20 percent growth per annum). Overall, 28.0 percent of young micro and SMEs achieve high growth (over 2002 to 2007). In comparison, 29.4 percent of young micro or SMEs that patent achieve high growth. This difference is much greater for firms in the high-tech industries. Moreover, the analysis shows that due to the skewed nature of the firm-level growth distribution, standard conditional mean estimators may fail to uncover important differences in the association between patenting and firm growth across the conditional growth distribution.

KEYWORDS: Firm growth, patents.

JEL Classification: L25, O12

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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 innovative firms still needs to be improved. In particular, while survey data do exist and have generated a series of insights, using population data in innovation studies is rare.[1] This paper reports on a new database of the patenting activity of the entire population of UK firms for the 2000 to 2007 period. The paper's primary objective is to provide a descriptive analysis of the new data, including trends, persistence and industry breakdowns. These provide a unique insight into the role of small, innovative firms in the UK. The paper's second objective to analyse the link between patenting and firm performance, again focusing specifically on smaller firms. This analysis finds interesting differences between micro firms and SMEs and, more generally, outlines some of the methodological problems in analysing population data.

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 registered and there were around 2 million existing firms. Second, there needs to be an indicator(s) of which firms are innovative and entrepreneurial.[2] 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, a large number of new firms 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 the patenting activity of firms. A new or young firm that makes a patent application considers that it has a new to the world innovation.[3]

[1] Perhaps the most well known survey related to innovation is the various waves of the Community Innovation Survey, which has generated a wide range of research. However, there are other surveys, such as the Australian Business Longitudinal Survey (see Bhattacharya and Bloch, 2004).

[2] 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 (2010) also discuss the distinction between entrepreneurship and innovation.

[3] 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. 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, as offered in this paper for the UK, is an important step in understanding the economy.

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 firms, small and medium-sized enterprises (SMEs) and large firms. Section 4 provides a descriptive 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).[4] In this paper we use 'firms' to mean registered firms. 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.[5]

The FAME database is a commercial database provided by Bureau van Dijk.[6] 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

[4] See also data appendix B.
[5] See also appendix C.
[6] http://www.bvdep.com/en/FAME.html

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, liquidated, entered receivership or declared non-trading.

In the analysis below firms are divided into size categories: micro, SME 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).[7]

For this updated version of OFLIP, the patent data come from the European Patent Office's (EPO) PATSTAT database.[8] Data on patent publications at the EPO, World Intellectual Property Organization (WIPO) and UK IP Office was downloaded from PATSTAT version October 2008.[9] 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.[10] 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 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

[7]See data appendix D for a full discussion.

[8]See Rogers, Helmers, and Greenhalgh (2007) for a description of the components of the previous version of OFLIP, which also contained trade mark data.

[9]See also data appendix E.

[10]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.

'published' after approximately 18 months, which means it is made public.[11]

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 application and 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 application and publication data? In our view, for the analysis of smaller firms, it does not: the use of patent applications and publications is 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.[12]

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 greater than SMEs or micro firms separately, but that the combined SME and micro patents roughly equals large firm patenting activity. This is an important new result. While there is literature on the increasing role of SMEs in general (e.g. Audretsch and Thurik, 2001), there is little evidence on absolute amounts of innovation performed by large versus small firms. The main proxy used for innovation —R&D expenditure data —suggests that larger firms are dominant (e.g. Sheffer and Frankel, 2005).[13] In contrast, the patenting

[11] 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 it is possible 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 (Henkel and Jell, 2009).

[12] 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).

[13] Actual estimates on the R&D split between small and large firms are rare (there appear to be none for the UK). An exception is Statistics Canada who estimate that 75 percent of R&D is done by firms

data in the second panel indicates that innovative activity is evenly split (as proxied by patenting). We do not know whether the SME and micro patents are, on average, more or less valuable than large firm patents. Tether (1998) reviews the literature on small versus large firm innovation rates, which tends to find that small firms produce more innovations per employee than large firms. However, Tether also provides some evidence that small firm innovations are less valuable. This issue is linked the idea of radical versus incremental innovation but, of course, it may take decades to reveal which (if any) of the patents Table 1 are most important. 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.

Table 1: Patenting activity

	UK	EPC	PCT
Size	Number of Patentees		
Large	4,151	4,153	3,292
	30.54%	32.46%	29.93%
SME	3,718	3,329	2,852
	27.35%	26.02%	25.93%
Micro	5,724	5,311	4,854
	42.11%	41.51%	44.14%
	Number of Patents		
Large	12,964	18,983	14,153
	47.26%	50.78%	49.65%
SME	6,370	8,748	5,786
	23.22%	23.40%	20.30%
Micro	8,100	9,652	8,567
	29.53%	25.82%	30.05%
	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 13,593 firms that had one or more UK patents published over 2000 to 2007, only 154 (1.1 percent) had 15 or more patents published in a year. In contrast, in 71 percent 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.

with greater than 100 employees http://www.ic.gc.ca/eic/site/sbrp-rppe.nsf/eng/rd02412.html

3.2 Persistence in patenting

Table 2 shows the transition matrix by patent type and firm size category. Regardless of the patent type (UK, EPC, PCT), large firms are more persistent in their choice whether to patent. For example, 90 percent of large firms that did not have a UK patent publication in year t did not have one in year $t+1$. At the same time slightly more than 70 percent of large firms that had an EPC patent publication in t also had one in $t+1$. In contrast, there appears to exist more movement in the micro firm category. Only half of all micro firms that had no EPC publication in t also had none in $t+1$. This comparison suggests that large firms are much more persistent in their patenting activity, while micro firms and SMEs are less able to patent year after year. Nevertheless, for micro and SMEs, the persistence rates are generally 50 percent or above, suggesting that while some firms may simply file for one patent, there is a core of persistent innovators. Notice also that the persistence of UK and EPC patenting (within firm size groups) is higher than PCT patents. This is consistent with the view that only the highest (expected) value patents are filed via the PCT route.

