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Abstract

Changes in patent law, global competition, and the rise of several new technologies suggest that patents could be of greater value than secrecy for many innovative firms, particularly small firms that are unable to use market power or other factors to appropriate their investments in innovation. Data from the 1993 European Community Innovation Survey (CIS) for up to 2849 R&D-performing firms is analysed to determine the relative importance of secrecy vs. patents. This particular combination of appropriation methods is interesting because secrecy can act as a mutually-exclusive alternative to patents. The results show that a higher percentage of firms in all size classes rate secrecy as more valuable than patents. However, ordered logit regressions show that the probability that a firm rates secrecy as more valuable than patents declines with an increase in firm size for product innovations, while there is no relationship for process innovations. The firm's R&D intensity has no effect on the relative value of secrecy vs. patents. There is weak evidence to show that participation in cooperative R&D increases the value of patents over secrecy for product innovations. The results are relevant to ongoing debates over changes to the patent system and the need for policies to encourage small firms to patent more.

Keywords: Appropriation; Innovation surveys; Patents; Secrecy

1. Introduction

Both anecdotal and empirical research suggest that patents have increased in importance since the early 1980s. The evidence for this ranges from a marked increase in the number of patent applications in the United States, from approximately 60,000 in 1984 to 120,000 in 1995 (Kortum and Lerner, 1999), to the decision of several large firms, such as Texas Instruments and IBM, to aggressively pursue licensing revenue from their patented inventions (Thurow, 1997). These changes are partly thought to be driven by the establishment in 1982 of a new Federal Court of Appeals, which strengthened the ability of firms to enforce their patent rights in the United States. A second possible explanation is an increase in the economic importance of proprietary knowledge, due to a shift from competition based on price towards competition based on technical innovation. A third explanation is the rise of new technologies, such as biotechnology and information technology, where a large number of small firms have been active. These small firms could rely on patents to signal expertise,

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either to attract research partners or investment (Mazzoleni and Nelson, 1998). All of these factors, taken together, are thought by some observers to have created a ‘pro-patent era’.

A shift in business strategies towards patenting could be marked by either an increase in patent propensity rates (the percentage of innovations that are patented) or a more intensive exploitation of patents, or both. Whether or not either of these outcomes has occurred is subject to debate. Both Thurow (1997) and Granstrand (1999) use case studies and other data sources to argue that firms are exploiting their patents more intensively. In contrast, Kortum and Lerner’s (1999) analysis of patent statistics shows that the increase in patenting in the United States is more likely to be due to an increase in the generation of patentable inventions than to an increase in patent propensities, although their results do not address the issue of whether or not patents are exploited more intensively.

The European policy-making community tends to accept the ‘pro-patent’ view, as illustrated by a recent report on patent policy to the European Commission (ETAN, 1999) and the discussion of patenting issues in major European policy documents such as the *Green Paper on Innovation* and the *First Action Plan for Innovation*. The possible rise of a ‘pro-patent era’ has created some concern, based on the belief that the presumed decline in the global competitiveness of European firms is partly due to their failure to aggressively use patents to protect their investments in innovation. The response of policy-makers within the European Commission, as shown by the policy prescriptions in the *Green Paper on Innovation* and the *First Action Plan for Innovation*, is to encourage European firms, particularly Small- and Medium-sized Enterprises (SMEs), to patent more. Another thrust of European policy is to strengthen the patent system by lowering application costs and by considering other changes, such as the introduction of a grace period, that would permit the release of information about an invention without forgoing the right to apply for a patent at a later date.

These policy proposals to encourage patenting do not always consider why firms might choose alternative appropriation methods to patents. Patents have several disadvantages as an appropriation mechanism, which partly explains why the majority of innovations in the United States and Europe in the early 1990s were not patented (Arundel and Kabla, 1998). One important drawback to patents is the requirement to fully disclose the invention, since the disclosed information can release valuable information to competitors on potentially profitable research areas or how to invent around the patent. The importance of disclosure as a reason not to patent has been established in both theoretical models of patent behaviour (Horstmann et al., 1985; Scotchmer and Green, 1990; Harter, 1993) and in survey-based research (Arundel and Kabla, 1998; Cohen et al., 1998). Firms that do not wish to disclose information can forgo patenting and use secrecy to protect their investment in the invention.

Given that patents and secrecy are mutually exclusive in this scenario, an interesting question is which method is more effective as an appropriation mechanism, and under what conditions? I would argue that there is a widespread although subtle bias on the part of some policy-makers, economists, and jurists in favour of patents, which are seen as a ‘gold standard’ for effective appropriation. As an example, Friedman et al. (1991) comment that some of the legal decisions in the United States on trade secrecy suggest that ‘no rational person with a patentable invention would fail to seek a patent’. Although Friedman et al. then give three situations in which secrecy would be preferred to patents, they agree with the underlying assumption that patents are best. Similarly, some of the theoretical literature assumes, either implicitly or explicitly, that all inventions are patented (Tandon, 1982; Scotchmer, 1991), leaving no room at all for secrecy. The theoretical models of patenting and disclosure also start with the assumption that firms will patent all of their inventions *unless* disclosure is of sufficient concern to impel the firm not to patent, although a more balanced perspective is provided by Takalo (1998).

