Economic
and Social
Research Council

Enterprise Research Centre

Doing innovation. Creating value from innovation: How does IP protection help? A UK analysis with a focus on smaller firms

ERC Research Paper 103

February 2023

www.enterpriseresearch.ac.uk

Doing innovation. Creating value from innovation: How does IP protection help? A UK analysis with a focus on smaller firms

Joanne Turner
Enterprise Research Centre
Warwick Business School
Joanne.E.Turner@wbs.ac.uk

Stephen Roper
Enterprise Research Centre
and National Innovation Centre for Rural Enterprise,
Warwick Business School
Stephen.roper@wbs.ac.uk

The Enterprise Research Centre is an independent research centre which focusses on SME growth and productivity. ERC is a partnership between Warwick Business School, Aston Business School, Queen's University School of Management, Leeds University Business School and University College Cork. The Centre is funded by the Economic and Social Research Council (ESRC); Department for Business, Energy & Industrial Strategy (BEIS); Innovate UK, the British Business Bank and the Intellectual Property Office. The support of the funders is acknowledged. The views expressed in this report are those of the authors and do not necessarily represent those of the funders.

ABSTRACT

Innovation – the market introduction of new products, services or processes – lies at the centre of most firms' value creation strategies. Through differentiation, innovation adds value for a producer, driving growth and profitability and increasing a firm's chance of survival and growth. Here, using matched data on IP protection holding for the population of UK firms and innovation survey evidence from the UK Innovation Survey, we examine how formal IP protection mechanisms – patents, registered designs and trade marks – contribute to innovation individually and in combination. We focus particularly on small firms and consider how IP protection contributes both to the propensity to innovate and to firms' ability to capture value from their innovation. Our analysis suggests that registered designs combined with patents promote the propensity for product or service innovation. To some extent, trade marks combined with registered designs also boost the returns to innovation by protecting a firm's market-oriented capabilities. Both effects prove rather similar for small firms as they are to the general population of businesses. Each IP protection instrument therefore plays a role in supporting innovation, although registered designs play a critical role in 'unlocking' the potential for firms' IP to contribute to innovation and subsequent value creation. Hopefully, this better understanding of the benefits of design in driving innovation and value creation may help to raise the profile of design as a public policy issue and ensure that public-sector support for design no longer remains 'meager' relative to that for R&D.

ACKNOWLEDGEMENTS

We are grateful to the Intellectual Property Office for making available the IP data on which this paper is based. We are also grateful for comments on this paper received from the Department for Business, Energy and Industrial Strategy, Innovate UK and the Intellectual Property Office. This work has been supported by the Enterprise Research Centre (ERC), ESRC grant ES/W005301/1. The statistical data used here is from the Office of National Statistics (ONS) and is Crown copyright and reproduced with the permission of the controller of HMSO and Queens Printer for Scotland. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. The analysis upon which this paper is based uses research datasets which may not exactly reproduce National Statistics aggregates.

Keywords: Innovation, patents, trade marks, registered designs, small firms.

CONTENTS

ABSTRACT 3
1. INTRODUCTION 5
2. Conceptual background and hypotheses development 8
2.1 Innovation, appropriability and intellectual property (IP) protection 8
2.2 IP protection and the propensity to innovate 10
2.3 IP protection and the propensity to innovate in small firms 16
2.4 IP protection and value creation from innovation 19
2.5 IP protection and value creation from innovation in small firms 22
3. Data and methods 25
3.1 Data 25
3.1.1 Dependent variables 28
3.1.2 Independent variables 29
3.1.3 Control variables 29
3.2 Estimation methods 32
4. Results 33
4.1 IP protection and innovation propensity 33
4.2 IP protection and creating value from innovation 35
4.3 Other influences on innovation propensity and value creation 37
5. Focusing on small firms 38
6. Discussion and conclusions 42
References 65

1. INTRODUCTION

Innovation – the market introduction of new products, services or processes – lies at the centre of most firms' value-creation strategies (Aaker 2007). Through differentiation, innovation adds value for a producer, driving growth and profitability and increasing a firm's chance of survival (Geroski et al. 1993; Hall 2000; Czarnitzki and Kraft 2004; Cefis and Marsili 2005). Indeed, there is evidence to suggest that innovative firms grow twice as fast as non-innovators (NESTA 2009). However, the extent of any performance benefits depends on a firm's ability to capture the profits generated by an innovation (Teece 1986; Levin et al. 1987). When an innovating firm is unable to limit other firms from imitating an innovation, the appropriability problem (Arrow 1962) arises. Consequently, the innovating firm may fail to appropriate the returns to an innovation (Ceccagnoli and Rothaermel 2008) and be unable to gain and sustain a competitive advantage (Laursen et al. 2013). As a firm's incentive to invest in innovation derives from the expectation of returns (Laursen and Salter 2005; Du et al. 2007), an anticipated failure to appropriate returns leads to an under-investment in research and development (R&D) and innovation. To help overcome this problem, firms incorporate knowledge protection methods (both formal and informal[1]) into their innovation strategies to help maximise returns (Laursen and Salter 2005; Greenhalgh and Rogers 2007). These knowledge protection methods make an innovator's knowledge, or 'intellectual property' (IP), excludable so that the innovating firm can appropriate returns. In so doing, the knowledge protection methods encourage firms' investment in innovation (Grandstrand 1999).

