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Abstract

This paper brings together ideas about technological regimes and looks at their influence on patterns of sustained or persistent innovation across UK manufacturing and services industries using two waves of the UK Community Innovation Surveys. It builds a link between technological regimes and Schumpeterian patterns of innovation, and tests these on the CIS databases. It creates a model using the variables within the technological regime to see whether these can explain sustained patterns of innovation. These variables include appropriability, cumulativeness, technological opportunity and closeness to the science base as well as enterprise size. The paper finds that strong appropriability, a high degree of cumulativeness, and closeness to the applied science base are strong predictors of sustained innovation activities. The results on technological opportunity are ambiguous. High tech manufacturing industries, i.e. chemicals and scientific instruments as well as some high tech services i.e. telecoms are more likely to register persistent innovation.

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1. Schumpeterian patterns of innovation

Our starting point is the discussion of Schumpeter's patterns of innovation. The issue of particular patterns associated with innovation goes back to the distinction made by Schumpeter in *The Theory of Economic Development* (1934) where he talked about the process of creative destruction and in *Capitalism, Socialism and Democracy (*1942*)*, where he talked about the process of creative accumulation, about the different patterns in innovative activities. Schumpeter distinguished between those types of innovation that were built on previous innovations and were incremental in nature and done by those firms that were already doing innovation; this he called creative accumulation and he thought that this would be characterised by the predominance of large firms in concentrated industries which would reap the advantages of their previous successes in innovation to build further on them. He contrasted this with his earlier ideas about creative destruction where innovation was characterised as a radical breakthough, creating a new technological trajectory, more likely to be done by new firms entering the field than by the larger established firms, and more likely to upset the stability and place of existing firms.

This distinction was built on later by Nelson and Winter (1982) who characterised these two types of process as Schumpeter Mark I and Schumpeter Mark II models. A Schumpeter Mark I model sees technological change as a process of creative destruction which is an uneven and random process where a population of firms is seeking out technological opportunities which are available to any firm. Although innovation creates monopoly power, this is only temporary since it is challenged by imitators of those innovations. The knowledge base is assumed to be also accessible to all firms and so challenges are not confined to specific sectors but may come from anywhere. So as a consequence new firms come in on the back of new technological innovations and replace incumbent firms. In this model one would associate innovation with small newly established firms and low industrial concentration (Malerba, Orsenigo and Peretto 1997).

A Schumpeter Mark II model sees technological change as a gradual process of creative accumulation. This model stresses the tacit component in new technologies and that such technologies are highly specific to particular firms and applications and in particular that those firms need to be receptive to the creation of new technologies through having high absorptive capacities. So innovation is seen as a product of in-house R&D capabilities leading to the creation of technological competencies, and the process of technological change is cumulative rather than abrupt and is not destructive of existing competencies. This model leads to the dominance of innovation activities by large firms, as the cumulativeness of technological competencies creates high entry barriers to new firms. This view also emphasises a strong degree of path dependence ie that the firm is set on a particular trajectory in terms of its accumulated competencies which is hard to shift. So overall the picture we would expect from a Mark II model is of innovation activities dominated by highly concentrated industries with innovation occurring predominantly in large firms.

Malerba and Orsenigo (1996) introduce the idea of the importance of technological regimes, or the characteristics of particular technologies as being determining factors in these patterns of innovation. There is considerable overlap between some of the ideas associated with the different Schumpeterian patterns of innovation and the ideas associated with persistence of innovation. In particular the distinction between creative destruction and creative accumulation lends itself as well to thinking about the characteristics associated with cumulativeness of technology and persistence of innovation. It is also the case that some firms or entrepreneurs may be associated with radical breakthroughs in a persistent fashion, being the first to create a series of new innovations although not necessarily the first to commercialise them successfully. It is necessary in our analysis of persistence to distinguish between the types of innovation that are being persisted in: to identify the more radical and significant novel innovations from the more routine and minor modifications that are likely to be made on a continuous basis by a firm.

The characteristics of a technological regime depend on various conditions that accompany the introduction and development of that technology. In particular appropriability conditions, the degree to which the technology is cumulative and builds on incremental steps, the technological opportunity associated with the technology and how close to the science base is the technology, are all thought to be important factors that influence the shape and patterns of innovation associated with the technology.

Appropriability conditions describe how easily protected, either strategically or through formal methods, is the technology as it is adopted and innovation based on the technology proceeds. Tight appropriability means that the innovating firm producing or using the new technology can capture the benefits of its innovation without inducing spillovers into the wider environment.

Cumulativeness is a characteristic encapsulating whether advances in the technology proceed in an incremental fashion, likely to be done by firms already working on that technological path, or whether a new technology entails a radical break with the past, involving new firms entering and innovating. Cumulativeness is meant to capture the characteristics of the technology in relation to the individual firm.

Technological opportunity is the idea that technologies differ in their impact on different industries. Certain technologies and industries derived from those technologies are characterised by many opportunities for firms to innovate and one would expect to see high entry of new firms into those industries; whereas other industries are characterised by fewer opportunities to innovate and a lower prospect of new firms entering the industry.

In terms of closeness to the science base, a new technology can have its roots in the generic basic science base, such as biotechnology with its close links to university research, or it can be developed out of the applied science base with links being closer to applied research within industry or with suppliers and customers. A technological regime is therefore a collection of these characteristics that describe particular technologies and industries associated with those technologies.

Malerba and Orsenigo (1996) find that innovative activities across countries are organised into two distinct groups with the first group representing what they call a ‘widening’ pattern associated with creative destruction or a Schumpeter Mark I model of innovation. In other words in this group the innovators are small in size, there is considerable new entry into the industry and little stability in the ranking of innovators. Examples of industries with widening patterns of innovation are mechanical engineering and traditional sectors. The second group is characterised by what they call a ‘deepening’ pattern which is associated with creative accumulation or a Schumpeter Mark II model of innovation. These industries, typically chemicals and electronics, are characterised by stability amongst the innovators, low entry and the innovators are larger firms. Breschi, Malerba and Orsenigo (2000) go on to test the idea that the characteristics of technological regimes are the determining factors in these patterns of innovation. They find clear relationships between those technological characteristics described above, and particular patterns of innovation.

This challenges the older tradition, looking at the relationship between market structure and innovation (Kamien and Schwartz 1982) which focused on the relation between the rate of innovation and monopoly power. They were testing the Schumpeterian hypothesis that only a market structure with large firms had the resources to innovate, and therefore that a degree of monopoly power was necessary to generate revenues necessary to plough back into R&D and innovation. Schumpeter’s discussion in *Capitalism, Socialism and Democracy* stressed the advantages of large size which were innovation 'capability advantages’ stemming from economies of scale in R&D and management, capabilities to spread risk etc.

2. Persistence of innovation

In a related vein there is a literature on how persistent an activity innovation is. Is it characterised by firms who are innovators continuing to be innovators into the future, seeing innovation as a mode of behaviour with firms gearing up to innovate and continuing to do so successfully? Or is innovation characterised as a one-off activity, either because it is a radical breakthrough only to be done very occasionally by one firm which lives off the rents of that innovation, or because it is a more casual and minor activity undertaken occasionally, not requiring large resources but also not giving rise to a future path of similar activity?

Geroski, van Reenen and Walters (1997) distinguish between occasional innovators and persistent innovators. Occasional innovators are those firms that innovate on a one-off basis, and do not do so continuously. Geroski suggests that there are many such firms and that innovation is more typically characterised by one-off occurrences. They look at two data sets on the history of firms' innovation activities over a twenty year period and over a thirty eight year period, based on their patenting activity and find that only a very small number of firms produce patents or major innovations on a regular basis.

It in part depends on what one counts as innovations. There is clearly a spectrum of activities which at one end include minor improvements, raising of quality and altering processes that are likely to occur on a continuous basis by many firms. At the other end of the spectrum there are major innovations or breakthroughs that alter market opportunities, radically alter the way a firm is likely to organise itself and what it produces, and these are likely to be implemented by any one firm on a one-off basis with repercussions from that innovation lasting for some time. It is therefore going to matter how one measures innovation and what one includes as part of innovation activities. Geroski et al characterises persistence of innovation as caused by some sort of dynamic economies of scale, which capture the idea that by increasing the volume of innovation at any one time, a firm is then more likely to innovate subsequently. These increasing returns to innovation could be caused by firms building up 'dynamic capabilities' (Teece and Pisano 1994). This theorising argues that firms build up technological capabilities in a cumulative way. What Geroski et al find however is that the threshold for firms to innovate on a continuous basis is very high and that only a very small proportion of firms will reach this threshold. Most firms, if they do produce major innovations, do so on a sporadic basis and are unlikely to continue doing so year after year.

Malerba, Orsenigo and Peretto (1997) look at the characteristics of firms associated with persistence in their innovation activities, and see whether innovation patterns depend on the concentration of innovation activities amongst relatively few firms and stability in that ranking of innovators with relatively little entry and exit amongst innovators, or whether they are determined by more traditional indicators of innovation patterns such as firm size and industrial concentration. They use a patent database over the period 1969-1986 for 33 technological classes. They find evidence for strong persistence in innovation activities, both across countries and sectors, which generates high concentration amongst the population of innovators, and stability in that population with relatively low entry and exit. There is however a fringe of innovative activities around this stable core, with greater entry and exit, where innovators are small and innovate occasionally. The role of market structure variables such as industrial concentration is less clear. Firm size is an important determinant but is not directly related to firm's innovativeness per se, but to the continuity of their innovation activities. So small firms are more likely to stop innovating than large firms; in industries composed of many small firms and a few large ones, innovation will tend to be concentrated amongst the larger firms over time.

