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My Precious

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Abstract:
The strategies firms use to protect their intellectual property and knowledge can strongly influence their ability to capture the benefits of their innovative efforts. In attempting to appropriate their innovations, firms can chose from a range of mechanisms, including patents, trade secrets and lead times. Yet, little is known about how the use of different appropriability mechanisms may shape innovative performance. Using a large-scale database of UK manufacturing firms, we examine how legal (such as patents) and first mover (such as secrecy) appropriability strategies shape performance. We find that both strategies are curvilinearly (taking an inverted U-shape) related to innovative performance, indicting that some firms may suffer from a *myopia of protectiveness*, relying too heavily on appropriation to the detriment of other activities.

Key words: Appropriability, Intellectual property rights, Innovation, Innovative performance

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INTRODUCTION

The ability to appropriate or capture the benefits of an innovation is a central element in gaining and sustaining competitive advantage. Many innovators have found themselves forced out of markets because they were unable to appropriate the benefits of their innovative efforts. Firms can use a variety of mechanisms to protect their innovations, ranging from patents to trade secrets. Accordingly, strategies for protecting knowledge have become a central part of the development of an innovative strategy (Rivette & Kline, 2000). Moreover, managerial strategies for appropriability have been found to be an important source of performance heterogeneity (Teece, 2002).

In this paper, we add to the existing literature on appropriability of innovations in three different ways. First, most research on appropriability has been conducted at the industry level, and accordingly, has been targeted at policy makers (Levin, Klevorick, Nelson, & Winter, 1987; Cohen, Nelson, & Walsh, 2000). We conduct a firm-level study of appropriability strategy targeted at managers and management scholars. Second, to the extent that the firm-level literature exists, it deals almost exclusively with patents as the method of appropriation (see for instance, Rivette & Kline, 1999; Ziedonis, 2004). Yet, the empirical literature has shown that because innovations are typically complex and difficult to define completely and precisely, it is possible to invent around existing patent protection, and that firms that want to, generally succeed fairly quickly (Mansfield, Schwartz, & Wagner, 1981; Pavitt, 1999). Accordingly, managers need to think about appropriability strategies that involve more than just seeking patent protection (McGaughey, 2002). We deal with appropriability in the broad sense by looking at an array of mechanisms of appropriation. Third, drawing from Teece (1986) Levin et al. (1987), Winter (1987) and Cohen et al. (2000), we develop the concepts of *legal* and *first mover appropriability strategies* to highlight the different choices available to firms as they seek to profit from their innovative efforts.

A legal appropriability strategy evokes several legal and external mechanisms, such as patents, trademarks and registration of design, to protect the firm's innovations from imitation by competitors. Such a strategy involves the codification of knowledge and the demonstration of technological novelty of the innovation to external actors, such

as patent officers. In contrast, by adopting a first mover appropriability strategy, firms seek to protect their innovations by being first to market, maintaining trade secrets and by the complexity of the product. Accordingly, such a strategy relies on being silent, complex and quick.

Both legal and first mover appropriability strategies may be beneficial for innovative performance, but an overemphasis on either may lead firms to a *myopia of protectiveness*. In other words, firms may become too focused on exploiting their existing technologies, rather than exploring new ones (March, 1991). An overemphasis on appropriation may also lead firms to misallocate managerial attention, shifting their focus of attention within the firm away from activities that may be essential for ensuring the success of the innovation in the market, such as the mobilization of complementary assets (Teece, 1986). Firms may become too closed, unwilling to share their knowledge with other actors in the innovation system and, thus, unable to engage in knowledge trading with users, suppliers and competitors.

Using a statistical analysis of the data from UK innovation survey, we investigate the relationship between the two different appropriability strategies and innovative performance. The survey explores the innovation process inside firms and it contains a sample of 3159 manufacturing firms. Using a double censored Tobit model, we explain innovative performance by firms' strength of legal and first mover appropriability strategies and a number of control variables, including R&D and firm size.

We find that legal and first mover appropriability strategies are curvilinearly related (taking an inverted U-shape) to innovative performance. This suggests that both strategies are beneficial for innovative performance, but that an overemphasis on either can be costly. In addition – and in contrast to our expectations – we find that legal and first mover strategies are substitutes for one another, and accordingly, that firms that follow both strategies have a lower level of innovative performance, indicating the dangers of being "stuck in the middle" between the two strategies.

The remainder of the paper is organized as follows. The second section explores the literature on appropriability strategies while the third section examines the influence

of legal and first mover appropriability strategies on innovative performance, describing the hypotheses that drive the analysis. The fourth section outlines the database and describes the empirical model. The fifth section reports the results and the final section contains a discussion and conclusions.

CONCEPTUAL BACKGROUND

Without the possibility of capturing some of the benefits of their innovative efforts, there would be little incentive for firms to innovate. Although capturing the benefits of innovations is hard and many innovators fail to do so, innovation appears to have considerable benefits for those firms that are able to achieve an innovation. Evidence shows that innovators have higher rates of profits, greater market value, better credit ratings and stronger chances of surviving in the market (Geroski, Machin, & van Reenen, 1993; Hall, 2000; Cefis & Marsili, 2003; Czarnitzki & Kraft, 2004). This suggests that although innovators may only be partially able to appropriate their innovations, some firms are indeed able to reap the rewards from their innovative efforts.

Firms use a number of different mechanisms to appropriate their innovations. The Yale and Carnegie Mellon surveys of appropriability show that first mover means of appropriability – such as secrecy – are more important than legal mechanisms – such as patents – for protecting product and process innovations. Legal mechanisms appear to be important in only a small number of industries – and especially in pharmaceuticals. Surveys of European firms have also found similar results (Harabi, 1995; Arundel & Kabla, 1998; Arundel, 2001). The importance of legal mechanisms of appropriability does not appear to have increased from the 1980s to the 1990s in the US, despite a significant rise in the total number of patents. Instead, the importance of first mover mechanisms appears to have increased during this period (Cohen et al., 2000).