Previous studies have shown that the use of formal knowledge protection methods (hereafter, IP protection) differs across firms (Lopez 2009; Hall et al. 2014) and industrial sectors (Levin et al. 1987; Cohen et al. 2000). A firm's IP protection strategy is supported by its resources and capabilities, reflecting the notion that resources and positions are closely related (Wernerfelt 1984). The heterogeneous nature of firms' resources and capabilities gives rise to different IP protection strategies across firms, with factors such as finance and managerial capabilities being identified as key determinants of a firm's IP protection strategy (Kitching and Blackburn 2003; Leiponen and Byma 2009; Hall et al. 2014). Industry or sectoral characteristics also play an important part in the decision-making process when a firm determines its IP protection strategy. The tacit nature of

[1] Formal knowledge protection methods (e.g., patents and trade marks) are implemented through regulation and are effective by legally excluding imitators (Hall 1992), whereas informal protection mechanisms (e.g., secrecy and lead-time) are not based on structures and statutory enforcement possibilities (Hurmelinna-Laukkanen 2014).

knowledge in services, for example, means that applying IP protection is not straightforward (Blind et al. 2003; Maskus 2008). In manufacturing, some technologies are easier to protect than others. For example, in the chemicals and pharmaceuticals sectors, a specific compound (or a specific chemical formula) can be protected by a patent; it is clear what is protected and few disputes arise (Bessen and Meurer 2008). However, in other sectors (e.g., information technology), the applicability of patents is less clear. As a result, the probability of dispute is higher, and patent protection is less popular (Hall et al. 2014).

Innovating firms of all sizes face the appropriation problem and, hence, may derive value from IP protection. In particular, in the case of small firms that are often establishing their place in the market (university spinouts, for example), imitation can be catastrophic. The loss of revenue and reduced market share and growth following imitation may, in some cases, lead to business failure. In such cases, the use of IP protection to stave off imitation is critical for firm survival. Prior evidence suggests, however, that even in industries where IP protection is an effective appropriation tool, small firms are least likely to engage in its use to help safeguard innovations (Kitching and Blackburn 2003). Resource and capability barriers exist in relation to IP protection and small firms: owner-managers view IP protection as a complex process (some are even unaware of its existence); owner-managers perceive the costs of IP protection to be high; owner-managers perceive an ambiguous link between IP protection and innovation; and, owner-managers feel unable to adequately administer and enforce IP protection, especially when in conflict with larger firms (Blackburn 2003; EUPTO 2016)[2].

Where small firms do apply for patents, trade marks or registered designs they are more likely to grow quickly and succeed than smaller firms that do not (WIPO 2021). Despite this evidence, a recent EPO/EUIPO (2021) study identifies an imbalance with respect to firms' holdings of IP protection across sizebands – just 9 per cent of SMEs (small and medium-sized enterprises) owned at least one patent, trade mark or registered design, whereas some 60 per cent of larger firms owned at least one of these protection mechanisms. Every small firm has a trading name, has confidential now-how (in terms of its suppliers, customers, employees etc.), and commonly creates copyright material. Regardless, many small firms need persuading that IP protection is relevant to them. Small firms' reasons for

[2] It is well established that limited resources and capabilities create barriers to innovation in small firms, barriers that include R&D challenges due to the lack of specialist R&D departments (Love and Roper 2015), managerial challenges due to the lack of education and training (Hausman 2005) and investment challenges due to the lack of finance (Binks and Ennew 1996).

not using IP protection are often economic, with pressures of time and a lack of knowledge also playing a part[3]. By aiding the appropriation of firms' knowledge and ideas, IP protection helps firms of all sizes to capture the return on their investments into intangible assets and innovation. Firms reap the rewards of IP protection by achieving higher profits, entering into licensing and collaboration agreements, forming relationships with new investors and increasing their activity in foreign markets (EPO/EUIPO 2019). Accordingly, "Over and above the underlying product or service it protects, IP is a valuable asset in its own right. Indeed, it can become a company's most valuable asset," (WIPO 2021).

With a particular focus on small firms, this paper examines the part played by IP protection in the process by which firms do innovation and subsequently create value from innovation. First, we consider how IP protection can affect firms' propensity to innovate. Here, we expect the use of IP protection to protect a firm's technological knowledge and allow the firm to appropriate returns, thus incentivising engagement in innovation activities and increasing the probability of innovation. Second, we consider the commercialisation stage in which firms generate value from their innovation. Here, IP protection can protect market-related knowledge and positively influence a firm's ability to profit from an innovation. The paper contributes to our understanding of the relationship between firms' holdings of IP protection (part of knowledge stocks), as measured by patent, trade mark and registered design stocks, and innovation. We focus in particular on whether accumulated IP protection generates value for small firms by improving their ability to innovate and to profit from an innovation. In so doing, we are able to determine whether the innovation benefits of IP protection are different for smaller firms compared to firms more generally.

Our empirical analysis is based on UK IP protection data (patents, trade marks and registered designs) for the 1995-2018 period provided by the Intellectual Property Office (IPO) and three waves of the UK Community Innovation Survey (UKIS) covering the 2012-2018 period. Using the IPO data, we compile live IP protection histories for some 102,000 firms, and match these live IP protection histories to the pooled UKIS firm-level data. The data match allows us examine the part played by accumulated IP protection in shaping firms' innovation activity.

The remainder of the paper is organised as follows: Section 2 outlines our conceptual perspective and hypotheses development, focusing on innovation and appropriability and a firm's use of IP protection at different stages of the innovation process. In addition, we

[3] https://www.ucl.ac.uk/laws/events/2022/feb/can-ip-system-serve-small-businesses-better

present some of the evidence surrounding the use of IP protection in small firms, and the differences that exist between small firms and firms more generally. Section 3 profiles the data used and the empirical approach adopted, and Section 4 describes the main empirical results. Section 5 includes discussion and conclusions.