In a similar vein on the persistence of innovation Cefis (2003), and Cefis and Orsenigo (2001) class firms into categories according to their innovation status i.e. firms that are non-innovators, firms that apply for relatively few patents, and firms that are great innovators applying for many patents, and look for whether firms remain within their initial categories over time, or whether they are likely to switch categories. They look across countries and over the period 1978-1993, based on patent data, and find that there is not high persistence at the firm level. However there is a tendency for firms to stay within their original states ie for great innovators and non-innovators to remain in those categories and for the great innovators to account for a high proportion of innovation activities. So in that sense they detect substantial persistence of innovation, but with great differences between industries or sectors and sizes of firm. The intersectoral differences are consistent across countries and are therefore likely to be associated with the characteristics of the particular technologies.

What our paper is able to do is to look at persistence of innovation defined across a wide range of types of innovation, and defined also across a wide range of sectors. It moves away from the previous focus of the literature on patent data as the measure of innovation, and looks at measures of innovation output as defined by the Community Innovation Survey. So innovation is categorised into 5 classes of innovator: a product innovator, a process innovator, a novel product innovator, and being innovation active which is the broadest measure of innovativeness. Persistence means remaining within the firm's class of innovation across the two reporting periods of CIS 2 (1994-6) and CIS 3 (1998-2000). Moreover we look for persistence across a range of industries and service sectors, which we look at both at the 2 digit industry level, and grouped into high technology (R&D intensive) manufacturing industry, low technology manufacturing industry, high technology service sectors (such as financial services and telecomms) and low technology services sectors.

3. What is meant by the elements in the technological regime?

As noted above the main elements in the idea of a technological regime are the extent of technological opportunity associated with the technology, the degree of cumulativeness that is required by the firm in building up its capabilities in the technology, the appropriability conditions associated with the technology and the closeness of the technology to different parts of the science base.

Technological opportunity

The term technological opportunity refers to the potential for innovation in a particular industry. The idea that technological opportunity is meant to capture is the degree to which there are many new opportunities or openings associated with the development of a particular technology. A technology for which there are many opportunities may then be associated with the entry of new firms, exploiting those opportunities.

Cohen's (1995) discussion of technological opportunity starts with the idea that industries differ in the opportunities that present themselves for technical advance. However there are considerable problems in translating this into an operable proxy that reflects the degree of difficulty that exists in an industry in making technological advances.

Technological opportunity has been estimated by relating research expenditures to increases in unit cost (Dasgupta and Stiglitz 1980, Spence 1984). Pakes and Schankerman (1984) estimated the variance in R&D intensity explained jointly by opportunity and appropriability. Jaffe used the distribution of patents across patent classes and assigned firms to those classes as indicating the varying technological opportunity available to them (1986, 1988, 1989). Trajtenberg (1990) used patents weighted by their citations in other patent applications to develop a measure of opportunity. Patel and Pavitt (1998) measured technological opportunity as the absolute increase in patenting in a sector and thus identified sectors of high and low opportunity.

Scherer did pathbreaking work in classifying firms according to three basic technologies: chemical, electrical and mechanical, which captured some of the differences in the technical advances and opportunities open to firms to implement those advances. This classification explained a large degree of the variance in patenting activity (Scherer 1965, 1982) and R&D intensity (Scott 1984). Others have used proxies such as the numbers of scientific and technological employees by field across firms (Shrieves 1978) and Geroski (1990) used innovation counts in an earlier period to represent technological opportunity in the following period. Levin and Reiss (1984) used a set of technology class dummy variables with added measures of industry age, the proportion of R&D spent on basic research and government R&D as measures of technological opportunity. Levin went on to include several other factors in his measure of technological opportunity: the contribution of basic and applied science to an industry's technological advance and the contribution of external sources of knowledge such as suppliers, users, universities etc. Cohen et al (1987) and Cohen and Levinthal (1989) used opportunity variables constructed out of closeness to science and sources of external knowledge. Most of these models found their proxies for technological opportunity to be significant in explaining the variance in R&D intensity.

Breschi et al (2000) found some support for an association between high technological opportunity and widening or Schumpeter Mark I patterns of innovation, characterised by sporadic innovation, and industries with low technological opportunity and persistent innovation patterns.

Appropriability

The appropriability conditions in an industry refer to how easy it is for a firm to protect its innovation from imitation and therefore to gain the profits from that innovation. High appropriability means that there are ways to protect the innovation either through patents or through secrecy whereas low appropriability means that protection is difficult and innovations spill over into the wider environment (Levin et al 1987). Whether an industry is characterised by high or low appropriability creates two sorts of effects on innovation: an incentive effect and an efficiency effect. High appropriability boosts incentives for firms to invest in R&D but also reduces the extent of diffusion of new technologies to other firms in the environment, reducing the efficiency effect of innovation at the industry level (Breschi et al 2000). Low appropriability lowers the incentive for the firm to invest in R&D but extends the diffusion of the R&D that is done through spillovers into the wider environment.

Breschi et al have associated high appropriability with a deepening pattern of innovation; in other words being able to protect against imitation and receive the benefits of one's innovation encourages those firms that have already innovated to continue to do so, and is therefore also expected to be associated with persistence in innovation activities.

Cumulativeness

Pavitt (1987) stresses the idea that many technologies cannot simply be chosen by firms by dipping into some 'pool' of technological knowledge. Instead the technologies that firms use are individual to that firm and are built up out of the methods that the firm uses to produce goods, with much technology being developed in-house through modifying processes etc alongside contributions from other firms and the science base. It is more accurate to represent what firms do in terms of the choice of technology as improving and building upon their existing technological base rather than surveying the scene as an observer and picking technologies that have been externally developed. This idea he calls 'technological accumulation'. This concept is endorsed by Cantwell (1989) in discussing the firm's unique technological path with its own acquisition of skills and capacity. Although firms in any industry will be drawing on a similar set of original developments in a technology, they will each adapt the technology to their own ends differently and integrate it with their existing production methods.

The idea of cumulativeness of technical advances, as developed in this paper, stresses that today's innovation is built up from the firm's previous innovations, with incremental changes occurring in technologies. It downplays the importance of radical breakthroughs for the firm and stresses continuity in a firm's technological trajectory. High cumulativeness is thought to be associated with patterns of creative accumulation (Breschi et al 2000).

Properties of knowledge base

This relates to the degree of closeness to either basic science or applied science (Breschi et al 2000). Basic or generic science refers to broad knowledge, found in research work of universities, government research institutes and private research institutes. Applied science refers to specific knowledge generated within the industry itself through the research within the firm, through suppliers, competitors, consultants and customers. Breschi et al find that closeness to the basic science base is associated with a deepening of innovation activities and a closeness to applied science with patterns of creative destruction.

However an alternative theory is that closeness to basic science may be more associated with a widening pattern of innovation, giving rise to new entry based on more radical breaks in technology and therefore with one-off or sporadic innovation. Closeness to the applied knowledge base on the other hand may be thought to be more associated with cumulative and persistent patterns of innovation, with firms linking with the immediate industrial research base to further their progress incrementally down a particular technological path (Klevorick, Levin, Nelson and Winter 1993).

4. The data

The data used to analyse the relationship between patterns of sustained innovation activity and technological regimes derives from the second and third Community Innovation Surveys, conducted in the UK by the Department of Trade and Industry. The reference periods are 1994-1996 and 1998-2000. For the purpose of this paper we are examining the 786 enterprises which are common to CIS 2 and CIS 3. So far the CIS are the most comprehensive surveys into firms' innovation activities, providing data on a wide range of innovation related variables, including various forms of direct innovation outputs and inputs and factors influencing innovation.

The advantages of the CIS data are that they provide direct measures of innovation as well as information on research and development expenditures and patent data. The CIS data provide a wide range of measures of innovation: we can distinguish between firms that are innovative in the broadest sense; those introduced a new or improved product between 1994-1996 and 1998-2000 respectively; those that introduced new processes; and those that have introduced novel products (i.e. new to the firms' market). The CIS contain a section on a variety of R&D related expenditures and questions related to the turnover derived from innovations.

Furthermore, the CIS surveys cover the whole of manufacturing and services, so that we have a wider sample of companies in the economy than focusing on R&D intensive industries alone. We look at persistence across a range of sectors. In the literature, Mark I Schumpeterian models were associated with mechanical engineering and traditional industries such as textiles and Mark II Schumpeter models with sectors such as chemicals and electronics. Cefis (2003) found great persistence in the chemicals sector. Geroski et al (1997) found that the chemicals sector accounted for the highest percentage of patents and persistence, in other words that sector had the longest spells of innovation.

Here we look at persistence across a range of definitions of innovation plus across a range of sectors: high tech R&D intensive manufacturing; low tech, non-patent oriented manufacturing; high tech services such as financial services and telecomms which are not patent oriented; and low tech services.

A draw back of this study is that we are examining two time periods only; innovation activities between 1994-1996 and 1998-2000.

5. Methodology

As introduced above, this paper analyses the impact of technological regimes on patterns of sustained innovation activities associated with creative accumulation or Schumpeter Mark II, and sporadic innovation activities associated with creative destruction or Schumpeter Mark I. We are using regression methods, in particular logistic regression models, to examine the effects of technological opportunity, appropriability of innovation, cumulativeness of technical advances and closeness to the basic and applied knowledge base on persistence in innovation.

> Persistent innovation activity = f (low technological opportunity, high appropriability, high cumulativeness and closeness to applied science base, large size)

Innovation is considered to be *persistent* where an enterprise carries out innovation in CIS 2 as well as in CIS 3. Innovation activities are *sporadic* when an enterprise carries out innovation in either CIS 2 or CIS 3. The dependent variable, persistent innovation activity, is dichotomous selecting all CIS respondents which engaged in innovation in CIS 2 and CIS 3 (with a value of 1) and deselecting all firms that innovated in either CIS 2 or CIS 3 (value of 0). Firms not innovating during both survey periods are omitted from the analysis.