Gaining legal protection for innovative activities can be an extremely slow, time consuming and expensive process. For example, the costs of applying for patents can be prohibitive, varying from $10,000 to $100,000 – especially for small and medium sized firms. It can also take several years before a patent is examined and approved by a patent office. Once approved, the costs and time required to enforce a patent can be

very high. By using legal mechanisms, firms are also forced to display some of their technology in the public domain, demonstrating its novelty and value. Such a process forces firms to codify their technological activities by writing down the mechanisms used in the creation of the product and key features of its design and construction. The effort to win legal protection for an invention can be related to a number of different motivations. Cohen et al. (2000) find that firms patent not only to prevent other firms from copying their technology, but also to block other firms from entering their market (see also Reitzig, 2004). Patents are also used to prevent suits, in negotiations with other firms, and to enhance the firm's reputation. In addition, firms may wish to acquire trademarks, design registrations and other forms of legal intellectual property to complement their patent portfolio. A number of recent managerial books have suggested that firms should increase their emphasis on legal intellectual property rights protection to release the "hidden value" of their investments in intellectual capital (Rivette & Kline, 2000).

Alongside these legal mechanisms for intellectual property rights protection, there are a wide number of first mover mechanisms used by firms to capture the benefits of their innovations. In both the Yale and Carnegie Mellon surveys, secrecy appears to be the most important mechanism for appropriating innovations. In the case of secrecy, many firms make extensive efforts to control the communication flows between their workers and the external environment. Non-disclosure, confidentiality and subsequent employment agreements are often used to ensure that trade secrets are retained by the firm, although the effectiveness of these strategies remains open to debate (Liebeskind, 1997).

Studies have also shown that the timing of market entry can have implications for appropriation of innovations (Teece, 1986). In both the Yale and Carnegie Mellon surveys, a high percentage of firms indicated that they rely on first-mover advantages in their appropriability strategies. However, it should be noted that in some industries, the benefits of being "first-to-market" appear to be ambiguous (Christensen, Suarez, & Utterback, 1998). In those industries, many successful firms specialize in being fast followers, able to learn from the experiences of the first generation of innovators and quickly follow behind them in the market (Schnaars, 1994).

Complexity of products and manufacturing processes may also provide a mechanism for firms to appropriate their innovations. Many products rely on integration of wide range of different technologies, components and systems. The integration between these different technologies often requires deep knowledge of component technologies and ability to specify the interfaces between different sub-systems (Brusoni, Prencipe, & Pavitt, 2001). In this way, firms may rely on the fact that producing the product requires considerable specialized capital investment and capabilities in manufacturing that are not easily replicated (Utterback, 1994).

The discussion above suggests that no single appropriability mechanism is able to provide firms with security for their innovations. As Schumpeter (1912/1934: 131-132) suggests the advantages of innovation can be fleeting. In order to capture the benefits of innovations, firms appear to rely on a bundle of different appropriability mechanisms. Accordingly, such particular combinations or bundles of appropriability mechanisms used by firms, make up what Cohen et al. (2000: 8) term an "appropriability strategy".

Drawing from Winter's (1987) taxonomic dimensions of articulable versus tacit knowledge assets, we conceive of two related appropriability strategies – legal and first mover appropriability strategies. A legal appropriability strategy involves relying on legal and at the same time external mechanisms of protection, such as applications for patents and other forms of intellectual property rights. A first mover appropriability strategy involves using secrecy, market entry and technological complexity to appropriate the benefits of an innovation. The decision to follow a legal appropriability strategy forces firms to disclose and codify their technological activities. It brings into the open their capabilities and knowledge. By contrast, a first mover appropriability strategy relies on the ability of firms to keep secret what they know. Empirical evidence suggests that there are strong differences between firms across industries in that in some industries firms rely on legal mechanisms of appropriability, while in other industries firms rely more on first mover appropriability mechanisms (Cohen et al., 2000). However, this does not necessarily imply that the appropriability strategies are substitutes. For instances, as pointed out by Cohen et al. (2000: 6), different appropriability mechanisms may be used

successfully at the same time for a given innovation, when an innovation is comprised of separately protected components or features.

HYPOTHESES

The underlying proposition for the present research is that the use of appropriability strategies is associated with innovative performance. Those firms who have explicit strategies for appropriating innovations are more likely to be able to capture the benefits of their innovations. In order to examine appropriability strategies in detail, we have introduced the concepts of legal and first mover appropriability strategies to reflect the choices firms make about how best to capture the benefits of their innovation.

The use of either legal or first mover appropriability strategies requires firms to expend considerable efforts to render these strategies effective, and it can create an attention allocation problem. Such problems are the key element in the attention-based theory of the firm (Simon, 1947; Ocasio, 1997). This theory suggests that managerial attention is the most precious resource inside the organization and that the decision to allocate attention to particular activities is a key factor in explaining why some firms are able to both adapt to changes in their external environment and to introduce new products and processes. Central to this approach is to highlight the pool of attention inside the firm and how this attention is allocated. According to the theory, decision makers need to "concentrate their energy, effort and mindfulness on a limited number of issues" in order to achieve sustained strategic performance (Ocasio, 1997: 203).