2. CONCEPTUAL BACKGROUND AND HYPOTHESES DEVELOPMENT

2.1 Innovation, appropriability and intellectual property (IP) protection

Innovation – the application of knowledge (technological, strategic or market related) to change or create more effective processes, products and ideas – is translated into economic value through generating a variety of better-quality products and more effective processes. Indeed, the majority of economic growth in the long term is due to innovation (Innovation Report 2014). Innovation can be radical or incremental. A radical innovation has a significant impact on a market and on the economic activity of firms within that market. The innovation may lead to a change in the structure of the market, create new markets or displace existing products. Incremental innovation, however, is the improvement of an existing product, process or service, i.e., it is 'doing better what is already being done' (Tidd et al. 1997). Radical innovations create major, disruptive changes, whereas incremental innovations continuously advance the process of change (Schumpeter 1942).

Innovating firms face several challenges when engaging in innovation activities. In particular, developing and translating new ideas into products and processes is expensive, time consuming and risky, and once accomplished, there remains the risk of imitation by existing competitors and new firms entering into the market, attracted by the existence of high returns (Hurmelinna-Laukkanen 2009). In the face of imitation, an innovating firm's competitive advantage is eroded. This discourages firms from becoming innovation active, as there is no longer an incentive to innovate (Schumpeter 1942). This so-called appropriability problem (Arrow 1962) has implications for both firm performance and survival (Ceccagnoli and Rothaermel 2008). In light of this, a key strategic challenge for firms is to find a way to protect the returns to their innovation investments. One way for firms to achieve this protection is to use knowledge protection methods or mechanisms – practical means of IP protection that are both effective and available for use (Teece 1986; Levin et al. 1987; Teece and Pisano 1998).

IP protection is one dimension of the appropriability regime (i.e., the environmental factors a firm faces – excluding firm and industry structure – which govern its ability to capture profits from an innovation (Teece 1986)), and consists of legally enforceable knowledge protection methods that are implemented through regulation (Hall 1992). Typically, this protection comprises registered rights such as patents, design rights and trade marks and unregistered rights such as copyright. Another dimension of the appropriability regime is natural knowledge protection in the form of the nature of the technology being used (e.g., whether technological knowledge is tacit or codified). Combined, these two dimensions determine the barriers to imitation and the ease with which competitors can imitate an innovation (Ceccagnoli and Rothaermel 2008). An appropriability regime is said to be *weak* when innovations are difficult to protect i.e., when they can be easily codified and IP protection methods are ineffective, or *strong* when innovations are easy to protect because knowledge about them is tacit and/or available IP protection methods are effective. In reality sectoral appropriability regimes form a continuum, some emphasising IP protection over the nature of technology and some emphasising the nature of technology over IP protection (Teece 1998, 2000). For example, a strong regime can be achieved by different means; some industries may rely upon IP protection while others may rely upon tacit knowledge embedded deep within firms' structure (Levin et al. 1987). Whatever the combination, firms aim to create a first-mover advantage through innovation and earn higher than average returns.

In recent years, the emergence of the knowledge-based economy has resulted in a significant shift in the origin of most companies' value and source of revenue; for most firms, intangible assets have overtaken tangible assets as the dominant driver of value creation. However, creating and maintaining a competitive advantage based upon knowledge is a challenging prospect for firms, as the benefits of producing new knowledge spill over to competitors and create the appropriability problem (Arrow 1962). The recognition that intangible assets are a key driver of growth (Montresor et al. 2014) and that innovation stems from knowledge (Roper et al. 2016), combined with firms' recognition of a potential appropriability problem, has led to a shift within firms towards the creation and protection of knowledge assets. In 2016, firms in the UK private sector invested an estimated £134.3 billion in knowledge assets, of which £63.8 billion was protected by IP rights (6.8 per cent and 3.2 per cent of GDP, respectively) (ONS 2021). During the 2014-2016 period, industries with an above average use of IP protection accounted for 26.9 per cent of UK non-financial value-added output, 15.5 per cent of total UK employment and 52.1 per cent of goods exported (IPO 2020).

Successful innovation depends on knowledge – technological, strategic and market related (Roper and Hewitt Dundas 2015). When a firm innovates[4], a process of knowledge sourcing (e.g., R&D activities), transformation (i.e., turning knowledge into an innovation) and exploitation (i.e., an attempt to improve performance and generate value added (Roper et al. 2008)) takes place. Combined, this recursive process is what has become known as the innovation value chain (IVC) (Roper et al. 2008). The IVC, or life cycle of technologies, encompasses technological, strategic and market related knowledge. Initially, the innovation process involves gathering technological and strategic knowledge and codifying this to form new market offerings. Subsequently, commercial diffusion takes place using market-related knowledge adding value and generating sales for the firm.

2.2 IP protection and the propensity to innovate

Various knowledge-sourcing activities take place during the first phase of the innovation process. Intramural R&D (Shelanski and Klein 1995) – creative and systematic work undertaken by a firm to increase the stock of knowledge and to devise new applications of available knowledge (OECD 2015) – is the knowledge-sourcing activity most widely linked to innovation. Others include customer linkages (Joshi and Sharma 2004), supplier and external-consultant linkages (Horn 2005), competitor and joint-venture linkages (Link et al. 2005) and university/public-research-centre linkages (Roper et al. 2004). Knowledge sourcing during the exploration stage of the IVC leads to invention – the foundation of innovation (WIPO 2017).

