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Heads or Tails? The Openness-Appropriability Duality and its Implications for Innovative Performance among U.K. Manufacturing and Services Firms

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Abstract

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State of the Art

Capturing the value and appropriating the returns from innovation is an essential part of firmsâ?? strategy as innovation constitutes a main driver for companies to prosper, grow, and sustain a competitive advantage (Christensen 1997; Thomke, 2001). With the innovation process becoming more open, external collaboration is increasingly becoming a central part of a companyâ??s strategy (von Hippel, 1988, 2005; Chesbrough et al., 2006). But at the same time, the appropriation of the returns from innovation activities necessitates deploying protection strategies when companies cross the boundary of the firm (Cassiman and Veugelers, 2002; Heiman and Nickerson, 2004); Thus, the adoption of open innovation creates a dilemma for firms resulting in the â??paradox of opennessâ?• (Laursen and Salter, 2014) which should be carefully managed in order to mitigate the risks of openness and appropriate the profits from innovation activities.

Research Gap

From a firm level perspective, what still remains hidden is how the use of appropriability regimes affects the relationship between openness and innovative performance. Firstly, previous research has found a curvilinear relationship between collaboration and innovative performance (Laursen and Salter, 2006) and between appropriability and collaboration (Laursen and Salter, 2014), but did not address the interaction effects of using and mixing appropriability strategies for firmsâ?? innovative performance. Secondly, the extant open innovation literature on appropriability is not only limited for manufacturing firms but also for the nascent field of open services innovation (Chesbrough, 2011). Besides servicesâ?? central role in modern economies, prior research has found that services also benefit from openness and external collaboration, investment in R&D, and use of appropriability regimes (Tether and Massini, 2007; Leiponen, 2012).

Theoretical Arguments

This paper explores how the use of appropriability regimes moderates the relationship between openness and innovative performance among U.K. manufacturing and services firms. Innovation often entails openness, but the appropriation of the returns necessitates protection. The adoption of either formal or informal appropriability strategies is seen by external actors as an indication of the ownership of valuable knowledge. However, a high level of appropriability will not only decrease firmsâ?? appetite for openness as to limit IP theft but is also costly (Cohen et al, 2000; Teece, 2002; Chesbrough, 2003, 2006; von Hippel, 2005; Laursen and Salter, 2006, 2014). Given the servicesâ?? relative emphasis on the use of informal appropriability vs. more formal for manufacturing (Tether and Massini, 2007; Leiponen, 2012), we argue that the use of formal appropriability regimes will have a stronger moderating effect for manufacturing while the use of informal appropriability strategies will have a stronger moderating effect for services.

Method

We use a quantitative approach in using the dataset from the 7th UK Innovation Survey (2008-2010) which validity and reliability were confirmed by considerable testing across firms from different industries (Smith, 2005). Tobit regression analyses test the moderation effect of the use and the type of appropriability strategy on the relationship between openness (collaboration breadth) (IV) and innovative performance (radical, intermediate, and incremental) (DV).

Results

The novel results of this paper suggest that (i) the use of formal appropriability regimes in manufacturing moderates the effect of openness on radical innovation only (new to the world) (ii) the use of informal appropriability strategies in manufacturing moderates the impact of openness on intermediate innovation (new to the firm) especially at low levels of openness; (iii) the use of formal appropriability regimes in services has a moderating effect on radical and intermediate innovation while the use of informal appropriability has no significant moderation; (iv) the mixing of both formal and informal appropriability regimes in services moderates the effect of openness on radical innovation with an optimal performance combination of a low formal/high informal at low levels of openness and a high formal/high informal at higher levels of openness; (v) the use of formal and informal appropriability regimes has no moderation effect on incremental (improved product) innovation for both manufacturing and services.

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ABSTRACT

Companies face considerable challenges when configuring their appropriability strategies while collaborating with external partners as it is essential to capture the profits from their innovation activities. This study raises the important issue of the openness-appropriability duality and examines how firms' appropriability choices and combinations should be managed in order for companies to capture and appropriate the returns when collaborating with external partners. Analyzing the data from a large scale U.K. innovation survey, results suggest that (1) for highly collaborative manufacturing and service firms, the stronger the formal appropriability, the more effective collaboration breadth is on innovative performance. However for low collaborative service firms only, the opposite holds true; (2) a strong informal regime, on the other hand, at high levels of collaboration breadth is not associated with higher innovative performance for manufacturing; the same being interestingly insignificant for services and (3) firms would be better off deploying more informal regimes at lower collaboration levels and a higher mix of formal at higher levels of collaboration. But, relying too much on appropriability regimes in services is associated with a slight positive moderating impact on performance regardless of the level of collaboration.

Keywords: Appropriability strategy, innovation, collaboration breadth, innovative performance

INTRODUCTION

Capturing the value and appropriating the returns from innovation is an essential part of firms' strategy as innovation constitutes a main driver for companies to prosper, grow, and sustain a competitive advantage (Christensen 1997; Thomke, 2001). With more than 50% of Fortune 500 companies adopting open innovation in new products or services development such as Pepsi's Mountain Dew, Apple's iOS apps, and McDonald's Just Stevinho Burger, external collaboration is increasingly becoming a central part of a company's strategy (von Hippel, 1988, 2005; Chesbrough, West, & Vanhaverbeke, 2006). But at the same time, the appropriation of the returns from innovation activities necessitates deploying protection strategies when companies cross the boundary of the firm (Cassiman and Veugelers, 2002; Heiman and Nickerson, 2004); Thus, the adoption of open innovation creates a dilemma for firms resulting in the paradox of openness (Laursen and Salter, 2014) which should be carefully managed in order to mitigate the risks of openness and appropriate the profits from innovation activities.

From a firm level perspective, what still remains hidden is how the use and combination of appropriability strategies affect the relationship between openness and innovative performance. Firstly, previous research has found a curvilinear relationship between collaboration and innovative performance (Laursen and Salter, 2006) and between appropriability and collaboration (Laursen and Salter, 2014), but did not address the interaction effects of using and mixing appropriability strategies for firms' innovative performance. Secondly, the extant innovation literature on appropriability has not been adequately addressed for the nascent field of open service innovation even though service firms account for 75% of OECD GDP (Chesbrough, 2011; World Bank, 2013). Besides services' central role in modern economies, prior research has found that services also benefit from external collaboration, investment in R&D, use of

appropriability regimes (particularly informal) as well as the element of tacit transfer of knowledge (Sundbo, 1997; Tether and Massini, 2007; Miles, 2007; Leiponen, 2012).

In order to address these limitations in the innovation literature, this paper explores how the use and the combination of appropriability regimes (formal vs. informal) moderates the relationship between collaboration breadth and innovative performance among U.K. manufacturing and service firms. We adopt a quantitative approach in using the dataset from the 7th UK Community Innovation Survey (2008-2010) which validity and reliability were confirmed by considerable testing across firms from different industries (Smith, 2005). Tobit regression analyses tested the moderation effects of the strength and combination of appropriability strategy (high/low and/or formal/informal) on the relationship between external collaboration breadth and innovative performance (radical and incremental innovation).

This empirical study helps us to extend our knowledge about how manufacturing and service firms' appropriability choices and combinations should be managed in order for firms to capture and appropriate the returns from collaborating with external partners. Furthermore, this paper helps to shed some light on the emerging field of open service innovation and its respective appropriability dynamics as the majority of the extant literature has discussed IP protection in manufacturing firms.