In the case of a legal appropriability strategy, the process of winning legal protection can be time consuming and labor intensive. Firms who invest time and effort in gaining legal protection will have less time for other activities. Accordingly, it may lead firms to allocate attention away from some of the activities that might help the innovation in the market and they may become overly focused on protecting what they know. It should be stressed that the effort the firm has to devote to winning legal protection are much wider than the efforts and costs associated with having a legal function within the firm *per se*. Efforts with respect to legal protection may well affect the entire R&D organization in the sense that strong attention to legal appropriability

has to be paid through all the stages of the innovative process. In the words of Douglas Brotz, Principal Scientist, Adobe Software, at a public hearing on "The Use of the Patent System to Protect Software Related Inventions" (1994):

> Resources that could have been used to further innovation have been diverted to the patent problem. Engineers and scientists such as myself who could have been creating new software, instead are focusing on analyzing patents, applying for patents, and preparing defenses. Revenues are being sunk into legal costs instead of into research and development. (quoted from Macdonald, 2004: 152).

In the case of a first mover appropriability strategy, firms may also be locked into a mentality of control and secrecy, unable to share the ideas and benefits of their products with external actors. An overemphasis on legal and first mover protection may lead firms to a *myopia of protectiveness*, whereby efforts to appropriate dominate the process of commercialization. Instead of focusing on wide range of activities necessary to achieve the innovation, such as the mobilization of complementary assets, innovators may become obsessed with control, secrecy or legal protection. The fear of theft may lead them to become inward, focusing their attention away from opportunities for collaboration and the mobilization of complementary assets. Like Gollum in *The Lord of the Rings*, they become withdrawn and controlling, rather than open and collaborative, afraid that outsiders may steal their "precious" technology.

A number of different studies of innovators have suggested that many firms have moved away from tight appropriability strategies and adopted instead an "open" innovation model. Chesbrough (2003) suggests that innovators need to be careful not to become too closed to external actors and opportunities. In Chesbrough's model of open innovation, firms draw ideas from a large number of external sources and make available some of their technology to actors outside the firm in order to find new pathways to commercialization. The model suggests that firms that are overly protective of their intellectual property are forgoing opportunities.

A myopia of protectiveness may also limit opportunities to trade knowledge with suppliers, users and competitors. Von Hippel (1988: 76-92) shows that many innovators have dense networks of relations with their users, suppliers and competitors, and that trading certain ideas and secrets in strategic ways is often

mutually beneficial. Such knowledge trading reflects the willingness to be open to external actors. It suggests that firms that are too tight in their appropriability strategies may be foregoing opportunities for exchange.

The above discussion leads us to conjecture that there are clear advantages in following legal as well as first mover appropriability strategies in reaping the fruits of innovation, but that at some point, the focus on exploitation of existing ideas – in contrast to exploration of new ideas – becomes too strong (March, 1991; Levinthal & March, 1993). Accordingly, we hypothesize:

H1a. The strength of legal appropriability strategy is curvilinearly (taking an inverted U-shape) related to innovative performance

H1b. The strength of first mover appropriability strategy is curvilinearly (taking an inverted U-shape) related to innovative performance

Apart from the separate effects of legal and first mover appropriability strategies, these strategies may also by used together and have either complementary or substitution effects on performance. At the level of the industry, Cohen et al. (2000: 6-9) suggest that there may be complementarities between first mover appropriability and legal appropriability mechanisms. As pointed out above, legal and first mover appropriability strategies may be used successfully at the same time for a given innovation, when an innovation is comprised of separately protected components or features. An example of such "parallel protection" comes from the chemical industry, where firms sometimes protect an innovation by applying for one or more patents while keeping other parts secret (Arora, 1997). Related, since product and process innovations are often complementary (Pisano, 1996), legal and first mover strategies may also be complementary when they are used separately for (related) product and process innovations. In that case, legal mechanisms may predominantly be used to protect product innovation, while first mover mechanisms may predominantly be used to protect the complementary process innovation. Indeed, Cohen et al. find empirically that patents are more effective for product innovation than for process innovation at the level of the industry. Legal and first mover mechanisms may also be linked causally as when a complementary marketing capability or a patent confers a

lead-time (Cohen et al., 2000: 6-7). Moreover, different appropriability mechanisms may be used at different stages of the innovation process. Firms may initially rely on secrecy prior to the commercialization of a new product, but subsequently try to retain competitive advantage through legal means, such as patents. In sum, we conjecture:

H2. Legal and first mover appropriability strategies are complementary in influencing innovative performance.

DATA AND METHODS

Sample

The data for the analysis is drawn from the UK innovation survey. The survey was implemented in 2001 and is based on the core Eurostat Community Innovation Survey (CIS) of innovation (Stockdale, 2002; DTI, 2003a). The method and types of questions used in innovation surveys are described in the Organization for Economic Co-operation and Development's (OECD) Olso Manual (OECD, 1997). CIS data have been used in over 60 recent academic articles, mainly in economics (for recent prominent contributions using CIS data, see Cassiman & Veugelers, 2002; Mairesse & Mohnen, 2002). CIS surveys of innovation are often described as "subject-oriented" because they ask individual firms directly whether they were able to produce an innovation. The interpretability, reliability and validity of the survey were established by extensive piloting and pre-testing before implementation within different European countries and across firms from a variety of industrial sectors, including services, construction and manufacturing.

The CIS questionnaire draws from a long tradition of research on innovation, including the Yale survey and the SPRU innovation database (for examples, see Levin et al., 1987; Pavitt, Robson, & Townsend, 1987, 1989; Cohen & Levinthal, 1990; Klevorick, Levin, Nelson, & Winter, 1995). CIS data provides a useful complement to the traditional measures of innovation output, such as patent statistics (Kaiser, 2002; Mairesse & Mohnen, 2002). Patents vary in economic importance across different sectors and many patents do not lead to commercially successful products (Levin et al., 1987). CIS data offers "a direct measure of success in commercializing innovations for a broad range of industries…that more traditional measures may not capture." (Leiponen & Helfat, 2003).

The questionnaire asks firms to indicate whether the firm has been able to achieve a product innovation. Product innovation is defined as:

> ...goods and services introduced to the market which are either new or significantly improved with respect to fundamental characteristics. The innovations should be based on the results of new technological developments, new combinations of existing technology or utilization of other knowledge by your firm (DTI, 2003b).