Inventors develop new value-creating technologies with the aim of innovating and achieving commercial success. A firm's use of IP protection during the initial exploration stage of this process protects technological knowledge and increases the probability that the firm will innovate. IP protection shields the innovating firm from imitation, allowing the firm to appropriate any future returns. By controlling the commercial use of inventions, IP protection used at the invention stage helps the inventor protect future commercial success. Accordingly, IP protection provides the firm with an incentive to be innovation active (Granstrand 1999). The protection encourages investment into knowledge sourcing and transformation, and as a consequence, increases the probability that a firm will innovate.

[4] i.e., introduces 'a new or improved product or business process (or combination thereof) that differs significantly from the firm's previous products or business processes and that has been introduced on the market or brought into use by the firm,' (OECD/Eurostat, 2018, 3.9).

Over time, a firm may acquire a number of IP protection rights in relation to its knowledge exploration and transformation activities. A firm's stock of IP protection represents accumulated protected knowledge or protected knowledge stocks. Both the resource-based view (Wernerfelt 1984; Barney 1991) and the knowledge-based view (Kogut and Zander 1992; Grant 1996) of the firm suggest that firms that acquire high levels of knowledge stocks are better positioned in terms of their ability to innovate successfully (DeCarolis and Deeds 1999). From this, it follows that firms with more IP protection rights (larger stocks of protected knowledge) have a knowledge-based advantage (Dierickx and Cool 1989) and are more likely to be innovative.

Firms with a high stock of IP protection are able to gain from first-mover, knowledge-based advantages compared with firms that have a low stock of IP protection. These advantages are strengthened by the existence of asset mass efficiencies, where firms with high stocks of IP protection find it easier to add to their existing knowledge stocks, i.e., they have a greater absorptive capacity (Cohen and Levinthal 1990). In addition, firms with high IP protection stocks have more proprietary knowledge to contribute towards the novelty or complexity of new innovation (Lee 2010). As firms' IP protection stocks increase, their knowledge exploration and transformation activities can become a path-dependent process, and as a result, they learn to adopt and apply knowledge that leads to favourable innovation outcomes. Firm efficiency is increased, leading to specialisation and success (Levitt and March 1988). However, this learning behaviour suggests that firms are likely to innovate in areas related to previous innovations (linked with existing IP protection stocks) (Helfat 1994; Thrane et al. 2010). Knowledge investments and innovation outcomes may become contingent on current IP protection stocks, with complementarities existing between new IP protection and existing IP protection stocks. Such learning behaviour and specialisation reduces the extent of firms' wider knowledge search and transformation activities (Roper and Hewitt-Dundas 2015), potentially stifling innovation through path-dependency (Thrane et al. 2010), core-rigidities (Leonard-Barton 1992), or search myopia (Levinthal and March 1993). Furthermore, one firm protecting its IP can prevent diffusion/learning by other firms, creating a barrier to innovation elsewhere.

Patents and registered designs are the IP protection methods typically used by firms to protect knowledge acquired during the knowledge-sourcing and transformation stages of the innovation process (Llerena and Millot 2020)[5]. The procedure surrounding the acquisition of both patents and registered designs recognises the rights of an inventor and provides the inventor with an opportunity to exploit the invention for financial gain. Each patent and registered design owned by a firm represents protected knowledge, with the stock of patents and registered designs being part of the firm's protected knowledge stock or IP protection stock.

Patents

Patents protect the exploitation of inventions that are "new, involve an inventive step (non-obviousness) and are capable of industrial application" (TRIPS, Article 27, 1994). Reflecting invention rather than innovation, patents indicate innovation activity rather than signalling innovation success (Coombs et al. 1996). Patents cover how products work, what they do, how they do it, what they are made of and how they are made[6]. Patents solve the problem of appropriability by vesting an ownership right with the inventor and preventing others from profiting from the new knowledge. A patent allows an inventor to take legal action against anyone who makes, uses, sells or imports an invention without the inventor's permission. Rather than keeping an invention secret, a patent shares how to create or replicate an invention with the public, and once the patent has expired, others can make and sell the invention[7]. Patents protect innovations such as machines, industrial processes, pharmaceuticals and their production methods, computer hardware, electrical appliances and biological products and processes; they cannot protect literary, dramatic, musical or artistic works, or anything that is an idea, a way of thinking, or a scientific or mathematical discovery. Applying for a patent can be an expensive and lengthy process and may take several years. Once granted, renewal fees are payable for twenty years – the full period of protection (IPO 2018). During this period, it is the inventor's responsibility to enforce the patent and ensure that an invention is protected. Any legal action that may take place as a result of a dispute or an infringement must be paid for by the inventor.

Over the long term, it is suggested that patents are strongly correlated with increased innovation, knowledge sharing, and economic growth[8]. Moreover, the high value of patents

---

[5] Confusion sometimes arises between the protection offered by a design registration and that offered by a patent: a design registration protects the visual appearance of a product whereas a patent protects a technical product and how it functions.
[6] https://www.gov.uk/government/publications/ip-basics/ip-basics
[7] However, in reality, the pace of innovation means that many inventions become redundant long before the patent for them expires.
[8] https://www.forbes.com/sites/marshallphelps/2015/09/16/do-patents-really-promote-innovation-a-response-to-the-economist/#20c6d4691921

