INTELLECTUAL PROPERTY OFFICE

Patent Incentives

Returns to Patenting and the Inducement for Research & Development (R&D)*

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Executive Summary

The UK has one of the oldest and best regarded intellectual property rights (IPR) regimes in the world. Yet there is little evidence on private returns to patenting for firms operating in the UK, and on the incentive effects of patenting in encouraging R&D investment in patenting firms. Using available data from the UK innovation survey (known as the Community Innovation Survey or CIS) and linked business performance data the report assesses both the additional returns firms achieve by patenting, and the effects on R&D spending.

This report tests an economic model built upon the following intuition. The monopoly power conferred by a patent provides a firm a price premium in new product revenue, thus increasing profitability. At the same time this increased profitability also acts as an inducement to increase R&D spending by the firm. Using this idea we try to jointly estimate the extent of the premium and the inducement to R&D. In this way the research builds and extends work in two literature streams, viz. the economic literature on the value of patents and the literature on effect of patents on R&D expenditures.

The analysis uses two approaches derived from Arora et al. (2008) for estimating the patent premium. The first approach relates innovation survey data on new product revenues to R&D investments and measures of patent effectiveness (self assessed by businesses). It then measures the incremental revenue (from new products) earned by a firm that can be attributed to patent protection. We term this the *revenue patent premium.* The second approach estimates what we call the *profit premium* (the additional profitability on account of patent protection) and the inducement to invest in R&D due to patent protection by building a model of profits generated by innovative products that are patented.

To make the assessment empirically requires estimates of:

- The value of new product / service revenue firms achieve and their R&D expenditure (from the innovation survey);
- The effectiveness of patents in exploiting each firms technology in its market (self assessed within the innovation survey);
- The ‘propensity to patent’ a term used to capture the proportion of innovations which firms choose to patent. Data on this are currently unavailable for the UK and we were forced to rely on imputation from the US CMU surveys to establish a range for the patent propensity. Thus, we could make only broad predictions (within a range) on the extent of premium and the inducement for R&D.

The UK innovation survey data shows support for the theoretical model. Patent premiums for UK are positive, and in the case of larger firms, comparable to the premia demonstrated in similar US studies. Furthermore, the prospect of patent protection provides inducement for R&D. The extent of the patent premium and inducement to R&D varies by type of firm and industrial sector.

There were some variation in estimates when we grouped firms by size and industrial sector. The premia estimated, in terms of additional returns to R&D associated with patents, are less pronounced for smaller firms, and for firms outside the biotech and pharma industries. In computers and equipment, and in instruments, the premium is around half the biotech level. The premium and incentive effects appear to apply equally to younger and older firms, suggesting the patents can be as great an incentive to new innovators as to established businesses. These broad conclusions suggest that the role and importance of patents varies considerably across industries, and a 'one size fits all' approach may not be appropriate.

There is also some evidence that the increasing numbers of service businesses in the most recent innovation surveys have led to some drop-off in patent premia and incentive effects. To the extent that all service firms are not persistent R&D performers this result is unsurprising. At present there is insufficient data to look separately at impact by business size and by sector at the same time.

Introduction

The UK has one of the oldest intellectual property rights (IPR) regimes in the world and yet policy makers and Intellectual Property Office (IPO) officials would be hard pressed to say what exactly the private returns to patenting are for firms operating in the UK. As more and more countries around the world embrace stronger IPR regimes, precise estimates of the returns to patenting and comparison of these benefits with the costs incurred in the enforcement of patents are likely to become important as an evidence base for policy evaluation.

In this report, we argue that patenting allows firms a price premium in new product revenue thus increasing profitability. At the same time this increased profitability acts as an inducement to R&D expenditures made by the firm. Thus, we contribute to two literature streams viz. the literature on the value of patents and the literature on the effect of patents on R&D expenditures.

Our analysis employs two approaches derived from Arora et al. (2008) to the estimation of a patent premium. The first approach relates Community Innovation Survey (CIS) data on new product revenues to R&D investments and measures of patent effectiveness and measures the incremental revenue (from new products) earned by a firm that can be attributed to patent protection. We term this the *revenue patent premium.* The second approach estimates the profit premium (the additional profitability on account of patent protection) and the inducement to invest in R&D due to patent protection by building a model of profits generated by innovative products that are patented.

Using the UK CIS data we find support for our theoretical model. Patent premiums are positive and the prospect of patent protection provides inducement for R&D. The extent of premium and inducement to R&D varies by type of firm and industrial sector - in particular, large firms and firms in the pharmaceutical and biotech sector have larger patent premiums.

Literature review

2.1 Measuring patent value

Arora, Athreye and Huang (2010) identify three mainstream approaches to estimating patent value: the market value approach, the patent renewal approach and the inventor survey approach.[1] The market value approach uses stock market values and the implicit the evaluation of the investor of the value of the firm's tangible and intangible capital stock (including patent stocks). The patent renewal approach on the other hand analyses patent renewal records and the associated costs of patenting and renewing in order to assess the distribution of earnings from patents from the perspective of the patent holder. Although what is measured is different we expect these two measures to be related. A valuable patent enhances a firm's profitability. This being the case, stock market investors will also value the firm higher than other firms who do not hold the patent. In a perfectly competitive market it should be possible to derive one measure from the other.

A key limitation of the renewal method is that the truly valuable patents, which are renewed to full term, cannot be accurately valued. Furthermore, the earlier studies did not link patents to firms, and therefore, could not relate patent protection to R&D.[2] In addition, patent renewal studies assume independence across patent values, an assumption at odds with the finding that commercially valuable inventions are often protected by a group of related patents. Finally, the reported values of patents in the earlier studies are so small as to be inconsistent with the legal and administrative costs of obtaining patents although more recent studies (e.g., Deng, 2007) do report higher values.

The inventor survey approach is very different from the market value and patent renewal approaches in that it represents a subjective evaluation (by the inventor) of the value of his/her invention. The great merit of this approach has been to provide data on how patents are used. For instance, these surveys show that a very substantial proportion of patents held by large firms are actually 'blocking' patents. At the same time these data show that smaller firms have a greater propensity to license patents that they take out. So the real challenge of the patent system is how to make it work for smaller firms and universities and thereby derive greater social value.

1 Their review found that 35 of 47 papers used one of these three methodologies. The Market value approach is the oldest and 19 papers used this methodology or a variant of it. There were 11 studies that used the patent renewal approach and 5 relatively recent studies have used the Inventor survey approach. See Arora, Athreye and Huang (2010) for further details.

2 Schankerman (1988) did use estimates of patent value from French data to infer that the implicit subsidy to R&D from patent protection amounted to 25% of R&D, which is related to the notion of a patent premium. However, to guide policy, one must understand not only the value of patent protection but also how R&D investments would change in response to changes in patent protection.

Though the estimates of patent value obtained through the three methods are comparable in principle, they vary greatly in scale. Arora, Athreye and Huang (2010) note there is in fact a wide discrepancy in estimates of returns to a patent as measured under the three main approaches. Studies using the renewal approach find the smallest returns to patenting, ranging from thousands to tens of thousands of US dollars; the value estimated by market value approach is around hundreds of thousands of US dollars; and the inventor survey approach has the largest point estimates of patent value at over a million US dollars. It should be pointed out that the inventor surveys typically focus on “important” patents. For instance, the Patval survey focused on “triadic” patents: inventions for which patents were filed in the US, Japan and Europe.

Studies that focus on the value of patenting for UK firms are sparse. Using the patent renewal approach and based on an analysis of patents filed between 1950-79, Pakes (1986) and Schankerman and Pakes (1986) reported median estimates of UK patent value (in US$2005) are $3,897 per patent while mean values are $14,580 per patent. The PatVal survey included data on 1542 patent applications by UK inventors to the EPO distributed across 29 technology classes. Over 40% of all patents reported a value of between 100 and1000 million euros. The dominant technology classes in terms of value are chemical and petrol; basic materials chemistry; macromolecular chemistry & polymers; analysis, measurement & control technology; nuclear engineering; machine tools and pharmaceuticals and cosmetics.

A striking feature of the PatVal data for the UK is that 12 patent applications accounted for very high values – together they amounted to roughly 36-42% of all value. These 12 values may of course be outliers of some sort but it is worth noting a similar finding in the Bloom and Van Reenan (2000) study which used the market value approach. The authors also noted that 12 firms accounted for 72% of the UK patent count held at the United States Patent and Trade Mark Office (USPTO).

While all three approaches to deriving patent value emphasise the positive returns from patenting and the differences in these returns across technological sectors, they do not directly model the fact that patenting allows the inventor/inventing firm to charge higher prices for the patented innovation, and this by itself can result in higher revenues and profits.

2.2 Patent protection and the inducement for R&D

Although the prospect of greater exclusivity in the market (due to patent protection) should induce investment in innovation, the literature on the inducement for R&D that patent protection provides has yielded mixed findings.

Horstmann et al. (1985) argue that the costs of disclosure that patents require may offset the prospective gains (cf. Further, the effect of “stronger” patents on firms’ incentives to innovate is not obvious since “stronger” patents may mean that rivals will also benefit (cf. Jaffe 2000; Gallini 2002). Moreover, when innovations build upon earlier ones, Merges and Nelson (1990) and Scotchmer (1991) argue that broad patents may slow the rate of technical change.

Prior empirical work(largely survey-based) has often found patents to be of limited importance (c.f., Scherer et al. 1959; Taylor and Silberston, 1973). Mansfield (1986), based on a survey of 100 respondents for 1981-83, found that other than pharmaceutical and chemicals firms only a few inventions would not have been developed in the absence of patents. On the other hand, Cockburn and Henderson (2003), based on a survey of IP managers from 66 leading firms in the US, report that well over half of their respondents agreed with the statement that their R&D spending would significantly decline without patent protection.