The above tables show 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 and assignments of patents.

3.3 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.[14] 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 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.[15] 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.

[14]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.

[15]For a concise review see Greenhalgh and Rogers (2010).

Table 2: Transition matrix: Patenting persistence

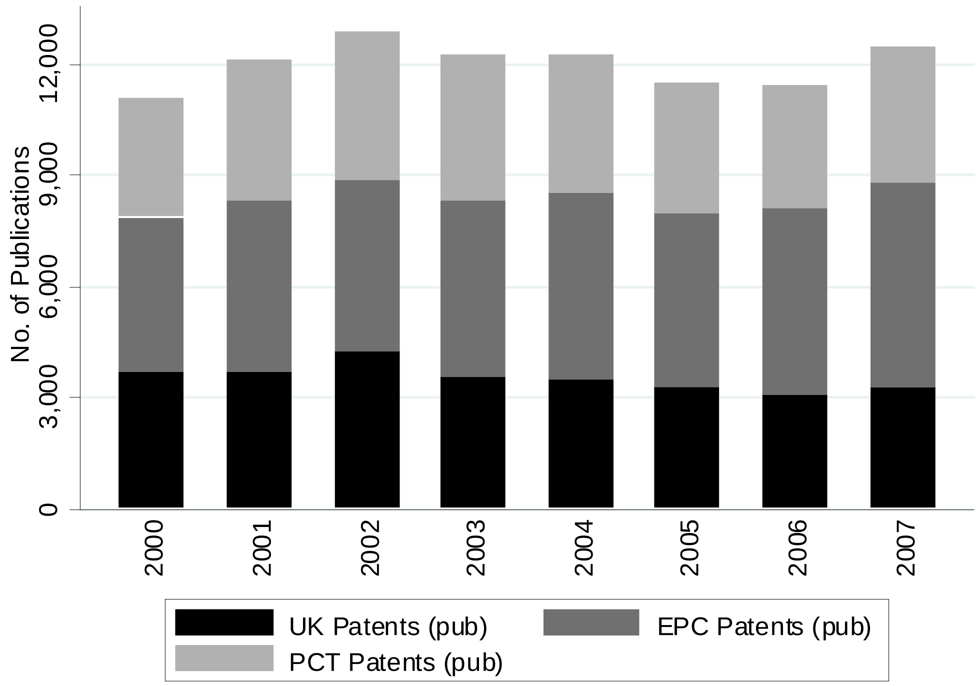
	Patent = 0	Patent = 1
UK Patents – Large Firms		
Patent = 0	90.38	9.62
Patent = 1	27.88	72.12
UK Patents – SMEs		
Patent = 0	81.50	18.50
Patent = 1	32.22	67.78
UK Patents – Micro Firms		
Patent = 0	78.21	21.79
Patent = 1	46.26	53.74
EPC Patents – Large Firms		
Patent = 0	86.75	13.25
Patent = 1	27.72	72.28
EPC Patents – SMEs		
Patent = 0	66.92	33.08
Patent = 1	38.08	61.92
EPC Patents – Micro Firms		
Patent = 0	49.20	50.80
Patent = 1	39.22	60.78
PCT Patents – Large Firms		
Patent = 0	90.57	9.43
Patent = 1	38.35	61.65
PCT Patents – SMEs		
Patent = 0	80.10	19.90
Patent = 1	50.99	49.01
PCT Patents – Micro Firms		
Patent = 0	71.56	28.44
Patent = 1	66.61	33.39

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.

One way of assessing whether the trend in patenting reflects the actual amount of innovation generated within an economy is to relate the total number of patents to business entreprise R&D data. Figure 2 plots both the total number of patents and R&D conducted by the private sector in the UK over the period 2000-2006.[16] We split

[16]The R&D data comes from the OECD ANBERD database (version April 2009) and only covers the

