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Combining appropriability mechanisms for innovation collaboration by knowledge-intensive services firms

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Abstract

We explore the relation between the choice of appropriability mechanisms and that of innovation collaboration with external organisations for knowledge-intensive business services (KIBS) firms. Our research paves the way for a better understanding of firm choices of appropriability strategy and innovation collaboration in sectors where formal appropriability mechanisms (such as patents) play a less important role in capturing value from innovation. Multivariate analyses - using data from an original survey of UK and US publicly-traded KIBS firms - indicate that KIBS firms do not consider formal appropriability mechanisms as significant value capture mechanisms. Despite this, we find a positive association between the importance accorded to formal appropriability mechanisms (such as patents, copyrights and trademarks) and to innovation collaboration (especially with public research organisations). Nevertheless, high levels of

emphasis placed on formal appropriability mechanisms are associated with assigning less importance to collaboration with clients. Contractual appropriability mechanisms (confidentiality agreements and employment contracts) are considered the most important appropriability mechanisms, but high levels of emphasis on these are associated with assigning less importance to innovation collaboration (especially with clients). We finally find that different combinations of appropriability mechanisms are associated with an enhanced or diminished importance of innovation collaboration with (different) external organisations.

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Combining appropriability mechanisms for innovation collaboration by knowledge-intensive services firms

1. Introduction

Few studies of firms' choice of structures (including governance modes and appropriability mechanisms) to both source external knowledge and prevent unwanted spillovers of knowledge (Fey and Birkinshaw, 2005; Laursen and Salter, 2014) have addressed service firms. Collaboration for innovation has long been the norm for services firms (Arundel et al., 2007; Chesbrough, 2011; Tether, 2005), and especially for knowledge-intensive business services (KIBS) firms, which rely heavily on technical or professional knowledge, applying this to solve the problems of specific clients (Miles, 2005).

Since they routinely create knowledge assets jointly with external partners (especially clients), KIBS firms may find value capture more challenging than do manufacturing firms. Innovations made by service firms are often not technological, are largely intangible, and are difficult to promote or protect through formal intellectual property protection mechanisms (such as patents) or contract and tort rules (Blind et al., 2003; Samuelson, 2010). Just as is the case with innovating manufacturing firms, innovating services firms tend to combine a number of different appropriability mechanisms to protect their innovations (including many informal ones) (Amara et al., 2008). Notwithstanding, we know little about the relation between KIBS firms' choice of different appropriability mechanisms and their innovation collaboration.

Drawing on an original survey of 153 British and American publicly-traded KIBS firms, this paper presents the results of an exploratory study of the relation between the choice of appropriability strategies and collaboration for innovation by KIBS firms. This research paves the way for a better understanding of firms´ choice of appropriability strategy and innovation collaboration, in sectors where formal appropriability mechanisms (such as patents) play a less important role in vale capture from innovation. This is important since even manufacturing firms are now shifting from selling products to selling product-service systems (Neely, 2008).

We identify distinctive types of appropriability strategies that firms adopt with different types of partners for innovation collaboration. We build on and extend previous contributions from the literature on strategy and innovation, in three main ways. First, we build on previous work on the determinants of innovation collaboration for services firms (Love et al., 2011; Mina et al., 2014). Second, we draw on and extend research showing that

the choices of firms to collaborate for innovation with different external organisations are related to choices about their appropriability strategy (Hagedoorn and Ridder, 2012; Laursen and Salter, 2006; 2014). Third, our study addresses the call from Gallie and Legros (2012) to examine the use of different appropriability mechanisms, going beyond the opposition of patents and secrecy. We consider the use of eleven appropriability mechanisms, including formal and informal appropriability mechanisms. Furthermore, we consider innovation collaborations with a wide range of external organisations - including suppliers, clients, competitors, consultants, universities and public research organisations.

To anticipate the results, despite the fact that KIBS firms do not consider formal appropriability mechanisms (such as patents, copyrights and trademarks) as significant mechanisms for value capture, we find a positive association between the importance accorded to formal appropriability mechanisms and to innovation collaboration (especially for collaboration with public research organisations). Nevertheless, high levels of emphasis on formal appropriability mechanisms are associated with assigning less importance to innovation collaboration with clients. Contractual appropriability mechanisms (confidentiality agreements and employment contracts) are considered the most important appropriability mechanisms, but high levels of emphasis on these are associated with assigning less importance to collaboration (especially with clients). Finally, we uncover associations between the combination of different appropriability mechanisms and assigning more or less importance to innovation collaboration with (different) external organisations. Our findings underscore the importance, in the context of collaboration for innovation, of considering choices (and combinations) over the full spectrum of appropriability mechanisms - rather than just examining the use of single types of appropriability mechanisms; they also underscore the relevance of exploring the choice to collaborate for innovation with different partners.

2. Conceptual background: innovation collaboration and appropriability in KIBS firms

Evolutionary economics highlights the role of search in enabling firms to create variety, new combinations of knowledge, and pursue new technological paths (Nelson and Winter, 1982; Melcalfe, 1994). Access to external knowledge through collaboration with other organisations has long been regarded as a key to success in innovation (Rothwell et al., 1974; von Hippel, 1976). But there are dangers in opening up to sharing knowledge with external organisations: there is scope for unintentional knowledge leakages and, indeed, imitation. Appropriability mechanisms may be employed to avoid these unwanted spillovers, though excessive emphasis on appropriability mechanisms may discourage potential innovation collaborators, reducing

incentives for, or the scope or effectiveness of innovation collaboration. Little attention has been paid to the role of the choice of appropriability strategies when conducting search for innovation (Laursen, 2012). Moreover, research has not addressed service firms when examining the organisational processes or structures (including appropriability mechanisms and governance modes) firms use both to source external knowledge and to prevent unwanted spillovers of knowledge (Fey and Birkinshaw, 2005; Laursen and Salter, 2014). As noted above, these issues are particularly relevant for KIBS firms, with their high reported collaboration with clients and levels of innovation.

The study of the relation between the choice of appropriability strategy and that of collaboration for innovation by KIBS firms with different external organisations is complicated by the difficulties in conceptualising innovation in KIBS. Indeed, innovation by KIBS firms is hard to analyse, categorise, and measure, as it can (and often does) involve simultaneously new services, new ways of delivering services, new forms of client interaction and of quality control and assurance (den Hertog, 2000). Furthermore, there is great heterogeneity among KIBS firms regarding the way they undertake innovation. Some KIBS, for example, are "system integrator" firms, which develop complex engineering or IT "solutions" that meet the needs of large client organisations through highly developed divisions of labour, and employing sophisticated technologies (see the cases of Cable &Wireless, Atkins or IBM as discussed by Davies, 2004 and Miozzo and Grimshaw, 2011). In contrast, professional services firms, such as legal, advertising or consulting services, engage in innovation in a very different way from those "solutions" providers. For example, a management consultancy can help its client organisations to change in the course of implementing new or improved technologies or operations. Whether or not it has its own proprietary methodologies to guide in the identification of problems and produce recommendations, it will always work closely with clients for the development of new services, either putting organisational mechanisms in place to support codification of knowledge or, alternatively (and sometimes simultaneously), building up expertise to supply highly customised offerings to address unique problems of individual customers (Hansen et al., 1999, Miozzo et al., 2012).

Despite this heterogeneity, it is typical for KIBS firms to be involved in continuous creation and transfer of knowledge in collaboration with other organisations (Doloreaux and Shearmur, 2012; Gallouj and Weinstein, 1997; Jones et al., 1998), especially client organisations. Many authors refer to the notion of "co-production" of knowledge with clients to denote the way that routine work for specific clients relies on clients´ transfer of (partly

tacit) knowledge, and how this is intertwined with learning and innovation on one or both sides of the relationship (e.g. Bettencourt et al., 2002; den Hertog 2000).

Drawing on surveys such as the European Innobarometer and the Community Innovation Survey, researchers have explored the nature of collaboration for innovation by services firms. Among their findings is that service firms are less likely than manufacturing firms to collaborate with universities for innovation, less likely to draw on knowledge from suppliers, but more likely to draw on knowledge from clients for innovation (Arundel et al., 2007). Also, service firms are less likely than manufacturing firms to source new technologies through in-house R&D or through the acquisition of advanced machinery and equipment or through collaborations with universities and research institutes. Instead, innovating services firms are more likely to source new technologies through collaborations with customers and suppliers, or through the acquisition of external intellectual property (Tether, 2005).

A more recent stream of research on open innovation in services (see Chesbrough, 2011) has stimulated interest on collaboration for innovation by services firms. Mina et al. (2014) designed an original survey to study the open innovation practices of UK firms and find that business services are in fact more open seekers of external knowledge than manufacturing firms; innovation collaboration by business service firms tends to increase with R&D intensity and with human capital intensity. They also show that while both customers, on the one hand, and universities and other research organisations, on the other, are important as a source of external knowledge for business services, surprisingly, universities and public research organisations are relatively more important. This may be understood in the light of Love et al.'s (2011) exploration of openness in different stages of UK business services firms' innovation processes: collaboration with clients is important at the early stage, collaboration with research organisations at the intermediate stage, and collaboration with professional associations at the exploitation stage of innovation.

Like other firms, KIBS firms seek to reduce involuntary leakages or transfers of knowledge in the process of innovation collaboration. Since joint knowledge creation, especially with clients, is the norm, this opens up greater possibilities of conflict over ownership of the jointly-developed knowledge asset. The services provider is likely to want to replicate the solution, process, or design in projects with other clients; the client might want to use it in its own other activities, and may want to prevent it from being offered to competitors. For example, a study of IT services found evidence of cases where IT services providers also provided services to firms in direct competition with its existing clients; this led to client firms fearing knowledge leakages and the replication of IT systems that had delivered them a

competitive edge (Miozzo and Grimshaw, 2005 p. 1433). The study stressed the need for frequent discussion, negotiation and re-negotiation to reconcile objectives and interests between the client and KIBS supplier, and to institutionalise processes for managing such conflicts over intellectual property rights.