We found that the same appropriability strategy yields different moderating impact for services and manufacturing firms when engaging in open innovation. Firstly, for highly collaborative manufacturing and service firms, the stronger the formal appropriability regime, the more effective collaboration breadth is on innovative performance. However for low collaborative service firms, the weaker the formal regimes, the better off companies are when collaborating

with external partners. Secondly, deploying high informal regimes at high levels of collaboration breadth is not associated with better innovative performance for manufacturing; the same coefficient being surprisingly insignificant for services. Thirdly, in terms of appropriability combinations, firms would be better off deploying more informal regimes at lower collaboration levels and a higher mix of formal at higher levels of external collaboration. However, relying too much on high appropriability regimes (e.g. high formal/high informal) is associated with a diminished and barely positive moderating impact on innovative performance regardless of the level of external collaboration.

This paper is structured as follows: In Section 2, we explain the conceptual background with relevant literature review. In Section 3, we develop our hypotheses. In Section 4, we outline data and methods which are followed by the empirical analysis. In Section 5, we discuss and conclude the paper, highlighting limitations and avenues for future research.

CONCEPTUAL BACKGROUND

Openness and Appropriability

The era of open innovation, as initiated by Chesbrough (2003), has redefined the boundary between companies and its adjacent environment in the extensive use of external knowledge sourcing and external pathways to the market, complementing or even substituting in-house R&D as per the closed model (Chesbrough, 2003; Chesbrough et al., 2006; Lazonick, 2007).

As such, the firm level open innovation process would require the existence of external interfaces making the firm entrenched in a network of various actors ranging from customers, competitors, suppliers to universities in the aim of commercialising new knowledge (Chesbrough, 2003; Powell and Grodal, 2005). Indeed, the type of knowledge search and

collaboration breadth have been found to significantly impact innovation performance (Katila, 2002; Katila and Ahuja, 2002; Laursen and Salter, 2006; Grimpe and Sofka, 2009).

Laursen and Salter (2006) analysed open innovation practices related to search strategies and its impact on firm innovativeness amongst a sample of 2,700 U.K. manufacturing firms between 2002 and 2004. They found that innovation performance increases with the intensity of use (depth) and diversity of knowledge sources (breadth) forming an inverted U-shape. This reveals that, after a certain point, there is a trade-off from over-searching and innovation performance is bound to drop.

As such, several scholars have stated that external collaboration is becoming an integral part of a company and managerial strategy and as a result, the innovation process is now more open and distributed (von Hippel, 1988, 2005; Chesbrough, 2003; Coombs, Harvey, & Tether, 2003; Chesbrough et al., 2006). But previous research has also shown that, at the same time, companies want to protect themselves when they engage in external collaboration outside its boundary (Cassiman and Veugelers, 2002; Heiman and Nickerson, 2004).

Thus, this gives rise to the so-called "paradox of openness": innovation often entails openness, but the appropriation of the returns necessitates protection. Laursen and Salter (2014), drawing from a sample of UK manufacturing companies found a concave relationship between companies' breadth of external search and external collaboration, and the strength of the firms' appropriability strategies. The "paradox of openness" (Laursen and Salter, 2014) was inspired from the "paradox of disclosure" of Arrow (1962) where the latter states that "there is a fundamental paradox in the determination of demand for information; its value for the purchaser

is not known until he knows the information, but then he has in effect acquired it without cost" (Arrow, 1962).

In light of this, firms and managers can respond to this paradox by using appropriability strategies and protect their intellectual property rights (Gans and Stern, 2003). In fact, the innovation literature differentiates between two types of appropriability regimes: formal (patent, industrial design, trademark, and copyright) and informal (secrecy, lead time, and complexity of design) which can be seen as substitutes (Kultti, Takalo, & Toikka, 2007; Somaya, 2012) or also as complements (Levin, Klevorick, Nelson, & Winter, 1987; Cohen, Nelson, & Walsh, 2000; Hall, Helmers, Rogers, Sena, 2014).

Hence, companies have to carefully plan how to deploy of their appropriability strategies vis-à-vis their involvement with external collaboration for innovation activities. In fact, companies that signal the usage of appropriability mechanisms are perceived to detain important information and as a consequence can attract more external partners (Bhattacharya and Ritter, 1983; Laursen and Salter, 2014). But at the same time, the extant literature on open innovation shows that a too strong focus on appropriability strategies can have adverse effects on the collaboration with external partners (Laursen and Salter, 2006, 2014; Alexy, Criscuolo, & Salter, 2009).

Thus far, it seems that the company's level of external collaboration is connected with the company's appropriability strategy. Firms need to figure out an appropriability strategy in order to protect their Intellectual Property (IP) and appropriate the returns from their innovations while at the same time needing to be open to various external parties.

However, the extant literature on the duality between appropriability and openness has broadly been addressed for manufacturing companies. As such, there is not only a limited literature on

appropriability mechanisms and collaboration breadth related to open innovation but also especially related to open service innovation. Although previous research has found a curvilinear relationship between collaboration and innovative performance (Laursen and Salter, 2006) and between appropriability and collaboration (Laursen and Salter, 2014) in manufacturing firms, the moderating role of appropriability has not been explored in both goods and services despite its implications for firms' innovation strategy.

How is (Open) Service Innovation Different?

In order to better grasp the implications and characteristics of service innovation on modern economies, it would be beneficial to discuss first whether and how innovation in services is any different from manufactured goods. The extant literature provides contrasting views about the topic. The assimilation approach considers that innovation in services is no different than innovation in manufacturing and as such the theory and conceptual tools that were applied to manufacturing can clearly be assigned to innovation in services (Barras, 1986; Coombs and Miles, 2000; Drejer, 2004; De Vries, 2006; Nijssen, Hillebrand, Vermeulen, & Kemp, 2006). Thus, this approach aims at assimilating services into the bigger stream of innovation studies which has generated much of the studies related to innovation in services. Other scholars, in the so-called demarcation approach, consider that services have distinctive features (e.g. intangibility, co-production with customers, simultaneity, heterogeneity and perishability) and thus are inappropriate to derive theories and concepts from manufacturing (Coombs and Miles, 2000; Gadrey, Gallouj, & Weinstein, 1995; Sundbo, 1997; Tether, 2005). In this paper, we aim to build on the recent stream of the synthesis approach (Gallouj and Savona, 2009) seeking to construct a more integrative and holistic understanding of innovation beyond the boundaries of services and manufacturing.

Why should services make open innovation any different than manufactured goods or regular R&D processes? First, following our review of service innovation, services have unique characteristics (intangibility, heterogeneity, inseparability, and perishability) with distinct taxonomies and schools of thoughts that should allow services to be studied on their own (De Brentani, 1991; Kotler, 1994; Gadrey et al., 1995; Sundbo, 1997). Second, the value chain constitutes a differentiating factor for services versus manufactured goods as it consists of an iterative process of a customer experience in connecting the customer to the desired outcome, unlike Porter's linear process value chain for goods where the service comes only at the end (Chesbrough, 2011). Third, open service innovation is different from traditional internal R&D as service innovation process differs from manufacturing. Looking at some characteristics of service firms, Tether (2003) shows that R&D is of a lesser importance in services comparing to manufacturers while intangible assets such as human and organisational features seem to be more important. Fourth, it is in the process of engagement and co-creation that tacit knowledge is produced both ways from and to the customer, making the element of tacit knowledge a core and differentiating factor on the uniqueness of services in general but more importantly when it comes to its applicability to the field of open innovation (Chesbrough, 2011).

As for appropriability, the innovation literature has usually linked the service sector with the use of more informal appropriability and practices when developing a new service as this is usually conducted by informal teams than regular R&D units (Sundbo, 1997; Miles, 2007). Also, collaboration breadth and R&D investments are found to be economically significant determinants of innovation for both service and manufacturing firms (Leiponen, 2012). In fact, service companies adopt less IP rights than manufacturing firms (Arundel, Lorenz, Lundvall, & Valeyre, 2007; Tether and Massini, 2007) but mainly rely on informal appropriability

mechanisms (e.g. lead time and secrecy) although they may indeed use formal appropriability regime such as patents (Bader, 2007) although most rely on copyrights when they have the possibility (Miles, Andersen, Boden, & Howells, 2000).