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

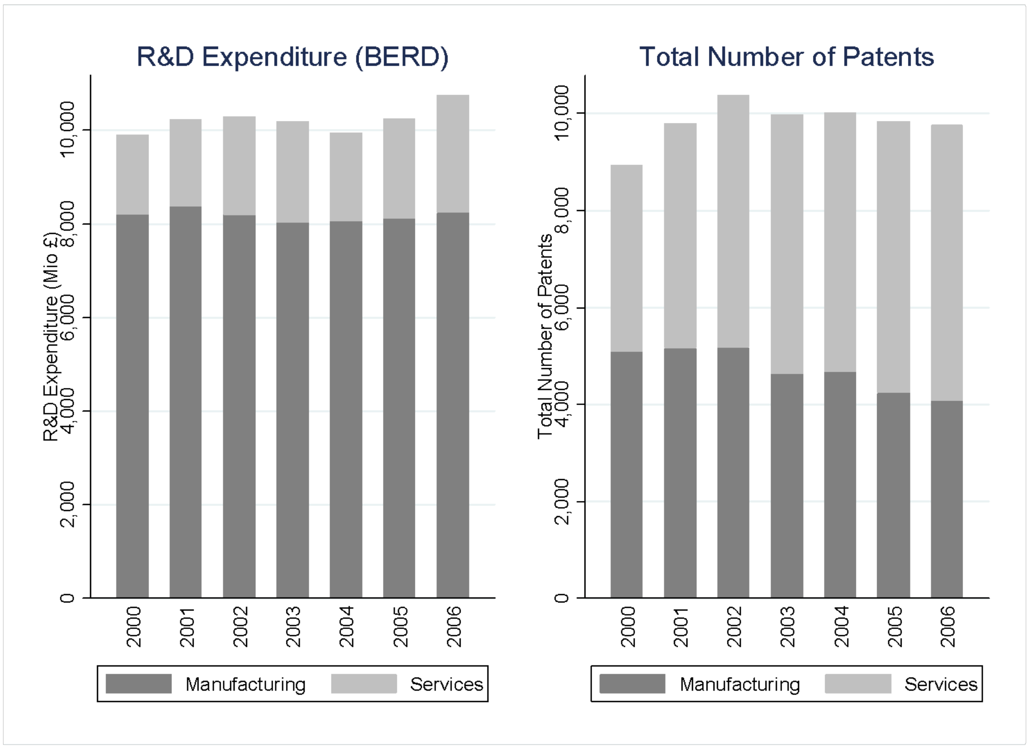


both R&D and patent data into manufacturing and services. Figure 2 shows that R&D is mainly conducted by the manufacturing sector whereas patents are roughly equally split between the manufacturing and services sectors where patenting in the services sector even overtakes patenting by the manufacturing sector from 2003 onwards.[17] The UK reports R&D data mainly by product field, i.e., for large firms R&D is allocated according to the 'actual industrial orientation of the R&D carried out by units in the business enterprise sector' (OECD 2002: 82) rather than the principal activity of the performing unit. R&D firms are redistributed independently of their size to the industry served. This implies that in situations in which service firms are specialised in conducting R&D for manufacturing firms, R&D expenses are allocated to the manufacturing sector, while patents may still be held by the R&D service firms that have conducted the R&D (see Section 3.4 below). While this could partly explain the pattern displayed in Figure 2, the relationship between patenting and R&D demands further research.

period up to 2006. The UK's Office of National Statistics data on R&D is very similar (ONS, 2007).

[17]Note that the total number of patents is somewhat lower than in Figure 1 because SIC codes are not available in FAME for a number of firms included in Figure 1. Moreover, firms in SIC 40-41 and 45 are excluded from Figure 2.

Figure 2: BERD vs. Number of patent publications, by year



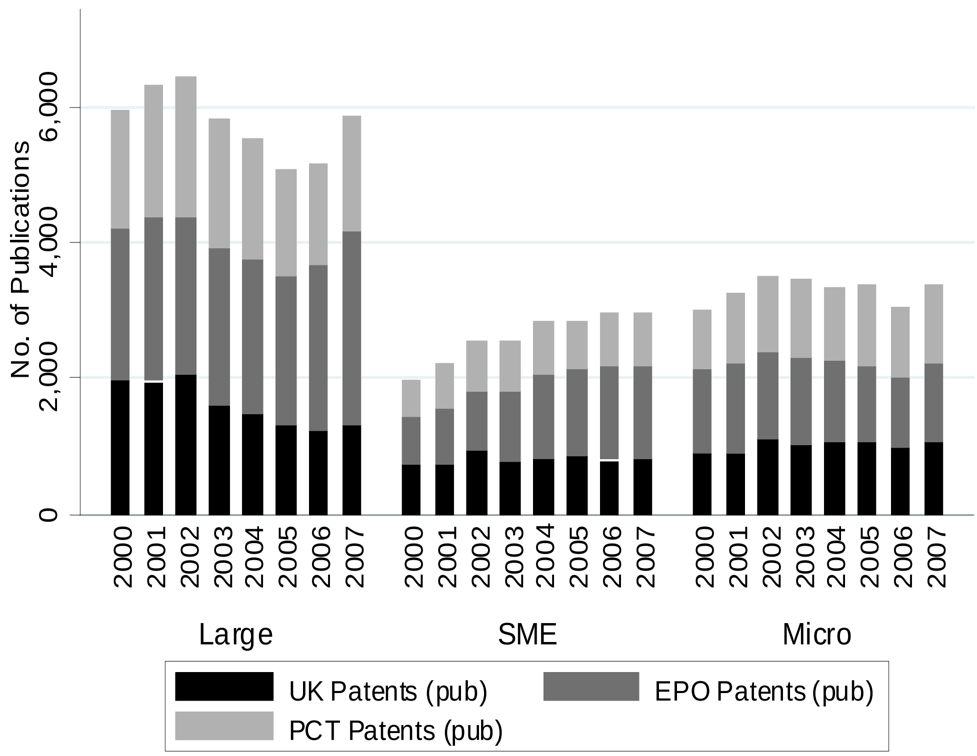
A further, and related, issue concerns the trend in patenting for smaller firms.[18] One of the issues mentioned in critiques of the patent system is that it does not allow smaller firms to protect their inventions effectively. The argument is that larger firms may be much better able to afford the high costs (including litigation costs), as well using the patent system strategically.[19]

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 3 shows the total patenting activity by year and again across the three different firm sizes: micro, SME and large. 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.

[18]Of course, at this point one would like to compare R&D trends for smaller firms, however, this data does not exist in the UK. The Office of National Statistics does not survey all small firms that are likely to conduct R&D. This is one reason why patent data is valuable.

[19]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.

Figure 3: Number of patent publications, by year and firm size



3.4 Industry breakdowns

Table 3 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 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.[20] 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 percent. Over the same period, patenting in R&D services grew most rapidly (86 percent), compared to a 19 percent growth in high-tech and 10 percent growth in medium-tech. 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. Lastly, the table shows that patenting

[20]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.

by micro and SME firms in ‘Computer’ (which is computer and related activities, both hardware and software) has steadily increased.