Levin et al. (1987) and, more recently, Cohen et al. (2000), do not directly ask about the impact on R&D, but do report that in most industries patents are viewed as less important in protecting rents from innovation than first mover advantages or secrecy. Indeed Moser (2005) analyses invention records from two World's Fairs in the second half of the 19th century, and finds that in those industries where patent protection was not readily available, inventors tended to focus their effort on technologies where other means of protection were available. However, though patents may be less important than first mover advantage, it is patents that are the subject of public policy, not first mover advantage. Moreover, patents do not preclude first mover advantage (though they might compromise secrecy), and thus it is important to understand the incentives that patent protection provides for R&D.

A similar mixed picture emerges from the econometric findings reported in the literature. Studies using aggregate cross-national data have found a positive and significant effect (Eaton and Kortum 1999, Kanwar and Evenson 2003, and Lederman and Maloney 2003). On the other hand, based on his examination of the impact of 177 policy changes on innovation over 150 years, across sixty countries, Lerner (2002) concludes that strengthening patent protection does not seem to encourage patenting by domestic firms.

A key problem is that national level patent policy changes may be measured very coarsely. Sakakibara and Branstetter (2001) exploit the change in patent policy in Japan allowing patents with multiple claims (which they interpret as a reduction in the cost of patenting) and find only a small positive effect of on R&D investments. However, since building productive R&D programmes can take time, enhanced patent protection may not result in an immediate increase in R&D investment.

2.3 Approach followed in this report

We rely upon differences in reported patent effectiveness, matched to the R&D investments firms made and the profits they reported to identify the effect of patent protection on profits and the inducement for R&D. To tie them together, we develop a simple structural model that allows us to estimate jointly the relationship between patent protection and profitability as well as that between R&D investments and patent protection. In this sense, our paper touches on the literature linking R&D to patent production by firms (e.g. Pakes and Griliches, 1984). We do not estimate a patent (or innovation) production function, although one is implicit in our equation linking profits to R&D and patent effectiveness.

Our model builds upon the framework developed in Arora, Ceccagnoli and Cohen (2008), in that they too estimate a structural model where patent effectiveness is reflected in R&D investments. However, there are two important differences, which arise from differences in the available data. First, they observe the share of product innovations for which the responding firm had sought patent protection. This measure allows them to relate patent effectiveness directly to patenting propensity. This is significant because patent protection ought to matter for profits only to the extent that the firm patents. Firms with only a small share of innovations protected by patents must derive less benefit from them than firms that patent a larger share of their innovations. For this reason, the share of innovations patented is also directly informative about how valuable patent protection is to the firm, and by extension, how patent protection will encourage the firm to invest in R&D.

The CIS does not ask about the share of innovations protected by patents. However, we are able to obtain a direct measure of profits. Thus, unlike Arora et al. (2008), who must rely only on the relationship between patents and R&D to infer the value of patent protection, we are able to estimate this relationship directly, in addition to estimating the relationship between patent effectiveness and R&D. In addition, we use the results reported in Arora et al. (2008) to develop an estimate of how patent propensity varies with changes in patent effectiveness. Assuming that a similar relationship holds for UK firms allows us to estimate both the increment to profits due to patent protection, as well as the inducement to R&D from patent protection.

3. Patents, profits and the inducement for R&D - two models

Two main ideas underpin our structural models developed in the sections below. The first is that the monopoly power conferred by a patent allows the inventor/firm to charge a higher price for the *new products* developed through innovation. Secondly, we think about R&D as the cost of innovation and innovation as the outcome of R&D. This idea is integral to any argument that links patenting with higher R&D. If patenting increases the returns from innovation, then firms undertaking innovation will factor these returns into their decisions about R&D outlay.

3.1 New product revenue (NPR) and the patent revenue premium

Patents increase the revenue that a new product will earn (relative to without a patent). Let this increment in revenue δ be termed the patent revenue premium. New product revenue from innovation thus depends upon two factors: the extent of the patent premium and the percentage of new products that are patented (patent propensity). Patent propensity multiplies the patent premium because the benefits of patent protection accrue only to patented products. Thus, the greater the share of products that are patented (i.e, the greater is the patent propensity), the greater the impact on revenues of any given level of patent protection.

As we know innovation can take the form of process innovations (which improve productivity) and product innovation where pricing plays a more direct role in generating higher revenues and profitability. Thus, this part of our analysis has little to say about process innovation unless that also resulted in new product development.

Following Arora et al. (2008), we specify a model (derived in appendix A) that relates the log of new product revenue (npr_i) to the log of in-house R&D expenditures (R_i), characteristics of the firm (represented by Z_i), and finally, the patent premium δ multiplied by patent propensity, Φ_i:

$$npr_i = A + b_1 \ln(R_i) + \ln(1 + \delta\Phi_i) + b_3 Z_i + \varepsilon_i \quad (1)$$

However, unlike the Carnegie Mellon University (CMU) data used in the Arora et al(2008) paper, which report the total number of innovations and the proportion that are patented (hereafter the patent propensity), the CIS asks firms only if they innovated and how much they earned from innovation. In other words, CIS does not report the proportion of innovations that is patented.

To estimate the model, we therefore assume a linear relationship between perceived patent effectiveness, x_i, and patent propensity (Φ_i). Specifically, we assume that

$$\Phi_i = a_1 x_{1i},\ a_1 > 0 \quad (2)$$

where x_1 is perceived patent effectiveness of the reporting unit, scaled from 0 to 3.

Assuming $\ln(1 + \delta\Phi_i)$ can be approximated as $\delta\Phi_{i,}$ we can rewrite (1) as

$$npr_i = A + B_1 \ln(R_i) + B_2\, x + B_3 Z_i + e \quad (3)$$

where

$$B_2 = a_1\delta,\ \text{or}\ \delta = B_2 / a_1 \quad (4)$$

As we have no measure for Φ_i, we estimate the compound coefficient $a_1\delta$. At different levels of a_1, we can infer the implied patent premium δ.

3.2 Profits, the patent premium and the inducement for R&D

The second method uses a different definition and estimates of the patent premium, using the accounting data on profits (gross operating surplus) as a dependent variable. The intuition behind this model is that firms invest in R&D in order to generate innovations. If patent protection is strong then firms might respond by patenting a larger proportion of their innovations. This increases profitability from innovation because patented innovations earn a higher profit per unit – this is formalised in equation (6) below. At the same time, higher profits from innovations will stimulate spending on innovation and thus act as a stimulus for R&D - this is formalised in equation (7) below.

We can write total profits of a firm *i* as (we suppress the firm subscript for convenience):

$$Y - R = Q\pi(R)(1 - f + (1+\gamma)\Phi) - R \quad (5)$$

where Y = profits gross of R&D expenses, π(R) is the profit per unit of output in the absence of patent protection (in essence, equal to the average price cost margin), and Q is the total output. As before, Φ is the share of the focal firm's products and services that are covered by patents and 1+γ is the patent premium, which, unlike in model 1, is defined as the incremental profits from all products and services due to patent protection. We assume that Π(R) is linear in logs, i.e. it is a Cobb-Douglas function. Assuming firms choose their R&D investments to maximise returns, so that actual profits and R&D are jointly determined by underlying firm and industry characteristics (denoted by X), the estimating equations become:

$$LnR = C_1 + \Sigma X_j \lambda_j + \beta Ln(1+ \Phi\gamma) \quad (6)$$

$$LnY = C_2 + \Sigma X_j \theta_j + (\alpha)LnR + Ln(1+ \Phi\gamma) \quad (7)$$

where $\lambda_j = \beta\theta_j$ and $\beta = 1/(1-\alpha)$, i.e. cross equation constraints derived in Appendix A, and where C_1, C_2 are vectors of intercept terms in equations (6) and (7) respectively, λ_j is a vector of unknown coefficients of the exogenous variables in equation (6), θ_j is a vector of unknown coefficients of the exogenous variables in equation (7), X_i is a vector of exogenous variables (controls) in both equations; R_j is in-house R&D expenditure. In order to estimate this system, we need an "instrument" for R&D, i.e. a variable that affects R&D but does not directly affect profits. We use lagged values of R&D for this purpose.

As before, we do not observe patent propensity Φ and therefore posit that it is a function of reported patent effectiveness, x_1, as given in (2). The system of equations to be estimated is:

$$LnR = C_1 + \Sigma X_j \lambda_j + \beta Ln(1+ a_1 x_1 \gamma) \quad (6')$$

$$Ln Y = C_2 + \Sigma X_j \theta_j + (\alpha)LnR + Ln(1+ a_1 x_1 \gamma) \quad (7')$$

subject to $\lambda_j = \beta\theta_j$ and $\beta = 1/(1-\alpha)$; where x_1 is patent effectiveness of the reporting unit, scaled from 0 to 3;

Note that (7) is very similar to (1). However, by estimating (6) and (7) together we accomplish two objectives. Firstly, we improve the efficiency of the estimate, because parameters are shared between the two equations. Secondly, because we have linearised the model for estimation, we are able to estimate the implied elasticity of R&D due to patent protection (E_R) by computing the product β (a_1 γ).[3]

Please see Appendix A for the formal derivation of the two equations.