for the innovating firm is a common conclusion of many empirical studies. Arora et al. (2008) construct a structural model of R&D investment and innovation outcomes using the Carnegie Mellon Survey (Cohen et al. 2000). The study finds that, on average, patents provide a positive (greater than unity) expected premium gross of patent application costs in the pharmaceuticals, biotech and medical instruments industries, with machinery, computers, and industrial chemicals close behind. However, factors that drive the patent premium are unexplored in this study. Using a modified model more suited to the UK Community Innovation Survey (CIS) data structure, Arora and Athreye (2012) find that a unit increase in perceived patent effectiveness increases revenue from new products by 160 to 200 per cent. The same increase in perceived patent effectiveness leads to an 11 to 27 per cent increase in R&D. Furthermore, results suggest that patents boost larger firms' revenue most; the average patent premium is 66 per cent for larger firms compared with 46 per cent for smaller firms. In addition, results show some sectors (e.g., biotechnology and pharmaceuticals, computer and electronic equipment, instruments, machinery and medical instruments) have a higher-than-average patent premium, suggesting that they may benefit more from patenting. In another study, Park and Lippoldt (2008) find that stronger patent protection has a significant, positive effect on R&D expenditure and high-tech product development, and Lo (2011) finds that strengthening the Taiwanese patent system in 1986 led to more inventive activity, especially in R&D-intensive industries and those industries more commonly associated with patent use.

Contrary to the view that patents foster ex ante innovation – patents induce inventions, given the prospect of profiting from those inventions – there is also the view that patents hamper innovation. In industries where many patent-protected technologies are used to manufacture a single product (e.g., the smartphone industry), the potential for patent thickets arises (i.e., '…a dense web of overlapping intellectual property rights that a company must hack its way through in order to actually commercialize new technology' (Shapiro 2000: 120). Patent thickets can lead to hold-up of innovations, increases in the complexity of negotiations over licenses and increases in litigation, and can also create incentives to add more and weaker patents to the patent system (Hall et al. 2016). In this case, firms inadvertently block each other's innovations. The costs arising from patent thickets add to those already arising from R&D, reducing the overall incentive to innovate (Yale Insights 2015). Consequently, patent thickets may stop firms entering markets for technologies in which patent thickets are widespread. Hall et al. (2016) show that patent thickets reduce entry by 20 per cent, a substantial amount given that the average probability of entry into a technology area is around 1.5 per cent in their data sample. Arora et al. (2008) suggest that broadening the scope of patents does not necessarily increase firms' expected returns, as a rival firm operating in the same industry may be able to limit another's ability to innovate and commercialise innovations. In addition, broad patent protection may slow the rate of technical change by impeding subsequent innovations where technologies develop cumulatively (Merges and Nelson 1990; Scotchmer 1991). Empirical work also suggests that the inducement provided by patents for innovation is small, with Scherer et al. (1959), Taylor and Silberston (1973) and Mansfield (1986) suggesting that, in most industries, patent protection may not be essential to induce innovation. Moreover, the reduction in imitation that results from greater patent use itself reduces competition and, therefore, leads to a reduction in the production and assimilation of new technologies (Giménez 2018). Giménez (2018) suggests that imitation activities associated with a weak patent system increase the benefits to the industry as a whole, leading to a larger social surplus than would have been the case with a strong patent system. In their study, Cohen et al. (2000) find evidence that US firms use patents for reasons other than to deter imitation and appropriate returns. They use them for strategic reasons such as to block competitors and to improve their own reputation. Moreover, Blind et al. (2006) find evidence that German firms used patents to block competitors and to improve firm image. Strategically blocking competitors supresses innovation within the industry. Furthermore, some studies find no benefit to economic and financial performance in terms of return on assets (ROA), sales growth and market value (Griliches et al. 1991; Rivette and Kline 2000; Kretschmer and Soetendorp 2001) from patent use. In addition, evidence also exists of a negative association between patent use and performance (Artz et al. 2010). Further to the evidence suggesting varying returns to patents across firms and sectors, Turner and Roper (2020) identify a marked distinction between manufacturing and service sectors in relation to patent use, with many service sectors having no patent-holding firms. In those sectors where patents are used, the proportion of firms with patents is very small.

Registered designs

A design registration protects the visual appearance of a product, part of a product, or its ornamentation (IPO 2018), providing it is new and has individual character. To be registered, the design must have a special shape, configuration, pattern or ornamentation. By registering a design, a firm is able to prevent other firms from using that design without permission. The process of registering a design is relatively short compared with applying for a patent. Once the application has been made and fees have been paid, the process takes around four weeks providing the design meets the required criteria. Design protection lasts for five years and can be renewed every five years, for up to twenty-five years (IPO 2018).

The literature surrounding registered designs and the link to innovation is much more limited than that for patents. Much of the evidence that exists is descriptive, with relatively few studies adopting an econometric approach. In general, the evidence suggests that effective design protection is important for design innovation, and that attitudes towards registered designs, together with attitudes towards enforcement, have a significant effect on a firm's motivation to create or innovate (Ahmetoglu and Chamorro-Premuzic 2012). However, not all evidence supports a positive correlation between registered designs and innovation. In a study of 1,400 Australian firms, Jensen and Webster (2009) find significant negative correlations between registered designs and process and organisational innovation. Moultrie and Livesey (2011) use a cross-sectoral sample of 32 UK firms and 10 design agencies to conduct a questionnaire to explore the role and value of registered designs. Responses indicate a very strong feeling that the design of a product helps to differentiate against competitors, and that design registrations affect commercial success. Using successful innovation information deduced from good product design award-winners' data, Yoshioka-Kobayashi et al. (2018) suggest that firms frequently use registered designs for the protection of award-winning design products. They examine industrial designs registered between January 2011 and August 2016 in Japan, Korea and the US, and find 150 products received at least one of the selected design awards in 2015. In another study, Bascavusoglu-Moreu and Tether (2011) examine UK design-intensive firms during the late 1990s and early 2000s. They find registered designs to be positively related to firm performance and commercial success; registered design use is associated with a 17 per cent performance benefit in terms of sales per employee. As with patents, firms' use of registered designs is found to be more concentrated in manufacturing sectors, with the proportion of firms using registered designs also being higher in manufacturing sectors (Turner and Roper 2020).