We assume that sustained innovation activities is linked to low technological opportunity, high appropriability, high cumulativeness, closeness to the applied science base and large firm size. Conversely, we expect sporadic innovation to be associated with high technological opportunity, low appropriability, low cumulativeness, closeness to the generic knowledge base and small firm size.

We examine 6 measures of innovation. Starting with our broadest measure of innovation, we look at: 1) innovation active firms, 2) product innovators, 3) novel product innovators 4) process innovators, and 5) firms with at least 20 per cent of their turnover generated from new or improved products and 6) enterprises with expenditures on in-house research and development.

1) The broadest measure of innovation used is called 'innovation active'. Innovation active are all those enterprises which engage in any of the following activities: product innovation, process innovation, research and development, co-operations related to innovation as well as enterprises with delayed or abandoned innovation projects.
2) We then examine patterns of innovation activities by selecting all product innovators. Product innovators are enterprises which have introduced any new or technologically improved products which were new to the firm but not necessarily new to the firm's market.
3) This is followed by innovation activities amongst novel product innovators. Novel innovators are firms which introduced a new product which is also new to the firms' market.
4) We consider patterns of process innovation. A process innovator is an enterprise which has introduced any new or technologically improved processes new to the firm.
5) We go on to consider enterprises that derived at least 20 per cent of their overall turnover through the sales of new or improved products.
6) Finally we examine enterprises with sustained or sporadic expenditures on in-house research and development.

The following paragraphs deal with the operationalisation of the theoretical concepts of technological opportunity, appropriability, cumulativeness and closeness to the knowledge base, the explanatory model variables.

Technological opportunity

Technological opportunity is an industry level measurement, assessing the ease of innovation or opportunity to innovate in particular sectors. We develop two measures of technological opportunity. The first variable (OPP1) is defined by the relative number of product and/or process innovators in each sector (number of innovators over the number of total firms in each sector). This latter is calculated for CIS 2 and CIS 3. We then take the average between the two values/periods.

The second variable (OPP2) is the proportion of newly established firms in the reference period of CIS 2 in each sector. There are no enterprises that were newly established during CIS 3 as our sample refers to firms which answered CIS 2 as well as CIS 3.

We tested for a possible relation between our two measurements of technological opportunity. The result was a non-significant Pearson correlation coefficient of -0.035 indicating little or no relationship between OPP1 and OPP2.

Appropriability

High appropriability to innovate is given where protection from imitation is high. High appropriability is positively associated with patterns of creative accumulation or deepening patterns of innovation (Breschi et al 2000) and in our model may be associated with persistence. In relation to appropriability of innovation we are using a question from CIS 3 related to the importance of formal and strategic protection methods. Enterprises were asked to rank on a four point likert-scale the importance of eight specific protections methods (0=not used, 1=degree of importance low, 2=medium, 3=high). We have used factor analysis, a data reduction tool, to bring down the number of variables.

The first factor, explaining 37 per cent of the variance in the data, is related to strategic methods of protection; secrecy, confidentiality agreements, complexity in design and lead-time advantage on competitors. Factor 2, explaining 36 per cent of the total variance, gives high scores to formal methods of protection. The latter are the registration of design, trademarks, patents and copyrights. As regards appropriability, the scores of factor 1 and 2 are used in the regression models, analysing the impact of technological regimes on persistent innovation.

Table 1 gives the factor loadings of each of the 8 variables in the CIS 3 dataset which are related to innovation protection methods. Values below 0.3 are suppressed. In following calculations the two appropriability variables are labelled APP 1 referring to strategic protection methods and APP 2 meaning formal protection methods.

Table 1 here

Cumulativeness

Technological cumulativeness means that today's innovations and technological capabilities are the basis for future innovations. Cumulativeness is an indicator of how committed a firm is to a particular technological trajectory. A high level of cumulativeness is associated with deepening patterns of innovation and in our model may be linked with sustained innovation activities.

Cumulativeness is measured at the firm level using CIS 2 data. We developed one index that combines measures of product and process innovation with in-house research and development expenditures and the proportion of qualified scientists or engineers. The index is calculated by adding the values of the separate variables. CIS variables on product and process innovation and R&D engagement used are dichotomous, whereas the proportion of the workforce holding a degree is given in percentages; 0-1. We calculate the index by adding all four components. The outcome is a variable whose values lie between 0 and 4. We then standardize the latter (i.e. $\mu=0$ and $\sigma=1$). We call this variable CUM.

Properties of the knowledge base

Properties of the knowledge base refer to closeness to either basic science or applied science. Basic or generic science is associated with broad knowledge found in the research work of universities, government research organisations and private research institutes. Applied science refers to specific knowledge generated within the industry itself through research within the company group, suppliers, competitors, customers and consultants.

We use a question from CIS 3 in which the respondents were asked to rank the importance of sources of information on innovation on a four point likert-scale (0=not used, 1=degree of importance low, 2=medium, 3=high). Sources of information are universities, commercial laboratories, governmental and private research institutes, other enterprises within the enterprise group, suppliers, competitors, consultants and clients.

In order to reduce the number of variables we have run a factor analysis on 10 CIS variables related to the importance of information sources on innovation. Table 2 gives an overview.

Table 2 here

As table 2 shows factor 1 gives high scores to information sources associated with the generic science base and factor 2 to information sources related to the applied knowledge base. Values below 0.3 are suppressed. Factor 1 explained 32 per cent of the variance in the data and factor 2 30 per cent. In further calculations the factor scores for factor 1 and 2 were used. They are labelled KB 1 (generic science base) and KB 2 (applied science base) respectively.

Size

As our measure of size we use the number of employees as registered on the Intern-Departmental Business Register (IDBR) available in the CIS 2 dataset and compute the natural log. This variable is called ‘ln(emp)’. In our model large size may be linked with sustained or persistent innovation activities.

6. Patterns of sustained and sporadic innovation activities in UK industries

First we look at the data and categorise sectors into those associated with one-off innovation and those characterised by sustained innovation. Figures 1 to 6 compare the proportion of sustained and sporadic innovators within different industries, according to our 6 different measures of innovation engagement of firms stated above. All underlying data is listed in Annex A.

Figure 1 here

Figure 1 is a scatter diagram, each dot defined by the proportion of sustained innovators on the y axis and the proportion of sporadic innovators on the x axis using our broadest definition for innovators; ‘innovation active’ firms. Industries with a high proportion of sustained innovators and a comparatively low proportion of sporadic innovators are located in the top left quadrant of figure 1.

Broadly, those industries where sustained innovation is a characteristic are high tech manufacturing industries such as chemicals and scientific instruments, machinery and equipment and some high tech services such as telecoms. The sporadic, one-off innovators are low tech manufacturing such as textiles and publishing and low tech services.

Figure 2 looks at product innovators and again identifies sustained and one-off innovators. Again the sustained innovators are high tech manufacturing sectors such as chemicals, scientific instruments, machinery and equipment as well as high tech services such as telecoms. The occasional innovators are low tech manufacturing and low tech services sectors.

Figure 2 here

Figure 3 is examining the proportion of novel product innovators. When it comes to introducing new products to the market, each sector is more mixed with an even distribution of sustained and occasional innovators in chemicals, other high tech manufacturing and some high tech services. Lower numbers of innovators are found in low tech manufacturing and low tech services, again with a mix of sustained and one-off innovators. By this more challenging definition of innovation, there are more one-off innovators than sustained innovators in all sectors.

Figure 3 here

Figure 4 looks at process innovation. The sectors that emerge with clearer patterns of sustained innovation are chemicals, telecoms, metals and mining. Scientific instruments is a sector dominated by one-off process innovators, as are most low tech manufacturing and service sectors.

Figure 4 here

Figure 5 categorises industries according to whether 20% of their turnover is generated by new or improved products. This is a measure of the success of innovations. By this measure, there is again a distribution between sustained and one-off innovators in most sectors, with the more innovative sectors overall being chemicals, scientific instruments, machinery, telecoms and business activities but not dominated by sustained innovation.

Figure 5 here

Figure 6 looks at the division between sustained and one-off innovators but based on their commitment to in-house R&D. Those that have high levels of R&D are again chemicals, scientific equipment and machinery and equipment, but with all sectors having more one-off innovators than sustained innovators.

Figure 6 here

Overall the picture from the data is that certain sectors, such as high tech manufacturing sectors of chemicals, scientific instruments and machinery plus some high tech services like telecoms are characterised by sustained innovation if one's definition of innovation is relatively broad or where the focus is on product innovation. Once one moves away from product innovation to process innovation or to measures of turnover based on innovation or R&D indicators of innovation, then the incidence of sustained innovation becomes less and the numbers of one-off innovators are predominant.

7. The technological environment of UK sectors.

The following tables 3 to 6 rank UK industries according to their degree of technological opportunity, appropriability, cumulativeness and closeness to the knowledge base.

Table 3 shows industries ranked according to technological opportunity. OPP1 measures the proportion of firms that have introduced a new product and/or a new process, taking the mean of CIS 2 and CIS 3 per industry. OPP2, which captures the ease to entry into an industry, is looking at the proportion of newly established firms in CIS 2.

For OPP1 the leading industries are chemicals, scientific instruments, machinery and telecoms. OPP2 ranks real estate, utilities, transport equipment and wholesale trade, indicating that there was not much new entry into those industries where most innovation occurred. In one sense this confirms the ideas associated with technological opportunity and Schumpeterian patterns of innovation: that continuous incremental innovation is more likely to occur in industries with relatively little new entry and where firms are in the industry for the long term. However OPP1 does identify those sectors most associated with sustained innovation as also ranking highest in terms of numbers of innovators.