The strategic importance of intellectual property rights has been discussed by both strategy and innovation management scholars - mainly in the context of manufacturing firms. Formal appropriability mechanisms include patents, trademarks, copyrights, and design rights; these have been considered in the strategic management literature as mechanisms to prevent rivals from replicating valuable firm-specific assets (Somaya, 2003). Patents have been the main focus of attention in the debates on innovation incentives. They provide a temporary exclusive right to inventors; but they have disadvantages such as the costs of filing and renewal, the limits of their efficacy in terms of product and geographic market, and the disclosure of technical details, which can be used by competitors to identify potentially profitable research areas and the scope for inventing around the patent (Arundel and Kabla, 1998; Cohen et al., 2000; Gans et al., 2008; Horstmann et al., 1985; Lanjouw and Schankerman, 2001; Ordover, 1991; Ziedonis, 2004). Trademarks, though relatively neglected by innovation scholars, play a key role in innovation by helping to attract customers, differentiate products and generate revenue (see Hall et al., 2014; Mendonca, 2004). Firms that do not wish to disclose information via patenting may use secrecy to protect their innovation, withholding the technical details of an innovation from public dissemination both within and outside the organisation (Arundel, 2001; Liebeskind, 1997). [1] This may be preferred in contexts with weak intellectual property protection, where patents are less efficient (Cohen et al., 2002) or where knowledge is more inductive or practice-based (Arora, 1997). Another, more strategic, method for retaining value involves lead-time (first mover) advantages, which result from early development of product or process innovations or advantages from learning and experience with a technology (Lieberman and Montgomery, 1988). More broadly, Teece (1986, 2006) draws attention to complementary assets - such as management, manufacturing, and marketing skills, distribution networks, after-sales support, finance and relations with lead users - that can help firms capture value from innovation.

[1] Although there are trade secrets laws which legally forbid employees of a firm to provide outsiders with documents connected to the business of the firm, unlike formal appropriability mechanisms such as patents, trade secrets laws do not protect against competitors using 'fair' means to replicate the knowledge, protection does not extend to non-codified knowledge, and infringement is difficult to prosecute unless the employee has entered into an explicit contract of trade secrets with the firm, and the firm has made efforts to safeguard the secrecy of the piece of knowledge concerned. Thus, the firm needs to design different mechanisms to keep knowledge secret, such as secrecy rules, compensation or structural isolation (Liebskind, 1997).

Strategy and innovation management scholars argue that appropriability mechanisms can help heterogeneous partners collaborate for innovation because they provide a common language (Penin and Wack, 2008) and can enable pecuniary knowledge exchanges, facilitating the transfer of intangibles and allowing licensing revenues to flow into the firm (Arora, 1997; Arora et al., 2001). Some can also facilitate the flow of the tacit component of knowledge - for example when clauses of assistance and/or exchange of employees are included in licensing contracts (Foray, 2004). Appropriability mechanisms can facilitate innovation collaboration by providing a framework for what knowledge is shared and what remains private, as argued by Hagedoorn and Ridder (2012). These authors report on a survey of firms active in innovation collaboration in a range of countries: 90% of firms regarded patents and trade secrets as the most important instruments for protecting the innovative capabilities of firms from their innovation partners; 75% of firms surveyed regarded trademarks, 65% design rights, and 53% copyrights as important.

Appropriability mechanisms can also play the role of signals of innovative capabilities to potential partners. For instance, having control over particular and valuable knowledge assets helps partners to identify each other, and can alert potential users as to the availability of the technology; indeed, some firms are known to screen patent databases to identify potential partners for collaboration (Penin and Wack, 2008). This signalling dimension of appropriability mechanisms is all the more important as firms operate with incomplete information as to what other firms' activities and innovative capabilities, and the value of their innovations. Hagedoorn and Ridder (2012) report that - while this was less emphasised than the protection rationale - appropriability mechanisms (and particularly patents and trade secrets) played an important role as signals of innovative capabilities.

Patents and secrecy are often regarded as mutually exclusive (Arundel and Kabla 1998; Cohen et al., 2000; Horstman et al., 1985). In practice, however, firms' value capture strategies include a bundle of mechanisms (Cohen et al., 2000; James et al., 2013). In weak appropriability environments, or where firms combine product and process innovation (where tacit knowledge may play a more important role), it may be more effective for firms to combine patents with secrecy for different types of innovations or at different innovation stages (Arora, 1997; Polidoro and Theeke, 2012). Even in strong appropriability environments, ownership of complementary assets can increase the effectiveness of patents as appropriability mechanisms (Hall and Ziedonis, 2001; Teece, 2006). Firms in many countries tend to prefer secrecy as an appropriability mechanism for both product and process innovation (Levin et al., 1987; Harabi, 1995), while in Japan firms use patents for product

innovations and secrecy for process innovations (Cohen et al., 2000). Arundel (2001), drawing on the Community Innovation Survey for manufacturing firms in a number of European countries, shows that secrecy is a more prevalent means of appropriation than patents, and that secrecy and patents may be combined, especially by large firms. Gallie and Legros (2012), using data on French manufacturing and service firms, show that formal appropriability mechanisms and strategic appropriability mechanisms tend to be complementary between their own categories, but less so across categories. Thoma and Bizer´s (2013) exploration of small manufacturing firms (through the German Innovation Survey) shows that innovators combine several appropriability mechanisms: strategic protection mechanisms play a significant role in all appropriation modes, sometimes in combination with complexity of design, patents, trademarks or copyrights. Fischer and Henkel (2013) show that when firms try to profit from innovation there can be both complementarities and substitutabilities between different appropriability mechanisms. In particular, they find that although patents alone might not be perceived by managers in communications equipment companies as being effective methods for patent protection, their effectiveness is leveraged through the accumulation of a large patent portfolio. However, they also find evidence that patents are complementary to lead time advantages when firms have the requisite capabilities.

The findings of a number of studies imply that, even when particular appropriability mechanisms contribute to innovation collaboration, high levels of emphasis on them can be harmful for collaboration. For instance, while the evidence suggests that, within strong appropriability regimes (where imitation is difficult either because of strong formal appropriability mechanisms or difficult-to-imitate technology), firms are more willing to collaborate for innovation (Pisano and Teece, 2007), there is some evidence that innovation collaboration may be facilitated when firms deliberately reduce their use of some of their intellectual property rights. Henkel et al. (2014) and Alexy et al. (2009) note that revealing freely core technology can draw more users into firms´ product ecosystems.

Using panel data from three successive waves of a large-scale survey of UK manufacturing firms, Laursen and Salter (2014) find an inverted U-shaped relationship between firms' breadth of external search and formal collaboration for innovation, and the strength of the firms' appropriability strategies. However, they find that this effect is only present when the firms' product innovations are radical or when they are involved in significant product improvements, and/or when their industries are low-tech. The authors explain the negative association between very strong formal appropriability and innovation

collaboration on the basis of strict controls by legal departments of collaborative relationships, complex organisational processes in place for getting approval for joint projects, conflicts over ownership of intellectual property, and complex inter-organisational negotiations damaging trust. Similarly, a heavy emphasis on secrecy has been shown to cause discontent among employees, inhibit learning and restrict opportunities for innovation collaboration (Liebeskind, 1997). Indeed, imposing restrictive rules cause loss of trust, and labour and material costs from excessive use of security rules and monitoring procedures

By creating knowledge assets jointly with external partners routinely, however, value capture by services firms, and especially KIBS firms, is possibly more challenging than for manufacturing firms. There is some consensus on the reduced role of formal appropriability mechanisms for services (Hipp, 2008; Miles et al., 2000), although recent research by Mina et al. (2014) finds that the use of patents is as important for business services as for manufacturing firms, and is more important than strategic protection mechanisms. Not only is the product of service innovation in many cases not suitable for patenting, but also KIBS firms' innovations may require less upfront investment (for many KIBS - but not all - there is no need for large R&D labs, engineering teams, costly equipment or expensive clinical trials) and may be more difficult to copy, for example because of reliance on the input of experienced professionals (Samuelson, 2010). Indeed, much innovative output from services cannot be effectively protected by patents or copyright law, although since the 1990s patents have been applicable to some aspects of computer software in most economies (Hall and MacGarvie, 2006). Also, there have been historical swings in the patentability of business methods (including auction methods, e-commerce techniques, banking and financial services methods), with more patentability in the late 1990s and a more restrictive approach more recently (Andersen and Howells, 2000). The copyright system has long been applied to published works, but its history in terms of innovative activity is much more recent and ill-defined. Copyright offices in most countries have accepted registration of computer programs since the mid-1960s.

Services firms, including KIBS, are argued to use other mechanisms instead of, or sometimes alongside, formal appropriability mechanisms to protect ideas and knowledge. They attempt to capture value through secrecy, contracting and lead-time advantages, or by making intangible products more tangible (e.g. embedding software in microchips), creating lock-in effects (such as offering bounded value-for-money services, loyalty cards, and in the case of software and IT services, providing easy interoperability), enhancing their reputation, building entry barriers (such as the institutionalisation of professional qualifications and

accreditation systems) or through combinations of such mechanisms and formal ones (Greenwood et al., 2005; Hurmelinna-Laukkanen and Ritala, 2010; Miles et al., 2000).

Contractual arrangements may be one way of heading off conflicts in innovation collaboration by KIBS firms, or at least of limiting how far they escalate. The case of the collaboration between the aeroengine firm Rolls Royce and the IT services provider EDS (now part of HP) in a "business transformation programme", might be instructive. The IT services provided a wide range of activities, including support for product development, manufacturing processes, supply-chain management, repair and overhaul (inventory management). To facilitate knowledge transfer and avoid conflicts over jointly developed assets, the firms signed a complex contract with shared costs and profits (Miozzo and Grimshaw, 2005). Other studies also underline the importance of complex contracts between KIBS suppliers and their clients in joint innovation collaboration (Massini and Miozzo, 2012; Miozzo and Grimshaw, 2011). Also, KIBS firms´ clients may be concerned about knowledge leakages. Leiponen (2008) explores the role of exclusive arrangements, preventing KIBS suppliers from servicing the clients´ competitors. She shows that large and powerful clients may prefer tighter control of jointly-created knowledge, although they might benefit more from providing greater incentives for fast knowledge creation by KIBS suppliers than from tight control.

Amara et al. (2008) argue that the use of different types of appropriability mechanisms by the KIBS firms they studied depended on the degree of codification of knowledge and the degree of tangibility of service outputs. KIBS firms combined both formal mechanisms (patents, registration of design, and trademarks) and informal appropriability mechanisms (secrecy and lead-time advantages). This provides evidence suggesting that KIBS firms use combinations of mechanisms, that are interdependent and that may reinforce one another, to protect innovations.