Firms are then asked to state what share of their sales can be ascribed to different types of innovations, such as innovations that are "new to the world". Alongside these performance questions, there are number of questions about the sources of knowledge for innovation, the effects of innovation, intellectual property strategies and expenditures on R&D and other innovative activities.

The UK innovation survey is 12 pages long and includes a page of definitions. The sample of respondents was created by Office of National Statistics (ONS). It was sent to the firm's official representative for filling in information on the firm's activities, such as surveys for calculating the UK Gross Domestic Product and R&D expenditures. It was normally completed by the CEO or by the R&D manager of the firm. The implementation of the survey was administered by the ONS and to guide respondents a help service was provided (Stockdale, 2002).

The survey was sent to 13,315 business units in the UK in April 2001 and a supplementary sample of 6,287 was posted the survey in November 2001. It received a response rate of 41.7% (Stockdale, 2002). The second mail out was designed to top-up the number of regional responses to the survey. The responses were voluntary and respondents were promised confidentiality and that the survey would be used to shape government policy. The sample was stratified by twelve Standard Industrial Classification (SIC) classes and includes all main sectors of the UK economy, excluding public bodies, retail, and hotels and restaurants. The response rates for different sectors, regions and size is largely consistent with the overall response pattern (Stockdale, 2002). Our sub-sample of the survey includes 2707 manufacturing firms and draw from the entire UK manufacturing sector.

Descriptive results

Table 1 presents several of the legal and first mover appropriability methods listed on the survey for all manufacturing firms.[1] In the question of appropriability, each firm is asked to indicate on a 0-1-2-3 scale the degree of importance for each appropriability mechanism for their firm's innovative activities. Overall, the results indicate first mover mechanisms of appropriability, including lead times, secrecy and complexity of design, are the most important for UK firms. Among the legal mechanisms available, patents and trademarks are the most important. Only 21% of all firms indicate that they found registration of designs as being important.

Our findings are consistent with the Yale and Carnegie Mellon surveys of appropriability (Levin et al., 1987; Cohen et al., 2000). These studies and our own demonstrate that first mover mechanisms of appropriability are dominant among manufacturing firms. However, direct comparisons between Yale and Carnegie Mellon surveys and the UK innovation survey are extremely difficult. In both Yale and Carnegie Mellon, respondents were asked to assess the effectiveness of means of protecting innovation for their *industry*, whereas on the UK innovation survey the question is based on the importance of the mechanism to the *firm*. In this respect, the UK innovation survey is more directly focused on firm-level appropriability strategies than previous industry-oriented research on appropriability.

[Table 1, just about here]

In Table 2, we examine the legal and first mover mechanisms of appropriability across industrial sectors. Overall, we find strong industry differences in the importance of different mechanisms of appropriability. As expected, the importance of appropriability mechanisms is greatest in the chemical industry, which includes pharmaceutical firms. Machinery and electrical product industries are also heavy users of both legal and first mover appropriability mechanisms. It appears that industries characterized by low levels of technological opportunity use few appropriability mechanisms. In all industries, the mean scores for first mover mechanisms are greater

[1] The Yale and Carnegie Mellon use the term, "appropriability mechanisms", while the UK CIS Survey uses the term "appropriability methods", but the items are in most cases identical. We use the two terms interchangeably.

than for legal mechanisms of appropriability. In general, these findings are consistent with previous work on inter-industry differences in appropriability conditions and technological opportunities (Levin et al., 1987).

[Table 2, just about here]

Measures

Dependent and independent variables

For the dependent variable, we use a variable aimed at indicating the ability of the firm to produce major, new innovations. This variable is measured as the fraction of the firm's sales relating to products new to the world market. On the UK innovation survey, firms were asked directly whether their enterprise "introduced any new or significantly improved products which were also new to the enterprise's market" and "what share of total firm [sales] these products accounted for in 2000" (DTI, 2003b).

As determinants of innovative performance, we introduce two new variables reflecting the different types of firm-level appropriability strategy.[2] Both variables are constructed from a question of the UK innovation survey about the importance of different methods for protecting innovations. Firms were asked to assess the degree of importance for a variety of legal and strategic mechanisms for both recent and past innovations.

The first variable reflects *legal appropriability strategy* and it includes the items "registration of design", "trademarks" and "patents" from the survey. In order to ensure comparability with our first mover appropriability strategy variable, we removed two legal mechanisms – "confidentiality agreements" and "copyright" – those that were used least by firms responding to the survey. For estimating the cumulative importance of these legal mechanisms of appropriation, we simply added up the scores for each firm for the three legal mechanisms. The cumulative score represents the strength of the firm's legal appropriability strategy. The composite variable appears to have a high degree of statistical validity (Cronbach's Alpha=0.84).

[2] In their analysis of the determinants of R&D cooperation, Cassiman & Voeglers (2002), use a very similar variable to our *first mover appropriability variable* (see below) – they term their variable "strategic protection".

For the *first mover appropriability strategy*, we use three items from the survey that reflect non-legal or first mover mechanisms of appropriability. In particular, we used "secrecy", "complexity of design" and "lead-time advantage on competitors". As in the case of legal appropriability, we added the scores for each firm for all three mechanisms. Accordingly, the greater the score for each firm the greater the strength of the firm's first mover appropriability strategy. The cumulative variable for the first mover appropriability strategy also appears to be a valid construct (Cronbach's Alpha=0.88).