Even more relevant to open innovation, previous research has shown that service firms utilise more knowledge sources (Cainelli, Evangelista, & Savona., 2006; Tether and Tajar, 2008; Hipp, 2010) and engage in more collaboration with their customers and suppliers than manufacturing firms (Tether, 2005). Also, some scholars have examined service firms' open innovation collaboration and innovation performance which has yielded a positive relationship (Leiponen, 2005; Mansury and Love, 2008; Love, Roper, & Hewitt-Dundas, 2010). Given the potential differences in the innovation process for both manufacturing and service firms and the above discussion on openness and appropriability, there seems to be a gap to explore the respective role and combination of appropriability regimes when manufacturing and service firms engage in external collaboration.

HYPOTHESES

Without the possibility to generate profits from the commercialisation of innovations, firms would have little incentive to engage in innovative activities as innovation has been identified by the extant literature as one of the main drivers for companies to prosper, grow and sustain a high profitability (Christensen 1997; Thomke, 2001; Cefis and Marsili 2005). One way to capture the benefits of innovation, companies use a variety of appropriability regimes that can help the innovator capture the respective profits (Teece, 1986). A multitude of appropriability choices is available, ranging from formal (e.g. patent, industrial design, trademark, and copyright) and informal (e.g. secrecy, lead time, and complexity of design). It is then crucial for manufacturing

and service companies to use and configure an adequate appropriability strategy in order to have a stronger association with higher profits when engaging with external partners.

The extant literature has shown that the use of formal appropriability regimes, particularly patents, can facilitate openness, disclose and protect knowledge assets, and enable a smoother transfer of tacit knowledge (Ordover, 1991; Foray, 2004; Pisano and Teece, 2007; Penin and Wack, 2008). Also, companies engaged in open innovation seem to have a "strong preference for the governance of their open innovation relationships through formal contracts" and that their IP rights are highly significant to signal and protect their innovative capabilities (Hagedoorn and Ridder, 2012). In fact, formal appropriation mechanisms offer a higher degree of protection to the innovation, and a strong appropriability regime is directly associated with more open innovation and promotes vertical specialisation (Chesbrough et al., 2006). As a matter of fact, open innovation is found to be more present in manufactured goods companies with a high appropriability regime than in manufactured goods companies with low appropriability regimes (Laursen and Salter, 2005). This argument suggests that a strong appropriability strategy is an enabler for external collaboration and that there is a complementarity between collaboration and the use of formal appropriability strategies as a strong regime may facilitate the exchange of knowledge assets. Following this line of reasoning, it seems that, when the formal appropriability regime is strong, firms will benefit more from collaborating with various external partners than when firms have low collaboration. Hence we hypothesise that:

> H1a: The stronger the formal appropriability regimes in manufacturing firms, the more effective external collaboration will be on innovation performance at higher levels of collaboration

As for service firms, they also use various appropriable mechanisms to protect their innovations: formal and informal methods (Bader, 2008; Hanel, 2006) although most service companies use informal mechanisms such as lead time and secrecy (Tether and Massini, 2007). Contrary to what is expected given their unique characteristics, service firms may indeed use formal appropriability regime such as patents (Bader, 2007) although most rely on copyrights (Miles et al, 2000). In the case of service firms, formal regimes should be adopted when the innovation has an elevated level of knowledge codification and output tangibility (Miles, 2008) such as in insurance and software design (Bader, 2008; de Laat, 2005). In fact, the use of formal appropriability regimes in knowledge intensive business services (KIBS) seems to have a positive effect on new products and service development (Hipp and Grupp, 2005). Following these arguments and those from H1a, we expect that service firms, when having the possibility of deploying formal regimes such as copyrights, will do so as it signals valuable knowledge when collaborating with external partners and will facilitate the exchange in open innovation.

> H1b: The stronger the formal appropriability regimes in services firms, the more effective external collaboration will be on innovation performance at higher levels of collaboration

Companies do use both formal and informal appropriability: formal regimes (e.g. patent, industrial design, trademark, and copyrights) are mostly used to protect manufactured goods innovation while informal regimes (e.g. secrecy, complex design, and lead-time) are used to protect process innovation (Levin et al, 1987; Cohen et al, 2000). When it comes to informal regimes, companies consider lead time and secrecy as more important ways to protect their IP than patents (Arundel, 2001). In this context, innovators find that exchanging strategic ideas and secrets is most of the time mutually beneficial as they build dense networks of relations with their customers, competitors, and suppliers (Von Hippel, 1988). However, firms engaging in

collaborative R&D are likely to capture more value from their innovation activities through the use of patents than secrecy (Granstrand, 1999). This suggests that secrecy is less effective with external collaboration as the risks of knowledge leakage become higher. More to this line of thought, informal appropriability mechanisms can lead firms to limit their interaction with external actors in order to protect their ideas from imitators and competitors unlike formal mechanisms where the risks of knowledge leakage are lower and cooperation seen as more attractive (Gans and Stern, 2003). Hence, these arguments suggest that the use of high informal appropriability regimes will hinder firms' from further collaborating with external parties because of the danger of loss of control over knowledge and as a result diminish the positive effects of external collaboration on innovative performance. Thus, we hypothesise:

> H2a: The stronger the informal appropriability regimes in manufacturing firms, the less effective external collaboration will be on innovation performance at higher levels of collaboration

With regards to service firms, the extant literature has usually associated the service sector with the use of more informal appropriability and practices when developing a new service as this is usually conducted by informal teams than regular R&D units (Sundbo, 1997; Miles, 2007). Also, collaboration breadth and R&D investments are found to be economically significant determinants of innovation for both service and manufacturing firms (Leiponen, 2012). Linking the discussion to appropriability strategies, service companies use less IP rights than manufacturing firms (Arundel et al, 2007; Tether and Massini, 2007) but mainly rely on informal appropriability mechanisms such as lead time and secrecy to protect themselves (Tether and Massini, 2007). However, informal appropriability mechanisms such as secrecy can lead firms to limit their interaction with external actors in order to protect their ideas as the risks of knowledge

leakage in using secrecy are higher when companies are collaborative (Gans and Stern, 2003). As per these arguments and H2a discussion, we suggest that the use of high informal appropriability regimes will hinder firms' from further collaborating with external parties because of the danger of loss of control over knowledge and as a result weaken the positive effects of external collaboration on innovative performance. And since services mainly rely on informal regimes, we expect that the moderation effect will be stronger and more negative for services than manufacturing. Thus we hypothesise:

> H2b: The stronger the informal appropriability regimes in service firms, the less effective external collaboration will be on innovation performance at higher levels of collaboration

Several companies use formal and informal appropriability mechanisms simultaneously and adopt value capture strategy that combines a bundle of mechanisms (Arora, 1997; Cohen et al, 2000; Howells et al, 2003; Arora and Gambardella, 2006; James, Leiblein, & Lu, 2013). In fact, companies' reliance on a single choice of appropriability, either formal or informal, can be problematic (Liebskind, 1997; Fleming, 2001; Murray and O´Mahoney, 2007; Laursen and Salter, 2014) and that a combination of appropriability regimes is associated with a higher economic performance (Arora, 1997; Gans and Stern, 2003). Based on the above discussion and hypotheses (H1 and H2), we argue that the four way combinations of low/high with formal/informal both in manufacturing and services will differently moderate the relationship between collaboration breadth and innovative performance. We expect that when the formal appropriability regime is high combined with a low informal, firms will benefit more from collaborating with various external partners than when firms have low collaboration. This is driven by the positive moderating effect of formal as outlined in H1. We also expect that when the informal appropriability is high combined with a low formal, firms will not benefit from

external collaboration. This is driven by the negative moderating effect of informal as outlined in H2. When the combination is low/low and high/high, we expect that firms will still benefit from external collaboration than when firms have low collaboration. The positive moderating effect is expected to be stronger for manufacturing vs. services as they deploy more formal methods (more positive effect) and less informal (less negative effect) at higher levels of collaboration. Thus we hypothesise:

H3a: The combination of high formal/low informal regime positively moderates the relationship between collaboration and innovative performance for both manufacturing and services

H3b: The combination of low formal/high informal regime negatively moderates the relationship between collaboration and innovative performance for both manufacturing and services

H3c: The combination of high formal/high informal regime moderates the relationship between collaboration and innovative performance; the moderation being positive in manufacturing and negative in services

H3d: The combination of low formal/low informal regime positively moderates the relationship between collaboration and innovative performance; the moderation being stronger for manufacturing than services

DATA AND METHOD

Data

The data set is drawn from the 7th U.K. Community Innovation Survey (CIS) with the data covering the years between 2008 and 2010. The survey is funded and developed by the U.K. Department of Business, Innovation and Skills (BIS) and administered by the Office for National Statistics (ONS) as part of the UK's contribution to the EU Community Innovation Survey (CIS). The types and methods used in the questions used in the undertaken surveys are described in the OECD Oslo Manual (OECD, 2005). This data set has been used extensively by previous studies as its validity and reliability were confirmed by considerable testing before implementation within various European countries and across firms from different industries (Smith, 2005).

The 7th U.K. CIS was administered in 2011 by the Office for National Statistics (ONS), the U.K. government's official division for statistics (Robson and Ortmans, 2006). The survey was sent to 28,079 firms, of which 14,342 responded, a solid 51% response which help avoid non-response bias (Armstrong and Overton, 1977). The sample of manufacturing and service firms comprised of 5,624 and 22,276, of which we use around 1,070 and 2,410 companies with non-missing values respectively. In order to circumvent any common method bias issue, we ran Harman's one factor test on the designated items in our study. Results suggest that the primary factor was less than fifty percent of the variance (30% for manufacturing and 26% for services); hence we can exclude any potential issues related to common method bias (Podsakoff and Organ, 1986). Besides, the survey questionnaire administered by ONS comprised of various questions types

such as Likert scales, percentage estimation / calculation, and absolute numbers, which was answered by companies' managers.

Measures

Dependent Variable. We use two measures aimed at reflecting firms' innovative performance. First, radical innovation represents innovations new to the market where it is calculated as a percentage of companies' total turnover in relation to goods or services that are new to the market. Second, incremental innovation refers to innovations new to the firm where it is also measured as a percentage of companies' total turnover in relation to goods or services that are new to the firm. We then computed logarithmic transformations for both of these variables in order to enhance the normality of the distributions.

In this setting, we are capturing the radical and incremental innovations by using single item dependent variables which has already been applied in previous innovation research (Cassiman and Veugelers 2006; Laursen and Salter 2006; Ritala and Hurmelinna-Laukkanen, 2013). The proxy of measuring innovative performance through a turnover weighted measure can be the subject of some concerns regarding its robustness and validity, using this method yields valid results when scholars "researchers seek to measure an object that in the minds of respondents refers to a concrete object", a check list that is applicable for the fraction of turnover (Rossiter, 2002; Bergkvist and Rossiter, 2007).

Independent Variables. Two multi-items explanatory variables were used to measure the level of collaboration breadth and the strength of appropriability strategies which will act as a key moderating variable on the relationship between collaboration breadth and innovative performance.

First, for collaboration breadth, firms were asked to report whether they had collaborated on innovation activities with any of the six external partners: (i) suppliers, (ii) customers, (iii) competitors, (iv) consultants, (v) universities, and (vi) government or public research institutes. Each of these six sources is re-coded as a binary variable with 0 representing no or minimal and 1 indicating medium or high collaboration breadth. We then sum these six sources so the range consists of 6 if firms collaborate with all external actors and 0 if firms do not engage in any external collaboration on innovation activities.

Second, in order to measure appropriability regimes, we have used a question in the UK CIS survey asking if the "business use/register for: (i) patent (ii) industrial design (iii) trademark (iv) copyrights (v) secrecy (vi) complex design (vii) lead-time". Each of the seven sources is coded as a binary variable where there is a score of 1 if firms have used the respective protection regime or 0 if it has not been used. From these seven sources of appropriability regimes, we categorise them into two categories: formal (patent, industrial design, trademark, and copyrights) and informal (secrecy, complex design, and lead-time) (Levin et al, 1987; Cohen et al, 2000; Hall et al, 2014). We then sum the scores for the formal and informal regimes so the maximum is 4 for formal and 3 for informal if firms use all appropriability regimes while the minimum is 0 for both formal and informal if firms do not deploy any protection mechanisms.

Control Variables. In order to increase validity and robustness of the quantitative study, we add several control variables that were used and validated in previous innovation studies on the determinants of innovative performance.

First, we include R&D intensity measured a firm R&D expenditure divided by turnover as to control for absorptive capacity (Cohen and Levinthal, 1990; Laursen and Salter, 2006). We

calculated this variable by taking the data from the UK CIS for the R&D expenditure while total turnover was provided by ONS register data.

Second, we add search breadth which represents the external sources of knowledge utilised by the firm in its innovative activities. We took the data from a question in the survey asking "how important to this business's innovation activities was information from" various sources of information. Although the list of sources comprises of 10 items, we include the six sources where interaction with external partners is happening: (i) suppliers, (ii) customers, (iii) competitors, (iv) consultants, (v) universities, and (vi) government or public research institutes. This measure has been used extensively in previous studies (Laursen and Salter, 2006, 2014; Tether and Tajar, 2008; Grimpe and Sofka, 2009; Lee, Park, Yoon, & Park, 2010; Leiponen and Helfat, 2010; Garriga, von Krogh, Spaeth, 2013; Love, Roper, & Vahter., 2014). This variable will take into account the effect of having a search strategy on innovative performance.

Third, we control for the number of employees which has been transformed into a logarithmic expression (Cohen, 1995). The data for the firm size is drawn from ONS register data which was provided with the innovation survey. Fourth, we account for the start-up factor where we incorporate a measure on whether the company was founded after 2008 although we the survey does not provide information on companies with less than ten employees. Fifth, market size is included to control for companies' involvement in various markets such as U.K. local, U.K. regional, U.K. national, or international. Sixth, we include 12 geographical dummies as well as 9 industries dummies for both manufacturing and services in order to control for potential differences across industries and geographies when firms engage in openness.

Regression Analyses

Table 1 and Table 2 present descriptive statistics and correlations for the above mentioned variables for both manufacturing and service firms. Although none of the correlations are above 0.5, we have tested for multi-collinearity and found no single VIF to be greater than 3, which satisfies the rule of thumb of a maximum of 5 (or even 10 in some cases). From these tables, we can see that the mean of radical innovation (0.037) is lower than that of incremental innovation (0.049) in manufacturing; the same trend is confirmed in services where the mean of incremental (0.032) is higher than that of radical innovation (0.024). Besides, manufacturing firms seem, on average, to collaborate relatively more (1.19) than services (0.70) although the standard deviation is higher in manufacturing. As for appropriability regimes, manufacturing firms deploy, approximately and on average, two times more formal (0.41) and informal (0.45) regimes than service firms.