As we have argued above, a central feature of KIBS is that other organisations, such as clients or (increasingly) universities, play a substantial role in their knowledge creation and innovation. As a result, there can be conflicts in establishing and enforcing ownership over co-produced knowledge assets or preventing leakages of knowledge. The relation between the choice of appropriability strategies by KIBS firms and their innovation collaboration with external organisations, appears to be quite complex: it quite possibly involves a reduced role of formal appropriability mechanisms, and relies on complementarity (if not substitutability) between these mechanisms and contractual and strategic appropriability.

We know very little about how far the choice and combination of appropriability mechanisms may be associated with knowledge exchange in innovation collaboration for KIBS. In order to enrich our understanding of how the choice of appropriability strategies of knowledge-intensive service firms is related to innovation collaboration with different types of partners, this paper presents exploratory research addressing the following three research questions:

1. What is the relation between KIBS firms' choice of (formal, contractual and strategic) appropriability mechanisms and their innovation collaboration activity?
2. What is the relation between KIBS firms' choice of combinations of different types of appropriability mechanisms and their innovation collaboration activity?
3. How do the above vary when KIBS firms collaborate with different types of partners?

3. Methods

We draw on an original survey based on a questionnaire developed for the purpose of the present study and administered through telephone interviews between September and December 2012. The sampling frame is a list of the UK and the US publicly-traded knowledge intensive service firms in Datastream.[2] UK and USA have relatively similar business and innovation systems, with broadly similar legal frameworks for intellectual property protection, and KIBS accounting for a large percentage of GDP. The initial list comprises 406 UK and 1892 US firms. The respondents were in senior managerial positions including CEO, CFO, head of marketing, head of communications, head of business development and technical project manager. The survey resulted in 223 responses (92 UK and 131 US firms).[3] The overall response rate is 10.3%, which is comparable to several previous studies (e.g. Fey and Birkinshaw, 2005; Mina et al., 2014). However, the response rates are significantly different in the UK and the US (23% and 7% respectively). Appendix Table A1 shows details of the assessment of the survey's non-response bias using the characteristic comparison method (Lambert and Harrington, 1990; Lawton and Parasuraman, 1980) by comparing respondents and non-respondents by country, firm size (number of

[2] These include firms operating in the following sectors: telecommunication, financial intermediation and auxiliary activities, research and development, legal services, accounting, book-keeping and auditing, tax consultancy, market research and public opinion polling, business and management consultancy, management activities of holding companies, architectural and engineering activities and related technical consultancy, technical testing and analysis. The first two of this list have substantial consumer markets, and thus are usually excluded from business services and thus as KIBS, though since they are essential for business activities they are often described as belonging to the category of "business-related services".

[3] We use Cochran's sample size formula (Cochran, 1977) to determine the adequacy of our sample size. As our key variables are constructed from a five point scale (as illustrated later in the section about variables) and we set an alpha level of 0.1 and the acceptable level of error at 5%, the required sample size is around 68. Therefore our achieved sample size is adequate for regression analysis.

employees) and industrial sector (2-digit SIC code): UK firms and large firms are over-represented in the final sample.

Most previous empirical studies on the management of intellectual property, other than those using large compulsory or weight-adjusted surveys commissioned by public organisations (such as the Community Innovation Survey), tend to suffer from some sort of non-response bias. In our case, the biases in favour of UK and large firms make necessary the use of appropriate weight adjustment techniques (see Love et al., 2011). We have assigned underrepresented groups of respondents higher weights compared with overrepresented groups in our regression, based on the inverse response propensity as assessed using logistic regression modelling (David et al., 1983; Kalton and Flores-Cervantes, 2003).[4] Indeed, we regress whether each of the 406 UK and 1892 US firms responded to our survey (yes=1 and no=0) on variables capturing auxiliary firm information about firm size (the number of employees) and country of origin (US or UK). The reciprocal of each firm's propensity to respond to the survey is then used to weight observations on each sample firm.[5]

The unit of analysis in the regressions is the portfolio of product or process innovations that were introduced by our sample firms between 2009 and 2011 (see the description of the dependent variables below). We adopt a two-stage cluster sampling design. The primary sampling units are firms, and the secondary sampling units are their portfolios of product or process innovations.[6] Because some firms introduced both product and process innovations over the same period, we use the Huber-White cluster-robust standard error estimator (Rogers, 1993; White, 1980; Williams, 2000) in order to adjust for intra-firm correlation and ensure consistent inference. Furthermore, using a robust heteroscedasticity-consistent (rather than the standard OLS) estimator, we account for the presence of heteroscedasticity of unknown form (White, 1980). The relationship between the importance of innovation collaboration and that of appropriability mechanisms is analysed using multiple regression analysis (adjusted by country and firm size). The analysis was carried out using STATA 10. The final sample in the analysis comprises 233 product and process innovations,

[4] Eisen et al. (2012) provide a detailed empirical example of the application of inverse response propensity weights to adjust non-response bias for survey analysis.

[5] The advantage of using this weighting method for the adjustment of non-response bias (compared to post-stratification weighting for instance) is that any continuous variable that are associated with non-responses (such as the number of employees) can also be adjusted without assigning them to somewhat arbitrary categories.

[6] The sample is self-weighted in that all the sampling frame firms were contacted and for each firm that responded, its portfolios of product or process innovations were surveyed. Therefore, weights are given only to adjust for non-response bias (because of the sampling design, the sample does not have to be weighted). As there is no information available at the innovation level about the survey population, non-response bias is adjusted at firm level.

clustered into 153 innovating firms (i.e., firms that failed to introduce any innovation during 2009-2011 are excluded).

There are two reasons for this research design. First, for each portfolio of product or process innovations, we asked each respondent to give scores regarding the significance of the various types of appropriability mechanisms to protect the specific group of innovations. This enables us to distinguish whether product and process innovations are protected differently.[7] Second, if a firm had introduced no innovation at all during the survey period, there would be no reason to ask how the firm protected its innovation.[8]

Dependent variable

Following the questions used in Community Innovation Survey, we asked firm representatives whether the firm cooperated with each of the following partners for innovation: 1) suppliers, 2) clients or customers, 3) competitors, 4) consultants, commercial labs, or private R&D institutes, 5) universities and 6) government or public research institutes. We also asked them to score from 1 to 5 to how important the partner is for the firm's creation of innovation (when the firm did not collaborate with a particular type of partner, a score of zero is awarded). In order to take into account the fact that the firm may not cooperate with some types of partner for innovation, we follow the approach of Amara et al. (2008), in this case creating the index "*importance of innovation collaboration"* as the average of the scores of perceived importance for the 6 types of partners ($\alpha = 0.627$). This index measures the aggregate level of importance of innovation collaboration with potential external partners without differentiating by partner type. The value of the composite index that captures the average importance of collaboration with all external partners can range from 0 to 5, and is not necessarily an integer. Since a firm may collaborate with only one or few types of partners, we also look into the relationship between the importance of innovation collaboration and the importance of appropriability mechanisms by each type of external partner. Hence, scores for the importance of collaboration for innovation for each of the six different types of partners are also used for separate regressions.

Explanatory variables

[7] Many innovation surveys ask about product and process innovations, but then do not request information specific to these.

[8] Non-innovative firms might have appropriability mechanisms in place, but they are not within the scope of the current study.

For each portfolio of product or process innovations, we asked respondents to give a score from 1 to 5 indicating how significant each of several mechanisms has been in protecting this specific group of innovation from copying or imitation by competitors or for otherwise capturing value from their firms´ innovation. The mechanisms are: 1) patents (excluding business method patents), 2) business method patents, 3) copyrights, 4) trademarks, 5) design rights, 6) confidentiality agreements, 7) employment contracts, 8) secrecy, 9) lead-time advantages, 10) complexity of the service or service process, and 11) complementary service development and delivery capabilities (this list follows the Community Innovation Survey, but includes more appropriability mechanisms). Responses were factor analysed, using principal component analysis as the extraction method, Varimax as the rotation method, and retaining factors that explain more than 70% of the variance as factor selection criteria. Three types of significant appropriability orientations were thereby identified (Kaiser-Meyer-Olkin measure of sampling adequacy=0.864) (Table 1), and factor scores for each orientation are calculated by regression methods. The three orientations identified are labelled 'formal appropriability mechanisms', 'contractual appropriability mechanisms' and 'strategic appropriability mechanisms'. The first orientation, '*formal appropriability mechanisms*', emphasises the significance of patents, copyrights, trademarks and design rights to capture value from innovation by firms. The second orientation, '*contractual appropriability mechanisms*', highlights the significance of confidentiality agreements, employment contracts, and secrecy to capture value from innovation.[9] The third orientation, '*strategic appropriability mechanisms*' stresses the importance of lead-time advantages, complexity of the service or service process, and complementary service development and delivery capabilities to capture value from innovation. Appendix A2 provides further information on data validity.

[Insert Table 1 about here]

Control variables

We include a number of control variables that the literature suggests to be relevant. First, a firm's R&D activities may affect its capacity to absorb external knowledge (e.g. Cohen and Levinthal, 1990). The index '*R&D activities*' is constructed based on the survey question following the Community Innovation Survey about the assessment of whether the firm has spent a significant amount in support of innovation on each of the following activities: 1)

[9] Secrecy is typically classified as a strategic appropriability mechanism in the literature (James et al., 2013), but it has been grouped together with confidentiality agreements and employment contracts on the basis of the factor analysis, so we call this group for simplicity 'contractual appropriability mechanisms'.

conducting R&D internally (yes=1 and no=0), 2) acquisition of machinery, equipment and software (yes=1 and no=0), 3) training for innovative activities (yes=1 and no=0), and 4) all forms of design (yes=1 and no=0), using the average of the standardised item scores (α = 0.657). Second, factors, such as product or process innovation and whether the innovation is radical, have been shown to affect a firm's collaboration with different types of partners (Fitjar and Rodríguez-Pose, 2013). Thus, variables identifying whether the innovation is a product innovation or not (product innovation=1 and process innovation=0) and whether the innovation is radical (i.e. innovation new to market/industry) (no, yes and radical innovation is not reported dummies are created), are included in the model. Third, formal appropriability mechanisms require in house intellectual property expertise to search effectively historical records of product or process innovations (Wacker, 2011). Therefore we include whether the firm has in-house intellectual property expertise (yes=1 and otherwise=0). Additionally, we control for other variables, including whether the firm is located in the USA (USA=1 and UK=0), firm size (log of the number of employees), whether the firm is a subsidiary (yes=1 and no=0) and the type of sector in which the firm operates (seven industry dummies using the firms' primary 2-digit SIC code).