Although there is a strong overlap in our empirical approach and previous studies of appropriability mechanisms, there are several important differences. The first of these differences relates to the empirical treatment of appropriability strategy. Despite the fact that the items listed on the UK innovation survey and the Yale and Carnegie Mellon surveys of appropriability are similar, there are some key differences in mechanisms used in different surveys. Both the UK innovation survey and Carnegie Mellon include patents, lead times and secrecy as mechanisms of appropriation, yet Carnegie Mellon does not include "complexity of design" and it groups other legal mechanisms, such as trademarks into one item. However, it also includes two items not used in the UK innovation survey: complementary sales and service and complementary manufacturing.

Second, Cohen et al. find that strong differences between firms that use legal mechanisms of appropriability with those that use first mover mechanisms. They conduct a factor analysis of the responses and it yields several factors that load onto either first mover or legal mechanisms. We follow a different empirical approach. Since we want to assess the strength of the use of legal and first mover appropriability strategy at the firm-level and relate this strategy to innovative performance, it is necessary to use a cumulative construct. The use of the factor analysis would focus attention on the pattern of use of appropriability mechanisms rather the strength of their use.

Third – as mentioned before – the Yale and Carnegie Mellon surveys focus on the importance of appropriability mechanisms for the industry, not the firm (Arundel,

2001). In fact, in the Yale study, individual firm-level scores were aggregated and great efforts were made to make sure that individual firm responses were representative of the industry as a whole (Levin et al., 1987). While these pioneering industry-level studies of appropriability have greatly deepened our understanding of the relationship between technological opportunities, appropriability and market structure, these studies remove the scope for managerial choice. Unlike the studies using the results of those surveys, we attempt to link the use of appropriability mechanisms to innovative performance at the level of the firm. In this approach, we assume that firms have a degree of choice in how they seek to protect their innovative efforts. This assumption is consistent with the literature on appropriability and managerial strategy in that it ascribes an important role to managerial choice in shaping the outlook of the firm to its external environment (Rumelt, 1994; Bowman & Helfat, 2001).

Control variables

Given that many studies of innovation have found that a key source of innovations are lead users, we include a variable reflecting the use of lead users in innovation (Rothwell, Freeman, Jervis, Robertson, & Townsend, 1974; von Hippel, 1988; Urban & von Hippel, 1998). The variable (*lead user*) is constructed by using a question on the survey about the importance of different sources of knowledge for innovation. The variable takes the value of 1 when the firm indicates that it uses clients or customers to a high degree as a source of knowledge for its innovation activities, and 0 otherwise.

We also include – using a binary variable – a control for whether or not firms engaged in co-operation arrangements on innovation activities (*innovation cooperation*), based on a supplementary question on the survey. Previous studies have found a relationship between cooperation and innovative performance (Powell, Koput, & Smith-Doerr, 1996; Ahuja, 2000; Cassiman & Veugelers, 2002). Firm size may also influence the propensity to innovate. Although empirical research indicates that advantages of size for innovative performance are ambiguous, size is commonly used variable in studies of innovative performance (Cohen, 1995). We measure *firm size* (expressed in logarithms) by the number of employees.

Like most other studies on innovative performance, we include a measure of *R&D intensity*, measured as firm R&D expenditure divided by firm sales, as a proxy for level of firm-level investments in the innovation process. The numerator is taken from the UK innovation survey, while the denominator firm turnover or sales is based on Office of National Statistics register data, supplied with the survey data. We also control for the size of the perceived product market (*market size*). The variable measures whether the largest market of the firm is perceived to be local, regional, national or international. This variable takes the values from 1 to 4, with 1 corresponding to "local" and 4 corresponding to "international" (Laursen & Salter, 2004). Finally, we include 13 industry controls to account for different propensities to innovate across industries (Levin et al., 1987; Cohen et al., 2000).

Descriptive statistics are given in Table 3. From the table it can be seen that on average, 2.47 per cent of firms' turnover can be attributed to products new to the world. On average, firms indicated that they attach greater importance to first mover appropriability than to legal appropriability. Simple correlations between our explanatory variables can be found in Appendix Table 1. The strong correlation between legal and first mover appropriability strategies indicates the possible presence of multicollinearly, an issue that is further examined in the regression analysis.

[Table 3, just about here]

RESULTS

The dependent variable in the regression model is (double) censored, since the variable is the percentage of innovative sales and therefore by definition ranges between 0 and 100. Accordingly, a Tobit analysis is applied (see Greene, 2000: 905-926). However, the assumption of normality of residuals in the standard Tobit model is not satisfied in our case. Under these conditions, the Maximum Likelihood estimators of the standard Tobit model are not consistent. Alternative specifications of the Tobit model have been formulated that account for departures of the distributions from normality (see Greene, 2000: 916). The variables reflecting the innovative performance of firms are highly skewed, and accordingly, the pattern observed in the empirical distribution is better represented by lognormal distributions. Other studies,

facing similar problems in terms of similar characteristics of skewness and departure from normality, have proposed a log-transformation of the Tobit model with a multiplicative exponential error term (Filippucci, Drudi, & Papalia, 1996; Papalia & Di Iorio, 2001). We apply this approach to the study of innovative performance and assume a lognormal distribution for the residuals of the Tobit model. This model introduces a latent variable, INN*, as a logarithmic transformation of an observed measure of innovative performance, INN: that is, INN* = ln (1 + INN). It is then assumed that the latent variable of innovative performance of a firm *i* is a function of a number of explicative variables.

The results of the Tobit regression analysis can be found in Table 4. When looking at Model 1, we find strong support for the two hypotheses asserting that the strength of legal and first mover appropriability strategies are curvilinearly – taking an inverted U-shape – related to innovative performance (H1 & H2). First, the parameters for the strength of both appropriability strategies are significant and positive in explaining innovative performance. Accordingly, firms having both legal and/or first mover strategies appear to have higher levels of innovative performance. Second, the two parameters for the squared terms are significant as well, showing that when firms become too focused on appropriability decreasing returns set in.