INSERT TABLE 1 AND TABLE 2

Table 3 and Table 4 display average values for the strength of collaboration breadth, formal appropriability, informal appropriability, and percentage of innovations that are new to the market and new to the firm. We compare and contrast these for manufacturing and service firms and observe that high R&D intensity manufacturing firms (e.g. chemicals, electronic) and knowledge intensive service firms (information and communication, professional and scientific activities) engage in higher external collaboration, use more formal and informal regimes, and have higher fraction of sales due to radical innovations. Besides, Table 5 shows averages values of formal and informal appropriability strategies as well as radical and incremental innovation for given levels of collaboration breadth. Although we cannot draw inferences from descriptive

statistics, we can observe that, at a very high level, there is a sort of a broad pattern between levels of appropriability, collaboration breadth, and radical and incremental innovations across manufacturing and service firms.

INSERT TABLE 3 AND TABLE 4

INSERT TABLE 5

In terms of statistical methodology, our dependent variable of innovative performance is measured as a percentage of total turnover which takes by definition values between 0 and 100. As such, tobit regression analyses is best suited (Greene, 2000; Wooldridge, 2002) to test the various hypotheses and respective moderation effect on the role of appropriability strategy on the relationship between collaboration breadth and innovative performance. However, the data should have a normal distribution under the tobit model. This is not the case for innovative performance as our data is skewed and concentrated towards zero; hence not satisfying the standard tobit requirements. As such, an alternative way to solve this problem is to apply a logarithmic transformation (Filippucci, Drudi, & Papalia, 1996; Papalia and Di Iorio, 2001; Wooldridge, 2002; Laursen and Salter, 2006). Thus, we include a latent variable, Y*, which is a log-transformation of the dependent variable of innovative performance: $Y^* = \ln(1 + Y)$. it is then this latent variable of innovative performance that will serve as a function of the various explanatory variables.

Table 6 and Table 7 show the result of the tobit regressions on the impact of appropriability regimes on the relationship between collaboration breadth and innovative performance. Looking at Model 2 in Table 6, we find support for Hypothesis H1a that the stronger the formal

appropriability regimes in manufacturing firms, the more effective collaboration breadth will be on innovation performance at higher levels of collaboration. The result is significant for radical innovation both at high and low external collaboration levels (Graph 1). We also find support for Hypothesis H1b (Table 7, Model 2) stating that the stronger the formal appropriability regimes in service firms, the more effective external collaboration will be on innovation performance. The result in services is significant for both radical and incremental innovation (Graph 2) However, at high levels of collaboration breadth, deploying high a formal regime is better while at low levels of collaboration breadth, deploying low formal appropriability strategies positively moderates the effect of collaboration on innovative performance. One way to explain this is that radical innovations requires more attention to the use of appropriability regimes than incremental innovations as the former is like 'the carrot of spectacular reward or the stick of destitution' (Schumpeter, 1942/1987) and is associated with higher performance while the latter is more common, more imitable, and with a lesser reward (Marsili and Salter, 2005; Ritala and Hurmelinna-Laukkanen, 2013). The reason why we obtain a significant effect for radical innovation in manufacturing where radical new product development are important to protect while we both radical and incremental innovations are significant for services as the latter use less IP rights than manufacturing firms (Arundel et al, 2007; Tether and Massini, 2007) given also the unique characteristics (intangibility, simultaneity, heterogeneity and perishability).

INSERT TABLE 6 AND TABLE 7

Looking at Model 4 in Table 6 and Table 7, we find contrasting results for the role of informal appropriability regimes. We obtain significant result for Hypothesis H2a so that the stronger the informal appropriability regimes in manufacturing firms, the less effective external collaboration

will be on innovation performance; the result being validated for incremental innovation. In other words, deploying high informal regimes at high levels of collaboration breadth will not yield higher innovative performance than if low informal regimes are used at high levels of collaboration (Graph 3). Despite that services mainly rely on informal appropriability mechanisms for their innovation activities (Tether and Massini, 2007), Hypothesis 2b did yield a negative moderating effect on the relationship between collaboration breadth and innovative performance but the moderation coefficient is not significant in itself despite that the standalone informal appropriability coefficients (0.812 and 0.334 for radical and incremental) is highly significant.

As for the combinations of different appropriability regimes, H3 results suggest interesting results for services where combinations of appropriability regimes moderate differently the impact of collaboration breadth on innovative performance. We find, when doing a three way interaction effect regression in manufacturing (Model 6), that the moderation coefficient is not significant despite having an inverted u-shape relationship where the use of low/high formal/informal display decreasing returns at higher levels of collaboration breadth and hence innovative performance slightly varies. For services, we obtain a significant three way interaction effect for radical innovation (Model 6; $p<0.10$; Graph 4)). Hypotheses H3a and H3b are significant and validated so the combination of high formal/low informal regime positively moderates the relationship between collaboration breadth and innovative performance while the combination of low formal/high informal regime negatively moderates the relationship between collaboration and innovative performance for services. We find that hypothesis H3c is also significant but rather has a slight positive moderation effect, contrary to our negative moderation expectations. In other words, having a high formal/informal regime in service firms is positively

but very slightly correlated with higher innovative performance at high levels of collaboration breadth. Lastly, Hypothesis H3d, or the combination of low formal/low informal regime, has a significant positive moderation on the relationship between collaboration and incremental innovation, although this combination is linked with the lowest overall innovative performance regardless of the strength of external collaboration.

DISCUSSION AND CONCLUSION

Capturing the value and appropriating the profits from innovation activities is an essential but a challenging part of any firms' pathway to grow and maintain a competitive advantage when engaging in openness. Indeed, innovation increasingly entails the collaboration with various external actors; but at the same time, the appropriation of the returns or profits from innovation activities necessitates deploying protection strategies and mechanisms. This empirical study helps us to extend our knowledge about how firms' appropriability choices and combinations impact should be managed in order for firms to capture and appropriate the returns from collaborating with external partners. Furthermore, this paper helps to shed some light on the emerging field of open service innovation and its respective appropriability dynamics as the majority of the extant literature has discussed IP protection in manufacturing firms. An additional contribution is to explicate what level of appropriability strategies by services companies will facilitate external collaboration and enhance innovative performance and whether any of these appropriability mechanisms any different from manufacturing when firms engage in openness. This study points to the firm level and organisational challenges that companies have to deal with in in formulating and deploying their appropriability strategy when engaging in openness; Surprisingly, these challenges in managing an adequate appropriability regimes is often underestimated by managers (Liebeskind, 1997).

Formal appropriability appears to be amongst the most powerful methods in order to capture value from innovation. For highly collaborative manufacturing and service firms, the stronger the formal appropriability, the more effective collaboration breadth will be on innovation performance. But for weakly collaborative service firms only, the weaker the formal appropriability, the more effective collaboration breadth will be on innovative performance. In other words, for collaborative companies, the use of formal regime seems to have an inhibiting effect on the negative consequences of under and over collaboration on innovative performance. Informal appropriability regimes, on the other hand, seem to have a dampening moderating effect on the relationship between collaboration breadth and innovative performance for manufacturing firms specifically. Even though services mainly rely on informal appropriability for their innovation activities (Tether and Massini, 2007), we found no support for a moderating effect when using informal regimes in service companies, contrary to what we expected. Besides, choosing the right combination of appropriability regimes at various levels of collaboration breadth has a resulting effect on radical innovative performance in service firms. For low collaborating firms, a combination of low formal / high informal seems to have the greater positive impact on innovative performance. However, for highly collaborative firms, the highest the formal regime contribution versus informal, the higher the positive impact on radical innovative performance. In other words, managers would be better off deploying more informal regimes at lower collaboration levels and a higher mix of formal at higher levels of external collaboration. Nevertheless, relying too much on high appropriability regimes (e.g. high formal/informal) can indeed be related with a diminished and barely positive moderating impact on innovative performance regardless of the levels of collaboration breadth.