Table 3: 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
	1%	1%	1%	1%	1%	1%	1%	1%
High-tech	286	280	378	320	365	390	354	321
	8%	7%	8%	7%	7%	7%	7%	6%
Medium-tech	334	310	378	341	320	379	354	355
	9%	8%	8%	7%	6%	7%	7%	7%
Other Manufacturing	754	820	745	715	775	809	801	769
	20%	20%	16%	15%	16%	15%	16%	14%
EGW, Constr.	64	55	99	101	93	94	107	108
	2%	1%	2%	2%	2%	2%	2%	2%
Whole, Retail, Hotel	415	461	462	517	583	671	699	672
	11%	11%	10%	11%	12%	13%	14%	12%
Transport, Telecom	50	38	99	63	73	52	51	61
	1%	1%	2%	1%	1%	1%	1%	1%
Finance, Real Estate	39	27	49	37	44	58	52	45
	1%	1%	1%	1%	1%	1%	1%1%	
Computer	167	345	443	499	479	457	328	411
	5%	8%	10%	11%	10%	9%	6%	8%
R&D Services	568	535	610	768	784	984	962	1,090
	15%	13%	13%	16%	16%	19%	19%	20%
Business Services	760	933	995	1,080	1,111	1,077	1,091	1,307
	21%	23%	22%	23%	22%	20%	21%	24%
Health, Educ., Cult.	227	246	255	261	278	252	272	259
	6%	6%	6%	6%	6%	5%	5%	5%
Total	3,694	4,079	4,568	4,743	4,950	5,256	5,109	5,442

3.5 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 patent continuously (there is a literature on how persistently large firms innovate see Geroski, Van Reenen and Walters (1997), and Table 2 provides support for this). For smaller firms, and also for new firms, it is interesting to understand when patenting first 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 the incorporation date of the company.[21] In such

[21]The data extracted from PATSTAT for this research does not, currently, contain priority date.

cases, any IP policies, such as free consultancy on IP, need to be targeted at scientists and entrepreneurs, rather than existing firms.

Figure 4: Age of firm when patent(s) applied for in 2006, by firm size

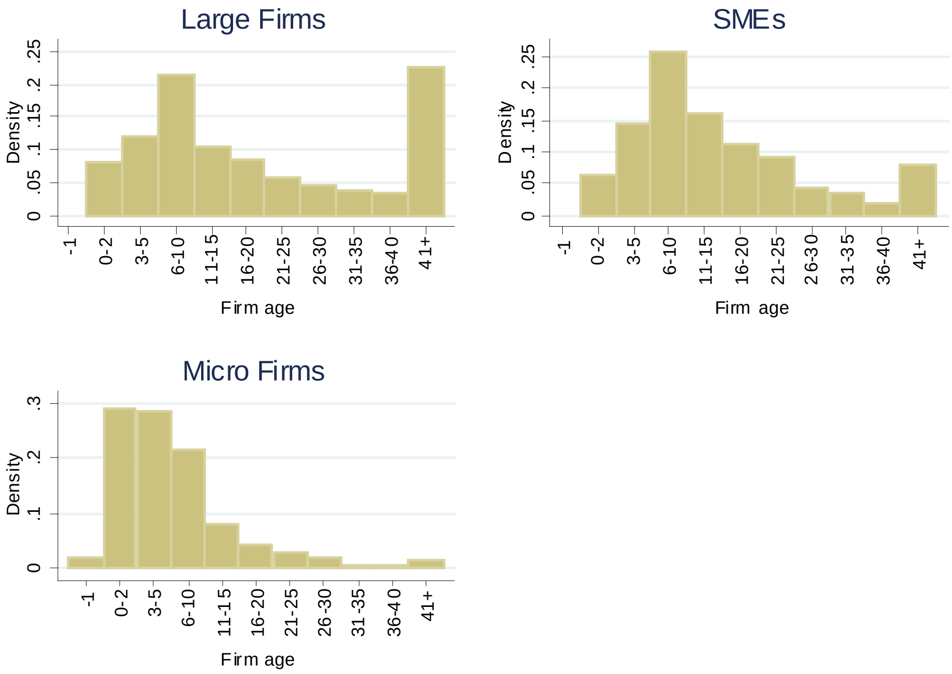
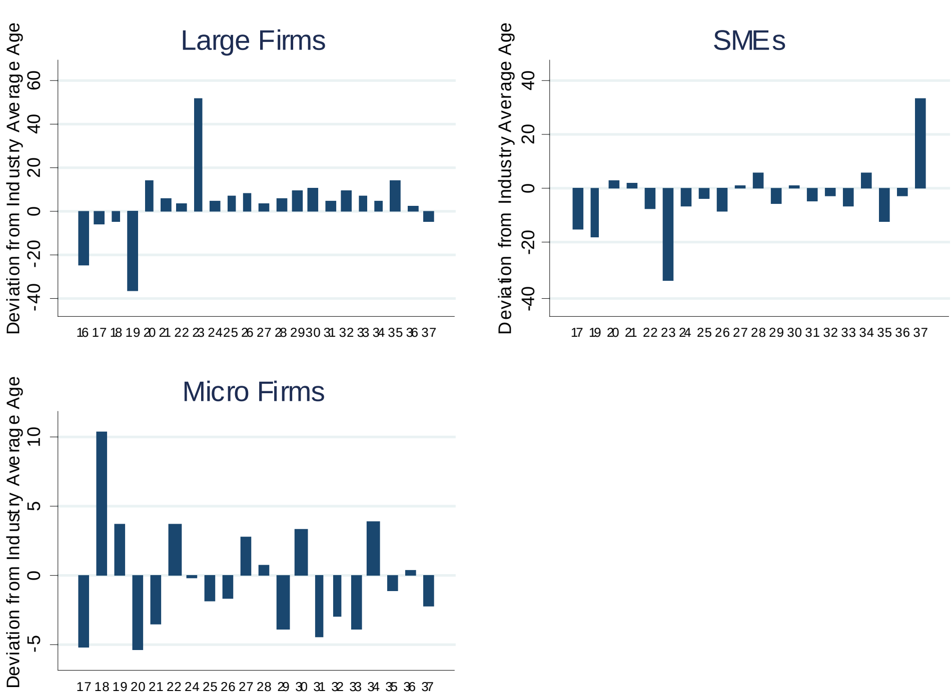