This preference for patents is called into question by the empirical evidence based on innovation surveys in the United States (Levin et al., 1987; Rausch, 1995; Cohen et al., 1998), Europe (Arundel et al., 1995; Harabi, 1995), and Australia (McLennan, 1995). These surveys consistently show that manufacturing firms give secrecy a higher average rating as an appropriation method for both product and process innovations. The single exception is Japan, where firms give a higher rating to patents for product innovations, although secrecy is more valuable for process innovations (Cohen et al., 1998).

The survey results for process innovations can be explained by the ability of firms to keep process innovations hidden from their competitors for long periods of time. In contrast, the role of secrecy is not as evident for product innovations, since once the product is on the market it can be reverse-engineered by competitors. This creates a puzzle. One explanation is that secrecy could be used during the pre-market development phase. This would give the firm time to refine its invention and build up a lead-time advantage over competitors.

These possible uses of secrecy for product innovations show that patents and secrecy are not always mutually exclusive appropriation methods, as assumed by many of the theoretical models cited above. A firm could use secrecy to protect an invention during a development phase and then rely on patents or other appropriation methods when the invention is on the market. Of course, firms can also use secrecy for some of their innovations and patents for others. The ability of firms to strategically use both patents and secrecy complicates an evaluation of their relative effectiveness. It also suggests that a clear understanding of appropriation strategies requires better information about the conditions that impel firms to prefer secrecy to patents — or the *relative* value of secrecy vs. patents to appropriation.

One factor of policy significance, given the desire in the European Union to encourage SMEs to patent more, is the relationship between firm size and the effectiveness of secrecy and patents. One possibility is that small firms could find patents to be more effective than secrecy. In addition to the value of patents for small high-technology firms, as noted above, small firms frequently lack the manufacturing capacity or marketing networks to be able to rapidly recoup their investment in innovation through the sales of their own products. Consequently, these firms could be forced to rely on patents to create a breathing space from competition while they build up their manufacturing or marketing capabilities. In contrast, large firms could be less reliant on patents, both because they can use their marketing strength to create lead-time advantages and because large markets increase the financial returns from investment in process innovation (Cohen and Klepper, 1992; Klepper, 1996), where patents are of less value than secrecy.[1]

There are also several plausible reasons why small firms could find patents of *less* value than large firms, leading them instead to rely more on secrecy. In addition to patent application costs, which could be a greater barrier to small than large firms, small firms could find it exceedingly difficult to protect their patents from infringement, which would increase the relative value to them of secrecy compared to patents. This difficulty could be expressed, relative to large firms, as either a higher level of concern over legal costs or as a lower appreciation of the effectiveness of patents as an appropriation mechanism. Another possibility is that many small firms, with the exception of those that are pursuing a high-technology strategy, could be less likely than large firms to develop patentable innovations. Instead, many of their innovations could be based on minor incremental improvements that are not worth patenting.

Policies to encourage firms to patent more, particularly high-technology SMEs, could improve the competitiveness of these firms if patents are relatively more effective, under real conditions, than secrecy. In contrast, these policies could be less effective than expected if firms find secrecy to be more valuable than patents. Clearly, the design of patent policy would benefit from empirical evidence on the relative importance of secrecy and patents and a better understanding of the factors that shape the decision to keep an invention secret or to seek patent protection.

The purpose of this paper is to provide some empirical evidence of relevance to these issues, using

[1] The greater manufacturing and marketing capabilities of large firms imply that they should also patent proportionately fewer of their innovations than small firms. Some evidence on this issue is available from the PACE survey of Europe's largest industrial firms, although many of these 'firms' are in fact divisions with sales in the range of SMEs. The PACE results show that the percentage of both product and process innovations that are patented *increases* with sales as a measure of firm size (Arundel and Kabla, 1998).

the results of the 1993 Community Innovation Survey (CIS) in Europe. The empirical analyses focus on three questions. First, what is the relative importance of secrecy vs. patents for European manufacturing firms? Second, do small firms find patents of greater value than secrecy compared to large firms? Third, what factors other than size influence the relative importance of secrecy vs. patents? The results also provide some information of relevance to the debate over a 'pro-patent' era, although it is not possible to determine, using a cross-sectional survey at one point in time, if the value of patents has been changing over time.

The most important questions for European policy concern the relative importance of patents and secrecy for Europe's most innovative firms. For this reason, all analyses are limited to a subset of R&D-performing firms. Of course, firms that do not perform R&D can also develop patentable innovations, but many firms in this group probably only develop very minor innovations that do not meet the novelty requirements for a patent. These firms are, therefore, excluded in order to maximise the percentage of firms that have the option of using patents, in addition to the option of using secrecy. Furthermore, a few of the analyses are limited to a subset of highly innovative firms with R&D intensities (RDINTENS) above 10%.

The measure of the relative importance of patents vs. secrecy is at the firm level and therefore differs from the published results of other surveys which compare average differences in the importance of patenting and secrecy. For example, the most commonly used approach is to calculate the percentage of firms that give a rating of '4' or '5' on a five-point subjective scale. These are subject to inter-rater differences in the interpretation of the importance scale. Using relative scores, as described below, avoids these problems.

The results show that firms of all sizes find secrecy to be relatively more important than patents, but small firms find secrecy to be of greater importance than larger firms. This relationship with firm size, however, is less marked for small firms with RDINTENS above 10%. Several additional factors, such as the types of information sources used by the firm, also influence the relative importance of secrecy vs. patents.