Table 3 here

Table 4, ranking the importance of appropriability by industry, with APP1 ranking strategic methods, and APP2 ranking formal methods, comes up with very similar results for both types of protection methods. In both cases, chemicals, machinery and scientific instruments rank highly on the importance of appropriability by both strategic methods such as secrecy and formal methods such as patenting.

Table 4 here

Table 5 ranks cumulativeness by industry, using an amalgam of resources committed to innovation (how much R&D, scientific personnel at the firm level). CUM as presented in table 5 is an index where possible values range from 0 to 5. Again the industries which score most highly are chemicals, scientific instruments, machinery and equipment, and also utilities and transport equipment.

Table 5 here

Table 6 constructs a ranking for closeness to the knowledge base, creating two variables KB1 ranking closeness to basic science, and KB2 ranking closeness to applied science. Those industries closest to the basic science base in terms of links with universities etc are the utilities, machinery and equipment, and chemicals. Those industries closest to the applied knowledge base are telecoms, scientific instruments, finance, chemicals and transport. So chemicals appears in practice to have links with both types of knowledge base and there is not the clear distinction between the basic science base being associated with radical innovations and applied science base with more incremental, continuous innovations.

Table 6 here

Table 7 ranking the size of industries shows that the largest enterprises are in the finance, telecoms, and utilities sectors, with chemicals and transport and equipment enterprises falling some way behind them.

Table 7 here

8. The impact of technological regimes on patterns of sustained and sporadic innovation activities

Can technological regimes be linked to the existence of sustained and sporadic patterns of innovation across UK industries?

In the following paragraphs we are testing the impact of technological regimes on patterns of sustained and sporadic innovation activities using logistic regression methods. For the purpose of the statistics all explanatory variables have been standardised (μ=0 and σ=1).

In our logistic regression models the dependent variable is a binary or dichotomous variable selecting all enterprises with sustained innovation activity between CIS 2 and CIS 3 as opposed to sporadic innovators. The regression is run for each of our 6 measures of innovation. Non innovators (i.e. firms not innovating in both surveys) are not included in the analysis. The independent variables are technological opportunity (OPP1: ease to innovate and OPP2: ease of entry), appropriability (APP1: strategic protection and APP2: formal protection methods), cumulativeness (CUM), closeness to the knowledge base (KB1: basic science and KB2: applied science) and size (ln(emp)) as introduced above. Reported are the B coefficients raised to the e power. This is interpreted as the shift in terms of the odds of the outcome of the dependent variable, sustained innovation. The results are presented in table 8.

Table 8 here

In model 1 to 6 the same predictor variables are used, the dependent variables, however, differ and represent our 6 different measures of innovation.

The dependent variable in Model 1 refers to *innovation active* enterprises as defined in section 5. According to the Chi-square (χ^2) statistic, the overall model is significant at the 1 per cent level. The Nagelkerke R^2 indicates that around 53 per cent of the variation in the dependent variable is explained by the logistic regression model. Moving to the predictors, our two measures of technological appropriability, representing the importance of strategic and formal methods of protection, are significant at the 5 per cent level and are associated with an increase in sustained innovation activities and a decrease in sporadic innovation activities, indicted by an odds ration above 1. Cumulative, past innovation activities, have the strongest positive impact on sustained innovation patterns, which is significant at the 1 per cent level. Looking at our measures of closeness to the science base, closeness to applied science has a positive impact significant at the 1 per cent level. Finally neither the size variable nor the two predictors of technological opportunity have a significant impact on increasing sustained innovation patterns.

Our model 2 analyses innovation patterns in terms of *product innovation* and is also significant at the 1 per cent level. Around 51 per cent of the variation in patterns of sustained and sporadic product innovation is explained. Both measures of technological opportunity are significant. OPP1, representing the number of innovators per industry, contrary to our expectations, is positively related to sustained innovation. The number of new market entries in an industry (OPP2), is, in line with our expectations, negatively related to sustained innovation and thus has a positive impact on patterns of sporadic innovation. Both measures of appropriability are positively associated with persistent innovation significant at the 1 per cent level. Again cumulativeness has the highest positive and significant impact on patterns of sustained innovation. Usage of the applied science base is positively related to persistent innovation, significant at the 1 per cent level. Neither the closeness to basic knowledge nor enterprise size are significant in explaining sustained product innovation.

Model 3 examines *novel product innovation.* Overall this model is significant at the 1 per cent level with a sufficiently large enough χ^2. It explains in total 27 per cent of the variation in sustained novel innovation, significantly less than models 1 and 2 accounted for. Two of the predictors show a significant relationship, in both cases at the 1 per cent level, to the dependent variable: appropriability in terms of strategic protection methods and the cumulativeness of past innovations. Closeness to the knowledge base and technological opportunity are not associated with persistence in novel innovation. One needs to point out that the number of valid observations in model 3 is much lower than in model 1 and 2. This is the case, because when looking at novel innovators as opposed to innovation active and product innovation, there are more non innovators in sample. Non innovators are not included in the analysis. In model 3 we have 178 observations. This is below the recommended minimum of 240 observations needed in a regression model with 8 independent variables and hence all results have to be treated with caution.

In our fourth model we are looking at the persistence of *process innovation*. Again the overall model is significant at the 1 per cent level and explains around 28 per cent of variation in the dependent variable. Three elements of the technological regimes are significantly related to innovation patterns of creative accumulation. These are: appropriability (strategic protection) with a significance level α of 10 per cent, cumulativeness with α = 1 per cent and closeness to the applied science base with α = 5 per cent.

Model 5 refers to sustained innovation when an enterprise has generated at least *20 per cent of its total turnover from new or improved products* in both surveys. The overall model is significant at the 1 per cent level. In total the model accounts for 20 per cent of the variation in the dependent variable. The number of observations is just below 240. There is only one significant predictor in the model; APP1, the strategic protection methods. All other independent variables are not significantly related to patters of persistence.

Model 6 examines persistence in terms of engagement in in-house or *intramural R&D*. The overall model is significant, explaining around 20 per cent of the variation. Three independent variables show a positive association to sustained in-house R&D activity, all with a significance level of 1 per cent. The latter are both measures of appropriability and cumulativeness of past innovation.

9. Conclusions

Certain features of the models are apparent. The most important variables in explaining the persistence of innovation across all types of innovation are cumulativeness and appropriability, especially strategic appropriability methods. This accords with our prior thinking that those industries more reliant on past innovations and on building on them will be those that are likely to innovate continuously. It is interesting that even for novel product innovation,cumulativeness appears to be an important signal of sustained innovation, indicating that even products new to market are more likely to come out of an enterprise with substantial resources committed to innovation and undertaking innovation on a continuous basis. It is therefore hard to identify a clear distinction between novel innovations that are radical and pathbreaking that are more likely to emanate from new firms entering the industry, or on a one-off basis, from those coming out of incumbent firms in an industry. The greater importance of strategic appropriability methods over formal methods such as patenting in sustaining innovation accords with other literature that indicates that patenting is not a particularly pervasive activity across many industries, although it is important in a few.

The relative insignificance of the technological opportunity variables across most types of innovation in explaining the persistence of innovation tallies at least with the theory that when technological opportunity is high, this is likely to attract newly innovating firms into the market which will displace incumbent firms. So the existence of low levels of technological opportunities and their relative insignificance in explaining sustained innovation fits with the idea that sustained innovators depend on relatively stable technological environments with few radical disruptions. The exception to this is in product innovation where the opportunities in the industry, as measured by the numbers of innovators of various types in that industry, indicates more persistent innovation.

Size of enterprise does not of itself seem to predispose a firm towards more persistent innovation. This is perhaps due to the smaller sizes of those enterprises in chemicals, machinery and scientific instruments, which are those sectors where most sustained innovation is found. This presents an argument suggesting that economies of scale in research and innovation are relatively small and that even persistent innovation and R&D is carried out through smaller or medium sized enterprises, rather than in larger enterprises which characterise the finance, telecoms or utilities industries.

Closeness to the applied science base appears to be more significant in leading to persistent innovation than links with the generic science base. This accords with the thinking that sustained innovation is more likely to come out of highly directed trajectories and applications, building on previous projects, and with linkages that relate to the existing state of affairs with greater reliance on customers, suppliers and industry specific research rather than the more distant university-based research. This is not to decry the significance of basic research to industrial innovation but as Swann (2003) argues, that the linkages with the basic research base are more likely to be indirect than through direct associations.

In looking at the range of models measuring different types of innovation, it is clear that the more broadly innovation is defined, covering a variety of indicators of being active in innovation, the more clearly the various characteristics of the technological regime can distinguish sustained from one-off innovation. This accords with Geroski et al's (1997) observation that measurement matters in looking at persistence: the more radical and significant the innovation, the less likely it is that the firm does this on a regular, routine basis; whereas if one is picking up the more routine incremental improvements that are made, these are more likely to be done on a regular basis by the same firm. These results also accord with Cefis and Orsenigo's (2001) work that persistence is largely a technology or sectoral specific phenomenon. It is worth noting that it is a phenomenon as much of some of the newer higher technology service sectors such as telecoms as it is of the more traditional R&D oriented manufacturing sectors. Also according with Cefis and Orsenigo's results, the relationship between persistence and size does not seem to be a clear one, with persistence registered by some of the medium-sized enterprises, albeit in industries which are characterised by large firms such as chemicals. This suggests that economies of scale in innovation are not particularly large, and that some of the more persistently innovative units are medium-sized enterprises.