Figure 4 shows three histograms of patentee's age; one histogram for each for the large, SME and micro firm size groups. These histograms refer to patents *filed* in 2006 (via any route) and the age of the firm in that year. Note that a few patents are applied for when the age of the firm is '-1' – i.e. in the year prior to when the firm was incorporated. For large firms it is clear that the age of firms that applied for patents in 2006 has a peak in the +41 year category but is distributed across the age range. SMEs 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 with most firms applying for a patent when they are between 0 and 10 years old.

The age distributions in the Figure are calculated only for the year 2006. The data also allow us to calculate the age distribution for each year between 2000 and 2006. 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 for micro firms was 62.4 percent, and this increased to 79.5 percent in 2006. For SMEs the comparable percentages are 45.4 percent and 46.6 percent. While for large firms the 2000 average is 34.6 percent which grew to 41.4 percent (average of 2006).

Figure 5 plots the difference in average age between firms that applied in 2006 for a patent and those that did not by 2-digit SIC manufacturing industry.[22] Since the overwhelming share of firms in each SIC 2-digit industry do not patent, this difference can also be interpreted as the deviation in age of patenting firms from industry averages. Positive bars indicate that patenting firms are older than non-patenting firms, whereas negative bars indicate that patenting firms are younger than non-patenting firms. Figure 5 reveals striking differences across firm size categories. First, age differences for large firms are larger in absolute terms than for SMEs or micro firms (note differences in scale on y-axis). Second, in the large firm category, firms that patent are on average older. In contrast, in the SME category, except for the major exception of SIC 37 'Recycling', patenting firms tend to be younger than non-patenting firms. This pattern is more mixed for micro firms where age differences vary substantially across sectors. Figure 5 thus suggests that among large firms it is mostly the established ones patent, whereas among SMEs on average younger firms apply for patent protection.

Figure 5: Deviation of Average Age of Patenting and Non-patenting firms by 2-digit SIC manufacturing industry in 2006, by firm size



[22]We use all the data available in FAME to calculate differences depicted in Figure 5.

3.6 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 relatively high levels of R&D funded from overseas, hence there is an interest in isolating patenting by foreign controlled firms (around 24 percent of total UK R&D is funded from overseas sources, ONS (2007)). 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 4 shows the numbers of micro and SME patents by foreign owned firms is significant. Again, in this table the patents are the sum of UK, EPC and PCT publications. In 2000 the share of foreign patents was 17 percent, rising to 20 percent in 2004, but falling to 18 percent in 2006. In 2007, the share dropped to 14 percent. Hence, since 2004 the trend is a falling share of foreign activity in the total patenting of SME and micro firms.

Table 4: 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
	83%	81%	82%	82%	80%	82%	86%	86%
Foreign owned	643	773	833	874	994	923	701	762
	17%	19%	18%	18%	20%	18%	18%	14%
Total	3,694	4,079	4,568	4,743	4,950	5,256	5,109	5,442

4 Performance and patenting in smaller firms

4.1 Overview

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. The analysis above shows that there are substantial numbers of SMEs and micro firms using patents and there is considerable policy interest in understanding how such firms perform.

There are many studies that use the Community Innovation Survey and its questions based on innovation (e.g. Cefis and Marsili, 2006, Love et al, 2009). In contrast, studies on patenting and performance in smaller firms are rare. Cockburn and Wang (2007), for the US, find that patenting helps survival in a sample of 356 internet related start-ups. The only large sample study that we know of is Buddelmeyer et al. (2009). Using a sample of 260,000 Australian firms (of all sizes) that were alive at some stage over 1997-2003, they find recent patenting has a negative association with survival. This result is, of course, surprising. Patents might be expected to proxy for innovative effort. Also, the fundamental rationale for patents is to allow protection from competition. However, their paper also finds that the *stock* of patents has a positive influence on survival. They suggest that recent patenting (i.e. within last two years) is a proxy for radical innovation, which is inherently more risky and hence is associated with lower survival. The Buddelmeyer et al. paper raises important issues relating to innovation and patenting. First, do the results on (recent) patenting hold in other countries? Second, since their sample included all firms (of any age and size), what are the results when studies focus on newer, or smaller, firms?

For the UK, previous analysis using the earlier version of OFLIP has allowed a number of partial insights. 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 be positively correlated with 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 and impeded any causal interpretation of the relationship between survival, growth and patenting.

Responding to these concerns, Helmers and Rogers (2008, 2009) 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 percent of IP active firms survive compared to 60 percent 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 the hazard rate by around 40 percent.

The strong, positive associations between patenting and survival found by Helmers and Rogers (2008) are consistent with a) that patenting is a proxy for innovation and b) 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.[23] 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 percent and 17 percent per annum faster than non-patentees.

The analysis in this paper adds to our knowledge of patenting and performance for two main reasons. First, the previous OFLIP analysis was limited to tracking performance to 2004 or 2005, whereas now the data allow analysis to 2007. Adding these additional two years is important in assessing performance outcomes, especially since Rogers et al. (2007) suggested that performance could be polarised. Second, this paper focuses on younger firms (less than 10 years old), which is a cohort closely related to entrepreneurship and innovation policies. Looking at this cohort provides a broader assessment than solely looking at new firms. The next two subsection provide an overview of the relation between firm age and survival, as well as growth rates, in the updated OFLIP data for 2000 to 2007.