Limitations and Future Research

This study has some limitations we would like to address besides some thoughts for future avenues for research. First, the 2011 UK Innovation Survey (CIS 7) is a cross sectional data and as such it is difficult to draw causality between appropriability, collaboration breadth, and innovative performance. We are aware that this constitutes a main limitation to our study as regression analyses do not prove any form of causality here. One way to go around this problem is to include a qualitative study of extreme cases or a wave of panel data. However, even with panel data, it would be challenging to detect the exact direction of causality. Second, it would be helpful if we complement the data set (ideally panel data) with additional information on companies' IP stocks such as patents, trademark, registration of industrial design, and copyrights amongst others. Furthermore, this study is limited by the questions listed in the questionnaire and as such, there are potentially other aspects of innovation activities especially regarding services such looking at norms, practices, and tacit knowledge as developing new service projects is usually conducted by informal committees (Sundbo, 1997; Miles, 2007).

This paper raises the important issue of the openness-appropriability duality and its implications for innovative performance in a comparison between U.K. manufacturing and service firms. Manufacturing and service companies face considerable challenges when configuring and setting up their appropriability strategies while collaborating with external partners while making sure that at the same time they exploit knowledge and capture the rents from innovation collaboration and activities. In this context, more research is needed on how companies and managers configure the elements of this tension and subsequently react to this duality. Besides, although this paper responds to the call for further research on open service innovation (Chesbrough, 2011, Love, Roper, & Bryson, 2011; Mina, Bascavusoglu-Moreau, & Hughes, 2014), little is still

known on whether openness in the service sector translates into higher performance, and if so under which context, where, and when is the case.

Table 1: Manufacturing Descriptive Statistics

	Variable	Mean	s.d.	Min	Max	1	2	3	4	5	6	7	8	9
1	Radical Innovation	0.037	0.090	0.00	- [a]									
2	Incremental Innovation	0.049	0.108	0.00	- [a]	0.33**								
3	Collaboration Breadth	1.190	1.617	0.00	6.00	0.39**	0.36**							
4	Formal Appropriability	0.415	0.890	0.00	4.00	0.32**	0.20**	0.42**						
5	Informal Appropriability	0.447	0.781	0.00	3.00	0.31**	0.24**	0.47**	0.47**					
6	R&D Intensity	0.011	0.043	0.00	- [a]	0.21**	0.15**	0.25**	0.26**	0.31**				
7	External Search Breadth	2.600	1.507	0.00	6.00	0.19**	0.15**	0.49**	0.25**	0.21**	0.11**			
8	Number of Employees (log)	4.173	1.395	0.00	- [a]	0.09**	0.07**	0.25**	0.26**	0.15**	0.05*	0.19**		
9	Startup	0.053	0.225	0.00	1.00	0.04	0.02	0.01	-0.03	-0.05*	-0.01	-0.02	-0.11**	
10	Market Size	2.961	1.078	1.00	4.00	0.20**	0.15**	0.26**	0.27**	0.27**	0.159**	0.207**	0.34**	-0.05*

*** $p \leq 0.01$; * $p \leq 0.05$; † $p \leq 0.10$. [a] : numbers suppressed in compliance with ONS rule on data disclosure*

Table 2: Services Descriptive Statistics

	Variable	Mean	s.d.	Min	Max	1	2	3	4	5	6	7	8	9
1	Radical Innovation	0.024	0.105	0.00	1.00									
2	Incremental Innovation	0.032	0.111	0.00	1.00	0.31**								
3	Collaboration Breadth	0.704	1.377	0.00	6.00	0.34**	0.32**							
4	Formal Appropriability	0.183	0.569	0.00	4.00	0.24**	0.17**	0.28**						
5	Informal Appropriability	0.181	0.513	0.00	3.00	0.34**	0.27**	0.37**	0.47**					
6	R&D Intensity	0.011	0.066	0.00	- [a]	0.20**	0.13**	0.18**	0.20**	0.24**				
7	External Search Breadth	2.497	1.475	0.00	6.00	0.14**	0.07**	0.40**	0.16**	0.18**	0.01**			
8	Number of Employees (log)	4.041	1.595	0.00	- [a]	-0.02	-0.04**	0.10**	0.07**	0.02	-0.01	0.11**		
9	Startup	0.068	0.251	0.00	1.00	0.05**	0.07**	0.02	0.00	0.00	-0.01	0.03	-0.09**	
10	Market Size	2.015	1.090	1.00	4.00	0.15**	0.14**	0.18**	0.28**	0.30**	0.15**	0.12**	0.14**	-0.05**

*** $p \leq 0.01$; * $p \leq 0.05$; † $p \leq 0.10$. [a] : numbers suppressed in compliance with ONS rule on data disclosure*

Table 3: Manufacturing Industry Averages

Industry	N	Collaboration Breadth (x6)	Formal Appropriability (x4)	Informal Appropriability (x3)	% Radical Innovation	% Incremental Innovation
Food, Beverage, and Tobacco	309	1.22	0.30	0.25	3.33	4.87
Textiles, Wearing Apparel, and Leather	144	1.07	0.40	0.22	2.79	4.54
Wood, Paper, Printing, and Publishing	334	0.71	0.23	0.25	2.17	3.57
Petroleum, Chemicals, Rubber, and Plastic	363	1.42	0.56	0.60	3.19	5.53
Metals, Metallic, and Non-Metallic Mineral	603	0.93	0.31	0.35	2.83	3.98
Computer, Electric, and Electronic Equipment	252	1.74	0.76	0.79	6.98	6.75
Machinery and Equipment	254	1.47	0.52	0.64	5.22	5.78
Transport	234	1.50	0.38	0.58	4.49	5.95
Other Manufacturing	356	1.01	0.37	0.39	3.72	4.24
Average Across Industries		1.23	0.43	0.45	3.86	5.02

Table 4: Services Industry Averages

Industry	N	Collaboration Breadth (x6)	Formal Appropriability (x4)	Informal Appropriability (x3)	% Radical Innovation	% Incremental Innovation
Electricity, Gas, and Water Supply	186	0.84	0.13	0.21	2.40	5.37
Construction	1,373	0.56	0.05	0.10	1.16	2.27
Whole Sale and Retail Trade	2,744	0.61	0.22	0.14	1.99	2.54
Transportation	759	0.59	0.07	0.11	1.11	2.27
Accomodation and Food Services	1,353	0.57	0.10	0.07	1.87	2.57
Information and Communication	666	1.29	0.48	0.58	4.87	7.86
Financial, Insurance, and Real Estate	856	0.79	0.15	0.13	1.36	2.90
Professional, Technical, and Scientific	1,958	0.98	0.33	0.33	4.52	3.90
Administration and Support	1,509	0.52	0.07	0.12	1.74	2.80
Average Across Industries		0.75	0.18	0.20	2.34	3.61

Table 5: Averages of formal and informal appropriability strategies, radical, and incremental innovations for given levels of collaboration breadth

Manufacturing

Strength of External Collaboration Breadth, Outcome	Frequency (N)	Formal Appropriability (x4), Average	Informal Appropriability (x3), Average	Radical Innovation, Average %	Incremental Innovation, Average %
0	1,012	0.13	0.14	1.17	2.14
1	261	0.43	0.46	3.58	6.90
2	273	0.55	0.71	5.39	7.81
3	170	0.85	0.91	10.17	7.46
4	81	1.16	1.06	7.42	7.12
5	56	1.43	1.34	8.50	8.20
6	59	1.32	1.31	7.60	9.86