2. Data sources and methodology

The 1993 CIS contains information on the value of both secrecy and patents for innovative manufacturing firms in Norway plus six EU countries: Germany, Luxembourg, the Netherlands, Belgium, Denmark, and Ireland. For further details on the CIS methodology, see Archibugi et al. (1994). The combined crude response rate for these seven countries is 36.1%, although the response rate varies from a low of 22% for Germany to a high of 79% for Luxembourg. The response rate exceeds 50% in Luxembourg, Norway, Denmark, and the Netherlands. The response bias in the 1993 CIS is in the direction of more innovative firms. This means that the response rate for R&D-performing firms is probably higher than the overall response rate. This bias will also favour the value of patents over secrecy, assuming that R&D-performing firms are more likely to develop patentable innovations.

A firm is defined in the CIS as innovative if it introduced a product or process innovation between 1990 and 1992. This definition of an innovator includes firms that only make minor improvements or introduce new products and processes developed by other firms. Many of these 'minor' innovators might not develop patentable innovations. To avoid this problem, all analyses are limited to a subset of firms that report that they perform R&D on a continuous basis. A maximum of 2849 R&D-performing firms are available for analysis, of which 1021 firms have fewer than 100 employees and 1689 firms have fewer than 250 employees.[2]

[2] Firms with more than 100 employees and with a reported R&D intensity of over 100% (less than 0.5% of the sample) are also excluded from the analyses because such high R&D intensities are unlikely to occur in firms of this size, suggesting either errors in data coding, or that the firm is a legally independent unit that provides R&D services to a much larger parent firm. In the latter case, an accurate analysis would require linking the R&D unit to the parent firm, which is not possible with the CIS data. Firms with less than 100 employees and R&D intensities over 100% are included because many of them will be new technology-based firms where R&D expenditures can exceed revenue for many years.

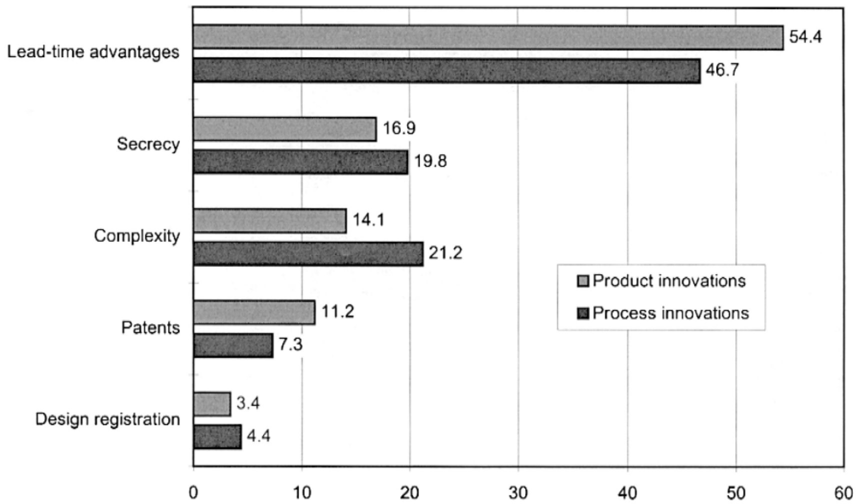

Fig. 1. Percentage of 2849 R & D-performing firms that give their highest rating to each appropriation method.

The relevant CIS question asks each respondent to ‘evaluate the effectiveness of the following methods for maintaining and increasing the competitiveness of product [or process] innovations introduced during 1990–1992’. The methods include patents, secrecy, design registration, complexity of product design, and lead-time advantages over competitors. Five ordinal response categories are provided, ranging from ‘insignificant’ to ‘crucial’.

One option for the presentation of descriptive results is to use the mean score for patents and secrecy, while another option is to use the percentage of respondents who reply that an appropriation method is ‘very significant’ or ‘crucial’. However, both of these methods suffer from inter-respondent variation in what is meant by each of the subjective response categories. For example, a response of ‘very significant’ for one firm could be equal to a response of ‘slightly significant’ for another firm.[3] This can create significant amounts of noise in the data that can mask possible differences in appropriation methods by a variable of interest, such as firm size or sector of activity. As an example, inter-rater differences in the interpretation of a subjective scale could have masked sectoral differences in the importance of secrecy in analyses using data from the American Yale survey of the early 1980s (Cockburn, 1992; Cockburn and Griliches, 1988).[4]

The method used here avoids these problems by relying on the internal consistency of each respondent’s answers. For example, assume that the respon-

[3] Inter-rater differences can be checked by including different questions about the same problem in the survey or by empirical tests of what respondents mean by their ratings. Although these techniques are widely used in health surveys (Streiner and Norman, 1995), it is not possible to use these techniques for the CIS.