4.2 Survival: the role of age and firm size

Survival studies commonly control for a firm's age as an indicator of experience, with the results indicating, as expected, that the propensity to exit falls with age. At the same time, survival studies generally include firm size as an indicator of resources available to the firm, with the prior hypothesis that greater resources (e.g. financial resources) reduce propensity to exit (e.g. Cefis and Marsili, 2005). The interest here is understanding in a purely descriptive way how age and firm size are associated with survival for patentees. Figure 6 shows the association between a patenting firm's propensity to exit the market between 2000 and 2007 and its age across the three different firm size categories. Propensities are obtained from running separate univariate probit regressions for each firm size category with firm age as the only variable in the conditioning set for the sample of patenting firms.[24] The predicted values are plotted against the age distribution within each size group.[25] The pattern shown in Figure 6 reveals considerable differences across age groups in terms of the correlation between

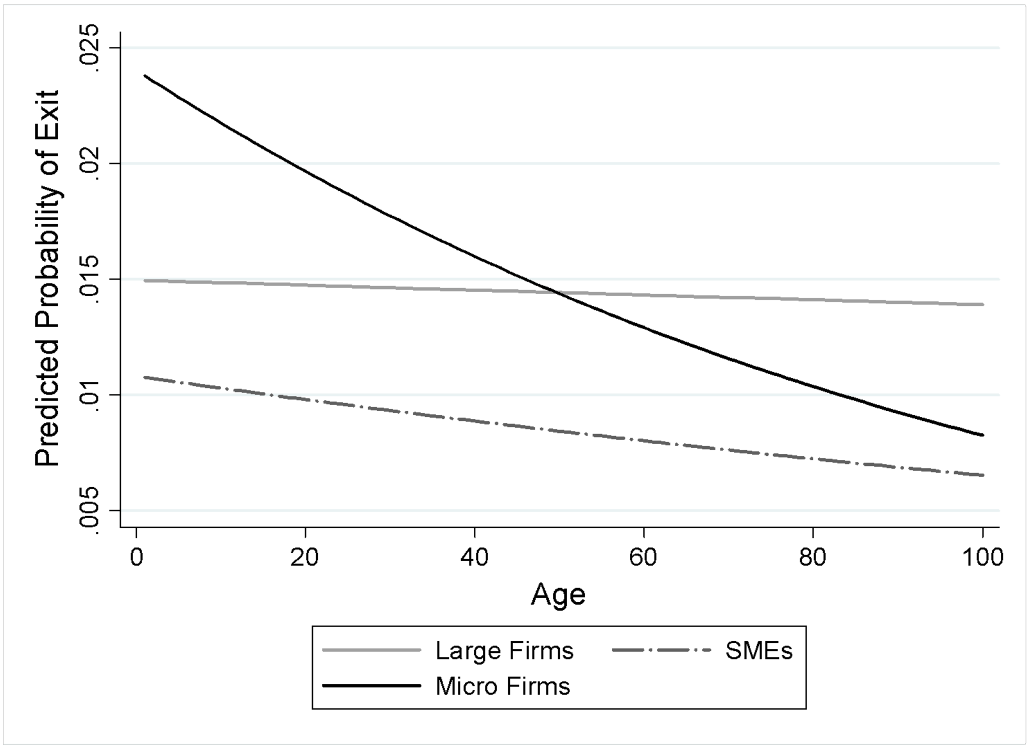
[23] Helmers and Rogers also take account of the fact that some firms have patents published prior to incorporation in the personal names of their directors.

[24] Note that any firm that has had at least one patent publication between 2000 and 2007 is included in the sample.

[25] Note that the graph truncates the age distribution at 100 years which excludes roughly 1 percent of firms in the sample from Figure 6. However, the probit regressions contain all firms and hence the entire age distribution.

a patenting firm's age and its probability of exit. Perhaps the most striking feature is that patenting SMEs have lower probability of exit (at all ages) than either large or micro firms. In contrast, the propensity to exit of a patenting micro starts off high, but then diminishes as the firm gets older. For large firms there is hardly any correlation between survival and age. These results suggest that patenting SMEs are 'well positioned' in the market, in the sense that the combination of their innovativeness, patent protection and relative size reduces their chances of exit, even when very young. The higher risk of failure in micro firms indicates that innovativeness and patent protection are not sufficient and that micro firms suffer from small size (resources). The policy implication is that supporting patenting micro firms may have substantial benefits (as it allows them to gain more experience and allows them the opportunity to grow larger and become an SME).

Figure 6: Predicted probability of exit conditional on age, by firm size



4.3 High growth firms

Although there is considerable policy interest in understanding high growth firms, to date there are relatively few data sets that allow large sample analysis. It also transpires that the techniques requires to analysis growth rates of micro and SMEs are different from standard techniques. This section explores these issues and provides some analysis for the cohort of all young firms in the UK economy.

To understand the core issues at stake it is useful to sketch out the processes at work. 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'. 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. 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? 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.

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. 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).