3 For a non-linear model, E_R would not be constant. Instead it would be calculated for the three ranges of patent effectiveness (x_1) viz. 0-1, 1-2 and 2-3 as:

For x_1 **from 0-1:** $E_R = \beta\,[\ln(1+ 1\,a_1\,\gamma) - \ln(1+ 0\,a_1\,\gamma)] = \beta\,[\ln(1+ 1\,a_1\,\gamma)]$ (8)

For x_1 **from 1-2:** $E_R = \beta\,[\ln(1+ 2\,a_1\,\gamma) - \ln(1+ 1\,a_1\,\gamma)]$ (8')

For x_1 **from 2-3:** $E_R = \beta\,[\ln(1+ 3\,a_1\,\gamma) - \ln(1+ 2\,a_1\,\gamma)]$ (8'')

4. Data sources, variable description and econometric issues

We exploited the availability of matched micro-data at reporting unit level at the Virtual Micro Laboratory of the ONS to estimate the two structural models. In our analysis we drew upon data in the CIS, the profits data in the Annual Respondent Database (ARD) and the R&D data in the Business Enterprise Research and Development (BERD) surveys.[4]

Our main data source was the CIS. We used the CIS data for information on business characteristics, such as the Standard Industrial Classification (SIC) of the reporting unit, employment and employees, turnover, enterprise group links, and the turnover generated by new products, innovators and non-innovators, and on types of aggregate innovative expenditures and perceptions of patent effectiveness.

The CIS is a voluntary postal survey carried out by ONS. For the survey, the ONS randomly selects a stratified sample of firms with more than 10 employees, drawn from the Inter-Departmental Business Register (IDBR) by SIC92 two-digit class and 8 employment size bands. ONS surveys tend to account for the majority of large sized businesses (for these have a greater economic impact), and then select a number of small and medium sized businesses sampled by industry and geographical region. To date there have been 5 rounds of CIS in the UK but in this report we only include data for CIS3, 4 and 5. The panel element of the CIS data sets is small except for the most recent CIS5 & 6 when large firms have been re-sampled.

CIS3 covers the period 1998-2000 and had 8,172 responses (a response rate of 42%). The survey covers both the production sectors (manufacturing, mining, electricity, gas and water, construction) and the service sectors. The retail sector has been excluded from the survey as this one has been a poor responder in previous surveys and, generally, has shown very little innovation. CIS4 covers the period 1998-2000 and is a larger survey than its predecessor. It was sent to 28,000 UK enterprises with a 58% response rate. The CIS4 survey also included the following sectors: sale, maintenance & repair of motor vehicles; retail trade, hotels and restaurants, which had not been included in CIS3. This was a new set of sectors due to the increase in the sampling size and better coverage. The latest CIS surveys were undertaken in 2007 (CIS5) and 2009 (CIS6). We included CIS5, as its sampling frame was quite similar to that of CIS4 and the coverage of questions was similar. We excluded CIS6 as it did not have a comparable question on patent effectiveness which was crucial for our analysis.

We estimate the structural models detailed in the previous section separately for the CIS3, 4 and 5 rounds because only a few firms feature in more than one panel. We imported the gross operating surplus (GOS) for reporting units in the CIS from the ARD database to estimate Model 2. Since the ARD data are annual data we took period averages to match the CIS variables. For example, the average GOS over 1997-2000 was used with CIS3 variables to estimate model 2 for the CIS3 wave of firms. We were able to match 4276 observations in CIS3 to ARD, 8700 observations in CIS4 and 4551 observations for CIS5. Table 1 below shows, for both models, the list of variables used, the source of data for each variable and the way the variable was constructed.

4 The Stata files used for matching the datasets are available from the author on request.

R&D expenditures (R) are endogenous in our model because R&D expenditures will depend upon unobserved firm specific differences in price and quantity. Put differently, demand shocks (which affect p and q) will also affect R. This can be easily seen by writing p = mp+ e, where mp is the average (across firms) price and e is a firm-specific component of price. All else being equal, the higher the value of e, the higher will be the value of R. Endogeneity of parameters creates a bias in the value of the estimated parameter. One solution is to instrument for R.

We instrument for in-house R&D expenditure in the innovation equation using fourth lagged value of R&D (using the third lagged value of R&D expenditure if the fourth lag is not available). R&D expenditure data were taken from the BERD surveys. We could have used R&D expenditure form the CIS which reports R&D expenditures at the responding unit level (or establishment level). Our reasoning was that in many firms, R&D is centralized at the firm level, with individual business units drawing upon the new knowledge created. This is especially true for research rather than development, which may be decentralized to a greater extent. Moreover, the extent to which the relevant R&D is conducted by the business unit varies across firms.

Using the BERD data to instrument R&D is also a consequence of the limited panel nature of the CIS. The BERD survey matches the CIS poorly and greatly reduced the number of firms from the CIS survey that we are able to use in estimation. More importantly, it also changes the sample properties (See Table 2 below). The instrumented sample consists of persistent R&D performers and contains a greater proportion of larger firms than the original CIS sample.

We experimented with other instruments for in-house R&D expenditure, such as ‘co-operation with overseas universities or other higher education institutions overseas’ and ‘proportion of enterprise’s employees educated to degree level in science and engineering using the CIS questionnaire itself. However, it is likely that these variables are themselves determined by similar unobserved factors that determine R&D. Accordingly we do not feature those results.

Lastly, we note both our models are non-linear. We linearise the equation (1) by assuming that $\ln(1 + \delta\Phi i) \sim \delta\Phi i$ and estimate both an OLS and a 2SLS version of the model. However, in the case of equation (6) and (7) (Model 2) we report the estimates based on GMM estimation.

Table 1: Variables used in the study

	Variable name	Source of the data	Measure description and construction
Dependent variables	New product revenue (npr) in £000	CIS 3, 4 & 5 (q810, q2420)	NPR is obtained by multiplying firm's share of products introduced that were new to firm's market by the firm's turnover. Measure included was ln(1+NPR)
	Gross operating surplus (GOS) in £000	ARD2	GOS is reported in ARD2 and we included ln(1+GOS)
Endogenous variable	R&D expenditure (R) in £000	BERD (mean R&D over the years corresponding to each CIS wave)	We use the mean R&D expenditures corresponding to the years covered by each CIS. This is 1997-2000 for CIS3, 2001-2004 for CIS4 and 2005-2006 for CIS5. We use the transformed measure ln (1+R)
Exogenous variables	Patent effectiveness (x), scale 0-3	CIS 3, 4 & 5 (q2130)	Reported the importance to enterprise of patents as a method to protect innovations. There are four mutually exclusive responses (0 - Not used; 1-Low; 2 - Medium; 3 - High).
	Firm size	CIS 3, 4 & 5 (q2520)	Natural log of the total number of employees
	Herfindahl index (HF Index) from 0-1	BSD (1997-2006)	Defined as the sum of the squares of the market shares of the reporting units within 4-digit SIC sectors, where the market shares are expressed as fractions. High values of the HF index denote concentration
	Global	CIS 4 & 5 (q230, q240)	Dummy variable=1 if the enterprise sells goods and/or services overseas (Other Europe and all other countries except the UK).
	Public	BSD (1997-2006)	Dummy variable=1 if the enterprise is a publicly traded company.
	Foreign	BSD (1997-2006)	Dummy variable=1 if the parent firm is located abroad (USA or other).
	Cooperation	CIS 3, 4 & 5 (q1861, q1862, q1871, q1872)	Dummy variable=1 if the co-operation partner (e.g. Universities or other higher education institutions; Government or public research institutes) is located locally/ regionally within the UK or a partner is a UK national. Reporting unit level
Instruments for R&D expenditures	Lagged R&D - $R\&D_{t-4}$ (in £000)	BERD (1997-2006)	Total intramural (in-house) R&D expenditure. We used the fourth lagged value of an enterprise's R&D expenditure, then computed $\ln(1+R\&D_{t-4})$ the natural logarithm.

Table 2: Descriptive statistics for the CIS and CIS/BERD sample

		CIS sample			Sample for which R&D lagged is available		
CIS 3	Variable name	Observations	Mean	Standard Deviation.	Observations	Mean	Standard Deviation.
	npr, log	6340	1.04	3.31	515	3.33	5.44
	npr, %	6451	1.92	10.02	519	5.03	14.84
	GOS, 000£	4276	3750.76	27409.49	410	11727.8	47718.88
	GOS, log	4268	6.12	1.84	410	7.50	1.88
	X	4276	0.32	0.83	527	1.27	1.32
	R, £000 (from CIS)	4276	81.87	1254.95	527	739.22	3158.89
	R, £000 (mean R&D, BERD)	-	-	-	527	1883.55	7053.01
	R, log	4276	0.45	1.46	527	5.63	1.70
	# employees	4248	174.65	447.90	522	426.5	856.03
	employees, log	4248	4.05	1.39	522	5.18	1.31
	Global	-	-	-	-	-	-
	Public	4276	0.86	0.35	527	0.99	0.08
	Foreign	4276	0.06	0.24	527	0.19	0.39
	cooperation	4276	0.04	0.20	527	0.20	0.40
	R&D lagged , log	-	-	-	527	5.38	1.85