[4] Cockburn (1992) evaluates five possible causes for statistical noise in the Yale survey: coding errors, scoring and scale construction, respondent heterogeneity in the interpretation of the rating scales, firm vs. sector conditions, and the wording of the question. Many of these problems either do not apply to the 1993 CIS or the analytical method used here avoids them. First, coding errors are unlikely to be a serious problem in either survey. Second, the Yale survey asks the respondents to evaluate the importance of each appropriation method for their ‘line of business’, while the CIS asks for an evaluation for the respondent’s own firm. The CIS version thereby avoids problems in confusing conditions for the firm and for the sector. Another effect of this change is that greater heterogeneity is expected in the CIS than in the Yale survey, since micro differences at the firm level are common, whereas the Yale survey should produce greater agreement among the respondents about the importance of each appropriation method for their line of business. Third, the CIS question is simpler than the Yale version, although there is still room for improvement. Fourth, the remaining two problems with scoring and inter-rater differences in the interpretation of the rating scale are avoided by the method of analysis based on relative differences in the importance of patents and secrecy.

dent for firm A gives a score of 3 (moderately significant) to patents and a score of 4 (very significant) to secrecy, while the respondent for firm B gives a score of 5 (crucial) to patents and a score of 4 to secrecy. Both respondents give an equal score to secrecy, but we do not know if the importance of secrecy is objectively equivalent, since respondents A and B could be using different subjective scales. In contrast, we can safely assume that each respondent gives internally consistent responses, so that the *relative* importance of secrecy vs. patents is robust. Using this method, we can conclude that the respondent for firm A rates secrecy as more important than patents while the respondent for firm B rates secrecy as less important than patents. A further advantage of this method for comparing two appropriation methods is that it is unaffected by the trend for large firms to give all appropriation techniques higher scores than small firms (Arundel, 1997).

This method is used to compare the relative importance of different appropriation methods, to determine the relative importance of secrecy vs. patents, and to serve as the dependent variable for a series of regression analyses, as discussed below.

3. Descriptive results

In order to place the relative importance of patents and secrecy in perspective, Fig. 1 gives the percentage of firms that gave their highest score to each of the five appropriation methods.[5] Lead-time advantages received the highest score from 54.4% of the respondent firms for product innovations and from 46.7% of firms for process innovations. Both patents and secrecy are given the highest rating by a notably lower percentage of firms. There is little variation in the rankings by firm size (results not shown). For example, lead-time advantages consistently receive the highest ranking for product innovations across all eight size classes shown in Table 1 below, followed by complexity, secrecy, patents, and design registration.[6]

3.1. Firm size, secrecy, and patents

Table 1 gives the relative importance of secrecy vs. patents for eight size classes. The rows in each subsection of Table 1 for products and processes add to 100%, aside from rounding-off errors. For example, all 183 firms with less than 19 employees are accounted for in the results for product innovations: 17.5% report that patents are more important than secrecy, 38.3% give equal ratings to patents and secrecy, and 44.3% give a higher score to secrecy than patents.

The results for product innovations show that a higher percentage of firms, in all size classes, rate secrecy as more important than patents. Furthermore, secrecy is relatively more important than patents for small firms than for large firms. The trend for the relative importance of secrecy to decline with firm size is statistically significant ($p = 0.001$). Most of the trend is due to a decline in the percentage of firms that give equal scores to patents and secrecy. The results differ for process innovations. The percentage of firms that give a higher score to patents than to secrecy remains comparatively stable, between 9.7% and 12.4%, with the exception of the largest size class. The trend by size class is also not statistically significant.

The results given in Table 1 are for all R&D-performing firms, including firms that spend very little on R&D. Since small, highly innovative firms have attracted a great deal of policy interest, the analyses were repeated after limiting the firms to those with RDINTENS above 10%, as shown in Table 2. The number of size classes has been reduced from eight to five to account for the smaller

[5] Tied maximum scores are divided equally between the relevant methods. For example, assume that the highest score given by firm A is 4, and that it is given to both patents and secrecy. Both of these methods would then be allotted 0.5 firms each. The percentages sum to 100% of the total firms for product and processes separately.

[6] The high importance given to lead-time advantages raises an interesting possibility in respect to patents that would be worth investigating in the future. Firms could forgo patenting if it reduces the ability of the firm to pursue lead-time advantages, e.g., if the time required to prepare patent applications distracts staff from more important tasks. This could be one explanation for Scherer et al., (1965) finding that the number of patent applications is closely related to the number of in-house patent lawyers.

Table 1
Relative importance of patents and secrecy for all R&D-performing firms (standard errors in parentheses)

Employees	*N*	Product innovations			Process innovations		
		Patents more important	Equal importance	Secrecy more important	Patents more important	Equal importance	Secrecy more important
< 19	183	17.5 (2.8)	38.3 (3.6)	44.3 (3.7)	10.4 (2.3)	40.4 (3.6)	49.2 (3.7)
20–49	386	17.6 (1.9)	23.6 (2.2)	58.8 (2.5)	12.4 (1.7)	27.5 (2.3)	60.1 (2.5)
50–99	452	23.0 (2.0)	28.5 (2.1)	48.5 (2.4)	11.1 (1.5)	37.4 (2.3)	51.5 (2.4)
100–249	668	20.7 (1.6)	28.0 (1.7)	51.3 (1.9)	11.8 (1.3)	35.9 (1.9)	52.2 (1.9)
250–499	479	20.5 (1.8)	30.1 (2.1)	49.5 (2.3)	12.3 (1.5)	29.6 (2.1)	58.0 (2.3)
500–999	319	24.5 (2.4)	24.8 (2.4)	50.8 (2.8)	9.7 (1.7)	23.2 (2.4)	67.1 (2.6)
1000–1999	186	23.7 (3.1)	33.9 (3.5)	42.5 (3.6)	10.8 (2.3)	30.6 (3.4)	58.6 (3.6)
> 2000	176	30.7 (3.5)	26.1 (3.3)	43.2 (3.7)	19.9 (3.0)	23.3 (3.2)	56.8 (3.7)
Significance of the trend by size				$p < 0.0001$			ns

number of firms. The trend is no longer statistically significant for either product or process innovations, although for all size classes more firms find secrecy to be more important than patents than the reverse. A comparison of Tables 1 and 2 indicates that small R&D-intensive firms find patents to be more important than the average for all small R&D-performing firms. For example, 33.3% of R&D-intensive firms with a workforce between 100 and 249 employees find patent more important than secrecy, compared to 20.7% of all R&D-performing firms in this size class.