In all, those industries with high cumulativeness, building on past innovations, such as chemicals or scientific instruments, are more likely to register sustained innovation. The importance of well developed appropriability mechanisms, especially strategic methods, is also important in allowing firms to reap the benefits of their continuous innovations.

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Table 1: Factor analysis of formal and strategic methods of protection

Rotated Component Matrix

Variables	Factors 1	Factors 2
Registration of design		0.8
Trademarks		0.8
Patents		0.8
Confidentiality agreements	0.7	
Copyrights		0.7
Secrecy	0.9	
Complexity of design	0.8	
Lead-time advantage over competitors	0.9	

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Source: CIS 2 and CIS 3, own calculations.

Table 2: Factor analysis of sources of information for innovation

Rotated Component Matrix

Variables	Factors 1	Factors 2
Other enterprise within the group		0.6
Suppliers		0.8
Clients		0.8
Competitors		0.8
Consultants		0.5
Commercial labs	0.7	
Universities	0.7	
Government research organisations	0.8	
Other public research organisations	0.7	
Private research institutes	0.8	

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Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization

Source: CIS 2 and CIS 3, own calculations.

Table 3: Industry patterns: Technological opportunity

Industry	OPP 1		OPP 2	
	Per cent	*Rank*	*Per cent*	*Rank*
Mining and quarrying	28	17	0	18
Food, beverages and tobacco	41	13	9	13
Textiles, textile products, leather, footwear	38	15	10	11
Publishing, printing, paper products and wood	45	9	7	15
Chemicals, pharmaceuticals, coke and refined petroleum	77	1	13	6
Non-metallic products	50	6	12	8
Metal products, except machinery and equipment	44	10	12	8
Machinery and equipment	64	3	10	12
Communications equipment and scientific instruments	66	2	7	15
Transport equipment	53	5	16	3
Manufacturing n.e.c. and recycling	43	11	13	6
Electricity, gas and water supply	46	8	21	2
Construction	26	18	9	13
Wholesale trade	36	16	15	4
Transport services	24	19	11	10
Post and telecommunications	54	4	0	18
Finance and insurance	42	12	3	17
Real estate activities	40	14	25	1
Other business activities	47	7	15	4

Source: CIS 2 and CIS 3, own calculations.

Table 4: Industry patterns: Appropriability (APP1 = strategic protection methods; APP2 formal protection methods)

Industry	APP1		APP2	
	Factor score	*Rank*	*Factor score*	*Rank*
Mining and quarrying	-0.5	18	-0.3	17
Food, beverages and tobacco	0.0	8	0.0	9
Textiles, textile products, leather, footwear	0.1	7	-0.2	13
Publishing, printing, paper products and wood	-0.3	13	-0.1	11
Chemicals, pharmaceuticals, coke and refined petroleum	0.9	1	0.5	1
Non-metallic products	0.3	5	0.2	2
Metal products, except machinery and equipment	-0.2	12	-0.1	12
Machinery and equipment	0.5	2	0.2	4
Communications equipment and scientific instruments	0.4	4	0.1	5
Transport equipment	0.1	6	0.2	3
Manufacturing n.e.c. and recycling	-0.4	14	0.0	7
Electricity, gas and water supply	-0.1	10	-0.4	18
Construction	-0.5	17	-0.3	15
Wholesale trade	-0.4	15	0.1	6
Transport services	-0.5	16	-0.2	14
Post and telecommunications	0.0	9	-0.1	10
Finance and insurance	-0.2	11	-0.3	16
Real estate activities	-0.8	19	-0.4	19
Other business activities	0.4	3	0.0	8

Source: CIS 2 and CIS 3, own calculations.

Table 5: Industry patterns: Cumulativeness of technological advance

Industry	CUM	
	Index	*Rank*
Mining and quarrying	0.37	19
Food, beverages and tobacco	1.24	9
Textiles, textile products, leather, footwear	1.01	12
Publishing, printing, paper products and wood	0.98	13
Chemicals, pharmaceuticals, coke and refined petroleum	2.37	1
Non-metallic products	1.51	6
Metal products, except machinery and equipment	1.12	11
Machinery and equipment	1.93	3
Communications equipment and scientific instruments	1.95	2
Transport equipment	1.59	5
Manufacturing n.e.c. and recycling	1.12	10
Electricity, gas and water supply	1.65	4
Construction	0.48	18
Wholesale trade	0.76	15
Transport services	0.52	17
Post and telecommunications	1.25	8
Finance and insurance	0.85	14
Real estate activities	0.60	16
Other business activities	1.27	7

Source: CIS 2 and CIS 3, own calculations.

Table 6: Industry patterns: Closeness to the knowledge base (KB1 = basic science; KB2 = applied science)

Industry	KB1		KB2	
	Factor score	*Rank*	*Factor score*	*Rank*
Mining and quarrying	-0.2	14	-0.4	15
Food, beverages and tobacco	0.1	5	-0.3	14
Textiles, textile products, leather, footwear	-0.2	13	0.0	10
Publishing, printing, paper products and wood	-0.4	18	0.1	8
Chemicals, pharmaceuticals, coke and refined petroleum	0.4	3	0.2	4
Non-metallic products	0.1	4	0.1	7
Metal products, except machinery and equipment	0.1	6	0.0	11
Machinery and equipment	0.5	2	0.2	6
Communications equipment and scientific instruments	0.0	9	0.3	2
Transport equipment	0.0	7	0.2	5
Manufacturing n.e.c. and recycling	-0.3	15	-0.1	12
Electricity, gas and water supply	0.8	1	-0.5	17
Construction	-0.1	10	-0.5	18
Wholesale trade	-0.1	11	-0.2	13
Transport services	-0.1	12	-0.5	16
Post and telecommunications	-0.3	16	0.5	1
Finance and insurance	-0.4	17	0.2	3
Real estate activities	-0.5	19	-0.5	19
Other business activities	0.0	8	0.0	9

Source: CIS 2 and CIS 3, own calculations.

Table 7: Industry patterns: Average enterprise size (number of employees)

Industry	Number of employees	
	Count	*Rank*
Mining and quarrying	198	13
Food, beverages and tobacco	315	8
Textiles, textile products, leather, footwear	328	6
Publishing, printing, paper products and wood	170	15
Chemicals, pharmaceuticals, coke and refined petroleum	423	4
Non-metallic products	234	11
Metal products, except machinery and equipment	70	19
Machinery and equipment	181	14
Communications equipment and scientific instruments	154	16
Transport equipment	325	7
Manufacturing n.e.c. and recycling	203	12
Electricity, gas and water supply	767	3
Construction	293	9
Wholesale trade	253	10
Transport services	380	5
Post and telecommunications	802	2
Finance and insurance	838	1
Real estate activities	145	17
Other business activities	85	18

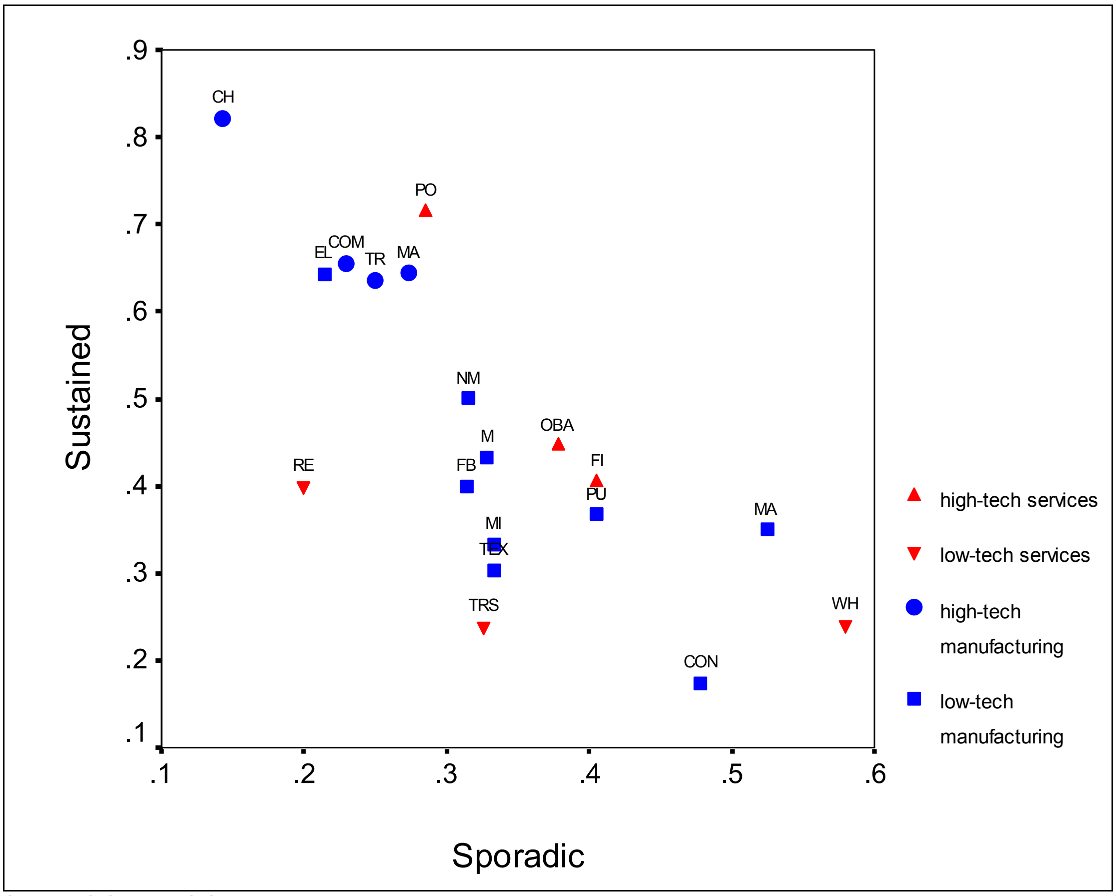
Source: CIS 2 and CIS 3, own calculations.