CIS 4	npr, log	16085	1.53	3.91	1109	5.04	5.96
	npr, %	16090	2.66	10.64	1110	8.29	17.64
	GOS, 000£	8700	8108.18	60214.79	772	14162.05	98760.07
	GOS, log	8666	6.49	2.05	772	7.59	1.86
	X	8700	0.46	0.93	1111	1.50	1.29
	R, £000 (from CIS)	8700	172.07	1834.76	1111	1065.8	4117.72
	R, £000 (mean R&D, BERD)	-	-	-	1111	3245.57	22505.1
	R, log	8700	1.07	2.03	1111	5.81	1.76
	# employees	8698	365.36	1827.86	1110	329.21	671.0
	employees, log	8698	4.02	2.05	1110	4.72	1.72
	Global	8700	0.22	0.41	1111	0.62	0.49
	Public	8700	0.87	0.34	1111	0.98	0.13
	Foreign	8700	0.12	0.32	1111	0.25	0.43
	cooperation	8700	0.07	0.26	1111	0.25	0.43
	R&D lagged , log	-	-	-	1111	5.58	1.89
CIS 5	npr, log	4248	3.79	5.39	1205	6.36	5.86
	npr, %	4249	5.57	13.86	1205	9.49	18.14
	GOS, 000£	4551	25667.73	72556.64	1232	17037.43	92568.69
	GOS, log	4537	7.11	2.14	1232	7.57	2.04
	X	4551	0.62	1.07	2608	1.04	1.27
	R, £000 (from CIS)	4551	217.26	1987.74	2608	584.66	4892.88
	R, £000 (mean R&D, BERD)				2608	1844.39	23204.5
	R, log	4551	1.22	2.19	2608	4.46	1.94
	# employees	4547	504.46	1988.60	2595	256.78	680.21
	employees, log	4547	4.57	2.06	2595	4.22	1.71
	Global	4551	0.25	0.43	2608	0.43	0.49
	Public	4551	0.92	0.28	2608	0.93	0.25
	Foreign	4551	0.53	0.50	2608	0.54	0.50
	cooperation	4551	0.06	0.24	2608	0.13	0.34
	R&D lagged, log	-	-	-	1031	5.45	2.00

Note: All variables used in the study are at the reporting unit level
(Source: ONS)

5. Effective patent protection and incomes from innovation - some descriptive analysis

IP protection enhances three kinds of potential revenues that firms can earn from their innovative activities. Firstly, firms can earn higher revenues and profits from existing products protected by IP. Secondly, IP protection may encourage firms to develop and market innovative products for which customers are willing to pay more, resulting in higher revenues to the firm. Lastly, firms can license their innovations (nationally and internationally) if their innovations are adequately backed by patents.

Data from the Community Innovation Surveys allow us to assess how these incomes vary according to the perceived effectiveness of patents. Table 3 shows the distribution of revenue from products that were new to a firm's market (NPR) across firms. The period of time covered is 1997-2006, which is split up by CIS3 (1997-2000), CIS4 (2001-2004) and CIS5 (2005-2006) samples.

Table 3: NPR and patent effectiveness (by CIS samples)

	CIS3			CIS4			CIS5		
	Number of reporting units	Mean, mill. £	standard deviation, mill. £	Number of reporting units	Mean, mill. £	standard deviation, mill. £	Number of reporting units	Mean, mill. £	Standard deviation mill. £
Patents not used	5425	47.50	1095.35	12833	94.48	4935.42	2951	61.93	636.26
The importance of patents is low	248	169.04	1339.10	1179	241.53	3935.35	404	256.32	1123.97
The importance of patents is medium	261	108.09	4510.79	923	776.62	10000.60	273	400.22	1758.30
The importance of patents is high	404	228.77	1040.78	1148	451.03	3730.84	618	1539.45	9706.62

Our table shows that a majority of CIS respondents said they did not use patent protection but some of these respondents appear to have reported some NPR. The mean of NPR is clearly higher for the firms which used patents, with the highest values reported by those who rate patent protection importance as medium (CIS4) or high (CIS3 and CIS5). This provides some initial evidence that price premiums due to patenting may be important in the UK economy. The large standard deviations however point to a high variability possibly due to the type of firm (large or small and young or old) and the industrial sectors they operate in and underscore the limited usefulness of the mean value.

Table 4 below reports the operating profit of firms by patent effectiveness. Since we constructed this table by matching CIS to the ARD2 data that contain information on gross value added, the number of firms in each column differs from that in Table 1.

Table 4: Gross operating surplus and patent effectiveness (CIS / ARD2 surveys)

	CIS3			CIS4			CIS5		
	Number of reporting units	Mean, mill. £	standard deviation, mill. £	Number of reporting units	Mean, mill. £	Standard deviation, mill. £	Number of reporting units	Mean, mill. £	standard deviation mill. £
Patents not used	3630	3.123	27.153	6729	6.433	57.630	3225	27.355	858.802
The importance of patents is low	180	5.726	19.800	697	12.647	52.069	439	16.362	81.236
The importance of patents is medium	193	10.890	4.659	559	13.451	63.212	301	26.739	181.640
The importance of patents is high	273	5.742	11.509	715	15.264	83.623	586	22.798	89.120

The mean value of the gross operating surplus for firms that use patent protection is higher than that for those that do not (although results for CIS3 and CIS5 suggest that the relationship between degree of rated importance of patents and size of gross operating surplus is not monotonic). This provides initial evidence that patent protection is related to the profitability of the UK firms.

6. Estimating new product revenue from innovation and the patent premium

Appendix Table B2 shows the estimation results of the equation (1). For each CIS round we report the Ordinary Least Squares (OLS) results and Two-Stage Least-Squares (2SLS) results with 4th (or 3rd) lagged value of R&D as an instrument for one digit sectors. We also estimated the models using two digit sector controls but have not reported them in the appendix as the results were not very different. The range of a1d is between 0.49-0.91 and is statistically significant for all the three CIS waves.

These results from estimating Model 1 suggest that one unit increase in patent effectiveness is associated with an increase in NPR of between 49% and 91% (depending upon which CIS round we use for coefficient values). Based on this information we can infer the implied increment to new product revenue due to patent protection as follows. In the CMU survey, average patent propensity is 28%, and for firms that do patent, patent propensity is 43%. Further, in the CMU measure, the patent effectiveness classes are defined as the share of innovations for which patents are effective in protecting the firm's competitive advantage from innovation: less than 10%, 10-40%, 41-60%, 61-90%, over 90%. This suggests, and estimates in Arora et al. (2008) confirm, that classes 4 and 5 are very similar in terms of the implied behaviour of the firm. Thus, the CMU survey effectively only has 4 patent effectiveness classes, comparable to those in the CIS.

Arora et al. (2008: fig 3) report that moving from the lowest patent effectiveness class to the second class increases patent propensity from about 10% to about 30%, the next move increases patent propensity to about 50%, the move from the third to the fourth class increases it to about 55%, and the move from the fourth to the fifth class leaves patent propensity largely unchanged. This implies that the average effect of increasing patent effectiveness from one class to the next, after weighting by the share of each class in the sample, is about 15%, i.e. $a_1 = 0.15$.

A second estimate of a_1 can be obtained using the reported elasticity of 0.6 of patenting propensity with respect to patent effectiveness (measured as a continuous variable using the mid-points of the patent effectiveness classes) in an unpublished working paper by Arora, Ceccagnoli and Cohen (1999). The average patent effectiveness using the mid-points is 32% (which corresponds to patent effectiveness class = 2), a doubling of patent effectiveness is equivalent to moving to the third patent effectiveness class from the second. An elasticity of 0.7 (evaluated at the mean patent propensity for firms that patent, of 43%) implies an increase in the patent propensity of 0.7 x 0.43 = 0.30. Thus, estimates of a_1 range from a low of 0.15 to a high of 0.30.

The patent premium (δ) is simply the estimated coefficient on patent effectiveness divided by a_1. Thus, for a coefficient value of 0.61, δ is 2.0 if $a_1 = 0.30$, but 4.06 if $a_1 = 0.15$. It should be noted that the patent premium resulting from model 1 relates to incremental new product revenues, rather than profits. Existing estimates of the patent premium reported in the literature typically relate to increment to profits rather than increments to new product revenues. Put differently, this estimate combines the direct effect from patents (of being able to exclude competitors and charge higher prices) and the indirect effects of investing in R&D and introducing new products.

Table 5a shows that patent premium varies from 1.63 to 6.06 depending on the estimated coefficient of patent effectiveness (which varies by the specification we use and, more importantly, by the CIS round), as well as the relationship between patent propensity and patent effectiveness. Excluding the extreme values, the implied range of the patent premium for new product revenues is between 1.63 and 3.87.

Table 5a: The patent (revenue) premium at different levels of patent propensity

Wave		CIS3		CIS4		CIS5	
Industry controls		1-digit	2-digit	1-digit	2-digit	1-digit	2-digit
a1δ		0.91	0.85	0.49	0.51	0.58	0.64
Coefficient of patent effectiveness on patent propensity (a1)	0.15	6.06	5.66	3.27	3.40	3.87	4.26
	0.3	3.03	2.83	1.63	1.7	1.93	2.13

Note: Each cell represents the value of the patent premium for propensity given estimate of a_1 the coefficient linking patent effectiveness and patent propensity, and based on coefficient estimates of patent effectiveness. The full estimates of the equations with 1-digit industry controls are reported in Table B2. The estimates with 2-digit controls are available on request.

We consider two split samples – for large and small firms (estimates reported in Table 5b below) and for young and old firms (estimates reported in Table 5c below) across all three CIS waves, there were 610 small firms (defined by employment of 50 employees or less) and 852 large firms (defined by employment of 250 employees or more). In estimating the split sample models we could not include controls for the CIS wave and for SIC at the same time. Thus the reported results control for CIS wave but not for the industry. The coefficient $a_1\delta$ was 0.45 for small firms while for large firms the estimate of $a_1\delta$ was 0.63. The implied patent premiums reported in Table 5b below range from 150% to 420%. Large firms clearly gain larger patent revenue premiums.

Table 5b: The patent (revenue) premium at different levels of patent propensity

(Model 1: split sample)

Firm type		Small (≤50 employees)	Large (>250 employees)
a1δ		0.45	0.63
Coefficient of patent effectiveness on patent propensity (a1)	0.15	3	4.2
	0.3	1.5	2.1

Note: Each cell represents the value of the patent premium for propensity given estimate of a1, the coefficient linking patent effectiveness and patent propensity, and based on coefficient estimates of patent effectiveness reported in Table B3 below.

Looking at the estimates for young and old firms we find again that older firms earn larger patent revenue premiums. The estimated coefficient of a1d is 0.46 for young firms and 0.66 for older firms - both results are statistically significant. The implied patent revenue premium then ranges from 153% to 440% with the premiums being higher for older firms. Again, we should interpret these results carefully as there are no industry controls in the estimation.