3.2. Other influences on the relative importance of secrecy vs. patents

The results of Tables 1 and 2 establish that R&D-performing firms rank secrecy as a more effective appropriation mechanism than patents for both product and process innovations. Furthermore, Table 1 shows that a higher percentage of small than large R&D-performing firms give a higher rating to secrecy for product innovations, although there is no notable difference by firm size for the most R&D-intensive firms. However, before concluding that it will be an uphill battle to encourage more patenting among SMEs, it is important to address other possible influences on the relative importance of these two methods and to check for confounding factors. Other than firm size, three groups of factors come to mind that could influence the relative importance of secrecy vs. patents: the firm's own innovation strategies, the influence of different types of information sources on the firm's innovative activities, and technology effects linked to the firm's sector of activity. Sections 3.3–3.5 describe each factor and the con-

Table 2
Relative importance of patents and secrecy by firm size for R&D-intensive firms (standard errors in parentheses)

Employees	*N*	Product innovations			Process innovations		
		Patents more important	Equal importance	Secrecy more important	Patents more important	Equal importance	Secrecy more important
< 19	59	22.0 (5.4)	33.9 (6.2)	44.1 (6.6)	15.3 (4.7)	39.0 (6.4)	45.8 (6.5)
20–99	92	23.9 (4.5)	27.2 (4.7)	48.9 (5.2)	16.3 (3.9)	25.0 (4.5)	58.7 (5.2)
100–249	57	33.3 (6.3)	19.3 (5.3)	47.4 (6.7)	12.3 (4.4)	36.8 (6.4)	50.9 (6.7)
250–999	53	24.5 (6.0)	24.5 (6.0)	50.9 (6.9)	9.4 (4.1)	24.5 (6.0)	66.0 (6.6)
> 1000	40	32.5 (7.5)	30.0 (7.3)	37.5 (7.8)	22.5 (6.7)	17.5 (6.1)	60.0 (7.8)
Significance of trend by size				ns			ns

struction of variables to capture their effect in the regressions. The influence of these factors on the relative importance of secrecy vs. patents is explored using regression models.

3.3. Innovative strategies

Two measures of a firm's innovative strategy are constructed using the CIS data. First, an important characteristic of a firm's innovative strategy is its RDINTENS. This could be positively related to the value of patents by increasing the proportion of inventions that are patentable, or by increasing the value of competing on the basis of innovation relative to price. A positive effect for RDINTENS is also suggested by the difference between Tables 1 and 2, particularly for small firms, as noted above.

Second, the percentage of R&D spent on product (RDPROD) and process (RDPROC) innovation could influence the relative importance of secrecy and patents. One would expect firms that focus on product innovation to rate patents more highly than secrecy, and vice-versa for firms that focus on process innovation.

3.4. Information sources

Firms can acquire the information that they need to innovate from both internal sources, such as from their own in-house R&D activities, and from external sources, such as the technical literature, patent databases, customers, their parent firm when applicable, and through cooperative research with other firms or publicly-funded research institutions. Firms that extensively use external sources that require the sharing of valuable information could find patents of great value. An example is cooperative research, where patents could play an important role in clarifying ownership of the results. A recent study that linked patent data to the CIS results for the Netherlands found that firms that participate in collaborative R&D are more likely to apply for a patent than firms that do not participate in collaborative R&D (Brouwer and Kleinknecht, 1999). Alternatively, firms that focus strongly on internal information sources could give greater emphasis to secrecy. Another factor is related to ownership. Subsidiary firms could rely on their parent firm for major innovations and therefore find patents of less value than secrecy.

The CIS contains relevant data for three aspects of information sources that are relevant to the trade-off between secrecy and patents. First, the CIS contains one question, in a yes-or-no format, that asks if the firm had any cooperative R&D arrangements with other enterprises or institutions in 1992 (COOPRD). Second, another group of questions are used to identify subsidiaries. Third, a series of questions ask about the value to the firm's innovative activities of both internal sources within the firm and 11 external information sources. A dummy variable is constructed using this information (INTERNAL). Firms are classified as focusing on in-house information sources if the rating for sources within the firm is equal to or higher than eight external sources that require sharing information.[7] Three publicly available information sources are not included in the construction of this variable because they are less likely to require the sharing of information and therefore should not affect the relative value of secrecy and patents to the inventive firm: patent disclosures; conferences, meetings or journals, and fairs or exhibitions.[8]

3.5. Technology or sector effects

Innovation surveys, including the CIS, have shown that there are large differences in the effectiveness of patents by sector of activity, with patents most useful for firms that market products that are expensive to develop but relatively cheap to imitate, such as chemical compounds and mechanical equipment. These differences can be partly captured by includ-

[7] The eight external information sources are suppliers of materials and components, suppliers of equipment, clients or customers, competitors, consultancy firms, universities, government laboratories, and technical institutes.