Table 8: Logistic regression

	Innovation active	Product innovation	Novel product innovation	Process innovation	Turnover from innovation	In-house R&D
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
OPP1	1.122	1.720***	1.245	0.961	1.28	0.917
OPP2	0.975	0.661**	0.906	0.847	0.802	1.244
APP1	1.312**	1.933***	2.148***	1.327*	1.708***	2.074***
APP2	1.342**	1.717***	1.111	0.994	1.074	1.592***
CUM	3.881***	2.691***	2.459***	2.993***	1.339	2.177***
KB1	1.186	1.100	1.246	1.075	1.223	1.064
KB2	2.387***	1.704***	0.891	1.494**	1.373	0.784
ln(emp)	1.073	1.051	0.640	1.152	1.047	1.075
N	500	357	178	296	237	261
Model χ^2	246.1	166.8	35.7	66.8	34.6	41.8
-2 LL	419.9	311.4	165.6	304.8	237.8	287.6
Nagelkerke R^2	0.528	0.506	0.268	0.282	0.199	0.206

Source: CIS 2 and CIS 3, own calculations.

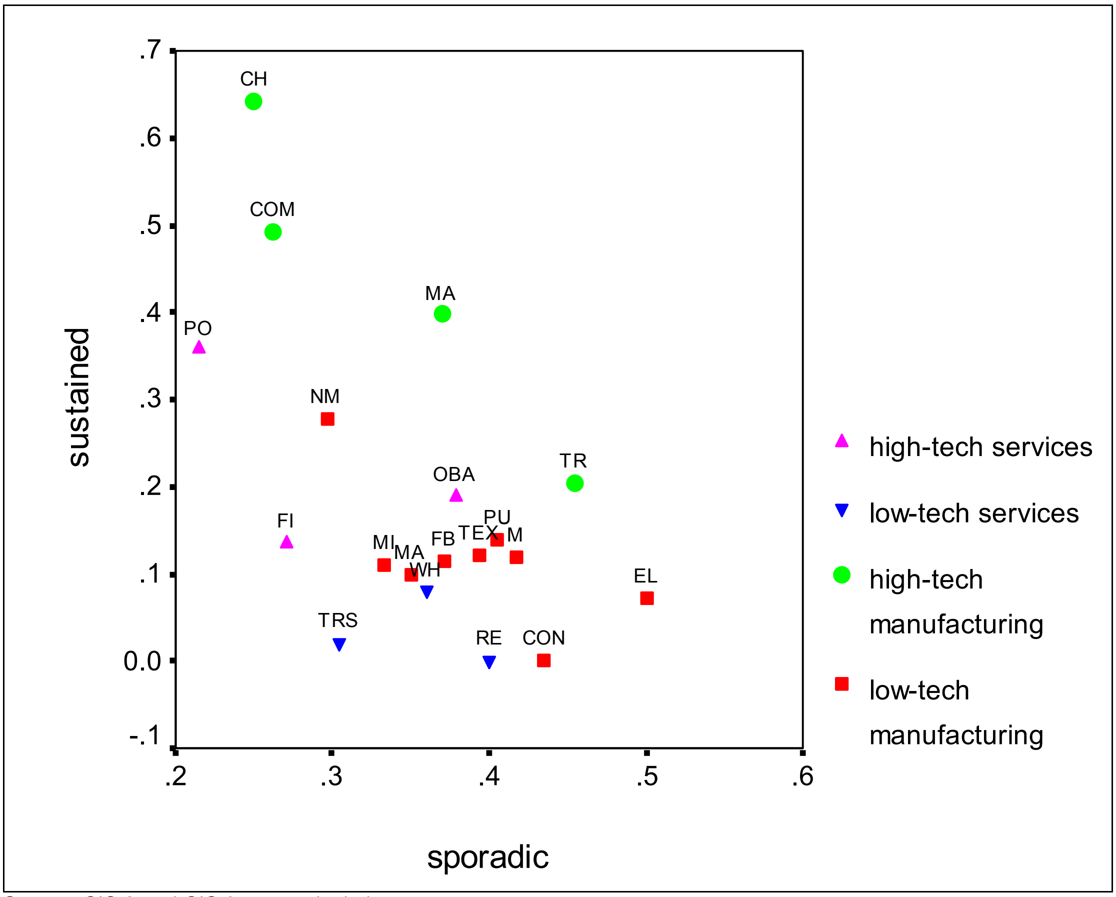
Figure 1: Innovation active



Source: CIS 2 and CIS 3, own calculations.

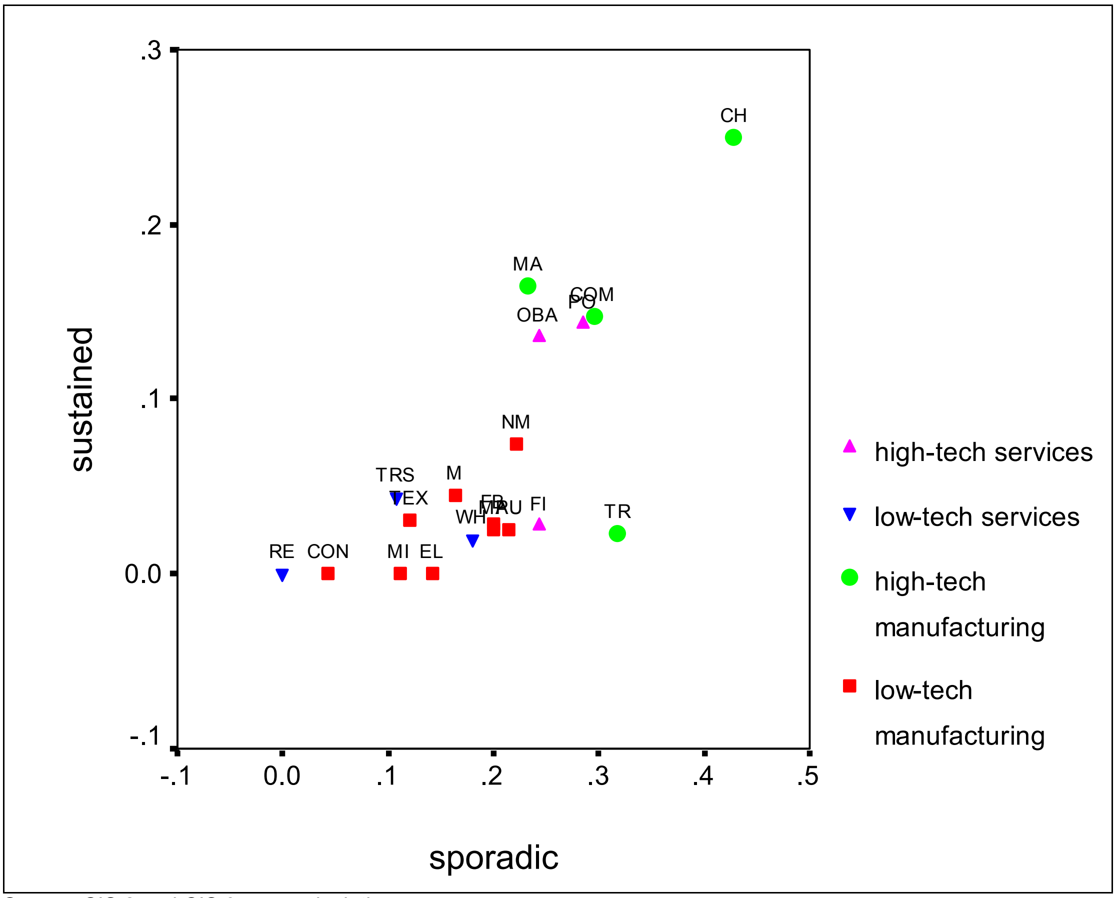
Mining and quarrying	MI	Manufacturing n.e.c. incl. Recycling	MA
Food, beverages and tobacco	FB	Electricity, gas and water supply	EL
Textiles, textile products, leather, footwear	TEX	Construction	CON
Publishing, printing, paper and wood	PU	Wholesale trade	WH
Chemicals & pharmaceuticals	CH	Transport services	TRS
Non-metallic products	NM	Post and telecommunications	PO
Metal products, excl. machinery & equip.	M	Finance and insurance	FI
Machinery and equipment	MA	Real estate activities	RE
Comm. equip. & scientific instruments	COM	Other business activities	OBA
Transport equipment	TR		