[Table 4, just about here]

Figure 1 displays our empirical model's prediction of the relationship between the strength of the legal appropriability strategy and innovative performance. From the figure, it can be seen that the point where search has negative consequences for performance – what could be called the "tipping point" – is at the score of five on the appropriability scale (the maximum score is nine), so that when a firm has a legal appropriability score over five, negative consequences arise. However, although the model *predicts* negative returns, we can only conclude that there are decreasing returns from a negative and significant squared term, since the downward bend of the curve may not be statistically significant. In order to investigate this issue, we estimate a model where we replace the legal appropriability strategy variable with a set of dummies, where the benchmark dummy is one, if the original legal appropriability variable takes the values from 4 to 8; zero otherwise. In a similar

fashion, we create dummies for values of legal appropriability equaling 0, 1-3 and 9. The results (not show for reasons of space, but available upon request) show that the parameters for the "0", "1-3" and "9" dummies are negative and significantly different from the benchmark (at the 1, 5 and 10 per cent levels respectively). In other words, there are negative returns for the (112) firms that obtain a legal appropriability score of 9. However, if the dummies are changed so that the benchmark no longer includes the value 8 and the last dummy represents the values 8-9 of the original legal appropriability variable, such a dummy variable ceases to be significant. In other words, these additional results indicate that there are only decreasing returns for a legal appropriability score of 9.

[Figure 1, just about here]

Figure 2 displays our empirical model's prediction of the relationship between the strength of the first mover appropriability strategy and innovative performance. From the figure, it can be seen that for first mover appropriability, there are decreasing returns from having stronger appropriability strategies in the sense that the curve predicting the relationship is concave with a top point of nine on the appropriability scale. So while there are strong decreasing returns the closer to nine one gets on the first mover appropriability scale, it should be noted that within the range of the first mover appropriability scale (0-9) no negative consequences arise.

[Figure 2, just about here]

When comparing the two sets of estimates, it can be seen that decreasing returns set in much quicker in the case of legal appropriability strategies as compared to first mover appropriability, since the maximum effect on innovative performance is at an appropriability score of five in the former case, while in the latter case the maximum impact arises at a score of nine – which is the highest possible score. In other words, the degree of use of first mover strategies has a stronger positive impact on innovative performance in comparison to legal strategies. Model 2 and 3 contain estimates of the empirical model with legal and first mover appropriability strategies entered separately into the regression, given that the two variables may be collinear. However,

the outcome of the separate estimations shows that the results are robust to this change in specification.

Model 4 and 5 examines Hypothesis 3, which contends that the two appropriability strategies are complements in influencing innovative performance. We find no support for the hypothesis – in fact we find evidence of the opposite, since the interaction term between the strength of the two strategies is significant at the one per cent level, but has a negative sign. One reason for this finding is likely to be that a legal appropriability strategy requires the disclosure of knowledge, which may be at least partly incompatible with a first mover appropriability strategy, associated with being silent, complex and quick (Cohen et al., 2000: 7). In addition, using both types of strategies strongly may require different skills that are not easy to integrate and orchestrate. Legal mechanisms require legal competencies, while first mover mechanisms often require strong competencies in science and engineering.[3] Due the different skill requirements an attention allocation problem may emerge when using both strategies strongly.

Nevertheless, an alternative interpretation could be that the negative parameter for the interaction term just reflects too much focus on appropriability in general, rather than a real substitution effect between the two variables. In order to investigate this potential problem in Model 5, we created two dummies simply reflecting whether or not each firm is using each of the two appropriability strategies at all. Subsequently, we interact the two dummies – and again we find a significant and negative parameter, confirming that the two types of appropriability strategies are indeed substitutes.

Among our control variables, the parameters for lead users, innovation cooperation, R&D intensity and size of the product market are consistently positive and significant in explaining the proportion of sales of innovative products. The size of the firms appears to have no bearing on the innovative performance of the firm. This finding is consistent with the findings from previous studies of innovative performance (see

[3] Scherer (1965) found that the number of patent lawyers employed by the firm was more strongly correlated to the number of patents taken out by that firm than the number of R&D personnel. This result suggests that development of in-house legal capabilities may lead some firms to become more focused on formal methods of appropriability.

Cohen, 1995; Laursen & Foss, 2003). With respect to the industry dummies, our results show that after controlling for the other factors in the regression, firms in chemicals, plastics, paper & printing, and electrical goods on average do better in terms of innovative performance.

DISCUSSION AND CONCLUSIONS

Appropriating innovations is hard and many firms find the rents from their innovations captured by their competitors or owners of complementary assets. No single mechanism of appropriation provides firms security for their innovations. However, as the importance of the economic value of knowledge has become more widely recognized in corporate and innovation strategy, more and more firms are beginning to pay attention to the potential advantages of appropriability mechanisms. Obviously, the ability of innovative firms to control the imitation strategies of other firms in their market will always remain limited. However, the choices managers make about how best to protect their intellectual capital can be a matter of life and death for their firm. Despite the fact that the legal strategy for appropriation has been widely lauded in some parts of the recent management literature, firms still appear to rely heavily on first mover mechanisms for protecting their innovations. Legal appropriability mechanisms are widely used, but they do not always provide sufficient security for innovators.

In order to expand the focus of past research on industry-level appropriability, we have examined the role of appropriability strategies on innovative performance among UK firms. Our approach focused attention at the firm-level and on how choices by managers about how to appropriate its innovations might shape the firm's ability to innovate and capture the returns for these innovations. In doing so, we developed the concepts of legal and first mover appropriability strategies to reflect the degree to which firms use different mechanisms for protecting their innovations. Like previous research, we found that the importance of these different appropriability strategies differs greatly by industry and that legal mechanisms are less frequently used than first mover mechanisms.