From the conceptual and empirical evidence discussed above, it is reasonable to expect both patents and registered designs to protect new knowledge during the knowledge-sourcing and transformation stages of the innovation process, ensuring that future returns are protected and, as a consequence, increasing a firm's propensity to innovate. In addition, we expect knowledge from existing stocks of patents and registered designs to be called upon and used during the knowledge-sourcing and transformation stages of the current innovation process i.e., to be used as an input into the current innovation process, further increasing a firm's propensity to innovate. Moreover, firms with stocks of both patents and registered designs have a broader knowledge stock to draw on during current innovation activities, resulting in an expected mutually reinforcing positive effect on a firm's propensity to innovate. This suggests:

H1a: Patents and registered designs have a direct positive effect on a firm's propensity to innovate.

H1b: Patents and registered designs have a mutually reinforcing effect on a firm's propensity to innovate.

2.3 IP protection and the propensity to innovate in small firms

A firm's IP protection strategy is partly determined by its resources and capabilities (e.g., its financial position), and the heterogeneous nature of these resources and capabilities across firms gives rise to a variety of IP protection strategies (Kitching and Blackburn 2003; Leiponen and Byma 2009; Hall et al. 2014). Seminal papers by Levin et al. (1987) and Cohen et al. (2000) identify different IP protection strategies across firms of different sizes, with larger firms valuing IP protection more highly than smaller firms. The costs and complexity associated with IP protection make it more likely that smaller firms rely on informal protection methods such as secrecy and speed to market (Arundel 2001; Thomä and Bizer 2013). Kitching and Blackburn (2003) suggest that many small firms choose not to protect their innovations in any way. This may be because owner-managers of small firms view the use of IP protection as a complex process (Hargreaves 2011), and lack the knowledge and information required to pursue protection (some owner-managers are even unaware of its existence); owner-managers perceive an ambiguous link between IP protection and innovation; and owner-managers feel unable to adequately administer and enforce IP protection, especially when in conflict with larger firms (Blackburn 2003; EUPTO 2016). Some owner-managers are reluctant to adopt IP protection because they perceive protection-related costs (both money and time) to be high, for example dealing with patent offices and patent lawyers and gaining the knowledge/skills required to enforce protection.

Small firms are likely to lack the necessary resources and capabilities to apply for, and to defend, patents (West 2006; Leiponen and Byma 2009; Olander et al. 2009). Applying for a patent can be a costly process, and a firm will continue to incur costs whilst keeping the patent in force (Hall et al. 2014), as protection enforcement requires firms to actively monitor markets for potential infringement. There are many studies that examine patent use and attitudes towards patent use across firms of different sizes. In a study of German firms, Blind et al. (2006) find that larger firms attach more importance to patents than smaller firms, and that there is an almost linear relationship between firm size and the existence of R&D departments within firms. This suggests that smaller firms are less R&D-active, or engage in external R&D activity, so that their demand for patents is lower than that of larger firms. Similarly, Leiponen and Byma (2009), in their study of (mainly high-tech) Finnish SMEs, find that patents become more relevant as firm size increases. They identify R&D-intensive small firms and science-based small firms to be those firms more likely to use IP protection to protect knowledge – other small firms are found to use speed-to-market or secrecy as protection methods. This is supported by Kitching and Blackburn (2003) who find that only the most innovative small firms use formal IP protection to protect their knowledge, and Hall et al. (2014) who highlight the importance of IP protection for small firms that specialise in knowledge production. In a study based on firms from seven European countries, Arundel (2001) finds that smaller firms favour informal knowledge protection methods (e.g., secrecy) over formal IP protection methods in relation to product innovation. The study suggests that informal protection methods become less important as firm size increases. All firms included in the study incur R&D expenditures, suggesting that this finding is due to factors other than a lack of innovations (e.g., a lack of financial resources). However, a firm's chosen knowledge protection method has been found to be correlated with the quality of the firm's innovation (Hall and Sena 2017), and therefore innovation quality will be one factor that determines whether small-firm innovations are patentable. Several more studies confirm the positive association between the use of IP protection and firm size (e.g., Brouwer and Kleinknecht 1999; Combe and Pfister 2000; Hanel 2005; Hall et al. 2013).

Hurmelinna and Puumalainen (2007) examine the availability and effectiveness of different IP protection methods, and conclude that firms use IP protection if it is available to them (i.e., if it is easy to obtain) and if it is effective, whereas a lack of availability (e.g., due to a lack of IP protection capabilities), prevents firms from using IP protection, despite the perception that the protection is extremely effective. In reality, smaller firms are those most likely to face barriers to the availability of IP protection. Smaller firms face challenges in capturing the value of their patenting activities because the patenting system is more appropriate for larger firms – especially those in the pharmaceuticals industry (Brouwer and Kleinknecht 1999). Furthermore, larger firms find that the use of the patent system is at a lower cost per patent than smaller firms find – for fixed cost reasons (Hall et al. 2014).

Arundel (2001) finds that small firms that engage in cooperation are more likely to use patents, as patents clarify knowledge ownership within collaborative arrangements, a finding supported by Cohen et al. (2000). In a study of German firms, Sattler (2005) finds that patent use is associated with cooperative R&D arrangements and R&D intensity, with larger firms perceiving patents to be more effective than smaller firms.