Figure 2: Proportion of sustained and sporadic product innovators by UK sector



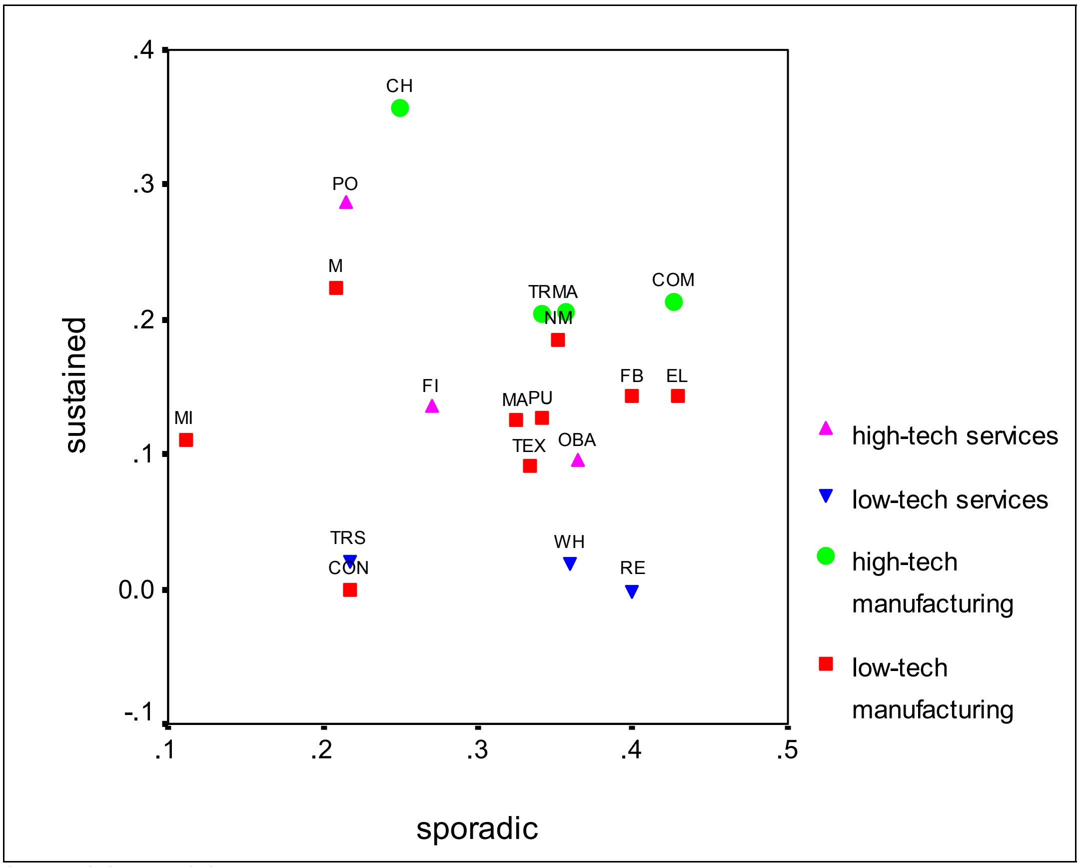
Source: CIS 2 and CIS 3, own calculations.

Figure 3: Proportion of sustained and sporadic *novel* product innovators by UK sector



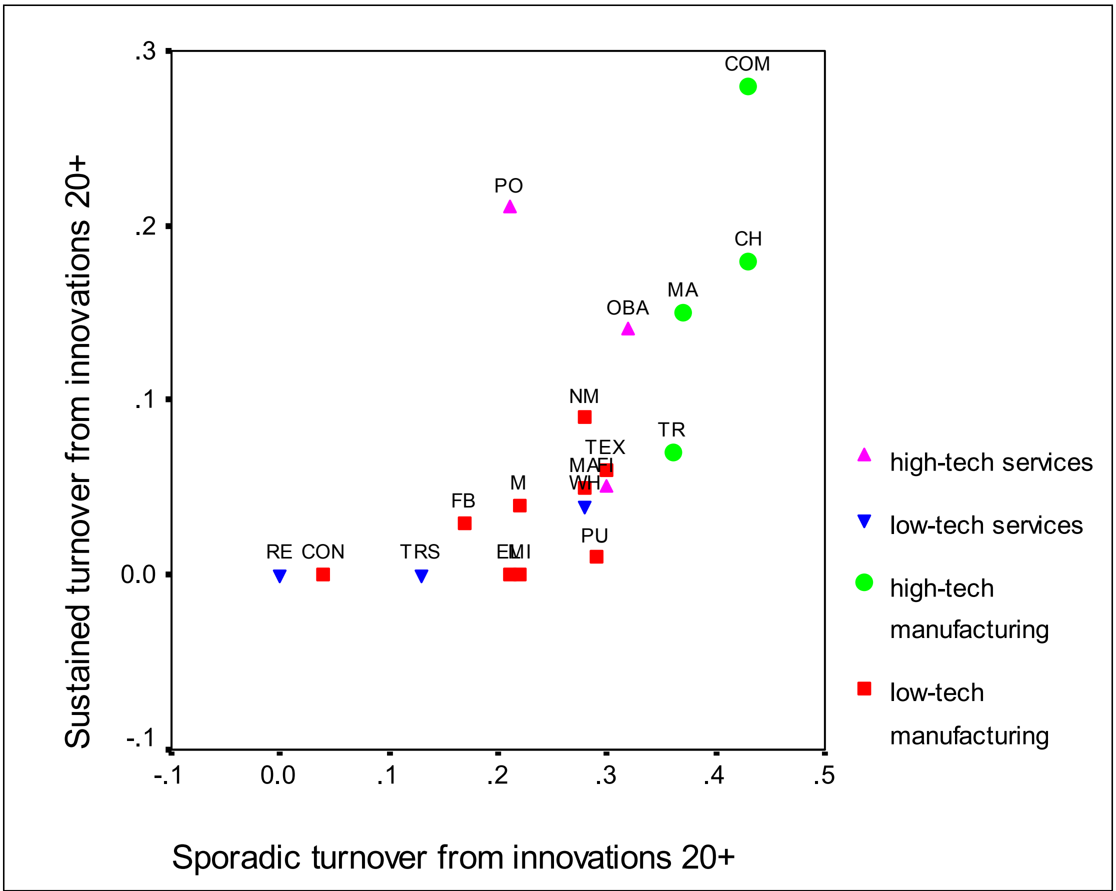
Source: CIS 2 and CIS 3, own calculations.

Figure 4: Proportion of sustained and sporadic process innovators by UK sector



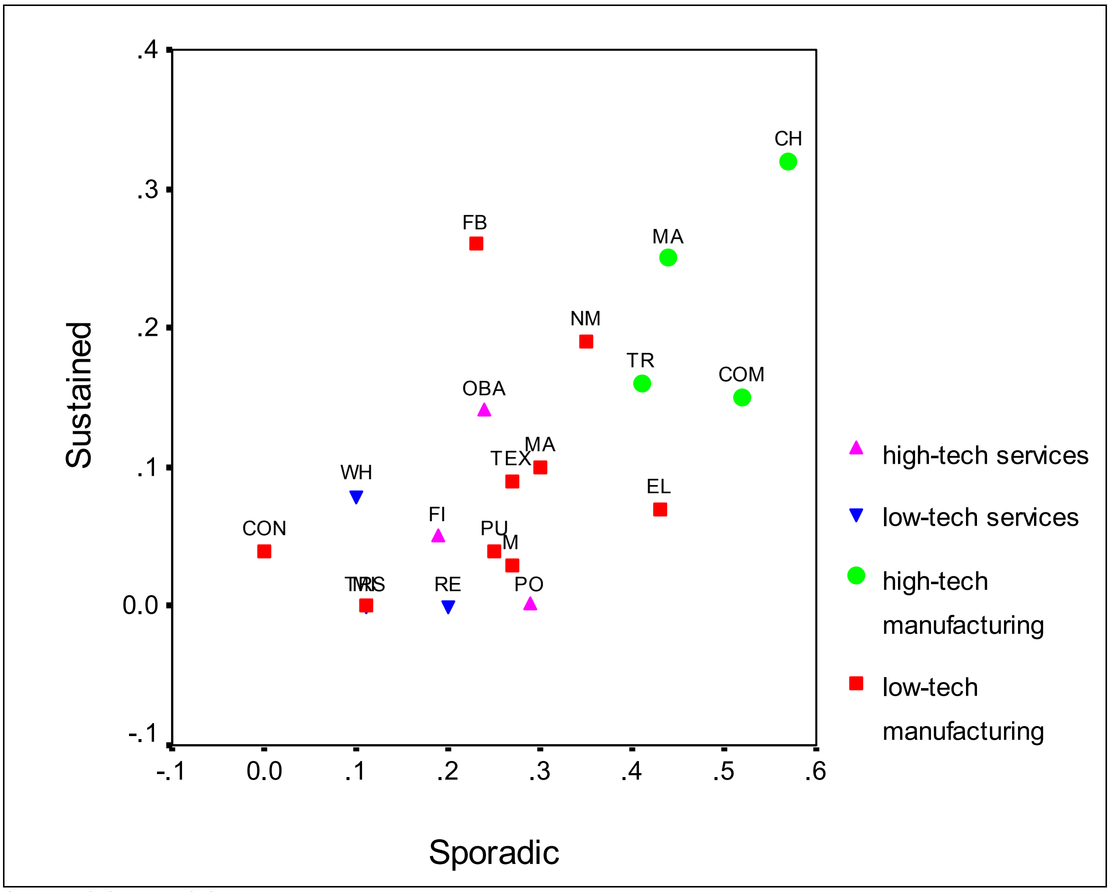
Source: CIS 2 and CIS 3, own calculations.

Figure 5: Proportion of sustained and sporadic innovators generating at least 20 per cent of turnover from new or improved products by UK sector



Source: CIS 2 and CIS 3, own calculations.

Figure 6: Proportion of enterprises with a sustained or sporadic engagement in in-house R&D by UK sector



Source: CIS 2 and CIS 3, own calculations.

Appendix A

Table 1 gives the number of observations in each sector and the count of sustained and sporadic innovators using the measure of innovation active enterprises as introduced above. The sectors are ranked by the proportion of sustained innovators in relation to sporadic innovators as given in column (f).