[8] Of course, information could be shared with other firms, including competitors, at a conference or through attendance at a trade fair. However, the type of information that is shared (or revealed) is likely to be less important than the type of information shared with other external sources such as suppliers or customers, where firms could have built up a long-term relationship.

ing sector dummies in a regression model. The drawback to including sector dummies is that it does not provide any information on what aspects of each sector influence the effectiveness of patents. In effect, sector dummies do not help to explain *why* there are differences by sector. An alternative approach is to try to identify the factors, operating at either the firm or sector level, that influence the effectiveness of different appropriation methods.

An important factor that should vary by sector consists of the disadvantages of patents. These include the disclosure requirement and limits to the effectiveness of patents in preventing imitation. Both can act at the level of an entire sector as a result of their link to other factors such as technological opportunity. For instance, the ability of firms to 'invent around a patent' will partly depend on the number of different technical solutions to a problem and the rate of technical progress. Similarly, many low-technology sectors with few technological opportunities, such as basic metals, should also find patents ineffective in preventing imitation since many technologies are based on general engineering principles that are not patentable.

Unfortunately, the CIS does not contain data on the disadvantages of patents. Instead, this information is obtained from 610 respondents to the PACE survey of Europe's largest industrial firms who answered a question on the reasons why they did not apply for a patent for one or more innovations. An average measure of the disadvantages of patents by sector is calculated from the percentage of firms that rate at least one of two drawbacks to patents as 'extremely important': "limits to the effectiveness of patents in preventing imitation" or "the amount of information disclosed in a patent application" (PATPROB). Separate variables for each of these disadvantages were also included in the regression models, but did not provide robust results. This is probably because these two disadvantages are linked — a patent can be ineffective in preventing imitation because it releases information, although there are other factors that can limit effectiveness, such as a high density of alternative technologies. Firms in sectors where these two disadvantages of patents are strong should prefer secrecy over patents. Sector averages for patent disadvantages are only calculated for manufacturing sectors with more than five PACE respondents, which required excluding the printing and publishing sector (NACE 22) from the regression analyses given below.[9]

3.6. Regression results

The dependent variable for product innovations in the regressions consists of six categories of the difference between the respondent scores for secrecy and patents. The highest value of the dependent variable is given when the respondent rates secrecy as three or more categories higher than patents. This occurs, for example, when the respondent gives secrecy a score of 5 (crucial) compared to a score of 2 (slightly important) for patents. The lowest value of the dependent variable occurs when secrecy is given a score that is two or more categories lower than the score for patents. The dependent variable for process innovations consists of five categories. Although the scoring system appears to be based on an interval variable, it is important to emphasise that it is only possible to assume an ordinal scale of measurement. For this reason, the ordered logit is the appropriate regression model to use since it makes no assumptions about the distance between two values of the dependent variable. Details of the model are given in Appendix A.

The results of four regression models, two each for product and process innovations, are given in Table 3. A positive coefficient for an independent variable increases the probability that firms find *secrecy* to be more effective than patents, while a negative coefficient shows the reverse. Models 1 and 3 include sector dummies, while models 2 and 4 include the sector-level measure of the disadvantages of patents (PATPROB).

The measure of firm size used in these regressions is not the number of employees, as in Tables 1 and 2, but the log of the absolute amount that the firm spends on R&D (LRDEXP). This measure of firm size improves the fit of the model, although using the log of the number of employees provides roughly

[9] In total, results are available in PACE for 17 sectors with an average of 36 respondents per sector, after combining three related sectors, textiles (NACE 17), clothing (NACE 18), and leather goods (NACE 19). These three sectors are also combined in the CIS analyses. The PACE methodology is given in Arundel et al. (1995).

Table 3
Ordered logit results for finding secrecy to be more important than patents to "maintain and increase the competitiveness of innovations"

Variable	Product innovations				Process innovations			
	1		2		3		4	
	β	p	β	p	β	p	β	p
Constant	1.583	0.000	1.202	0.000	0.363	0.024	0.180	0.288
Firm size								
LRDEXP	−0.084	0.007	−0.101	0.001	−0.062	0.059	−0.049	0.114
Innovation strategy								
RDINTENS	0.003	0.977	0.001	0.990	−0.045	0.565	−0.050	0.602
RDPROD	−0.143	0.120	−0.180	0.043				
RDPROC					0.236	0.028	0.238	0.020
Information sources (both dummy variables)								
INTERNAL	0.154	0.002	0.150	0.002	0.038	0.447	0.041	0.400
COOPRD	−0.089	0.078	−0.096	0.053	0.049	0.338	0.039	0.441
Sector level variables								
PATPROB			0.855	0.002			0.771	0.007
Sector dummies	Yes				Yes			
Model χ^2	122.3	0.0000	97.7	0.0000	273.3	0.0000	238.1	0.0000

All models include 1995 firms and control for the country of location, with Denmark as the reference country. The reference sector for models 1 and 3, which include sector dummies, is food and beverages. The estimated threshold values (μ) (not shown in the table) are statistically significant ($p < 0.0000$) in all models and increase monotonically. The number of firms is less than in Tables 1 and 2 because of the exclusion of firms with one or more missing values for the independent variables. Results are similar when the dependent variable consists of three categories, as used in Tables 1 and 2, or when an ordered probit model is used.

similar results. R&D spending probably works better than the number of employees because it is a more accurate measure of the innovative size of the firm. For product innovations, the relative importance of secrecy declines with firm size, which means that secrecy is more important to small than to large firms. In contrast, firm size is only of borderline significance for process innovations. Both of these findings corroborate the descriptive results of Tables 1 and 2.