Table 5c: The patent (revenue) premium at different levels of patent propensity

(Model 1: split sample)

Firm type		Young (≤10 years)	Old (>10 years)
a1δ		0.46	0.66
Coefficient of patent effectiveness on patent propensity (a1)	0.15	3.07	4.4
	0.3	1.53	2.2

Note: Each cell represents the value of the patent premium for propensity given estimate of $a_{1,}$ the coefficient linking patent effectiveness and patent propensity, and based on coefficient estimates of patent effectiveness reported in Table B4.

We also split the sample by industry group and identified revenue premiums for six technology intensive industry groups, viz. biotechnology and pharmaceuticals, computer and electronic equipment, instruments, machinery and medical instruments.[5] Unfortunately the numbers are small and the choice of lagged R&D as an instrument further restricts our ability to estimate our models corrected for endogenous R for all these sectors. We only report the OLS and 2SLS results for Model 1 in Table B8.

Table 5d: The patent premium at different levels of patent propensity for broad sectors

		biotech	computer & equipment	machinery	instruments	medical instruments
revenue premium (a1δ)		1.32	0.70	0.76	0.37	0.75
coefficient of patent effectiveness on patent propensity (a1)	0.15	8.8	4.7	5.1	2.5	5.0
	0.3	4.4	2.3	2.5	1.2	2.5

Note: Each cell represents the value of the patent premium for propensity given estimate of a_1 the coefficient linking patent effectiveness and patent propensity and based on coefficient estimates of patent effectiveness reported in Tables B8.

The implied patent (revenue) premiums by sector (a_1=0.15, 0.30) based on sector specific estimates of $a_1\delta$ in Table B8 are reported in Table 5d below. The overall range of values reported here is higher than those in Table 5b, suggesting that these technology intensive sectors do gain from patenting. Biotech, Machinery and Medical Instruments show higher revenue premiums than computer and equipment or instruments.

7. Estimating profitability and patent premium

Table B5 shows estimates of the parameter a_1g from the equation (6) in a system of simultaneous equations (6) and (7) – Model 2. We were unable to get estimates for CIS3 at the one digit level because the model did not converge but the value of $a_1\gamma$ is positive and significant for CIS4 and CIS5. It is 0.10 in CIS5 (2005-2006) and 0.096 in CIS4 (2000-2004). As before, we found the estimates with 1-digit and two digit industry controls to be fairly similar and have reported the full estimates only when we use industry controls at the one digit level.

These results from estimating Model 2 suggest that one unit improvement in patent effectiveness is associated with an increase in gross operating surplus of an amount between 7.3% and 10.4% (depending upon which CIS round we use for coefficient values). Based on this information we can simulate the impact of different patent propensities on the patent premium. This is shown in Table 6a below. As in the previous Model 1, we consider two values of a_1. The patent premium (γ) is simply $a_1\gamma$ divided by a_1. Thus, for a coefficient value of 0.096, γ is 0.32 if a_1 = 0.30, but 0.64 if a_1 = 0.15. Table 6a shows that patent premium (γ) varies from 0.32 to 0.67. These estimates are similar to those reported in Arora et al. (2008).

5 The SIC codes corresponding to the industry groupings is as follows: Biotech and pharmaceuticals (SIC 241, 244 &247); Computer and Electronic Equipment(SIC 300, 721,722, 723 & 724); Machinery (SIC 291, 292, 295, 296, 341, 343 & 353); Instruments (SIC 294, 332, 333, 334); Medical instruments (SIC 331) .

They report that an average patent premium for US manufacturing in the early 1990s ranging from 0.67 (medical devices) to 0.38 (food and drink), with an average of about 0.47.[6]

Compared with Table 5a the range of the patent premium in Table 6a is much tighter, as should be the case because Model 2 allows greater precision. However, we caution that the patent premium (γ) estimated here relates to the proportional increment to profit due to patent protection rather than the proportional increment to new product revenue.

Table 6a: The patent (profit) premium at different levels of patent propensity (Model 2)

wave		CIS3	CIS4		CIS5	
industry controls		2-digit	1-digit	2-digit	1-digit	2-digit
a1γ		0.092	0.096	0.104	0.10	0.073
coefficient of patent effectiveness on patent propensity (a_1)	0.15	0.61	0.64	0.69	0.67	0.49
	0.3	0.31	0.32	0.35	0.33	0.24

Note: Each cell represents the value of the patent premium for propensity given estimate of a_1 the coefficient linking patent effectiveness and patent propensity. Coefficient estimates of patent effectiveness are reported in Table B5 with one-digit sector controls.

We split the sample into two and ran the same estimations. Across the three CIS waves there were 330 small firms (<50 employees) and 822 large firms (>250 employees). These results are presented in Table B6. As before we were unable to control for industry and CIS wave at the same time. The estimate $a_1γ$ is 0.11 for small firms and 0.17 for large firms when controlling for which wave of CIS the observation came from. These results from estimating Model 2 suggest that one unit improvement in patent effectiveness increases gross operating surplus of a small firm by 11% and of a large firm by 17% (depending upon which CIS round we use for coefficient values). As before, we simulate the implied patent premium. The Table 6b shows that patent premium varies from 0.37 to 1.13.

We also split our sample into young firms (368 firms aged 10 years or less) and old (1391 firms with age 11 years or more). The estimated results for a_1g are 0.18 for young firms and 0.07 for older firms. The implied profit premiums (derived in Table 6c) indicate that young firms gain more from patent protection than older firms do and the range of premium is between 23% and 120%. It is difficult to interpret this result without controlling for the industrial sectors to which these firms belong.

6 Arora et al (2008) distinguish between the conditional premium i.e. the premium for products that are patented, and the unconditional premium (including the premium that would have been earned by unpatented products had they been patented). Our focus here is on the conditional premium.

Table 6b: The patent (profit) premium at different levels of patent propensity

(Model 2: split sample)

Firm size		Small (<50 employees)	Large (>250 employees)
$a_1\gamma$		0.11	0.17
Coefficient of patent effectiveness on patent propensity (a1)	0.15	0.73	1.13
	0.3	0.37	0.57

Note: Each cell represents the value of the patent premium for propensity given estimate of a_1 the coefficient linking patent effectiveness and patent propensity and based on coefficient estimates of patent effectiveness reported in Table B6 which do not include industry controls.

Table 6c: The patent (profit) premium at different levels of patent propensity

(Model 2: split sample)

Firm age		Young (≤10 years)	Old (>10 years)
$a_1\gamma$		0.18	0.07
Coefficient of patent effectiveness on patent propensity (a1)	0.15	1.2	0.47
	0.3	0.6	0.23

Note: Each cell represents the value of the patent premium for propensity given estimate of a_1, the coefficient linking patent effectiveness and patent propensity. The table is based on coefficient estimates of patent effectiveness reported in Table B7 which do not include industry controls.

8. New product revenue, profits and R&D

The two models we have estimated also link patenting and R&D expenditures. Model 1 allows us to assess the effect of R&D expenditure on NPR. Model 2 allows us to assess the effect of R&D on increase in profits *and* the implied effect of patent effectiveness on R&D. We report on these in turn.

8.1. Elasticity of new product revenue to R&D (Model 1)

The elasticity of new product revenue to R&D (coefficient b_1 from equation (1)) shows the impact of changes in the R&D expenditure on the revenue generated by products that are new to the market. As shown in Table B2, our point estimates for b_1 vary between 0.04 and 0.22 with one digit sector controls. However, when we estimate the same model at the two digit level the R&D coefficient disappears and we get estimated values that are insignificant and close to zero. The Arora et. al. (2008) study of the relationship between returns from innovation and R&D estimated this figure to be 0.66. We should note that the UK estimates relate all R&D by the firm to new products, while Arora et al (2008) relate R&D for innovative products to patentable innovations.

8.2. Elasticity of profits with respect to R&D (Model 2)

Table B5 estimates the parameter α (the elasticity of profits with respect to R&D). From the way the model is derived we expect α to lie between 0 and 1- that is we expect diminishing returns to R&D expenditure. The values of α we estimate are positive, and statistically significant at both one digit and two digit level but they are very sensitive to the definition of industries we use for estimation purposes. They vary from 0.17 CIS3 (two digit) 0.61 (CIS4, two digit estimates). When we split the sample into small and large firms in Table B6, we find α is positive and significant for both small (0.44) and large firms (0.13) although the lack of industry controls makes this difference hard to interpret. In the split sample by age of firm (see Table B7 in the appendix), the value of α is again positive and significant for both young and old firms but the difference is not statistically significant. The elasticity of profits with respect to R&D expenditure is 0.40 for young firms and 0.39 for the older firms.

8.3. The implied elasticity of R&D due to patent protection (Model 2)

The most interesting finding, however, concerns the direct effect of patent effectiveness in inducing R&D. Equation (6) of our structural model enables us to compute the direct effect of patent effectiveness on R&D expenditures, since we have linearised the model, $E_R = \beta (a_1 \gamma)$.

As noted earlier, $a_1\gamma$ is the composite coefficient of patent effectiveness estimated for CIS4 and 5, and $\beta = 1/(1-\alpha)$. Both of these coefficients are estimated jointly from equations (6) and (7), as explained above. Table 7 reports computed E_R by CIS round.