The objective of this paper is to explore the association between the perceived importance of collaboration with external partners in innovation, and that of different appropriability mechanisms. Two main sources of endogeneity that could undermine the findings should be considered. First are possible omitted variables or unobserved heterogeneity in the regression model. In particular, the dependent and explanatory variables might be simultaneously affected by other factors that are not identified in the model. If the explanatory variables were endogenous, then the estimated coefficients would be unreliable. In particular, results may be influenced by the self-selection of appropriability and collaboration strategies by "high-quality" firms (Laursen and Salter, 2014). One indicator of quality is the measures used for the number of innovations introduced by sample firms. Another indicator which we employ is a variable to measure the growth rate of the firms' total assets (in thousand US dollars) over the three-year period (2009-2011) leading to the year of the survey (e.g. Weinzimmer et al., 1998). Firm growth rate is calculated from the difference in total assets between 2011 and 2009, divided by the value of total assets in 2009 and multiplied by 100. In the absence of instrumental variables that would fulfil both the strength and validity requirements, these two proxies for firm quality, together with the estimation approach, should improve the robustness of our findings even if they do not represent a perfect solution (see Laursen and Salter, 2014 p.9). The second possible source of

endogeneity is reverse causality, i.e. the possibility that some supposedly dependent variables may be affecting independent ones. The nature of this study is exploratory; we intend to uncover associations, rather than to establish casual relationships between the nominally dependent and independent variables. Hence, we do not imply that firms decide on what appropriability mechanisms to use and then whether to seek (certain) external partners for innovation. Nor do we claim the reverse: firms decide first about their choice of collaboration strategy and then decide their choice of appropriability strategy. Both are possible in principle, and firm strategies almost inevitably evolve over time. The relation between the two sets of variables is liable to be determined by a number of factors including the nature of the service, the types of innovations introduced, capabilities of the firm, the type of knowledge required for innovation, the type of sector, etc.

Descriptive statistics

Strikingly, the sampled firms collaborate extensively for innovation. Cooperation with clients/customers is the most important type of collaboration in the innovation process, with 87% of firms cooperating with this type of partner (Figure 1). Suppliers of materials, equipment or software are the second most important partners in the innovation process, with 65% of firms cooperating with this type of partner. This is followed by cooperation with consultants, commercial labs, or private R&D institutes (58% of firms), competitors (49% of firms) and universities or other higher education institutions (34% of firms) and government or public research institutes (29% of firms).

[Insert Figures 1 about here]

Regarding the relative significance of each appropriability mechanism, we can see that confidentiality agreements, secrecy, employment contracts, complementary capabilities and complexity in service design are perceived to be amongst the most important means of capturing value from innovation (Figure 2). According to our respondents, formal appropriability mechanisms are not particularly important value appropriability mechanisms; in fact, patents were amongst the least significant of all the methods considered for capturing value from innovation.

[Insert Figure 2 about here]

4. Findings

Tables 2 and 3 present the descriptive statistics and correlation coefficients among the variables. Table 4 contains the results from the regression analysis. The analysis was carried

out for all collaboration partners and for each of the six types of partners separately. To assess the threat of multicollinearity in the regression analysis, we calculated the variance inflation factors (VIFs) among the predictor variables in the model. The maximum estimated VIF across our explanatory variables was 5 and the mean value was 1.92, which are well below the recommended ceiling of 10 (Wooldridge, 2000).

In light of previous research suggesting an inverted U-shaped relationship between the importance of innovation collaboration and that of appropriability mechanisms (Laursen and Salter, 2014), we expected to find a similar relationship between the two variables for our sample. Therefore, to capture the curvature of the relationship for our sample firms, we introduced square terms of the various types of appropriability mechanisms. Also, as we anticipated complementarities and sustitutabilities between appropriability mechanisms (Amara et al., 2008), to assess how the association between the importance of innovation collaboration and that of a specific type of appropriability mechanism is altered by the use of another type of appropriability mechanism, we introduced interaction terms between different types of appropriability mechanisms. We present results for both the full specification, and a reduced version without the interaction terms, in order to assess whether the estimated coefficients of the first and second order direct effects behave consistently in the two specifications. The inclusion of the interaction terms improves the fit of our model to the data in five out of the seven sets of regressions (including the regression of collaboration with all partners), as reflected in the lower values of small sample (second order) adjusted Akaike information criterion AIC_c (Hurvich and Tsai, 1989; Burnham and Anderson, 1998).[10]

[Insert Tables 2, 3, and 4 about here]

When we consider the importance of innovation collaboration with all partners (see column 2 in Table 4), two statistically significant associations emerge. First, we find a significant positive association between the importance of formal appropriability mechanisms and that of innovation collaboration. Figure 3 provides a graphical representation of the positive association between the two variables: firms perceiving formal appropriability mechanisms as relatively important for protecting or capturing value from innovation also tend to regard external partners as playing an important role in the innovation process.

[Insert Figure 3 about here]

[10] The AICc test from the sets of regressions of innovation collaboration with universities (columns 11 and 12) and public research organisations (columns 13 and 14) indicates a better fit of the reduced model specification. However, in both instances the full and the reduced model specifications lead to broadly comparable findings.

Second, there is a significant negative coefficient of the square term of importance of contractual appropriability mechanisms and that of innovation collaboration. Although the sign and magnitude of the coefficient is comparable between the two specifications, it is statistically significant only in the full model (column 2 of Table 4). There is some evidence for the existence of an inverted U-shaped association between the importance of contractual appropriability mechanisms and that of innovation collaboration. Figure 4 shows this relationship: the perceived importance of firms' innovation collaboration peaks around the average sample value of firms' orientation to contractual appropriability mechanisms. The perceived importance of innovation collaboration begins to decline when firms' emphasis on contractual appropriability mechanisms exceeds this value.[11]

[Insert Figure 4 about here]

There are significant interaction effects, and a better understanding of the estimated associations between the different appropriability mechanisms and innovation collaboration requires taking these into account. We find a significant positive interaction effect for firms that simultaneously combine formal and strategic appropriability mechanisms and the importance of innovation collaboration with all partners (column 2 of Table 4). Figure 5 shows how the importance of innovation collaboration varies by firms' orientation to formal appropriability mechanisms at different levels of orientation to strategic appropriability mechanisms (high when the score is above average and low when the score is below average), with 90% confidence intervals (following Shugart et al., 2005).[12] As can be seen in Figure 5, marginal increases in firms' orientation to formal appropriability mechanisms are associated with considerably increased levels of the perceived importance of innovation collaboration, when firms' orientation toward strategic appropriability mechanisms is also high.

[Insert Figure 5 about here]

The estimated associations, however, do not always hold when considering different types of partners. The positive association estimated between the importance of formal appropriability mechanisms and that of firms' innovation collaboration holds when firms are collaborating with government or public research institutes. The increasingly positive

[11] Our first order variables of appropriability mechanisms proxy the perceived importance of formal, contractual and strategic mechanisms in protecting a specific portfolio of innovations from copying or imitation by competitors or for otherwise capturing value from their firms´ innovation. High levels of a particular type of appropriability mechanism can be interpreted as evidence that this type of appropriability mechanisms dominates the overall IP management strategy of the firm in order to capture value.

[12] Shugart et al. (2005) use graphical representation combined with confidence intervals for the interpretation of interaction terms in cases when the coefficients of main effects are not statistically significant.

association between the importance of formal appropriability mechanisms and that of innovation collaboration with government or public research institutes (columns 13 and 14 of Table 4) is depicted in Figure 6. Instead, we find an inverted U-shaped relationship between the importance of firms' innovation collaboration with clients and that of formal appropriability mechanisms (see columns 5 and 6 of Table 4 and Figure 7). The negative relation between formal appropriability mechanisms and collaboration with clients appears at relatively high levels of perceived importance of formal appropriability mechanisms.

[Insert Figure 6 and 7 about here]

The estimated inverted U-shaped association between the importance of contractual appropriability mechanisms and that of innovation collaboration obtained for all partners (column 2 of Table 4) is also confirmed for collaboration with clients, where we obtain a significantly negative coefficient on the square term, but only in the full model (column 6 of Table 4 and Figure 8).

[Insert Figure 8 about here]

Although no significant associations emerge between the perceived importance of strategic appropriability mechanisms and that of innovation collaboration for all partners (columns 1 and 2 of Table 4), some significant associations emerge when considering different types of partners. There is evidence of a U-shaped relationship between the importance of strategic appropriability mechanisms and that of innovation collaboration with competitors (columns 7 and 8 of Table 4 and Figure 9).[13] Therefore, firms assign less importance to collaboration with competitors when strategic appropriability mechanisms are perceived to be only moderately important means of capturing value from innovation.

[Insert Figure 9 about here]

Again, the estimated direct associations may be better understood by turning to the interaction terms between different appropriability mechanisms for collaboration with different types of partners. We obtain significant positive coefficients for the interaction terms between the importance of formal and strategic appropriability mechanisms in the regressions for importance of innovation collaboration with suppliers and competitors (columns 4 and 8 of Table 4). As can be seen from Figure 10, marginal increases in firms' orientation to formal appropriability mechanisms are related to increased perceived importance of innovation collaboration with suppliers, when firms' orientation to strategic appropriability mechanisms

[13] The values of the lower bound of the confidence interval in Figure 9 however suggest otherwise.

is high; in contrast, marginal increases in orientation to formal appropriability mechanisms are related to decreased perceived importance of innovation collaboration with suppliers when a firm's orientation to strategic appropriability mechanisms is low. There thus appears to be some synergistic relation between combining high levels of formal and strategic appropriability mechanisms and the importance of innovation collaboration with suppliers. The overall relation between the combination of formal and strategic appropriability mechanisms and the importance of innovation collaboration with competitors is harder to characterise. As before, marginal increases in firms' orientation to formal appropriability mechanisms are associated with greater increases in the perceived importance of innovation collaboration with competitors, when firms' orientation to strategic appropriability mechanisms is also high (see Figure 11). This shows that there is some evidence of a synergistic relationship.