The firm's RDINTENS has no effect on the relative importance of secrecy vs. patents, which contrasts with the earlier comparison of Tables 1 and 2. This result suggests that what matters is not the firm's RDINTENS, but the absolute amount spent on R&D. For example, a very large firm with relatively high levels of R&D spending but a low RDINTENS will follow a similar strategy on patents and secrecy (other factors being equal) than a medium-sized firm with the same amount of spending on R&D. A comparable finding was noted in analyses of the PACE survey data, which found that the absolute amount spent on R&D had a much stronger influence on a range of innovation strategies than RDINTENS (Arundel et al., 1995). The explanation for this probably lies in the organisation of innovation. An R&D lab of a given size probably follows the same strategies as those of its peers, regardless of the total number of employees within the firm.

The other variable for the firm's innovation strategy is the percentage of all RDPROD or RDPROC, depending on the regression. RDPROD is negative, as expected, but not significant in both models for product innovations. In contrast, the equivalent variable RDPROC is more robust for process innovations, indicating that firms that spend a high percentage of their R&D expenditures on process innovations are more likely to use secrecy to protect them.

The two variables for information sources only influence the results for product innovations. Firms that focus on in-house information (INTERNAL) are more likely to give secrecy a higher rating than patents. In contrast, participation in cooperative R&D (COOPRD) reduces the probability that a firm will give a higher rating to secrecy than to patents, although the results are of borderline significance. This corroborates the results of Brouwer and Kleinknecht (1999) and provides further support, albeit indirect, for the theory that patents help to clarify the ownership of the intellectual output of cooperative R&D alliances. The firm's status as a subsidiary or as an independent firm had no effect in any of the models and is therefore not included in the regressions shown in Table 3.

The variable for the average disadvantage of patents (PATPROB), by sector, is strongly significant and positive for both product and process innovations. This supports the theoretical literature, which finds that firms will use secrecy when disclosure is a serious disadvantage to patenting. Another implication is that this sector-level variable is capturing some of the effect that is normally covered by sector dummies. However, it is not entirely clear if PATPROB is capturing the same effect for different sectors, since sectors where patents have a high rating for disadvantages include several low technology sectors such as food and beverages and several sectors where patents are known to be of value, such as chemicals and petroleum products.

The use of the relative importance of secrecy and patents as the dependent variable in the regressions has a considerable influence on the interpretation of the value of patents and secrecy. For example, the ordered logit analyses for product innovations were repeated using the responses for secrecy alone as the dependent variable. These range through five response categories from 'insignificant' (1) to 'crucial' (5). In this regression, the value of secrecy *increases* significantly with firm size, in contrast to the decline in the relative value of secrecy compared to patents with firm size, as shown in Table 3. Similar results were found for patents in an earlier study (Arundel, 1997). These results are due to the fact that large firms find all appropriation methods to be of greater value than small firms. The failure to look at the relative value of secrecy vs. patents would erroneously suggest that secrecy is less important to small firms than to large firms.

4. Conclusions

The results of these analyses show that a higher percentage of R&D-performing firms in all size classes find secrecy to be a more effective means of appropriation than patents. This is also true when the analysis is limited to firms with RDINTENS above 10%. Furthermore, small firms, on average, do *not* rely more on patents than on secrecy in comparison with large firms. Instead, small firms are less likely than large firms to find patents to be of greater value than secrecy for product innovations, although there is little difference by firm size for process innovations. These results are also confirmed by regression analyses that include the effect of other factors. There is one exception by firm size. As shown in Table 2, small R&D-intensive firms do not differ very much from large firms in their preferences for either secrecy or patents, although a higher percentage of all R&D-intensive firms find secrecy to be more important than patents than the opposite.

These results, showing that secrecy is an effective alternative to patenting, suggest that we should also see a negative relationship between the strength of secrecy as an appropriation method and the patent propensity rate. Relevant information on this issue is available from an analysis of the PACE survey (Arundel and Kabla, 1998). Firms that found secrecy to be an effective appropriation method had a lower propensity to patent product innovations than firms that found secrecy to be ineffective.

The CIS results, based on thousands of firms across the full spectrum of manufacturing sectors, have some relevance to the debate over the existence of a ‘pro-patent’ era. Between 1990 and 1992, patents were less important than secrecy to most European firms in this sample, including R&D-intensive firms. This indicates that there are marked limitations to the value of patents as an appropriation method. The timing of the survey is also well within the ‘pro-patent’ era, as shown by patent applications in the United States, which had already increased by about 60% between 1984 and 1992 (Kortum and Lerner, 1999). It is possible that there could have either been a lag in the adoption of pro-patent policies by European firms compared to American firms, or patents could have markedly increased in importance since 1993. A possible lag is supported by slightly lower patent propensity rates for European than American firms in the early 1990s (Arundel and Kabla, 1998). However, Cohen et al.’s (1998) recent comparison of the results of two American innovation surveys, in the early 1980s and then in the early 1990s, shows that secrecy *increased* in importance relative to patents over this time period. One possible explanation is an increase in concern over the ease of ‘inventing around’ a patent. The paradoxical result is that we could be witnessing a rise in the importance of both patents and secrecy, with the latter increasing in importance more quickly to make up for the inadequacies of the former.