Table 7: The implied elasticity of R&D due to patent protection (Model 2)

CIS wave	CIS3		CIS4				CIS5			
industry controls	2-digit		1-digit		2-digit		1-digit		2-digit	
parameters	β	$a_1\gamma$	β	$a_1\gamma$	β	$a_1\gamma$	β	$a_1\gamma$	β	$a_1\gamma$
	1.21	0.092	2.23	0.095	2.56	0.104	1.97	0.10	2.56	0.073
$\mathbf{E_R}$	0.106		0.21		0.27		0.197		0.186	

Table 7 shows that the implied % increase in R&D due to a higher level of patent effectiveness is 21% (in CIS4) and 20% (CIS5). These estimates are very close to the range reported in Arora et. al. (2008), whose results imply that an increase in perceived patent effectiveness from 2 to 3 (the median patent effectiveness in their data is equal to 2) is associated with an increase in R&D of 19.8% overall, with the largest increase in biotechnology and medical devices, and smallest in sectors such as textiles.

We also estimated the values of $\mathbf{E_R}$ for two split samples. Split samples estimate the implied elasticity of R&D due to patent protection by firm size and by firm age (Table 8 below). In Table 8, for both small firms and large firms the value of $\mathbf{E_R}$ is about 19%. The table also shows that the elasticity of R&D due to patent protection is much higher for the young firms. As before, these results control for the CIS wave the observation came from but we could not control for industry. A closer look at the data also indicates the small-sized establishments are often R&D units of larger enterprises and this is purely the consequence of matching to the BERD which picks up the larger R&D spenders in the economy. Therefore it is difficult to infer much from these differences.

Table 8: The implied elasticity of R&D due to patent protection by firm size and age (Model 2)

firm size	small		large	
parameters	β	$a_1\gamma$	β	$a_1\gamma$
	1.798	0.106	1.155	0.166
E_R	0.19		0.19	
firm size	young firms (≤10 years)		old firms (>10 years)	
parameters	β	$a_1\gamma$	β	$a_1\gamma$
	1.672	0.1810	1.650	0.074
E_R	0.30		0.122	

8.4 Summary and policy implications

This study aimed to assess the returns to patenting in the UK. We exploited the availability of matched micro-data to assess returns to patenting using a structural model of patenting and R&D. In this model, innovations depend upon the extent of R&D by the firm, and firms earn

higher returns on the patented portion of their innovations. We extend the model, allowing for R&D to respond to the higher profitability from innovation due to patent protection. Thus, the structural model developed by us allows the estimation of patent premiums (the incremental new product revenues and profits generated by patenting) and further, to measure the incentive that patent effectiveness provides for R&D expenditures.

We find that patent premiums are positive and the prospect of patent protection provides inducement for R&D but the extent of premium and inducement to R&D varies by type of firm and industrial sector. On average, a unit increase in perceived patent effectiveness is estimated to result in additional revenue from new products of about 160% to 200% and incremental profits of just over 32%. In addition, such an increase in patent effectiveness would bring forth an increase of between 11 - 27% in R&D. These estimates must be treated with caution because they depend upon assumptions about the share of innovations that are patented, a quantity that we do not observe for the UK, forcing us to rely upon extrapolations based on US data. Patent incentives for large firms work as well in the UK as they do in the US, but may not be as strong for smaller firms.

The differences in industry composition between different CIS rounds have influenced the estimated values of returns. The markedly lower premiums in CIS4 and CIS 5 when compared to CIS3 are probably a consequence of the larger number of service sector respondents in CIS4 and 5. These sectors are known to rely less on patents and so are likely to have lower returns to patenting.

We also reported product revenue premiums for a small range of sectors which may be thought of as technology intensive. These results show very clearly that the range of revenue premiums in response to a unit increase in patent effectiveness for these sectors lies between 230% and 510% - a much higher range of values than the 160-387% which we reported as the average range for all industries. Furthermore, we find (as have other studies) that revenue premiums are highest for the pharmaceutical and biotech sector and lowest for instruments. Computers and electronics, machinery and medical instruments occupy intermediate positions between these two extremes. These industry differences may also have some policy implications with regard to when strong IP may be vitally important for innovative growth.

Our ability to estimate patent premiums and R&D elasticity has been constrained by the availability of data - in particular the lack of information about what proportion of all innovations is patented. We also noted the sample selection biases introduced in our analysis when we use the 3rd and 4th lagged value of R&D as an instrument for R&D expenditures.

It should be emphasised that we have studied and tried to estimate only the private returns to patenting and the incentives they offer for R&D. We strongly recommend a re-design of the CIS questionnaires to overcome these types of constraints for researchers by including questions that clarify these issues. In particular using lagged R&D values drawn from the survey would have been statistically more efficient.

Patenting may have other beneficial effects to which we do not impute any value in this work. Thus, we do not model the impact of patenting on R&D spill-overs. Nor do we consider the impact of patenting on entry and associated innovation. Conversely, we do not address the impact of patenting by other firms on the revenues or profits earned by the focal firm. Doing so would require more extensive information on the nature of competitive interactions between various firms. All of these are important issues that need investigation with better data – perhaps generated through a customised survey- but this was beyond the scope of the present work.

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Appendix A: Derivation of Models 1 and 2

Model 1

From the CIS we first create a measure of the total revenue from new products, NPR as follows[7]

NPR ≡ TR X % of revenues from new products (1.1')

We consider as new products (N_1) those products that are new to the industry - not just to the firm. We can get TR and % of revenue from new products from CIS or in case we want to construct a panel, we can get TR from ONS and the percentage of revenues from new products from CIS.

$NPR \equiv P_1.N.Q_1$ (1.2')

Where P_1 = average price of new products, N = number of new products, and Q_1 = average quantity of new products.

We assume that

$P_1\ Q_1 = PQ\ (1\text{-}\Phi) + PQ\Phi(1+\delta)$ (1.3')

Where P is the price without patent protection and Q is the average quantity sold without patent protection. This equation says that the average revenue per product is a weighted average of revenue with and without patent protection, and that the revenue for patented items is greater (due to exclusivity from patents). Φ is the share of products for which patent protection was sought (patent propensity).

Finally, we assume a production function linking the number of new product innovations to R&D investments, N = f(R). For the moment, we do not specify the functional form of f. Note that R is the R&D spent on product innovation, not total R&D. We will measure R as λ(Total R&D), where λ = share of R&D devoted to product innovation in the focal industry (from CMS), and Total R&D is taken from BERD or CIS.

7 For ease of exposition, we suppress firm and time subscripts. For this discussion, we also ignore process R&D and process innovation, because we lack measures of the impact of process innovation. (The measures in CIS are qualitative and do not facilitate analytical use.)

Combining with (1.3’) and (1.2’), we get

$$NPR = PQ\ (1 + \Phi\delta)\ f(R) \qquad (1.4')$$

Taking logs, and transforming the model into econometric form we get

$$npr = p + q + \ln(1 + \Phi\delta) + \ln(f(R)) + \varepsilon_i \qquad (1.5')$$

where lowercases denote natural logs.

Now, if we specify an appropriate form for f(R), we can estimate (1.5’) as a non-linear least squares For instance, if f(R) is Cobb-Douglas, (1.5’) and formula becomes

$$npr_i = A + b_1\ \ln(R_i) + \ln(1 + \Phi\delta_i) + \varepsilon_i \qquad (1.5'')$$

where, A = p+q +a. This is in fact, the eq (1) in Section 2.1.1.

Model 2

Write total profit $\Pi = Q\pi(R)(1\text{-}\Phi + (1+\gamma)\Phi) – C(R)$ (2.1)

Where C(R) = cost of R&D = mR, where we set the marginal cost of R&D = m, and π(R) is the operating profit per unit in the absence of patent protection, and Q is the total output. As before, Φ is the share of the focal firm’s products and services that are covered by patents, and γ is the patent premium. Note that in model 1, we had defined δ to be the patent premium in terms of the incremental profits from new products. Instead, here we define γ in terms of the incremental profits from all products and services, so that we can use the reported accounting profits as a measure of innovative performance (instead of new product revenues, as was the case in model 1).

The first order condition for R is

$$Q\pi'(R) – m = 0 \qquad (2.1')$$

Let Y = profits gross of R&D expenses. Setting $\pi(R) = aR^{\alpha}$, we get

$$a\ Q(1+ \underline{\Phi\delta})\ R^{\alpha-1} = 1 \qquad (2.1'')$$

$$a\ Q(1+ \underline{\Phi\delta})\ R^{\alpha} = Y \qquad (2.2'')$$

letting $\beta = 1/(1-\alpha)$ and taking logs, we get

$$LnR = \beta(Ln(a)) + \beta LnQ + \beta\, Ln(1+ \Phi\underline{\delta}) \qquad (2.1^*)$$

$$LnY = Ln(a) + LnQ + (\alpha)LnR + Ln(1+ \Phi\underline{\delta}) \qquad (2.3^*)$$

Now we assume that Ln(a) + LnQ is a function of firm and industry specific characteristics, $\Sigma X_j\, \theta_j$ in equation (2.3*) and $\Sigma X_j\, \lambda_j$ in equation (2.1*) plus a constant term, C).

Thus the estimating equations become

$$LnR = C_1 + \Sigma X_j\, \lambda_j + \beta\, Ln(1+ \Phi\delta) \qquad (eq1)$$

$$LnY = C_2 + \Sigma X_j\, \theta_j + (\alpha)LnR + Ln(1+ \Phi\delta) \qquad (eq2)$$

where $\lambda_j = \beta\theta_j$ and $\beta = 1/(1-\alpha)$

These are eq. (6) and eq. (7) of Section 2.1.2.