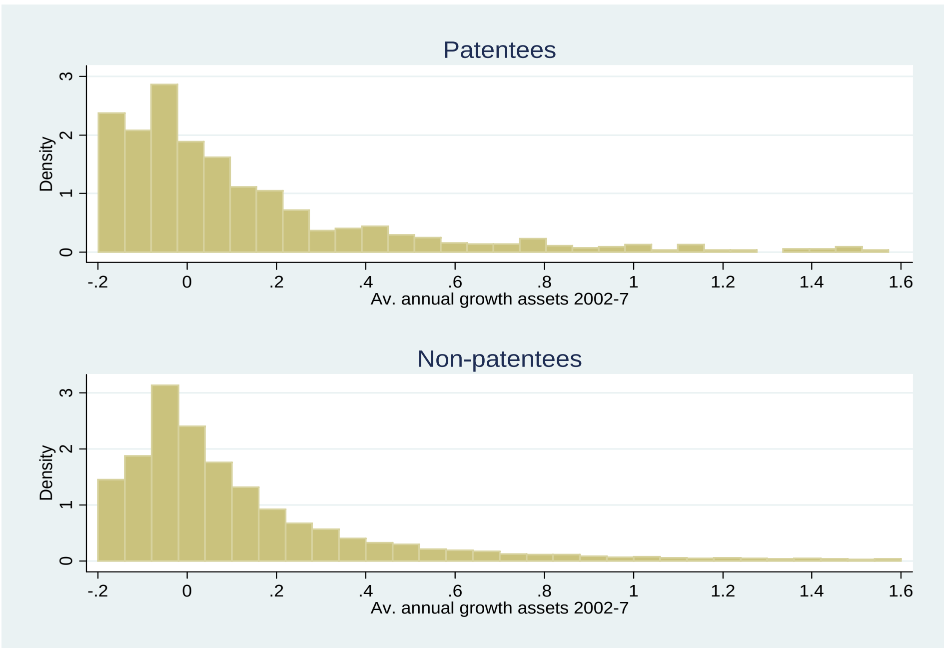
In order to calculate growth over the period 2002 to 2007 the firm must have total asset data in each year. This means that the analysis is conditioned on surviving firms. There are 266,928 micro and SME firms, aged between 0 and 10, which survived over the period 2002 to 2007 and have total asset data in both years.[26] Of these, 1,158 had a patent published in the 2000 to 2002 period or 0.4 percent. This percentage does vary by sector and industry, for example in the high-tech industries the percentage is 5.5

[26]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 percent). This is only an approximate survival rate since some of the firms may have missing asset data due to late, or incomplete, filing of information.

percent. 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.

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 percent per annum. The massive differences in growth rates means that standard regression analysis based on the conditional mean function may be misleading, which we discuss in more detail below. Figure 7 shows histograms of the growth distribution of patentees and non-patentees. The plots only show firms with average annual growth rates of below 160 percent (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 suggests that any association between patenting and performance may be complex.

Figure 7: 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 percent and 20 percent, and those with growth above 20 percent per annum. The latter category is generally considered 'high growth' (see BERR, 2008). Table 5 shows a cross tabulation of these groups and patenting. The patentees are over-represented in the negative growth group, which reflects Figure 7, but are under represented in the middle group. Patentees have 29.4 percent of their cohort in the high growth group compared to 28.0 percent of non-patenting firms in the high growth group.[27]

Table 5: 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

As might be expected, the exact pattern of results shown in Table 5 varies between (two-digit SIC) industries. However, in many industries the pattern is over-representation in the high growth group and also in the low growth group. Although this polarisation result is common in most industries, the results are often not statistically significant (using a χ^2 test and 0.1 P-value). The two exceptions are 'agriculture and mining' (with only 17 patentees) and 'high-tech', which is a set of industries of key interest. The results for high-tech are shown in Table 6. This shows that patentees perform better that non-patentees with 40 percent 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, this might be expected. However, this result is not always found. In results not shown in the paper, we find patentees do worse than non-patentees in the medium-tech sector (only 22 percent are in high growth group compared to 25 percent of non-patentees). Similarly, 'other manufacturing' patentees perform slightly worse. Nevertheless, it is important to stress that these results point out only associations in the data and does not prove any causal relationship.

4.4 Quantile regressions

The above results suggest caution in relying on traditional types of regression analysis. Given the skewed distribution shown in Figure 7 and the evidence reported in Tables 5 and 6, we explore the association between patenting and firm-level growth rates at different points of the conditional growth distribution using quantile regressions (Koenker and Bassett, 1978).[28] We use a simple linear Gibrat-Law type specification (Hart and Oulton, 1996, 1999, Helmers et al., forthcoming) with only a firm's initial size mea-

[27] A χ^2 test on whether the differences in the table are significant has a P-value of 0.004.

[28] See also Coad and Rao (2008) and Kaiser (2009) for applications of quantile regressions in a similar context.

Table 6: 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

sured as total assets in 2002 and its age in the conditioning set, as well as a patenting dummy.[29] The dependent variable is the annual average growth rate in a firm's total assets between 2002 and 2007.[30] Separate regressions are run for each firm size category.

Table 7 provides results for estimating this relationship using OLS and quantile regressions looking at the median, the 10th and 90th percentile of the conditional growth distribution. The results show that patenting is not statistically significantly associated with faster growth for the large firm and SME category. The only exception to this is a positive and statistically significant association at the median of the conditional growth distribution for the large firm category. This suggests that patentees are not characterised by significantly higher asset growth than non-patentees over the entire conditional growth distribution. A variety of issues and explanations may be at work including secrecy and first-mover strategies, which are often highlighted in survey findings, being more important than patents to capitalise on innovations.

In contrast, the results for the micro firm category provide evidence for how looking only at the conditional mean fail to recognise a more interesting underlying pattern. While the coefficient obtained from using OLS is positive and statistically significant (0.023), there is no statistically significant correlation when looking at the median of the conditional growth distribution. At the same time, the correlation is statistically significant and negative for the bottom 10th percentile while it is positive (and larger in magnitude than for OLS) at the top 90th percentile. This implies that patenting is associated with lower average annual growth rates at the bottom of the conditional growth distribution while it is correlated with faster growth at the top of the conditional growth distribution. Limiting the analysis to the conditional mean omits this potentially important variation in the relationship between patenting and growth.