Olander et al. (2009) find that smaller firms frequently require protection to guard the prerequisites for innovation, rather than the innovation itself. Such prerequisites are often tacit in nature (e.g., expertise and know-how) and difficult to protect in a formal way. Consequently, smaller firms turn to informal protection methods to protect these knowledge assets. In addition, smaller firms may not use IP protection to avoid disclosing inventions and attracting unwelcome interest from other firms, as a lack of financial resources would leave them defenceless in the face of imitation. Larger firms, on the other hand, are more likely to have the financial resources to defend inventions legally.

There is also evidence that the acquisition of IP protection may improve access to financing in small firms (Hsu and Ziedonis 2008). De Rassenfosse (2012) suggests that the financial motives of IP protection use are more important for smaller firms because investors and licensees help them to overcome financing constraints. Similarly, Veer and Jell (2012) and Holgersson (2013) highlight the importance of patents to smaller firms that seek to generate licensing opportunities and to attract investors.

A lack of familiarity with IP protection has been proposed as a reason why its use is less common in small firms (Blackburn 2003; EUPTO 2016). Small firms that use IP protection once, however, are likely to use it a second time (Hall et al. 2013). Indeed, the number of patent applications made by a firm is an important factor determining patent use, with patenting firms being more likely to make future patent applications (Sattler 2005). An IPO (2018) survey asked firms their reasons for not using IP protection. Results suggest that both small and large firms are motivated to protect their valuable inventions with patents. However, the scale of inventions produced by small and large firms is very different, and larger firms have many more valuable inventions worth patenting. As a consequence, larger firms patent more. Survey responses also signal that the costs relating to the patenting process are the main barrier to the use of patents in small firms. 20 per cent of small firms did not patent due to the cost of patenting, compared with 7 per cent of medium firms and 3 per cent of large firms (IPO 2018). Also, many small-firm inventions are not technological inventions and therefore are not suitable for patenting. Survey results also highlight that the lack of enforcement of IP rights deters firms from using IP protection, and firms choose to use secrecy instead.

As in the general case above (H1a), it is reasonable to expect (from the evidence discussed) that the use of patents or registered designs in small firms will have a positive impact on the propensity of small-firm innovation. However, given the much more limited use of IP protection in small firms – due to the barriers that they face (in terms of resources and capabilities etc.) and the type of innovations that they deliver, we expect this positive effect to be weaker than in the general case. Furthermore, we expect to see a mutually reinforcing effect from the combined use of patents and registered designs in small firms, but again, we expect this to be weaker than in the more general case above (H1b), given the evidence suggesting more limited use of IP protection in small firms. This suggests:

H1c: The magnitude of the direct positive effect of patents or registered designs on the propensity to innovate in small firms is less than that for firms more generally.

H1d: The magnitude of the mutually reinforcing effect of patents and registered designs on the propensity to innovate in small firms is less than that for firms more generally.

2.4 IP protection and value creation from innovation

After a firm sources knowledge and transforms it into innovation outputs, the new products and processes are presented to the market with the ultimate aim of increasing firm performance (e.g., in terms of growth or productivity). Subsequently, the successful commercialisation of innovation requires market-related knowledge (Roper and Hewitt Dundas 2015). By investing in market-related knowledge, a firm is able to develop marketing and commercialisation capabilities that allow it to establish a successful innovation branding strategy. Without a successful branding strategy, an innovation can be short-lived (Aaker 2007). Branding is more than merely placing a name and logo on an innovation. To be successful, the brand itself has to become part of the firm's commercialisation strategy. It is a corporate image that builds over time and creates a reputation for quality in the eyes of customers (Aaker 2007).

A firm's use of IP protection during the commercialisation stage of the innovation process protects market-related knowledge, increasing the firm's chances of profiting from an innovation. In addition, revenues generated from a firm's commercially successful innovations may allow further technological R&D to be financed, increasing the chance that superior technologies will be developed in the future (WIPO 2017). Accordingly, the commercial success of a firm's current innovation increases the probability of innovation in the future.

As with the knowledge-sourcing and transformation stages of the innovation process, a firm may acquire a number of IP protection rights in relation to its market-related knowledge and branding activities. We know from earlier discussion that the resource-based view (Wernerfelt 1984; Barney 1991) and knowledge-based view (Kogut and Zander 1992; Grant 1996) of the firm suggest that firms that acquire higher levels of knowledge stocks are better positioned in terms of their ability to innovate successfully (DeCarolis and Deeds 1999). It follows here that firms with higher levels of accumulated market-related knowledge will be better positioned to, and therefore more likely to, profit from an innovation.

A trade mark is the IP protection method typically used by firms to protect market-related knowledge acquired during the exploitation stage of the innovation process. It is an indicator of innovative and marketing activity rather than inventive effort (Greenhalgh and Rogers 2007). Typically protecting market-oriented capabilities (Llerena and Millot 2020), a trade mark provides IP protection for a firm's marketing investments – it is legal protection of a brand.

Trade marks

Registered trade marks protect brands, be it a business name, a product or a service. However, a brand is much more than a company logo – a brand is a 'promise of an experience' and offers consumers assurance about the nature of the product or service they will receive[9]. A trade mark can be a word, a phrase or logo, a shape, a colour, a sound, an aspect of packaging, it can be action based, or it can be any combination of these[10]. The most effective trade marks are those 'distinctive' to the products and services they protect. Drawing on the economic theories of information and reputation (Economides 1988; Landes and Posner 1987), trade marks are designed to signal to consumers the distinctiveness and quality of a product, addressing the presence of asymmetric information between buyers and sellers. They are designed to differentiate products from those provided by other firms, so that they have a significant role in the marketing of innovations (Turner 2019).