[Insert Figures 10 and 11 about here]

We find a statistically significant negative interaction effect for firms that simultaneously combine contractual and strategic appropriability mechanisms and the importance of collaboration for innovation with both suppliers and clients (columns 4 and 6 of Table 4). For innovation collaboration with suppliers (Figure 12), at low levels of emphasis on strategic appropriability mechanisms, the perceived importance of innovation collaboration with suppliers increases as firms' orientation to contractual appropriability mechanisms increases - only when firms' orientation to contractual appropriability mechanisms reaches a high level, a negative relation appears. At a high level of orientation to strategic appropriability mechanisms, in contrast, there is roughly a negative relation between the importance of collaboration and firms' orientation to contractual appropriability mechanisms. On balance, the evidence from the regressions as to the importance of innovation collaboration activity with suppliers suggests that the combination of high levels of strategic and contractual appropriability mechanisms runs counter to the importance of innovation collaboration with these partners. A comparable picture emerges for the importance of innovation collaboration with clients (Figure 13), as we can see from the graphical representation, an increase in firms' orientation to contractual appropriability mechanisms is associated with a greater increase or with a lower decrease in perceived importance of innovation collaboration with clients, when firms' orientation to strategic appropriability mechanisms is low (i.e. the derivative is always greater when firms' orientation to strategic

appropriability mechanisms is low) rather than high. This confirms the negative interaction effect.

[Insert Figures 12 and 13 about here]

Finally, the regression results concerning the effect of our control variables on innovation collaboration activity reveal two associations (columns 1 and 2 of Table 4). There is evidence that the more R&D-active the firms are, the higher is the perceived importance of innovation collaboration. Larger firms are also more likely to perceive collaboration for innovation with external partners as important.

5. Concluding discussion

This study offers new insights on how the choices and combinations of appropriability mechanisms by KIBS firms are associated with choices to collaborate with different external organisations. The results can contribute to the understanding of firm appropriability strategy and innovation collaboration, especially in sectors where formal appropriability mechanisms (such as patents) play a less important role in capturing rents from innovation.

KIBS firms generally do not consider formal appropriability mechanisms as significant mechanisms for value capture. But the first important finding from our analysis is that, when formal appropriability mechanisms are perceived to be important means of protecting or capturing value from innovation, KIBS firms tend to consider innovation collaboration with external partners during the innovation process to be more important. Thus, the use of formal appropriability mechanisms may facilitate knowledge exchange in strategic interactions with partners, by providing a clear framework for what is shared and what is private knowledge (Hagedoorn and Ridder, 2012).

This positive association between the importance of formal appropriability mechanisms and that of innovation collaboration is particularly notable in the case of strategic interactions with public or government research institutes. Firms and public research organisations have different comparative strengths: the latter are generally argued to be stronger in basic research, and the former in applied research, new product development and commercialisation. Additionally, collaborative relationships with public or government research institutes may be less subject to the problems raised by relationships with for-profit organisations (e.g. the challenges of "coopetition" with rivals and complementors, see Nalebuff and Brandenburger, 1996). It may be that firms active in collaborative relationships for innovation with public research organisations may be more aware of their intangible

assets, using formal appropriability mechanisms as quality signals for their products and processes. Conversely, it may be that public research organisations may be seen as "leaky" and requested to treat intellectual property rights seriously in the process of innovation collaboration.

However, in certain strategic partnerships, high levels of emphasis on formal appropriability mechanisms can be associated with assigning less importance to collaboration for innovation: our analysis shows this to be the case in collaborations with clients. This is a telling result, since clients emerge as the most important partners with which KIBS firms collaborate for innovation in our survey (and in much previous research). Collaboration for innovation with clients is especially important both at the early stage of the creation of innovation (requiring heightened interaction, project definition and re-definition, to understand the client organisation and its requirements), and at the final stage of project implementation (Dyer and Singh, 1998; Lehrer et al. 2013). It may be that while the use of formal appropriability mechanisms can facilitate knowledge exchange in strategic interactions with clients, high levels of emphasis on these, involving, for example, strict rules by legal departments, intended to ensure the patentability of future inventions, may act as a barrier to important information exchanges at the stages of project definition and implementation - limiting knowledge creation and incentives to innovate by either clients or services suppliers as property rights are tightly controlled (Alexy et al., 2009; Davis and Harrison, 2001).

Another important finding that emerges from our study is that, although the survey responses suggest that contractual appropriability mechanisms are perceived to be amongst the most important methods of capturing value from innovation, the regression results suggest that high levels of emphasis on contractual appropriability mechanisms contributes to the importance of innovation collaboration - up to some threshold. These findings are consistent with arguments that firms collaborating actively for innovation have a preference for the governance of their relation through written contracts, to either control or monitor the progress of collaboration. However, developing contracts to govern inter-organisational innovation collaborations is very challenging. The specification of the characteristics of the service may not be contracted for in advance, but rather, result from collaboration; and it is difficult to agree beforehand the sharing of profits and costs and the results of cooperation, as such, therefore, contracts in this context are highly incomplete. Thus, our results may suggest that, although contractual appropriability mechanisms may be effective mechanisms to govern and control innovation collaboration with external partners, high levels of emphasis on contractual appropriability mechanisms (e.g. by having very strict clauses), are associated

with less willingness to undertake or benefit from collaboration with external partners for innovation. Contracts can harm innovation collaboration when they entail restrictive clauses on exclusivity, excessive secrecy or barriers to labour mobility (Liebeskind, 1997; Laursen and Salter, 2014). Indeed, our findings suggest that when all partners are considered together, high levels of emphasis on contractual appropriability mechanisms are associated with assigning less importance to innovation collaboration. These problems with contracts are particularly prevalent in collaborative relationships with clients in service co-production (see also Leiponen, 2008).

Our analysis found no generalisable association between strategic appropriability mechanisms and innovation collaboration. However, we find some evidence of a U-shaped relationship between the perceived importance of strategic appropriability mechanisms and that of innovation collaboration with competitors. Therefore, collaboration with competitors is less likely to take place when strategic appropriability mechanisms are perceived to be only moderately important means of capturing value from innovation. This finding, that a high levels of emphasis on strategic appropriability mechanisms is associated with a high perceived importance of innovation collaboration with competitors, is consistent with evidence that lower risks are involved in collaborating with competitors when an innovator is in a strong bargaining position (such as when possessing the key complementary assets) (Teece, 1986, 2006). At the other extreme, when firms do not consider strategic appropriability mechanisms as important, they also tend to highlight the importance of innovation collaboration with competitors. In such case, the collaboration may be a means to secure complementary assets, enabling firms to co-create and capture value from innovation.

Furthermore, we find evidence for the existence of both synergies and mismatches from the combination of different appropriability mechanisms and the importance of innovation collaboration with external partners in our sample firms. The results suggest that there is a positive association from combining formal and strategic appropriability mechanisms and the importance of innovation collaboration in general. The analysis suggests that this finding holds for collaboration with suppliers and competitors. This is consistent with the view that, to profit from innovation, particularly when the appropriability regime is not strong, innovators need to be well positioned in both formal and strategic appropriability mechanisms (Desyllas and Sako, 2013; Teece, 1986, 2006).

There is also some evidence that combining high levels of strategic and contractual appropriability mechanisms, however, is associated with assigning less importance to innovation collaboration with suppliers and clients. High levels of emphasis on such

combinations may destroy the trust and reciprocity needed in knowledge-intensive partnerships with suppliers and clients (Laursen and Salter, 2014; Liebeskind, 1997).

These findings are consistent with previous studies suggesting that firms collaborate for innovation with different partners for different reasons (Wagner, 2013), cooperating largely with suppliers and customers for knowledge or technical inputs (Lehrer et al., 2013) and with competitors instead for complementary assets (Hamel et al., 1989). Our results suggest that particular combinations of appropriability mechanisms enable firms to relate effectively with vertical partners, making both parties more willing to share technical capability, research outputs, human resources and even intellectual property. Rather than pursue one or more forms of appropriability to the greatest extent possible, it could be that combining more modest degrees of contractual and strategic appropriability mechanisms may be more effective for innovation collaboration with such partners as suppliers and clients.

Finally, the evidence that the more R&D-active the firms are, the higher is the perceived importance of innovation collaboration may be interpreted in terms of absorptive capacity (Cohen and Levinthal, 1990), as R&D-active firms may be more capable of translating external knowledge into internal capabilities. Larger firms are also more likely to perceive collaboration with external partners for innovation as important. This may imply that larger firms may be more knowledgeable about how to manage inter-organisational relationships and better positioned to develop a more adequate appropriability strategy, through (for example) possessing requisite complementary assets.

Overall, our study illustrates the importance of combining different types of appropriability mechanisms and of tailoring appropriability strategies to the challenges of collaboration with different types of partners. Indeed, innovators can benefit from the compounding effect of using mixed strategies for appropriability (Amara et al., 2008). We conclude that firms need to be aware that the choice of the type of appropriability mechanism and the level of emphasis on different mechanisms should not be taken solely on the basis of the perceived effectiveness of single mechanisms for protecting or otherwise capturing value from proprietary knowledge. It is also worth taking account of the interaction of different appropriability mechanisms and of the possible implications that combining mechanisms may have for the capacity of the firm to collaborate for innovation with different external partners.

The findings from this study confirm that managers should pay attention not only to the role of formal appropriability mechanisms such as patents, trademarks and copyrights, but also to the other appropriability mechanisms that are more commonly used by KIBS firms instead of, or in combination with, formal appropriability mechanisms to protect innovations

from imitation. Admittedly, the study set out to explore associations (and not causal relationships) between intellectual property management and innovation collaboration. Nevertheless, a possible interpretation of our findings is that managers should account for the importance of collaborative relationships with different partners for the success of an innovative project and that this criterion should be an integral part of the firm´s intellectual property strategy and management.

As with all empirical research, this study is subject to limitations, and these should be acknowledged. An implicit assumption inherent in our dependent and independent variables is that the perceived importance of organisational actions, processes and practices reflect, leads to, or at least is associated with, actual organisational practices and behaviour. We have provided some evidence suggesting broad consistency between our sample firms' perceived importance of patents as means of value capture from innovation and their actual patenting activity. But the possibility that our proxies only measure perceptions and mental models from the interviewees of our sample firms, as opposed to reflecting the firms' actual behaviour should be acknowledged. There is thus a need for further research, using different indicators and set in different empirical contexts, to strengthen confidence in, and deepen our findings. In particular, future research needs to analyse the underlying mechanisms that explain the distinctive patterns of firms' appropriability strategies and innovation collaboration that this study has uncovered.