Services

Strength of External Collaboration Breadth, Outcome	Frequency (N)	Formal Appropriability (x4), Average	Informal Appropriability (x3), Average	Radical Innovation, Average %	Incremental Innovation, Average %
0	5,002	0.90	0.07	0.77	1.32
1	681	0.24	0.29	4.68	7.30
2	586	0.44	0.43	4.12	6.83
3	348	0.39	0.51	4.92	7.53
4	149	0.86	0.82	12.85	7.97
5	87	0.82	0.94	13.70	6.83
6	169	0.49	0.61	9.10	7.94

Table 6: Tobit Regression: The Role of Appropriability on the Relationship Between Collaboration Breadth and Innovative Performance

MANUFACTURING FIRMS

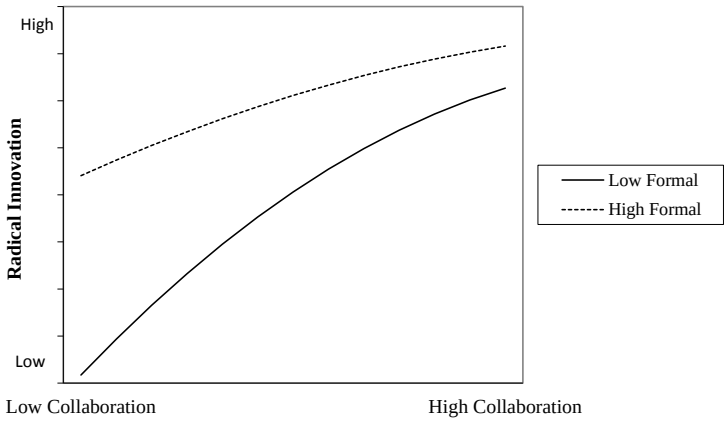
	Radical Innovation						Incremental Innovation					
Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Collaboration Breadth	0.601***	0.702***	0.581***	0.759***	0.560***	0.862***	0.240***	0.280***	0.228***	0.359***	0.226***	0.373***
Collaboration Breadth Sq.	-0.061*	-0.062†	-0.056*	-0.086*	-0.059*	-0.104*	-0.029**	-0.034**	-0.028**	-0.056***	-0.028**	-0.057***
Formal Appropriability	0.460***	0.959***			0.411***	1.119**	0.074*	0.180*			0.058	0.275*
Informal Appropriability			0.351**	0.687**	0.222†	0.711*			0.093*	0.228*	0.074†	0.327**
Collaboration x Formal		-0.287†				-0.392		-0.083				-0.094
Collaboration Sq. x Formal		0.028				0.047		0.011				0.008
Collaboration x Informal				-0.298		-0.413				-0.177*		-0.236**
Collaboration Sq. x Informal				0.044		0.070†				0.033**		0.041**
Formal x Informal						-0.642						-0.189*
Collaboration x Formal x Informal						0.200						0.089
Collaboration Sq. x Formal x						-0.029						-0.010
R&D Intensity	2.338	2.692	2.684	2.579	1.869	2.234	0.509	0.505	0.444	0.314	0.346	0.356
Search Breadth	0.124†	0.124†	0.149*	0.147*	0.128†	0.128	0.045†	0.044†	0.050†	0.048†	0.046†	0.046†
Number of Employees (log)	-0.163*	-0.154†	-0.090	-0.089	-0.155†	-0.155	-0.068*	-0.067*	-0.056	-0.061*	-0.065*	-0.070†
Startup	0.322	0.337	0.350	0.356	0.382	0.385	0.068	0.010	0.026	0.038	0.025	0.033
Market Size	0.388**	0.367***	0.408***	0.397***	0.367***	0.326	-0.007	-0.010	-0.010	-0.017	-0.015	-0.029
Constant	-3.733***	-3.855***	-4.201***	-4.336***	3.728***	-3.907***	0.158	0.144	0.107	0.100	0.164	0.138
Geography Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industries Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Chi-Square	158.6	165.5	144.6	146.9	162.1	173.8	85.1	87.3	85.6	94.5	88.0	103.8
Left Censored	679	679	679	679	679	679	548	548	548	548	548	548
N	1069	1069	1069	1069	1069	1069	1077	1077	1077	1077	1077	1077
Log Likelihood	-1271.7	-1268.2	-1278.7	-1277.5	-1269.9	-1264.0	-1123.9	-1122.8	-1123.7	-1119.2	-1122.4	-1114.5
R^2	0.0587	0.0612	0.0535	0.0544	0.0600	0.0643	0.0365	0.0374	0.0367	0.0405	0.0377	0.0445

Table 7: Tobit Regression: The Role of Appropriability on the Relationship Between Collaboration Breadth and Innovative Performance

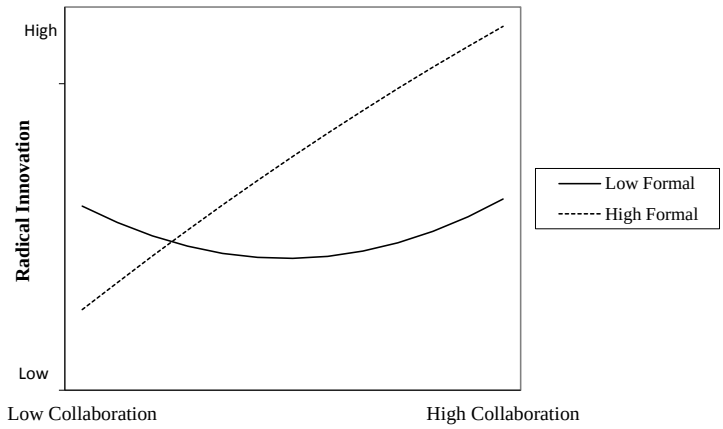
SERVICES FIRMS

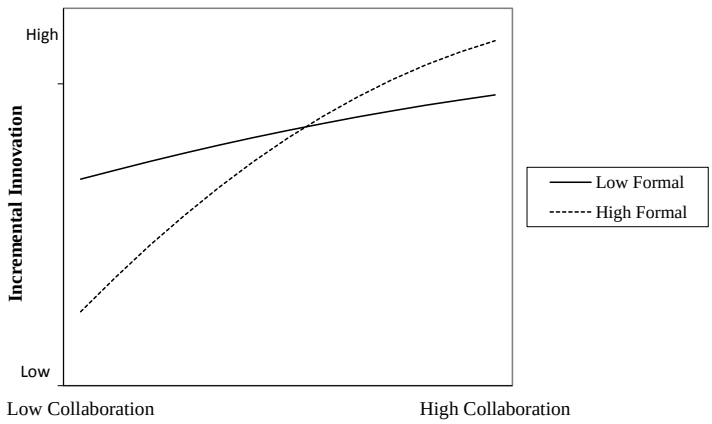
	Radical Innovation						Incremental Innovation					
Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Collaboration Breadth	0.152†	0.045	0.072	0.057	0.058	0.000	0.183**	0.134*	0.153**	0.171**	0.152**	0.124*
Collaboration Breadth Sq.	0.004	0.025†	0.011	0.021	0.013	0.030†	-0.020*	-0.013	-0.018*	-0.020†	-0.018*	-0.013
Formal Appropriability	0.339***	0.136			0.164**	0.299†	0.082†	-0.139			0.009	-0.218†
Informal Appropriability			0.646***	0.812***	0.587***	1.135***			0.259***	0.334***	0.256***	0.477***
Collaboration x Formal		0.254**				0.146		0.180*				0.278*
Collaboration Sq. x Formal		-0.045**				-0.031		-0.024*				-0.045*
Collaboration x Informal				-0.042		-0.291*				-0.063		-0.164†
Collaboration Sq. x Informal				-0.005		0.033				0.009		0.023
Formal x Informal						-0.517**						-0.066
Collaboration x Formal x Informal						0.227†						-0.01
Collaboration Sq. x Formal x						-0.027						0.004
R&D Intensity	2.039***	2.018***	1.704***	1.697***	1.533***	1.517***	0.420	0.406	0.204	0.203	0.193	0.194
Search Breadth	0.098**	0.102**	0.088***	0.091**	0.087**	0.088**	0.040†	0.041†	0.035	0.034	0.035	0.033
Number of Employees (log)	-0.095**	-0.092**	-0.075*	-0.071*	-0.081**	-0.077**	-0.085***	-0.083***	-0.080***	-0.079***	-0.080***	-0.078***
Startup	0.319†	0.308†	0.274	0.283†	0.282†	0.274†	0.375***	0.373***	0.361**	0.361**	0.362**	0.356**
Market Size	0.173***	0.174***	0.119†	0.117**	0.104*	0.084†	0.086**	0.088***	0.060*	0.059†	0.059†	0.054†
Constant	-2.329***	-2.288***	-2.334***	-2.390***	-2.245***	-2.242***	-0.706**	-0.678**	-0.668**	-0.678**	-0.664**	-0.635**
Geography Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industries Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Chi-Square	275.3	284.0	343.3	348.4	350.9	379.3	138.7	145.5	164.7	165.4	164.8	176.69
Left Censored	1858	1858	1858	1858	1858	1858	1569	1569	1569	1569	1569	1569
N	2414	2414	2414	2414	2414	2414	2410	2410	2410	2410	2410	2410
Log Likelihood	-1760.8	-1756.4	-1726.8	-1724.2	-1722.9	-1708.8	-2231.1	-2227.6	-2218.0	-2217.7	-2218.0	-2212.03
R^2	0.0725	0.0748	0.0904	0.0918	0.0924	0.0999	0.0301	0.0316	0.0358	0.0359	0.0358	0.0384