Table 1: Innovation active

	Number of observations	Sustained innovation active		Sporadic innovation active		Difference
			(b)/(a)*100		(d)/(a)*100	(c)-(e)
Industry	(a)	(b)	(c)	(d)	(e)	(f)
	Count	*Count*	*Per cent*	*Count*	*Per cent*	*Per cent*
Chemicals, pharmaceuticals, coke and refined petroleum	28	23	82	4	14	68
Electricity, gas and water supply	14	9	64	3	21	43
Post and telecommunications	14	10	71	4	29	43
Communications equipment and scientific instruments	61	40	66	14	23	43
Transport equipment	44	28	64	11	25	39
Machinery and equipment	73	47	64	20	27	37
Real estate activities	5	2	40	1	20	20
Non-metallic products	54	27	50	17	31	19
Metal products, except machinery and equipment	67	29	43	22	33	10
Food, beverages and tobacco	35	14	40	11	31	9
Other business activities	74	33	45	28	38	7
Mining and quarrying	9	3	33	3	33	0
Finance and insurance	37	15	41	15	41	0
Textiles, textile products, leather, footwear	33	10	30	11	33	-3
Publishing, printing, paper products and wood	79	29	37	32	41	-4
Transport services	46	11	24	15	33	-9
Manufacturing n.e.c. and recycling	40	14	35	21	53	-18
Construction	23	4	17	11	48	-30
Wholesale trade	50	12	24	29	58	-34
Total	786	360	46	272	35	11

Column (a) of table 3 gives the number of observations in each sector. The sector with the highest proportion of sustained innovators is chemicals and pharmaceuticals with 82 per cent of persistently innovating enterprises in the CIS sample. This is followed by communication equipments, transport equipment and machinery. Enterprises with a very high proportion of sporadic innovators are the wholesale sector, manufacturing not elsewhere classified and transport services.

Table 2 gives the number and proportion of sustained and sporadic product innovators.

Table 2: Product innovation

Industry	Number of observations (a)	Sustained product innovators (b)	(b)/(a)*100 (c)	Sporadic product innovators (d)	(d)/(a)*100 (e)	Difference (c)-(e) (f)
	Count	*Count*	*Per cent*	*Count*	*Per cent*	*Per cent*
Chemicals, pharmaceuticals, coke and refined petroleum	28	18	64	7	25	39
Communications equipment and scientific instruments	61	30	49	16	26	23
Post and telecommunications	14	5	36	3	21	14
Machinery and equipment	73	29	40	27	37	3
Construction	23	0	0	10	0	0
Real estate activities	5	0	0	2	0	0
Non-metallic products	54	15	28	16	30	-2
Finance and insurance	37	5	14	10	27	-14
Other business activities	74	14	19	28	38	-19
Mining and quarrying	9	1	11	3	33	-22
Transport equipment	44	9	20	20	45	-25
Manufacturing n.e.c. and recycling	40	4	10	14	35	-25
Food, beverages and tobacco	35	4	11	13	37	-26
Publishing, printing, paper products and wood	79	11	14	32	41	-27
Textiles, textile products, leather, footwear	33	4	12	13	39	-27
Wholesale trade	50	4	8	18	36	-28
Transport services	46	1	2	14	30	-28
Metal products, except machinery and equipment	67	8	12	28	42	-30
Electricity, gas and water supply	14	1	7	7	50	-43
Total	786	163	21	281	36	-15

Table 3: Product novel innovation

Industry	Number of observations	Sustained novel product innovators		Sporadic novel product innovators		Difference
			(b)/(a)*100		(d)/(a)*100	(c)-(e)
	(a)	(b)	(c)	(d)	(e)	(f)
	Count	*Count*	*Per cent*	*Count*	*Per cent*	*Per cent*
Construction	23	0	0	1	0	0
Real estate activities	5	0	0	0	0	0
Transport services	46	2	4	5	11	-7
Machinery and equipment	73	12	16	17	23	-7
Textiles, textile products, leather, footwear	33	1	3	4	12	-9
Other business activities	74	10	14	18	24	-11
Mining and quarrying	9	0	0	1	11	-11
Metal products, except machinery and equipment	67	3	4	11	16	-12
Electricity, gas and water supply	14	0	0	2	14	-14
Post and telecommunications	14	2	14	4	29	-14
Communications equipment and scientific instruments	61	9	15	18	30	-15
Non-metallic products	54	4	7	12	22	-15
Wholesale trade	50	1	2	9	18	-16
Food, beverages and tobacco	35	1	3	7	20	-17
Manufacturing n.e.c. and recycling	40	1	3	8	20	-18
Chemicals, pharmaceuticals, coke and refined petroleum	28	7	25	12	43	-18
Publishing, printing, paper products and wood	79	2	3	17	22	-19
Finance and insurance	37	1	3	9	24	-22
Transport equipment	44	1	2	14	32	-30
Total	786	57	7	169	22	-14

Table 4: Process innovation

Industry	Number of observations (a)	Sustained process innovators (b)	(b)/(a)*100 (c)	Sporadic process innovators (d)	(d)/(a)*100 (e)	Difference (c)-(e) (f)
	Count	*Count*	*Per cent*	*Count*	*Per cent*	*Per cent*
Chemicals, pharmaceuticals, coke and refined petroleum	28	10	36	7	25	11
Post and telecommunications	14	4	29	3	21	7
Metal products, except machinery and equipment	67	15	22	14	21	1
Mining and quarrying	9	1	11	1	11	0
Construction	23	0	0	5	0	0
Real estate activities	5	0	0	2	0	0
Finance and insurance	37	5	14	10	27	-14
Transport equipment	44	9	20	15	34	-14
Machinery and equipment	73	15	21	26	36	-15
Non-metallic products	54	10	19	19	35	-17
Transport services	46	1	2	10	22	-20
Manufacturing n.e.c. and recycling	40	5	13	13	33	-20
Communications equipment and scientific instruments	61	13	21	26	43	-21
Publishing, printing, paper products and wood	79	10	13	27	34	-22
Textiles, textile products, leather, footwear	33	3	9	11	33	-24
Food, beverages and tobacco	35	5	14	14	40	-26
Other business activities	74	7	9	27	36	-27
Electricity, gas and water supply	14	2	14	6	43	-29
Wholesale trade	50	1	2	18	36	-34
Total	786	116	15	254	32	-18

Table 5: Turnover from new or improved products at least 20 per cent

Industry	Number of observations (a)	Sustained innovators (b)	Sustained innovators (b)/(a)*100 (c)	Sporadic innovators (d)	Sporadic innovators (d)/(a)*100 (e)	Difference (c)-(e) (f)
	Count	*Count*	*Per cent*	*Count*	*Per cent*	*Per cent*
Construction	23	0	0	1	0	0
Post and telecommunications	14	3	21	3	21	0
Real estate activities	5	0	0	0	0	0
Transport services	46	0	0	6	13	-13
Food, beverages and tobacco	35	1	3	6	17	-14
Communications equipment and scientific instruments	61	17	28	26	43	-15
Metal products, except machinery and equipment	67	3	4	15	22	-18
Non-metallic products	54	5	9	15	28	-19
Other business activities	74	10	14	24	32	-19
Electricity, gas and water supply	14	0	0	3	21	-21
Machinery and equipment	73	11	15	27	37	-22
Mining and quarrying	9	0	0	2	22	-22
Manufacturing n.e.c. and recycling	40	2	5	11	28	-23
Wholesale trade	50	2	4	14	28	-24
Textiles, textile products, leather, footwear	33	2	6	10	30	-24
Finance and insurance	37	2	5	11	30	-24
Chemicals, pharmaceuticals, coke and refined petroleum	28	5	18	12	43	-25
Publishing, printing, paper products and wood	79	1	1	23	29	-28
Transport equipment	44	3	7	16	36	-30
Total	786	67	9	225	29	-20

Table 6: In-house R&D

Industry	Number of observations	Sustained innovators		Sporadic innovators		Difference
			(b)/(a)*100		(d)/(a)*100	(c)-(e)
	(a)	(b)	(c)	(d)	(e)	(f)
	Count	*Count*	*Per cent*	*Count*	*Per cent*	*Per cent*
Food, beverages and tobacco	35	9	26	8	23	3
Construction	23	1	0	0	0	0
Real estate activities	5	0	0	1	0	0
Wholesale trade	50	4	8	5	10	-2
Other business activities	74	10	14	18	24	-11
Transport services	46	0	0	5	11	-11
Mining and quarrying	9	0	0	1	11	-11
Finance and insurance	37	2	5	7	19	-14
Non-metallic products	54	10	19	19	35	-17
Textiles, textile products, leather, footwear	33	3	9	9	27	-18
Machinery and equipment	73	18	25	32	44	-19
Manufacturing n.e.c. and recycling	40	4	10	12	30	-20
Publishing, printing, paper products and wood	79	3	4	20	25	-22
Metal products, except machinery and equipment	67	2	3	18	27	-24
Chemicals, pharmaceuticals, coke and refined petroleum	28	9	32	16	57	-25
Transport equipment	44	7	16	18	41	-25
Post and telecommunications	14	0	0	4	29	-29
Electricity, gas and water supply	14	1	7	6	43	-36
Communications equipment and scientific instruments	61	9	15	32	52	-38
Total	786	92	12	231	29	-18

Appendix 2

Collinearity statistics of the predictor variables in models 1-6 in section 8 of this paper, using the example product innovation (model 2): *VIF and tolerance statistics*

	Collinearity Statistics Tolerance	VIF
OPP1	.805	1.242
OPP2	.948	1.054
APP1	.696	1.436
APP2	.785	1.274
CUM	.830	1.205
KB1	.798	1.253
KB2	.785	1.275
Size	.901	1.110

a Dependent Variable: Dummy sustained product innovation

If the largest VIF is greater than 10 then there is cause for concern and if the average VIF is substantially greater than 1 then the regression may be biased (Bowerman and O'Connell 1990). A tolerance below 0.1 indicates a serious problem and a tolerance below 0.2 a potential problem (Field 2000). For our model the VIF values are all well below 10 and the tolerance statistics is well above 0.2. Therefore we can assume that there is no problem arising from collinearity in our data.