On the basis of our statistical analysis, we found that using an appropriability strategy strongly influences the ability of a firm to achieve novel innovation. Both legal and

first mover appropriability strategies, associated with increased managerial attention to appropriability, helps innovative performance. This finding indicates that managerial researchers are right to point to the need for managers to greater attention to appropriation in the development of their corporate and innovation strategies. However, we also found that an overemphasis on either legal or first mover appropriability can have detrimental consequences for innovation performance – this is especially the case with respect to the legal appropriability strategy. In other words, we found that some firms are overly protective of their innovations.

There are several possible interpretations of this finding. We suggested that firms might develop a *myopia of protectiveness*, being overly protective of their new innovations. They focus their managerial resources and attention towards the acquisition of legal protection to the detriment of other activities, such as the mobilization of complementary assets. They may become obsessed with secrecy, limiting their opportunities to work with others, such as lead users, or to trade knowledge informally with suppliers, customers and competitors. In this respect, firms may suffer from a "Gollum effect", locking themselves away from the rest of society in the vain pursuit of full protection. As Chesbrough suggests, in order to capture the benefit of innovative efforts, firms may have to be willing to open themselves up to the outside world and work with others to help achieve the realize the opportunities that a new innovation may offer. In this respect, Rivette and Kline's exhortation for firms to acquire greater intellectual property may be harmful to innovative performance if it is pushed too far and too aggressively. Firms need to be careful not to draw their attention away from the broad range of activities that might help their innovation succeed in the market. They need to avoid becoming like Gollum, obsessed with preciousness of possession.

The present paper also examined the relationship between legal and first mover appropriability strategies. We found that firms who tend to use a legal appropriability strategy also tend to use a first mover appropriability strategy. In part this finding reflects that firms in industries with high levels of technological opportunities place a greater emphasis on appropriability mechanisms in general. However – and in contrast to our expectations – we found that managerial strategies at the firm-level that focus on both legal and first mover appropriability are incompatible – perhaps

because legal mechanisms require openness and disclosure and first mover mechanisms require secrecy and non-disclosure. In this respect, the results show that appropriating an innovation requires firms to make choices between different paths of appropriation and firms trying to go for both strategies may find themselves "stuck in the middle".

Future research

The current emphasis in managerial research on the management of intellectual property can yield many important insights in the factors that shape the ability of firms to appropriate their innovations. Yet much greater knowledge is needed about how appropriability strategies shape firm performance. In our study, we have focused on innovative performance, a central element in gaining and sustaining competitive advantage. Future research could examine how appropriability strategies shape the financial performance of the firm, its chances of surviving in the market and its patterns of diversification.

In the professional literature on managing intellectual property, great attention has been placed on a firm's patent strategies. Yet, it appears that "patents do not work in practice as they do in theory" and rarely do they confer perfect appropriability (Teece, 1986: 287). Only in a small number of industries do patents appear to be a central mechanism for the protection of product and process innovations. Given this context, the emphasis on patents in corporate and in innovation strategies appears to be somewhat misplaced. Other appropriability mechanisms in comparison have received scant attention. In order to overcome the bias towards patents in the prevailing debates on appropriability of innovation, greater efforts are necessary to find new empirical evidence on the role of different appropriability mechanisms in shaping firm performance.

The approach of this paper has been to examine appropriability mechanisms based on questionnaire data, yet the use of an appropriability mechanism involves a range of managerial activities that can only captured imperfectly in a survey. A better understanding of how firms choose appropriability strategies and how these different strategies are combined in particular firms would deepen our understanding of the organizational processes that give rise to an appropriability strategy.

It also may be possible examine the importance of different appropriability strategies for different types of innovation. As pointed out earlier, Cohen et al. find that patents are more effective for product innovation than for process innovation at the level of the industry. Extending on this approach, it could be possible to link appropriability strategy to different stages of the product life cycle, indicating where and when legal and first mover mechanisms are most effective.

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Table 1: The importance given to different appropriability methods for innovation 1998-2000

Type	Appropriability method	Not used	Low	Medium	High
		Percentages			
Legal	Registration of design	79	7	7	7
	Trademarks	73	6	9	11
	Patents	77	6	7	11
First mover	Secrecy	63	11	13	13
	Complexity of design	65	13	14	8
	Lead-time advantage on competitors	59	10	16	15
Average		69	9	11	11

Table 2: Means of legal and first mover methods of appropriability by industry

	Legal mean	First mover mean	No. of firms
Food, drink & tobacco	1.18	1.92	242
Textiles	1.03	1.76	197
Wood	1.31	1.98	185
Paper and printing	0.67	1.10	304
Chemicals	3.17	4.13	126
Plastics	1.84	2.79	157
Non-metallic minerals	1.75	2.60	85
Basic metals	1.22	2.11	64
Fabric. metal products	0.73	1.27	359
Machinery	2.21	3.16	233
Electrical	2.07	3.30	497
Transport	1.59	2.59	320
Other	1.52	2.03	390
Average	1.56	2.36	

Table 3: Descriptive statistics and simple correlations

Variable	Mean	Std. dev.	Min.	Max.	2	3	4	5	6	7	8
1 Share in sales of innovations	2.47	10.86	0.0	100.0							
2 Legal appropriability	1.51	2.58	0.0	9.0	0.13 ***						
3 First mover appropriability	2.30	2.94	0.0	9.0	0.19 ***	0.64 ***					
4 Lead user	0.14	0.34	0.0	1.0	0.14 ***	0.20 ***	0.30 ***				
5 Innovation cooperation	0.14	0.35	0.0	1.0	0.13 ***	0.21 ***	0.31 ***	0.21 ***			
6 Firm size	4.05	1.42	0.0	9.5	0.02	0.34 ***	0.32 ***	0.11 ***	0.22 ***		
7 R&D intensity	0.54	3.66	0.0	90.6	0.22 ***	0.16 ***	0.18 ***	0.07 ***	0.13 ***	0.06 ***	
8 Market size	2.73	0.92	1.0	4.0	0.12 ***	0.29 ***	0.33 ***	0.12 ***	0.20 ***	0.35 ***	0.13 ***