Graph 1: H1a: Formal / Manufacturing



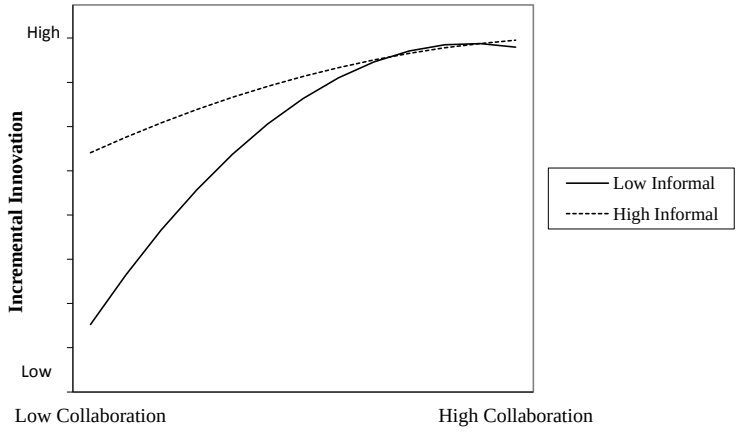
Graph 2: H1b: Formal / Services





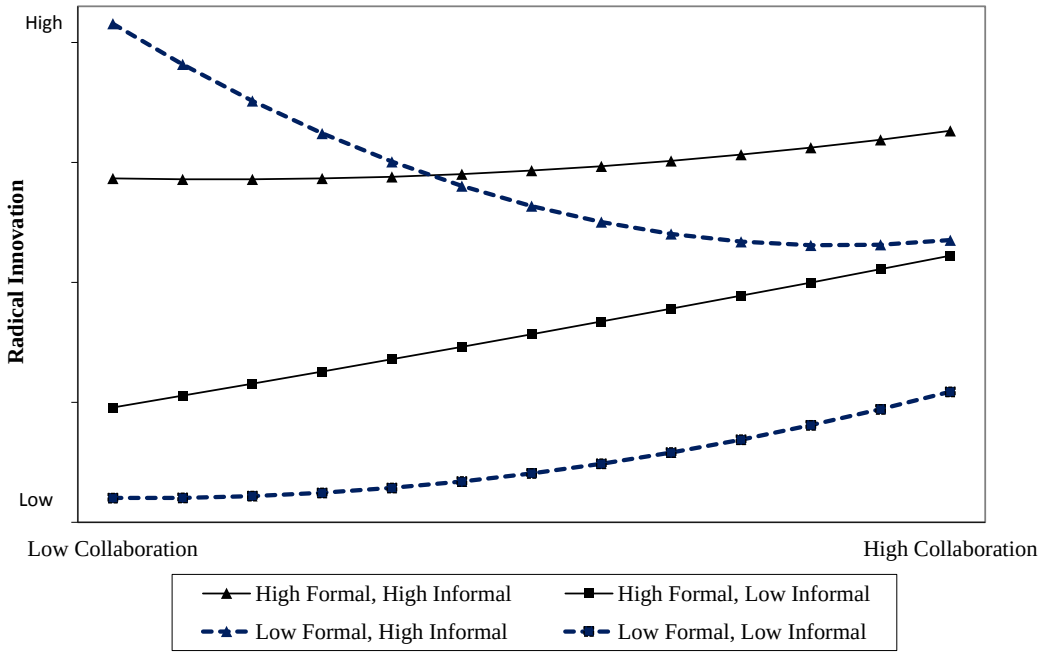
Graph 3:

H2a: Informal / Manufacturing

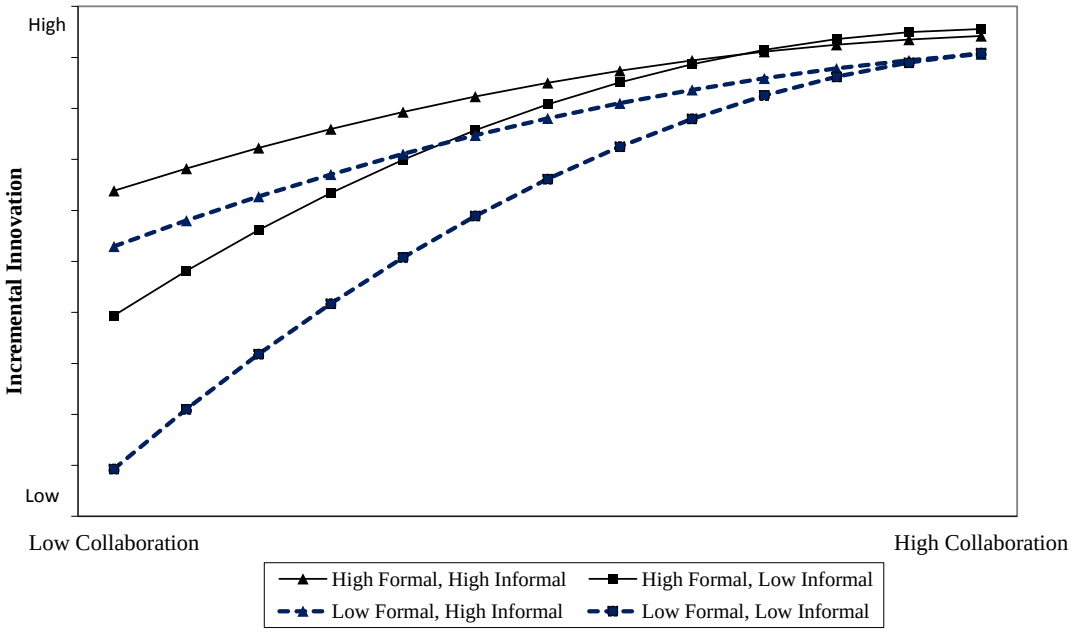


Graph 4:

H3: Combination / Services



Combination / Manufacturing: Moderation not Significant:



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