Appendix B: Other tables

Table B1: Summary statistics

		CIS sample			Sample for which R&D lagged is available		
	Variable name[1]	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
CIS 3	npr, log	6340	1.04	3.31	515	3.33	5.44
	npr, %	6451	1.92	10.02	519	5.03	14.84
	GOS, 000£	4276	3750.76	27409.49	410	11727.8	47718.88
	GOS, log	4268	6.12	1.84	410	7.50	1.88
	X	4276	0.32	0.83	527	1.27	1.32
	R, £000 (from CIS)	4276	81.87	1254.95	527	739.22	3158.89
	R, £000 (mean R&D, BERD)	-	-	-	527	1883.55	7053.01
	R, log	4276	0.45	1.46	527	5.63	1.70
	# employees	4248	174.65	447.90	522	426.5	856.03
	employees, log	4248	4.05	1.39	522	5.18	1.31
	Global	-	-	-	-	-	-
	Public	4276	0.86	0.35	527	0.99	0.08
	Foreign	4276	0.06	0.24	527	0.19	0.39
	cooperation	4276	0.04	0.20	527	0.20	0.40
	R&D lagged , log	-	-	-	527	5.38	1.85
CIS 4	npr, log	16085	1.53	3.91	1109	5.04	5.96
	npr, %	16090	2.66	10.64	1110	8.29	17.64
	GOS, 000£	8700	8108.18	60214.79	772	14162.05	98760.07
	GOS, log	8666	6.49	2.05	772	7.59	1.86
	X	8700	0.46	0.93	1111	1.50	1.29
	R, £000 (from CIS)	8700	172.07	1834.76	1111	1065.8	4117.72
	R, £000 (mean R&D, BERD)	-	-	-	1111	3245.57	22505.1
	R, log	8700	1.07	2.03	1111	5.81	1.76
	# employees	8698	365.36	1827.86	1110	329.21	671.0
	employees, log	8698	4.02	2.05	1110	4.72	1.72
	Global	8700	0.22	0.41	1111	0.62	0.49
	Public	8700	0.87	0.34	1111	0.98	0.13
	Foreign	8700	0.12	0.32	1111	0.25	0.43
	cooperation	8700	0.07	0.26	1111	0.25	0.43
	R&D lagged , log	-	-	-	1111	5.58	1.89

1 Variables used in the study are at reporting unit level

CIS 5	npr, log	4248	3.79	5.39	1205	6.36	5.86
	npr, %	4249	5.57	13.86	1205	9.49	18.14
	GOS, 000£	4551	25667.73	72556.64	1232	17037.43	92568.69
	GOS, log	4537	7.11	2.14	1232	7.57	2.04
	X	4551	0.62	1.07	2608	1.04	1.27
	R, £000 (from CIS)	4551	217.26	1987.74	2608	584.66	4892.88
	R, £000 (mean R&D, BERD)				2608	1844.39	23204.5
	R, log	4551	1.22	2.19	2608	4.46	1.94
	# employees	4547	504.46	1988.60	2595	256.78	680.21
	employees, log	4547	4.57	2.06	2595	4.22	1.71
	Global	4551	0.25	0.43	2608	0.43	0.49
	Public	4551	0.92	0.28	2608	0.93	0.25
	Foreign	4551	0.53	0.50	2608	0.54	0.50
	cooperation	4551	0.06	0.24	2608	0.13	0.34
	R&D lagged , log	-	-	-	1031	5.45	2.00

Table B2: Patent premium equation Model 1

Dep. var: NPR in 000s £, log	CIS3		CIS4		CIS5	
Estimation method	OLS	2SLS	OLS	2SLS	OLS	2SLS
Patent effectiveness (a_1δ)	0.90*** (0.19)	0.91*** (0.18)	0.50*** (0.14)	0.49*** (0.15)	0.58*** (0.21)	0.58*** (0.21)
R&D expenditure, log (b_1)	0.19 (0.22)	0.14 (0.24)	0.02 (0.13)	0.04 (0.14)	0.04 (0.15)	0.22 (0.17)
Employment, log	-0.01 (0.25)	0.03 (0.27)	0.48*** (0.10)	0.48*** (0.12)	0.75*** (0.14)	0.67*** (0.16)
Global			1.48*** (0.38)	1.48*** (0.37)	1.10** (0.54)	1.12** (0.52)
Public	1.71** (0.81)	1.77 (3.65)	0.25 (1.34)	0.24 (1.32)	-0.09 (2.14)	-0.26 (2.83)
Foreign	1.38* (0.71)	1.40** (0.62)	-0.73* (0.43)	-0.74* (0.42)	-0.82 (0.53)	-1.02* (0.58)
Cooperation	1.81*** (0.67)	1.84*** (0.60)	2.42*** (0.43)	2.41*** (0.41)	1.00* (0.55)	0.96* (0.54)
Constant	-2.44* (1.33)	-2.52 (6.36)	-0.75 (1.79)	0.16 (1.47)	1.01 (2.67)	2.72 (2.92)
Observations	512	512	1109	1109	588	588
R-square	0.113	0.112	0.131	0.131	0.152	0.150
F statistics			16.24		13.57	
Wald test		64.0		167.0		107.0
First Stage Estimates: Dep. variable: R&D expenditure, log						
Patent effectiveness		-0.07** (0.03)		0.05*** (0.01)		-0.07** (0.03)
Employment, log		0.15*** (0.02)		0.10*** (0.01)		0.15*** (0.02)
Global		-0.1 (0.07)		0.01 (0.04)		-0.10 (0.07)
Public		0.03 (0.42)		0.04 (0.15)		0.03 (0.42)
Foreign		0.11 (0.08)		0.10** (0.04)		0.11 (0.08)
Cooperation		-0.04 (0.08)		0.20*** (0.04)		-0.04 (0.08)
R&D (3^{rd} &4^{th} lags)		0.81*** (0.02)		0.77*** (0.01)		0.81*** (0.02)
Constant		0.66 (0.43)		0.93*** (0.16)		0.66 (0.43)
Adj. R2		0.85		0.86		0.82
F stat instruments†		1106		3434		1468
p-value		0.00		0.00		0.00

Notes: *** - significant at 0.01; ** - significant at 0.05; * - significant at 0.1 Standard errors are in parentheses robust to heteroskedasticity. 1 digit Industry dummies are suppressed to safe space. † F –test for instruments: F(1,498)=1106 (CIS3); F(1,1095)=3434 (CIS4); F(1, 574)=1468 (CIS5). Instrument for R&D viz. the 3^{rd} and 4^{th} lagged values of R&D expenditure are taken from BERD.

Table B3: Patent premium equation Model 1 (split sample by firm size)

Dep. var: NPR in 000s £, log	Small firms	Large firms	Small firms	Large firms
Estimation method	OLS	OLS	2SLS	2SLS
Patent effectiveness ($a_1\delta$)	0.42*** (0.13)	0.75*** (0.18)	0.45*** (0.15)	0.63*** (0.19)
R&D expenditure, log (b_1)	0.070 (0.09)	0.39*** (0.13)	0.12 (0.16)	0.51*** (0.15)
Employment, log	1.27*** (0.10)	0.31 (0.32)	1.04*** (0.16)	0.12 (0.33)
Global	1.71*** (0.36)	0.90* (0.53)	1.63*** (0.41)	0.93* (0.56)
Public	-0.15 (0.56)	2.01 (1.82)	0.03 (1.15)	-0.63 (2.59)
Foreign	-0.64* (0.35)	-0.37 (0.50)	-1.28*** (0.49)	-0.25 (0.51)
Cooperation	1.96*** (0.42)	1.34*** (0.48)	1.87*** (0.45)	1.38*** (0.50)
Constant	-2.17*** (0.74)	-4.12 (2.54)	-1.76 (1.48)	-0.96 (3.14)
No.obs	967	962	610	852
R-square	0.292	0.145	0.247	0.132
F statistics	80.35	20.22		
Wald chi2			201.0	132.0
First Stage Estimates: Dep. variable: R&D expenditure, log				
Patent effectiveness			-0.01 (0.02)	0.06*** (0.02)
Employment, log			0.01 (0.02)	0.19*** (0.03)
Global			-0.03 (0.06)	0.06 (0.06)
Public			0.24 (0.19)	0.08 (0.29)
Foreign			0.05 (0.08)	0.09* (0.05)
Cooperation			0.11* (0.07)	0.20*** (0.05)
R&D (3^{rd} &4^{th} lags)			0.76*** (0.02)	0.80*** (0.01)
Constant			1.01*** (0.24)	-0.04 (0.35)
Adj. R2			0.74	0.85
F statistics (1,600)			1410	3271
p-value			0.00	0.00

Notes: *** - significant at 0.01; ** - significant at 0.05; * - significant at 0.1 Standard errors are in parentheses robust to heteroskedasticity. Year 4 and year 5 dummies suppressed to safe space. † F –test for instruments: F(1,600)=1410 (small firms); F(1,600)=3271 (large firms). Instrument for R&D viz. the 3^{rd} and 4^{th} lagged values of R&D expenditure are taken from BERD.