This section's analysis has included all young firms and looked at the association of patenting with growth rates. The basic result is that patenting does not have a simple, linear association with growth (a result that resonates with the analysis in the

[29]As in Section 4.3, the patent dummy is equal to one if a firm has had at least one UK, EPC or PCT publication during the period 2000-2002.

[30]To avoid extreme values of the growth distribution to drive results, we eliminated the bottom and top 5 percentile of the growth distribution.

Table 7: OLS and Quantile Regressions

	OLS	P50	P10	P90
		Large Firms		
Patent	0.006	0.009*	0.003	0.009
	(0.014)	(0.005)	(0.008)	(0.047)
ln Assets (2002)	-0.004**	0.001**	-0.001*	-0.022**
	(0.001)	(0.0002)	(0.0003)	(0.002)
Firm Age	-0.006**	-0.001**	-0.00001	-0.013**
	(0.001)	(0.0002)	(0.0003)	(0.002)
Industry Dummies	Yes	Yes	Yes	Yes
No. Observations	13,257	13,257	13,257	13,257
		SMEs		
Patent	0.011	0.005	-0.007	0.027
	(0.013)	(0.009)	(0.009)	(0.042)
ln Assets (2002)	-0.010**	0.003**	-0.001	-0.044**
	(0.001)	(0.001)	(0.0007)	(0.004)
Firm Age	-0.005**	0.00002	0.001**	-0.018**
	(0.001)	(0.0003)	(0.0004)	(0.002)
Industry Dummies	Yes	Yes	Yes	Yes
No. Observations	21,813	21,813	21,813	21,813
		Micro Firms		
Patent	0.023^{+}	-0.001	-0.021**	0.152**
	(0.013)	(0.009)	(0.006)	(0.035)
ln Assets (2002)	-0.020**	-0.005**	0.002**	-0.067**
	(0.0004)	(0.0002)	(0.0002)	(0.001)
Firm Age	-0.011**	-0.006**	-0.0006**	-0.028**
	(0.0002)	(0.0003)	(0.0001)	(0.001)
Industry Dummies	Yes	Yes	Yes	Yes
No. Observations	219,757	219,757	219,757	219,757

Notes:

1. ** significant at 1%; * significant at 5%; $^{+}$ significant at 10%.

2. OLS: Robust Standard Errors.

previous section). In fact for large firms and SMEs being a patentee appears to have no significant impact on growth. For micro firms, the quantile regressions indicate that if the firm can achieve high growth, patenting will further raise growth rates. Patenting is associated with a 15 percent increase in growth rate for micro firms already in the top 10 percent of growth performers. This result suggests that patenting, when it is combined with other characteristics that are fostering high growth, can be very beneficial. However, for micro firms that are experiencing median growth, patenting has no significant association with growth. Further, for micro firms at the bottom of the conditional growth distribution patenting is associated with a two percent reduction in growth rates. Clearly these results concern associations not causality, but we can suggest a number of possible underlying mechanisms, including: patenting is costly and this can reduce growth rates; patents need to be combined with other strategies and resources to be successful; and since patenting causes disclosure of information this can increase competitive pressure.

5 Conclusion

This paper has focused on patenting as an indicator of innovative and entrepreneurial firms using a new database. 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 percent of young micro firms and SMEs patent (although this share is much higher in some sectors, e.g. 5 percent 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 data show that the combined patenting activity of micro and SMEs is around the same as that from large firms. This is an important finding since it suggests that micro firms and SMEs combine to produce a substantial share of 'innovation', in contrast to R&D data that suggests that large firms are dominant.

The last sections of this paper analyse the relationship between patenting and performance. Previous UK research has established that patenting 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). Section 4 adds a number of insights to this nascent literature. First, conditional on firm age, SMEs that patent tend to have higher survival rates than micro or large firms that patent. This is consistent with the idea that innovative SMEs have sufficient size (resources) to compete effectively in the market. In contrast, micro firms that patent tend to have lower initial survival rates, but these increase quickly with age. The policy implication is that support for micro firms that patent may have substantial benefits. Second, in terms of growth rates (of assets), the analysis finds that patenting firms have a tendency to have polarised performance (i.e. they are over-represented in both the negative growth group, and also the high growth group). For example, in high-tech industries, of the SMEs and micros that patent around 40 percent have growth above 20 percent per annum (compared to 26 percent of high-tech non-patentees).

This last insight motivates the last set of analysis which uses quantile regressions. The skewed distribution of smaller firms' growth rates, and the polarisation result for patentees, imply that on average there may be little correlation between patenting and firm growth. Specifically, the standard conditional mean estimators employed ubiquitously in the literature are likely to find little correlation between patenting and firm growth. One way of investigated these issues is to use quantile regressions (which allow the impact of patenting to vary across the growth distribution). The quantile regressions find evidence that patenting is associated with higher growth rates in the cohort of micro firms that are already high performers. An informal way of describing this result is that if a micro firm has both a good idea and sufficient resources, then obtaining a patent will generate even more growth. In contrast, the quantile regressions indicate that patenting for SMEs is unimportant at any point in the distribution. This result for SMEs must be set in context: patenting is associated with increased survival; and the trend for SMEs patenting has been increasing over 2000 to 2007. This suggests that patenting for SMEs is related to a defensive strategy, rather than an integral part of a high growth strategy. These issues are, however, in need of further research. The aggregate analysis presented above cannot unravel the various mechanisms at work, rather it is intended to provide a context for future analysis.

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A Data Appendix

B FAME

Firm-level financial data as well as information on other firm characteristics, such as 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). 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 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 8 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 70 percent. Patents may also be held under the names of the company

Table 8: 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.

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.

D 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).

E 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.