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Table 1: Factor analysis results

	Rotated factor loadings		
Items	Formal appropriability mechanisms	Contractual appropriability mechanisms	Strategic appropriability mechanisms
Patents	**0.81**	-0.001	0.381
Business method patents	**0.842**	0.016	0.322
Copyrights	**0.807**	0.408	0.027
Trademarks	**0.734**	0.553	-0.005
Design rights	**0.734**	0.405	0.136
Confidentiality agreements	0.208	**0.776**	0.333
Secrecy	0.222	**0.678**	0.394
Employment contracts	0.22	**0.744**	0.337
Lead-time advantages	0.237	0.244	**0.765**
Complexity of service product/process/design	0.147	0.199	**0.82**
Complementary service development and delivery capabilities	0.212	0.422	**0.739**

Table 2: Descriptive statistics for variables (weighted results)

Variables	Type of variables	Mean	Std. Err.
Firm level			
Importance of collaboration for innovation –all partners	Index: 6 items (Alpha value = 0.627)	1.912	0.962
Importance of collaboration with suppliers for innovation	Scores; continuous	2.444	1.996
Importance of collaboration with clients for innovation	Scores; continuous	3.674	1.681
Importance of collaboration with competitors for innovation	Scores; continuous	1.476	1.716
Importance of collaboration with consultants for innovation	Scores; continuous	1.959	1.816
Importance of collaboration with universities for innovation	Scores; continuous	1.059	1.606
Importance of collaboration with public/government organisations for innovation	Scores; continuous	0.860	1.569
R&D activities	Index: 6 items (Alpha value = 0.657)	0.166	0.659
Subsidiary firm	Categorical: yes=1 and no=0	0.162	0.369
Log number of employees	Continuous	5.680	2.159
Firm growth rate	Continuous (%)	77.781	382.836
US firm	Categorical: yes=1 and no=0	0.822	0.383
Whether has in-house IP expertise	Categorical: yes=1 and no=0	0.530	0.500
Groups of innovation level			
Orientation to formal appropriability mechanisms	Index: factor scores from regression methods	0.111	0.977
Orientation to contractual appropriability mechanisms	Index: factor scores from regression methods	-0.034	0.991
Orientation to strategic appropriability mechanisms	Index: factor scores from regression methods	-0.045	0.980
Product innovation	Categorical: yes=1 and no=0	0.587	0.493
Number of innovation	Continuous	6.777	24.638
No radical innovation	Dummy	0.368	0.483
With radical innovation	Dummy	0.281	0.450
Radical innovation not reported	Dummy	0.351	0.478

N=233

Table 3: Correlation table (weighted results)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Importance of collaboration for innovation – all partners	1.000														
2. Orientation to formal appropriability mechanisms	0.298	1.000													
3. Orientation to contractual appropriability mechanisms	0.127	0.033	1.000												
4. Orientation to strategic appropriability mechanisms	0.035	0.005	-0.023	1.000											
5. R&D activities	0.247	0.160	0.042	0.310	1.000										
6. Product innovation	0.042	0.079	0.091	0.034	0.027	1.000									
7. Number of innovation	0.083	-0.077	0.082	-0.046	-0.018	0.016	1.000								
8. Subsidiary firm	-0.049	0.089	0.061	-0.171	-0.169	-0.002	0.125	1.000							
9. Log number of employees	0.193	0.136	0.264	-0.108	-0.062	-0.009	0.127	0.124	1.000						
10. Firm growth rate	0.110	0.211	-0.016	0.094	0.170	-0.032	0.003	0.248	-0.254	1.000					
11. US firm	0.136	0.228	-0.029	-0.025	0.096	-0.021	-0.156	-0.263	-0.113	0.050	1.000				
12. No radical innovation	-0.135	-0.238	-0.041	-0.161	-0.072	-0.181	0.011	0.013	0.067	-0.103	-0.026	1.000			
13. With radical innovation	0.106	0.057	0.012	0.222	0.203	-0.119	-0.028	-0.079	-0.074	0.206	0.062	-0.477	1.000		
14. Radical innovation not reported	0.037	0.188	0.031	-0.046	-0.118	0.296	0.014	0.061	0.002	-0.090	-0.033	-0.561	-0.459	1.000	
15. Whether has in-house IP expertise	-0.026	0.244	0.117	0.041	0.059	-0.009	-0.006	0.084	0.322	-0.118	0.014	-0.127	0.175	-0.037	1.000

Table 4: Regression analysis (Dependent variable: Importance of innovation collaboration; N=233; weighted results)

	All partners		Suppliers		Clients		Competitors		Consultants		University		Public/government	
	Coef. (Robust Std. Err.)		Coef. (Robust Std. Err.)		Coef. (Robust Std. Err.)		Coef. (Robust Std. Err.)		Coef. (Robust Std. Err.)		Coef. (Robust Std. Err.)		Coef. (Robust Std. Err.)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
formal [2]	-0.087	-0.020	-0.202	-0.047	-0.403**	-0.326*	0.026	0.126	-0.119	-0.066	0.189*	0.114	-0.010	0.077
	(0.097)	(0.097)	(0.208)	(0.214)	(0.167)	(0.177)	(0.162)	(0.166)	(0.159)	(0.166)	(0.114)	(0.129)	(0.128)	(0.149)
formal	0.329***	0.218**	0.244	-0.005	0.511**	0.416**	0.379**	0.192	0.243	0.129	0.112	0.237	0.488***	0.339*
	(0.116)	(0.108)	(0.255)	(0.260)	(0.214)	(0.199)	(0.174)	(0.192)	(0.205)	(0.223)	(0.157)	(0.181)	(0.178)	(0.200)
contractual [2]	-0.082	-0.101*	-0.119	-0.201	-0.173	-0.247**	-0.138	-0.128	-0.136	-0.101	0.144	0.156	-0.067	-0.086
	(0.051)	(0.054)	(0.142)	(0.139)	(0.122)	(0.124)	(0.129)	(0.138)	(0.110)	(0.113)	(0.104)	(0.113)	(0.083)	(0.091)
contractual	0.055	0.020	0.100	-0.107	0.216	0.040	0.065	0.139	-0.146	-0.019	0.031	0.024	0.065	0.040
	(0.071)	(0.090)	(0.184)	(0.197)	(0.151)	(0.173)	(0.164)	(0.157)	(0.159)	(0.154)	(0.142)	(0.168)	(0.116)	(0.145)
strategic [2]	0.060	0.036	0.088	-0.035	0.201*	0.065	0.169*	0.210*	-0.030	0.049	-0.035	-0.021	-0.030	-0.050
	(0.053)	(0.071)	(0.120)	(0.147)	(0.103)	(0.124)	(0.092)	(0.112)	(0.098)	(0.107)	(0.090)	(0.105)	(0.100)	(0.127)
strategic	-0.020	-0.037	0.030	-0.063	-0.075	-0.164	-0.026	0.004	-0.168	-0.112	-0.049	-0.046	0.171	0.158
	(0.081)	(0.084)	(0.198)	(0.198)	(0.161)	(0.164)	(0.161)	(0.162)	(0.174)	(0.171)	(0.127)	(0.135)	(0.132)	(0.140)
formal*contractual		0.040		-0.079		0.022		0.198		0.181		-0.160		0.077
		(0.111)		(0.212)		(0.197)		(0.200)		(0.197)		(0.182)		(0.180)
formal*strategic		0.194**		0.431**		0.048		0.355*		0.250		-0.184		0.264
		(0.093)		(0.214)		(0.161)		(0.190)		(0.187)		(0.160)		(0.176)
contractual*strategic		-0.088		-0.389**		-0.343**		0.065		0.177		0.044		-0.083
		(0.073)		(0.163)		(0.154)		(0.141)		(0.121)		(0.118)		(0.096)
R&D activities	0.327**	0.343***	0.253	0.289	0.239	0.243	0.578**	0.606**	0.750***	0.769***	-0.140	-0.154	0.282	0.303
	(0.129)	(0.130)	(0.285)	(0.282)	(0.243)	(0.232)	(0.238)	(0.243)	(0.248)	(0.238)	(0.211)	(0.210)	(0.249)	(0.250)
product innovation	0.022	0.052	0.135	0.234	0.061	0.117	0.161	0.180	-0.097	-0.104	-0.090	-0.111	-0.039	-0.004
	(0.090)	(0.093)	(0.168)	(0.178)	(0.144)	(0.146)	(0.150)	(0.155)	(0.173)	(0.172)	(0.134)	(0.135)	(0.131)	(0.142)
number of innovations	0.004**	0.003	0.007**	0.004	0.005**	0.004	0.002	0.001	0.002	0.001	0.004	0.005*	0.006	0.004
	(0.002)	(0.002)	(0.003)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.002)	(0.003)	(0.003)	(0.003)	(0.006)	(0.006)
subsidiary firm	-0.182	-0.161	0.191	0.252	-0.701*	-0.643	0.039	0.053	-0.671	-0.678	-0.058	-0.084	0.109	0.134
	(0.230)	(0.240)	(0.508)	(0.532)	(0.418)	(0.423)	(0.435)	(0.456)	(0.443)	(0.427)	(0.402)	(0.404)	(0.336)	(0.330)
log number of employees	0.098**	0.098**	0.017	0.012	0.076	0.056	0.072	0.084	0.150*	0.164**	0.123	0.123	0.148*	0.151*
	(0.046)	(0.045)	(0.087)	(0.080)	(0.067)	(0.066)	(0.092)	(0.093)	(0.082)	(0.082)	(0.086)	(0.088)	(0.086)	(0.083)
firm growth rate	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.001*	0.001*	-0.001*	-0.001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
USA	0.009	0.035	0.239	0.257	-0.311	-0.358	0.087	0.178	0.110	0.198	0.337	0.301	-0.406	-0.364
	(0.212)	(0.213)	(0.480)	(0.471)	(0.445)	(0.428)	(0.335)	(0.346)	(0.355)	(0.362)	(0.369)	(0.378)	(0.288)	(0.293)
radical innovation	0.250	0.207	0.378	0.236	-0.136	-0.270	-0.311	-0.323	0.375	0.410	0.974***	1.018***	0.222	0.174
	(0.253)	(0.232)	(0.535)	(0.485)	(0.432)	(0.404)	(0.433)	(0.420)	(0.468)	(0.434)	(0.352)	(0.359)	(0.441)	(0.415)
radical innov. not reported	0.086	0.053	-0.865*	-0.998**	-0.080	-0.181	-0.221	-0.215	0.544	0.587*	1.048***	1.066***	0.091	0.056
	(0.190)	(0.188)	(0.445)	(0.455)	(0.325)	(0.308)	(0.385)	(0.380)	(0.374)	(0.351)	(0.334)	(0.344)	(0.309)	(0.307)
in-house IP expertise	-0.292	-0.290	-0.036	0.005	0.119	0.159	-0.320	-0.351	-0.244	-0.285	-0.833**	-0.823**	-0.441	-0.443
	(0.212)	0.205	(0.412)	(0.402)	(0.314)	(0.307)	(0.362)	(0.351)	(0.344)	(0.327)	(0.331)	(0.328)	(0.341)	(0.332)
industry dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.238***	1.234***	1.124	1.329	3.363***	3.744***	1.835*	1.571	0.087	-0.251	0.721	0.760	0.298	0.251
	(0.403)	(0.403)	(0.963)	(0.939)	(0.873)	(0.799)	(1.069)	(1.098)	(0.895)	(0.956)	(1.009)	(1.017)	(0.800)	(0.789)
R^2	0.276	0.303	0.147	0.200	0.229	0.266	0.173	0.203	0.244	0.269	0.259	0.270	0.209	0.226
F for model	3.910***	3.880***	2.010***	2.230***	2.730***	2.800***	1.490*	1.720***	4.220***	4.580***	4.120***	3.880***	2.360***	2.220***
AIC_c	620.749	619.495	998.865	991.556	895.485	891.829	921.549	920.404	926.850	926.787	864.677	868.803	869.248	871.765

*** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

Figure 1: Partners with which firms cooperate for innovation (%) (N=153; weighted results)

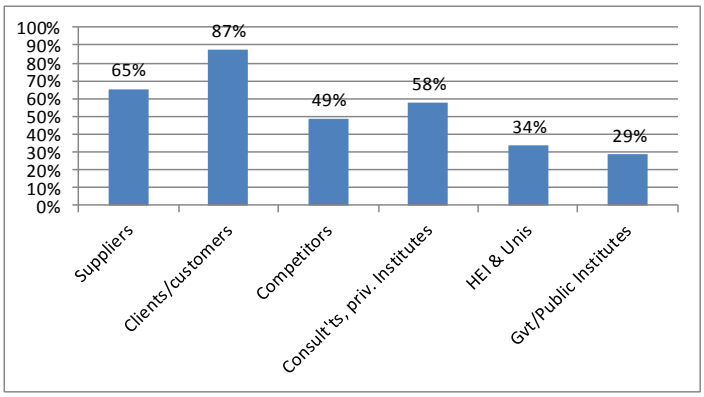

Figure 2: Significance of appropriability mechanisms (N=233; weighted results)

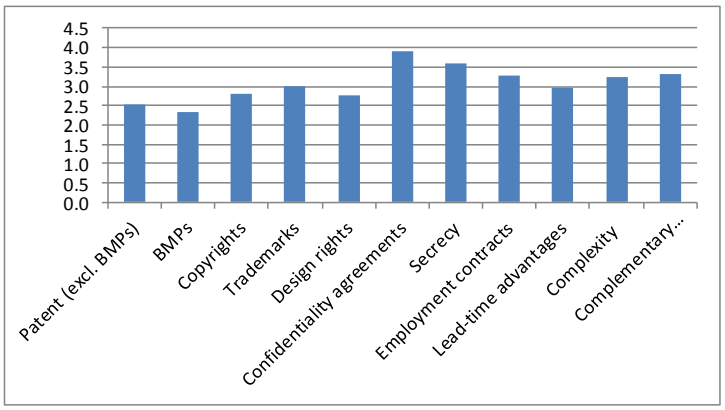

Figure 3. Importance of innovation collaboration and orientation to formal appropriability mechanisms

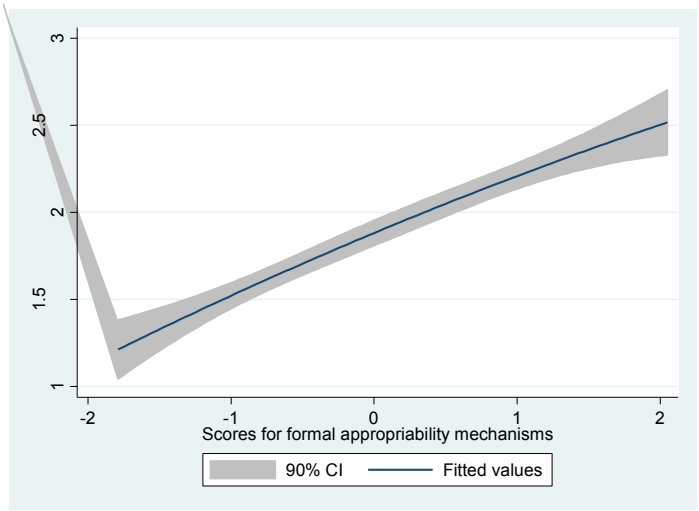

Figure 4: Importance of innovation collaboration and orientation to contractual appropriability mechanisms

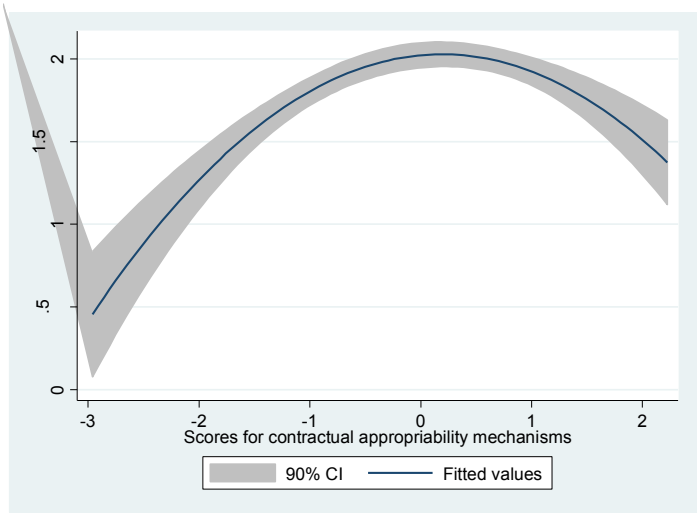

Figure 5: Importance of innovation collaboration and orientation to formal appropriability mechanisms by levels of orientation to strategic appropriability mechanisms

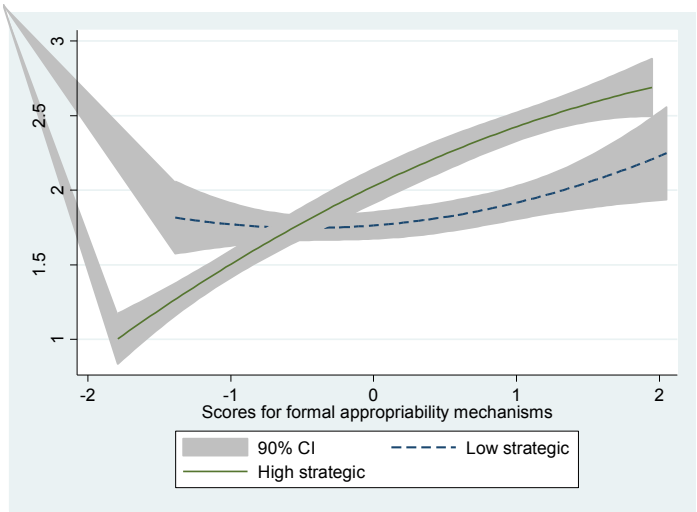

Figure 6: Importance of innovation collaboration with public research organizations and orientation to formal appropriability mechanisms

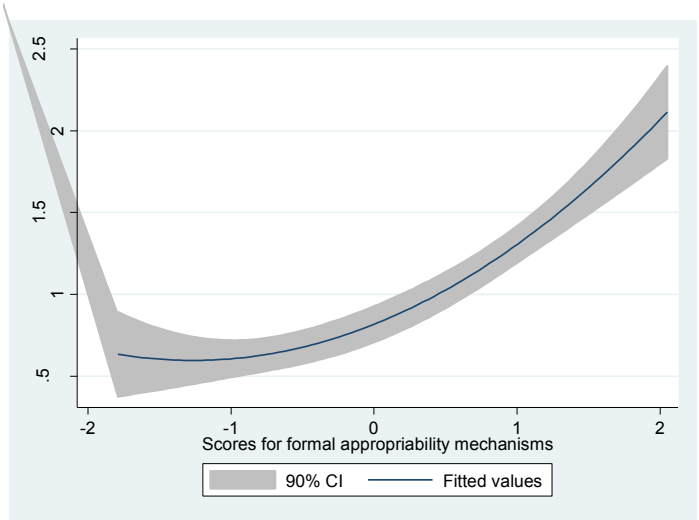

Figure 7: Importance of innovation collaboration with clients and orientation to formal appropriability mechanisms

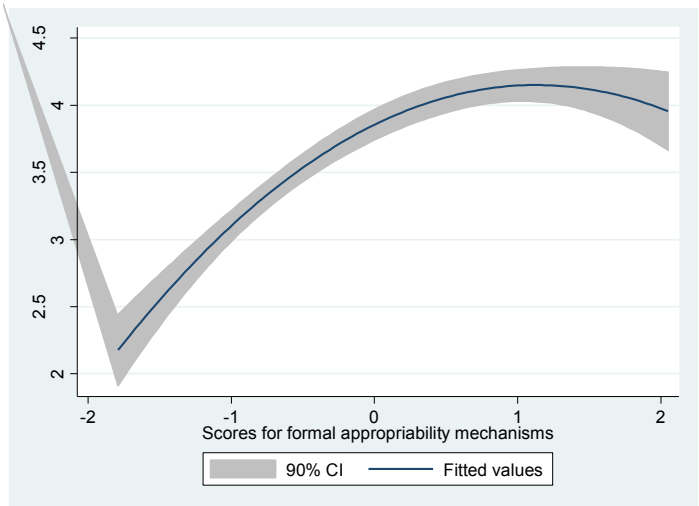

Figure 8: Importance of innovation collaboration with clients and orientation to contractual appropriability mechanisms