The finding that firms that engage in cooperative R&D are more likely to find patents of greater value than secrecy does, however, provide some support for a pro-patent era, given an increase in cooperative R&D over the last decade (Granstrand, 1999).

The results are relevant to three aspects of European innovation programmes: to encourage patenting among all firms, to encourage patenting by high-technology firms, and possible improvements in patent legislation.

First, the results suggest that policies to encourage overall patenting will not automatically influence either the patent policies of firms or the competitiveness of European firms. This is because patents are a relatively unimportant appropriation method in many different sectors, with more firms finding secrecy of greater value than patents than the opposite. The regression results for PATPROB, or the disadvantages of patents at a sector level, indicate that a major reason for why firms prefer secrecy is concern over disclosure or other limits to the effectiveness of patents in preventing imitation. This result is in line with theoretical models on the effect of disclosure as a reason not to patent, but the strong relative importance of secrecy compared to patents in this study suggests that future theoretical models should explore the opposite problem: under what conditions will a firm decide not to keep its invention secret?

Second, a major area of European policy concern is the competitiveness of small high-technology start-up firms. In this respect, the similarity between the relative importance of patents and secrecy among small R&D-intensive firms and large R&D-intensive firms suggests that the former do not need additional government support for patenting. The appropriation strategies of these small high-technology firms are already similar to that of their larger peers.

Third, the results suggest one problem with current patent legislation that deserves closer attention. The fact that most small firms value secrecy more highly than large firms, even after controlling for factors such as the sector of activity and RDINTENS, is of concern. This difference is unlikely to be due to smaller firms having few patentable innovations, because the analyses have intentionally excluded firms that do not perform R&D and are, therefore, less likely to develop patentable inventions. One explanation of the difference is that small firms lack the financial reserves to protect their patents from infringement. If true, this would point to the need for policies to provide a more level playing field for infringement suits. This possibility was investigated by looking for interaction effects between the measure of the disadvantages of patents (PATPROB) and firm size. These analyses suggested that patent disadvantages *were* a more serious problem for small than for large firms, but the results were not robust, probably because this data was only available at the sector level.

The results also raise several questions. One of the main justifications for a patent system is to disseminate knowledge through disclosure. This could be socially beneficial by reducing the amount that firms invest in R&D. The widespread use of secrecy by firms could arguably be both economically inefficient and retard the rate of technical progress, suggesting that patent policies should be designed to encourage firms to patent rather than using secrecy. However, repetitive R&D is not necessarily an entire loss, since some R&D is required for imitation and such R&D could also lead to useful discoveries, since no R&D programme is likely to be identical. Nor is secrecy likely to substantially slow down the rate of technical change, at least for product innovations, which can be reverse-engineered. How these factors play out in terms of imitation lags and costs, or the effect of patents in forcing competitors to explore new, unprotected avenues of research, could be a fruitful avenue for further research.

Finally, there are at least two important limitations to this study. The measure of the value of secrecy and patents in the CIS is a composite of all of the firm's innovations. Their relative importance could differ for the firm's most economically important innovation, or for innovations that include the greatest technical advances. Second, with the exception of Germany, all of the data are from the smaller European economies. Conditions could differ in the larger European economies, as well as in other countries outside of Europe.

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Appenidx A

The ordered logit model can be used to examine the impact of a range of exogeneous variables on a dependent variable which takes a finite set of ordered values $(1,2,\ldots,n)$ (Liao, 1994). The method of estimation is maximum likelihood. The model assumes that the dependent variable y is generated by a continuous latent variable y^* whose values are unobserved. The model assumes that there are a set of ordered values $(r1,\ r2,\ldots,rn-1)$ and a variable y^* such that:

$$y = 1 \text{ if } y^* < r1$$
$$y = k \text{ if } rk-1 < y^* < rk \qquad \text{for } 1 < k < n$$
$$y = n \text{ if } rn-1 < y^* \tag{1}$$

The unobserved variable y^* is modelled as a linear function of the (N,k) vector of exogeneous variables X:

$$y_i^* = \beta X_i + \varepsilon_i \qquad i = 1,\ldots,N \tag{2}$$

where ε_i has a distribution function f derived from the logistic cumulative distribution function:

$$F(x) = 1/(1+\mathrm{e}^{-x}) \tag{3}$$

Given the characteristics X_i of individual i, the probability that y_i is found in category k is:

$$\text{Prob}(Y_i = 1/X_i) = F(r1 - \beta X_i)$$

$$\text{Prob}(Y_i = k/X_i)$$

$$= F(rk - \beta X_i) - F((rk - 1) - \beta X_i)$$

$$\text{Prob}(Y_i = n/X_i) = 1 - F((rn - 1) - \beta X_i) \quad (4)$$

The scoring of the dependent variables in the regressions given in Table 3 are as follows: For product innovations: 0 = secrecy two or more categories less than patents, 1 = secrecy one category less than patents, 2 = secrecy and patents given equal scores, 3 = secrecy given a score one category higher than patents, 4 = secrecy given a score two categories higher than patents, and 5 = secrecy given a score three or more categories higher than patents. For process innovations: 0 = secrecy less than patents, 1 = secrecy equal to patents, 2 = secrecy one category higher than patents, 3 = secrecy two categories higher than patents, and 4 = secrecy three or more categories higher than patents.

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