*** $p < .001$

Table 4: Tobit regression, explaining innovative performance across UK manufacturing firms

Independent variables	Model 1	Model 2	Model 3	Model 4	Model 5
	Coeff	Coeff	Coeff	Coeff	Coeff
Legal appropriability	0.389 **		0.766 ***	0.517 **	0.497 †
	0.143		0.140	0.150	0.304
Legal appropriability squared	-0.033 †		-0.055 **	-0.012	-0.040
	0.017		0.017	0.019	0.029
First mover appropriability	0.673 ***	0.809 ***		0.589 ***	0.161
	0.137	0.131		0.139	0.281
First mover appropriability squared	-0.036 *	-0.044 **		-0.013	0.007
	0.016	0.015		0.017	0.026
Legal appropriability x				-0.052 **	
First mover appropriability				0.019	
Use of legal appropriability					1.498 †
					0.843
Use of first mover appropriability					2.003 **
					0.733
Use of first mover appropriability x					-2.252 **
Use of legal appropriability					0.678
Lead user	0.943 **	0.938 **	1.348 ***	0.961 **	0.919 **
	0.288	0.288	0.294	0.287	0.286
Innovation cooperation	1.728 ***	1.724 ***	2.103 ***	1.657 ***	1.665 ***
	0.288	0.287	0.296	0.288	0.286
Firm size	-0.097	-0.032	-0.050	-0.083	-0.085
	0.090	0.087	0.091	0.090	0.090
R&D intensity	0.069 **	0.071 **	0.081 **	0.071 **	0.070 **
	0.022	0.022	0.022	0.022	0.022
Market size	0.500 **	0.547 **	0.639 ***	0.475 **	0.463 **
	0.161	0.161	0.163	0.161	0.161
Food, drink & tobacco	0.900	0.846	0.756	0.974	0.907
	0.916	0.918	0.917	0.915	0.916
Textiles	1.158	1.130	0.924	1.294	1.186
	0.935	0.937	0.939	0.935	0.938
Wood	0.864	0.858	0.701	0.964	0.853
	0.952	0.954	0.956	0.951	0.954
Paper and printing	1.641 †	1.596 †	1.187	1.759 †	1.667 †
	0.902	0.905	0.904	0.902	0.904
Chemicals	1.762 †	1.777 †	1.823 †	1.830 †	1.809 †
	0.925	0.926	0.931	0.924	0.925
Plastics	1.635 †	1.601 †	1.754 †	1.672 †	1.667 †
	0.927	0.929	0.929	0.926	0.928
Basic metals	0.299	0.184	0.154	0.386	0.183
	1.215	1.217	1.221	1.218	1.222
Fabric. metal products	0.844	0.823	0.501	0.895	0.845
	0.900	0.902	0.902	0.900	0.903
Machinery	1.107	1.121	1.120	1.154	1.178
	0.889	0.891	0.893	0.888	0.890
Electrical	1.413 †	1.393 †	1.384 †	1.471 †	1.453 †
	0.841	0.843	0.844	0.840	0.842
Transport	0.693	0.666	0.610	0.756	0.708
	0.878	0.880	0.881	0.877	0.879
Other	0.626	0.659	0.382	0.670	0.655
	0.876	0.879	0.879	0.876	0.877
Non-metallic minerals	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark
Constant	-8.844 ***	-9.117 ***	-8.661 ***	-8.976 ***	-9.138 ***
	1.036	1.040	1.033	1.040	1.048
No. of obs	3159	3159	3159	3159	3159
No. of left censored obs	2755	2755	2755	2755	2755
No. of right censored obs	17	17	17	17	17
Log likelihood	-1705.61	-1711.20	-1739.56	-1701.96	-1697.89
Chi-square	444.47 ***	433.28 ***	376.56 ***	451.76 ***	459.91 ***
Pseudo R2	0.12	0.11	0.10	0.12	0.12

† $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$

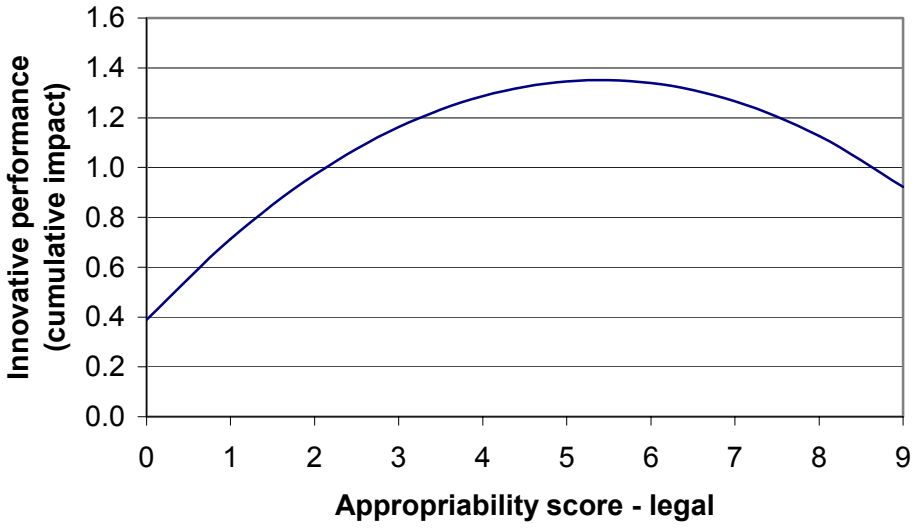

Figure 1: Predicted relationship between innovative performance and the legal appropriability score of the firm

Figure 2: Predicted relationship between innovative performance and the first mover appropriability score of the firm