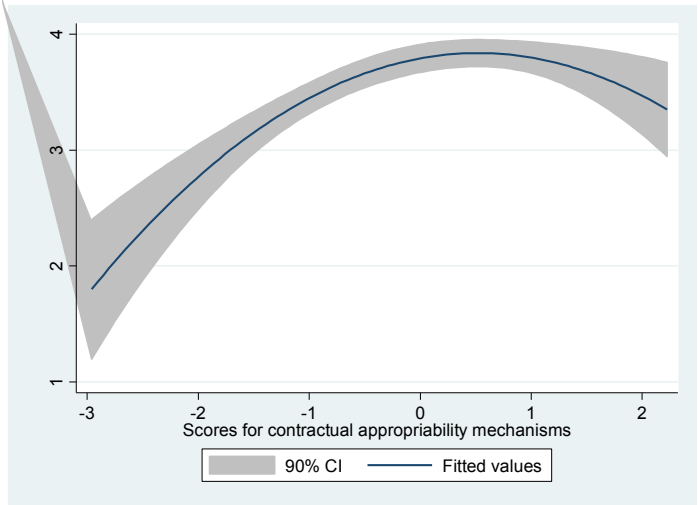

Figure 9: Importance of innovation collaboration with competitors and orientation to strategic appropriability mechanisms

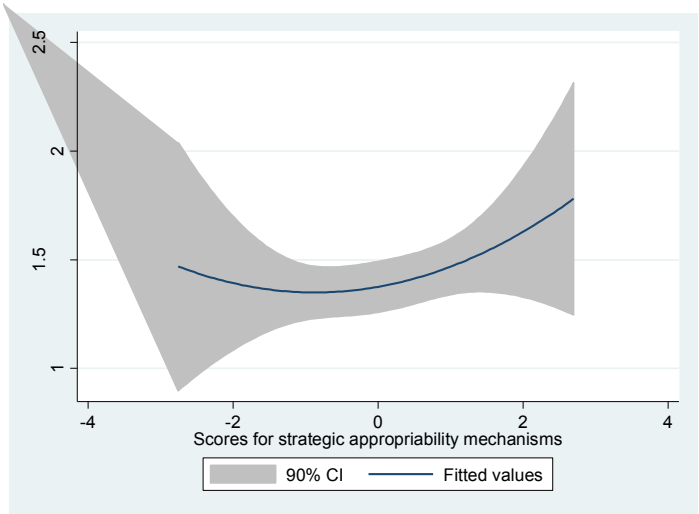

Figure 10: Importance of innovation collaboration with suppliers and orientation to formal appropriability mechanisms by levels of orientation to strategic appropriability mechanisms

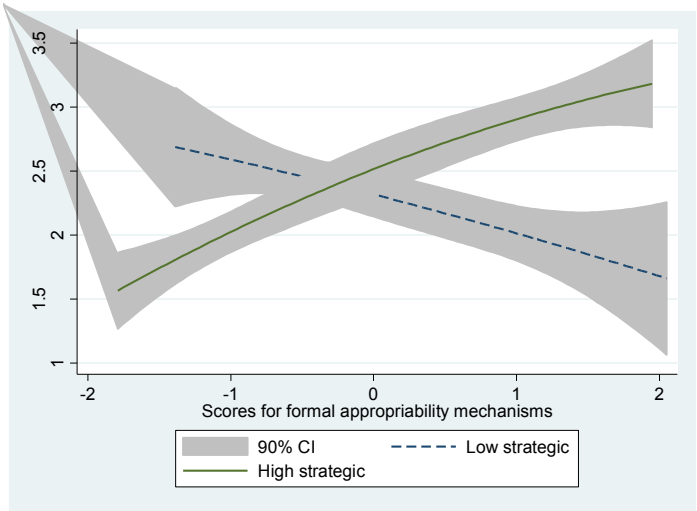

Figure 11: Importance of innovation collaboration with competitors and orientation to formal appropriability mechanisms by levels of orientation to strategic appropriability mechanisms

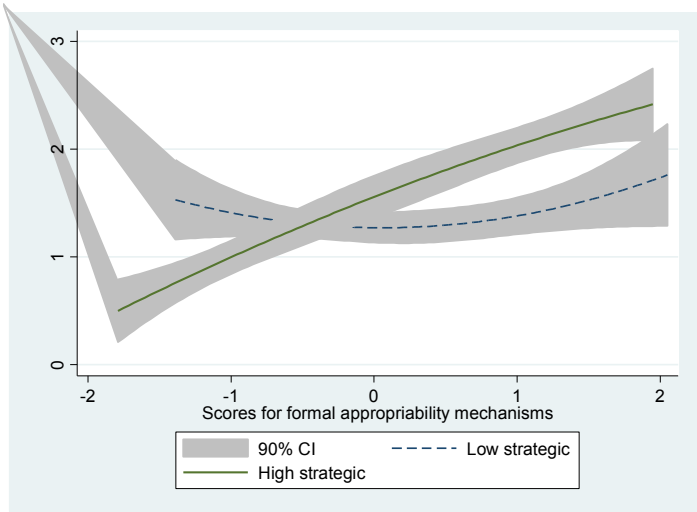

Figure 12: Importance of innovation collaboration with suppliers and orientation to contractual appropriability mechanisms by levels of orientation to strategic appropriability mechanisms

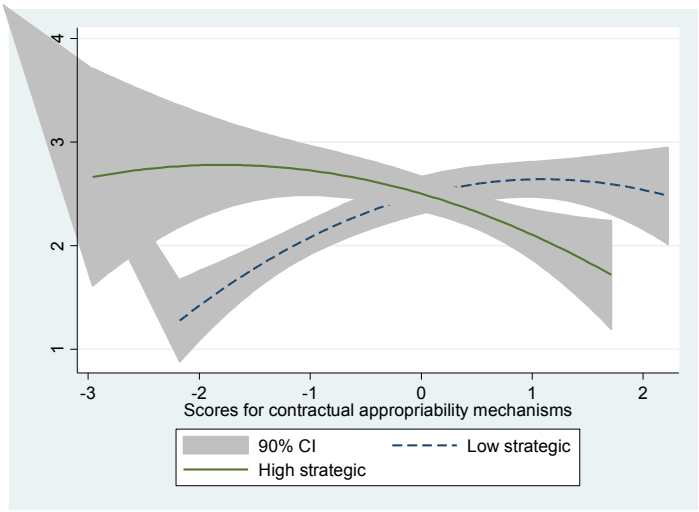

Figure 13: Importance of innovation collaboration with clients and orientation to contractual appropriability mechanisms by levels of orientation to strategic appropriability mechanisms

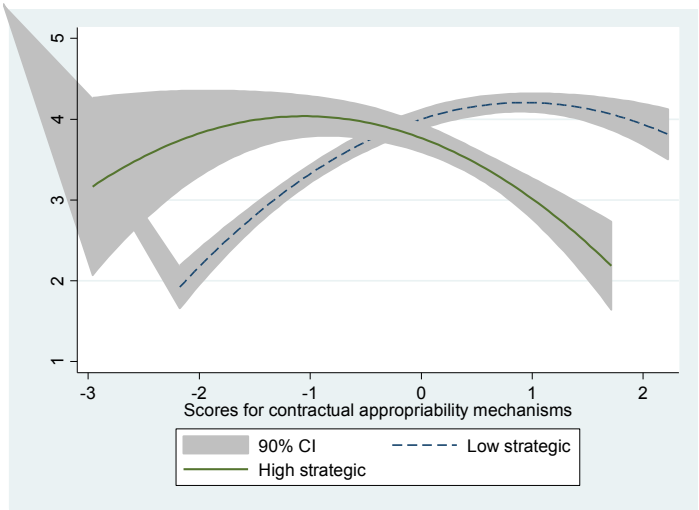

Table A1: Assessing non-response bias using the characteristic comparison method

	Non-respondents	Respondents	Total
CHI-SQUARE TEST FOR INDEPENDENCE			
Country			
UK	314 (15.13%)	92 (41.26%)	406 (17.67%)
US	1761 (84.87%)	131 (58.74%)	1892 (82.33%)
Total	2075 (100%)	223 (100%)	2298 (100%)
Pearson chi2(1) = 94.466; p = 0.000			
Industrial sector (2-digit SIC code)			
48	118 (5.69%)	12 (5.38%)	130 (5.66%)
60	547 (26.36%)	45 (20.18%)	592 (25.76%)
62	136 (6.55%)	15 (6.73%)	151 (6.57%)
63	110 (5.30%)	11 (4.93%)	121 (5.27%)
67	264 (12.72%)	21 (9.42%)	285 (12.40%)
73	618 (29.78%)	85 (38.12%)	703 (30.59%)
87	159 (7.66%)	22 (9.87%)	181 (7.88%)
Others	123 (6.00%)	12 (5.38%)	135 (5.87%)
Total	2075 (100%)	223 (100%)	2298 (100%)
Pearson chi2(7) = 10.770; p = 0.149			
COMPARE MEANS TEST			
Firm size (the number of employees)			
Observations	2075	223	
Mean	3897.145	11968.21	
SE	448.623	3735.294	
t(2296)= -4.3982; p=0.000			

Appendix A2: Survey data quality

An implicit assumption inherent in our empirical measures of the variables is that the perceived importance of organisational actions, processes and practices reflect, lead to, or at least are associated with, actual organisational practices and behaviour. However, one should acknowledge the possibility that our proxies only measure perceptions and mental models by the interviewees of our sampled firms as opposed to actual behaviour. In order to get a sense of the possible differences between perceptions and actions, we carried out a more detailed analysis of patenting behaviour in firms. For this purpose, we collected information from the Derwent patent database on the actual number of patents granted to our sample US firms during the period 2007 to 2011 and compared it with their recorded scores of perceived significance of patents as value appropriation mechanisms. As can be seen from Table A2, the average number of patent grants is indeed monotonically increasing with the recorded score of perceived patent significance, although there is considerable variation in patent numbers across firms within groups. Of course, one should not expect a one-to-one correspondence between the reported patent significance score and the recorded number of patents, since a small number of patents may have been critical to the capturing of returns from innovation. So at least in the case of patenting, there seems to be a fair degree of consistency between perceived importance and actual reliance on patents. Furthermore, to assess common method bias arising from self-reported measures, we applied Harman's (1967) one factor test. Un-rotated factor analysis of variables that are used in the analysis resulted in 12 factors with an eigenvalue greater than 1, thus common method bias can be regarded as insignificant in this study (Podsakoff and Organ, 1986).

Table A2: Number of granted patents per firm by "perceived patent significance" class

		Perceived significance of patents for value capture [1-5]			
	All sample US firms	[1-2)	[2-3)	[3-4)	[4-5]
Firm number	88	33	10	22	23
Mean patent number	37.6	0.1	1.1	20.1	124.0
St.dev. patent number	217.8	0.7	2.6	85.2	412.0

Notes: patents granted to sample US firms during the period 2007-2011 were collected from Derwent patent database.