Table B4: Patent premium equation Model 1 (split sample by firm age)

Dep. var: NPR in 000s £, log	Young firms	Old firms	Young firms	Old firms
Estimation method	OLS	OLS	2SLS	2SLS
Patent effectiveness ($a_1\delta$)	0.57*** (0.17)	0.68*** (0.10)	0.46** (0.19)	0.66*** (0.11)
R&D expenditure, log (b_1)	-0.03 (0.13)	0.12 (0.08)	0.02 (0.18)	0.20* (0.10)
Employment, log	0.60*** (0.12)	0.52*** (0.07)	0.50*** (0.16)	0.37*** (0.10)
Global	2.64*** (0.49)	1.37*** (0.29)	2.75*** (0.58)	1.23*** (0.33)
Public	1.96** (0.76)	1.09 (0.68)	2.58 (2.19)	-0.48 (1.30)
Foreign	-0.37 (0.49)	-0.49* (0.29)	-0.52 (0.57)	-0.41 (0.34)
cooperation	1.85*** (0.52)	1.83*** (0.32)	2.04*** (0.53)	1.85*** (0.34)
Constant	-2.77*** (1.04)	-2.22*** (0.77)	-3.03 (2.35)	-0.28 (1.41)
No.obs	749	2077	556	1653
R-square	0.211	0.168	0.197	0.148
F statistics	28.08	52.58		
Wald chi2			136.0	289.0
First Stage Estimates: Dep. variable: R&D expenditure, log				
Patent effectiveness			0.07** (0.02)	0.01 (0.01)
Employment, log			0.10*** (0.02)	0.10*** (0.01)
Global			0.09 (0.08)	-0.02 (0.04)
Public			0.31 (0.31)	0.04 (0.16)
Foreign			0.02 (0.08)	0.10** (0.04)
Cooperation			0.15** (0.07)	0.19*** (0.04)
R&D (3^{rd} &4^{th} lags)			0.74*** (0.02)	0.81*** (0.01)
Constant			0.75 (0.33)	0.49*** (0.17)
Adj. R2			0.81	0.84
F statistics (1,546)			1509	5975
p-value			0.00	0.00

Notes: *** - significant at 0.01; ** - significant at 0.05; * - significant at 0.1 Standard errors are in parentheses robust to heteroskedasticity. Year 4 and year 5 dummies suppressed to safe space.

Table B5: Patent premium equation of Model 2

Dep. variable: Gross operating surplus (Y) in 000s £, log	CIS4	CIS5
Estimation method	GMM	GMM
Patent effectiveness ($a_1\gamma$)	0.095** (0.04)	0.101** (0.05)
R&D expenditure, log (alpha)	0.551*** (0.05)	0.492*** (0.05)
Employment, log	0.318*** (0.05)	0.347*** (0.06)
Public	-1.083*** (0.34)	-0.230 (0.67)
Foreign	0.457*** (0.13)	0.781*** (0.15)
Cooperation	-0.051 (0.12)	0.181 (0.14)
Global	-0.295*** (0.11)	-0.249* (0.13)
Constant	4.540*** (0.41)	3.143*** (0.71)
R&D equation Model 2		
Employment, log	0.385*** (0.05)	0.383*** (0.07)
Public	0.710 (0.44)	0.112 (0.63)
Foreign	0.813*** (0.13)	0.739*** (0.16)
Cooperation	0.712*** (0.13)	0.687*** (0.17)
Global	0.186* (0.11)	0.001 (0.15)
Constant	-1.674*** (0.53)	2.097*** (0.72)
Observations	771	583

Notes: *** - significant at 0.01; ** - significant at 0.05; * - significant at 0.1 1 digit SIC dummies and year dummies used as instruments are not reported to save space. Standard errors are in parentheses robust to heteroskedasticity.

Table B6: Patent premium equation of Model 2 by firm size

Dep. variable: Gross operating surplus (Y) in 000s £, log	Small firms	Large firms
Estimation method	GMM	GMM
Patent effectiveness ($a_1\gamma$)	0.106* (0.06)	0.166*** (0.03)
R&D expenditure, log (alpha)	0.444*** (0.07)	0.134*** (0.03)
Employment, log	-0.283*** (0.07)	1.024*** (0.07)
Public	-0.368 (0.72)	0.184 (0.61)
Foreign	0.668*** (0.21)	0.276** (0.11)
Cooperation	0.088 (0.23)	0.200** (0.10)
Global	-0.225 (0.17)	-0.240** (0.11)
Constant	4.659*** (0.83)	0.812 (0.74)
R&D equation Model 2 (split sample)		
Employment, log	-0.381*** (0.07)	0.988*** (0.09)
Public	0.363 (0.61)	-0.343 (0.31)
Foreign	0.608** (0.24)	0.452*** (0.14)
Cooperation	0.609*** (0.21)	0.748*** (0.13)
Global	0.012 (0.18)	0.782*** (0.14)
Constant	5.007*** (0.61)	0.108 (0.61)
Observations	330	822

Notes: *** - significant at 0.01; ** - significant at 0.05; * - significant at 0.1 Year dummies are not reported to save space. SIC dummies are not included. Standard errors are in parentheses robust to heteroskedasticity.

Table B7: Patent premium equation of Model 2 by firm age

Dep. variable: Gross operating surplus (Y) in 000s £, log	Young firms	Old firms
Estimation method	GMM	GMM
Patent effectiveness ($a_1\gamma$)	0.181*** (0.06)	0.074*** (0.03)
R&D expenditure, log (alpha)	0.402*** (0.08)	0.394*** (0.03)
Employment, log	0.510*** (0.11)	0.465*** (0.04)
Public	-0.792 (0.65)	-0.287 (0.37)
Foreign	0.263 (0.18)	0.664*** (0.10)
Cooperation	0.032 (0.16)	0.059 (0.10)
Global	-0.589*** (0.20)	-0.471*** (0.09)
Constant	2.929*** (0.73)	2.910*** (0.41)
R&D equation Model 2 (split sample)		
Employment, log	0.460*** (0.09)	0.392*** (0.04)
Public	0.643 (0.81)	-0.217 (0.33)
Foreign	0.560*** (0.21)	0.799*** (0.10)
Cooperation	0.384** (0.19)	0.791*** (0.11)
Global	0.751*** (0.21)	0.220** (0.10)
Constant	2.346** (0.93)	3.332*** (0.39)
Observations	368	1391

Notes: *** - significant at 0.01; ** - significant at 0.05; * - significant at 0.1 Year dummies are not reported to save space. SIC dummies are not included. Standard errors are in parentheses robust to heteroskedasticity.

Table B8: Top 5 sector by patent premium (Model 1)

Industry	**Biotech**		**Computers & electronics**		**Machinery**		**Instrument**		**Medical instruments**	
Method	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Patent effectiveness ($a_1\delta$)	1.47*** (0.54)	1.32* (0.70)	0.59* (0.34)	0.70* (0.39)	0.70*** (0.27)	0.76** (0.30)	0.42 (0.37)	0.37 (0.37)	0.54 (1.01)	0.75 (0.81)
R&D expenditure, log (b_1)	0.03 (0.41)	0.23 (0.54)	-0.16 (0.33)	-0.44 (0.50)	0.19 (0.21)	0.29 (0.25)	0.04 (0.42)	0.29 (0.45)	-0.89 (0.64)	-1.07 (0.84)
Employment, log	0.29 (0.48)	0.45 (0.60)	0.93*** (0.23)	0.91** (0.37)	0.24 (0.20)	0.03 (0.26)	0.58 (0.43)	0.32 (0.47)	1.61** (0.63)	1.74** (0.68)
Global	2.66 (2.23)	1.68 (2.18)	1.03 (0.74)	0.74 (0.95)	2.71*** (0.83)	2.95*** (1.02)	-0.92 (1.43)	-1.14 (1.77)	-3.59 (2.26)	-4.22 (3.78)
Public			-0.11 (2.96)	0.36 (3.27)	3.74*** (0.98)	3.45 (5.72)				
Foreign	0.65 (1.72)	0.70 (1.71)	-2.02** (0.85)	-2.34** (1.17)	-0.19 (0.74)	0.12 (0.81)	1.31 (1.10)	1.57 (1.10)	1.83 (1.67)	2.24 (1.81)
cooperation	2.06 (1.80)	2.05 (1.61)	2.53*** (0.91)	2.80** (1.13)	1.89** (0.85)	2.17*** (0.84)	2.51** (0.89)	2.18** (0.89)	2.21 (1.89)	3.01* (1.58)
Constant	-2.17 (2.85)	-4.19 (3.36)	-0.25 (3.54)	1.12 (3.99)	-3.91** (1.86)	-3.32 (5.98)	-1.01 (1.71)	-1.13 (1.75)	0.94 (3.45)	0.41 (3.80)
No.obs	73	63	225	174	317	269	164	151	41	37
R-square	0.35	0.35	0.19	0.15	0.19	0.17	0.26	0.27	0.34	0.44
First Stage Estimates: Dep. variable: R&D expenditure, log										
Patent effectiveness		0.05 (0.07)		0.08** (0.04)		0.02 (0.03)		0.09** (0.05)		0.12 (0.08)
Employment, log		0.00 (0.06)		0.14*** (0.03)		0.09*** (0.03)		0.25** (0.05)		0.12* (0.06)
Global		-0.08 (0.23)		0.05 (0.10)		-0.24** (0.11)		-0.30 (0.22)		0.03 (0.38)
Public				0.29 (0.37)		-1.04* (0.64)				
Foreign		0.12 (0.17)		0.25** (0.13)		0.06 (0.09)		-0.05 (0.14)		-0.31* (0.18)
Cooperation		0.46*** (0.16)		-0.07 (0.13)		0.14 (0.09)		0.17* (0.11)		0.48*** (0.15)
R&D (3^{rd} &4^{th} lags)		0.86*** (0.04)		0.67*** (0.03)		0.85*** (0.02)		0.66** (0.04)		0.83*** (0.07)
Constant		0.74** (0.33)		1.20*** (0.43)		1.41** (0.67)		0.50** (0.21)		-0.35 (0.40)
Adj. R2		0.85		0.64		0.83		0.67		0.83
F stat (instruments)		312.11		298		1282		292		145
p-value		0.00		0.00		0.00		0.00		0.00

Notes: *** - significant at 0.01; ** - significant at 0.05; * - significant at 0.1. One digit industry dummies for Top5 industries as well as year dummies for (CIS4 and CIS5 waves) are not reported to save space. Standard errors are in parentheses robust to heteroskedasticity. Sector composition: Biotech and Pharma (SIC244, 241, 247); Computer and Electronics (SIC721, 723, 724, 300, 722); Machinery (SIC343, 292, 295, 341, 353, 296, 291); Instruments (SIC294, 332, 333, 334); Medical instruments (SIC331).

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