---

[9] https://www.gov.uk/government/publications/ip-basics/ip-basics#trade-marks

[10] A word mark is represented using words, letters, numbers or any other characters that can be typed; a figurative mark is represented using pictures, graphics or images and may also combine words, letters or numbers; a shape mark is represented using a three-dimensional shape, such as the actual product; a colour mark is used only to register an actual colour to distinguish products or services; a hologram mark is a three-dimensional image; and a sound mark is represented graphically using, for example, musical notation.

By registering a trade mark, it is much easier for a firm to take legal action against another firm that uses the trade mark without permission. In addition, it allows authorities to bring criminal charges against counterfeiters if they use the trade mark. A firm can sell a registered trade mark, franchise it or provide firms with a licence which allows them to use it. A firm pays a fee when registering a trade mark, and registration must be renewed every ten years for an indefinite period (IPO 2018). The application process is less time consuming than for patents, with the applicant receiving a formal report detailing the outcome of the examination within ten days of the application. If the trade mark is accepted, it can be registered in around three months from the original date of filing.

Much of the previous empirical literature supports the existence of a positive relationship between trade marking activity and firm performance. In a study using German survey data, Schmock (2003) examines how firms' trade mark use impacts upon the share of firm turnover attributable to new products and services. Results suggest that trade mark use has a positive effect on a firm's innovation success, with the strongest impact occurring in knowledge-intensive firms. In a study of 2,645 UK firms, Greenhalgh et al. (2011) show how trade mark use and trade mark intensity affect gross value added and turnover growth. Results of the study suggest that trade marking firms have a higher productivity level (as much as 21 per cent higher) and higher turnover growth (some 6 per cent higher) than non-trade marking firms. Krasnikov et al. (2009) examine 108 US manufacturing and service firms and investigate how trade mark stock and trade mark intensity impacts upon firm performance. Findings suggest that a firm's use of trade marks positively affects cash flows, Tobin's q, stock returns, return on assets (ROA) and return on sales (ROS) and reduces the variability of future cash flows.

Several studies identify firm age, size and industrial sector as factors which determine the performance effects of trade marks. Using data for 300 Australian-located public and private companies, trusts, associations, cooperatives and partnerships, Griffiths et al. (2005) find trade mark stocks, both registered and pending, to be strongly associated with annual profits. Furthermore, the positive impact on profits diminishes as the firm ages. In their study, Greenhalgh et al. (2011) find that higher trade mark intensity is associated with higher productivity in younger and smaller firms, although large firms have also been shown to experience a 10 to 30 per cent increase in value added premium following trade mark use (Greenhalgh and Rogers 2012). Greenhalgh and Longland (2005) suggest that returns to trade marks are higher in low-technology sectors, despite trade mark use being higher in high-technology firms (Mendonça et al. 2004). In their study, Greenhalgh and Longland (2005) use data for 740 large British firms, across a wide range of industrial sectors, to examine how the stock of trade marks and trade mark intensity affect firm net output or value added. Their results show a positive relationship between trade marks and value added, with those firms registering both patents and trade marks and undertaking R&D being more productive. However, immediate productivity benefits are shown to be short-lived. Trade mark use is found to be widespread across both manufacturing and service sectors, although the proportion of firms within sectors using trade marks is higher in manufacturing sectors (Turner and Roper 2020).

From the conceptual and empirical evidence discussed above, we expect trade marks to protect market-related knowledge during the commercialisation stage of the innovation process, ensuring that the innovator profits from an innovation. In addition to the direct effect on innovation returns we expect to see from a firm's trade mark use, we may also see positive effects on innovation returns from patents and registered designs embedded within the innovation during the earlier stages of the innovation process. We also expect a firm's existing stocks of knowledge (technological, strategic and market related), in the form of existing stocks of patents, registered designs and trade marks, to have a positive effect on a firm's ability to profit from an innovation. Furthermore, we expect firms that simultaneously hold stocks of trade marks and patents/registered designs to experience a mutually reinforcing positive effect on their ability to profit from an innovation. The literature suggests that trade marks are complementary to patents and that the two are used in conjunction with one another to offer more complete protection of IP assets (Blind et al. 2006; Thomä and Bizer 2013). This suggests:

H2a: Trade marks have a direct positive effect on a firm's ability to create value from an innovation.

H2b: Trade marks and patents/registered designs have a mutually reinforcing effect on a firm's ability to create value from an innovation.

2.5 IP protection and value creation from innovation in small firms

The literature suggests that small firms are relatively more trade mark active than larger firms (Rogers et al., 2007; Greenhalgh and Rogers, 2008). The liabilities of small firms limit the strategies available to them, and as a consequence, they often pursue differentiation strategies (McDougall and Robinson 1990; Carter et al. 1994; Lee et al. 1999). The use of trade marks forms part of these strategies as, for resource-constrained firms, they are relatively cheap and simple to register compared with other knowledge protection methods (Block et al. 2015). In addition, trade mark use can act as a quality signal for small firms.

For collaborating small firms, this strengthens their position in collaborations, and helps them attract additional financial resources (Srinivasan et al. 2008).

Trade marks are protection methods that are commonly used during the early stages of a firm's life (Helmers and Rogers, 2010) i.e., typically when the firm is at its smallest. Furthermore, firms that base their competitive strategy on the development of new markets are more likely to use trade marks than patents (Hanel 2005). Those firms that use both patents and trade marks tend to introduce new-to-market, radical innovations, with larger, high-tech firms most likely to use patents (Hanel 2005). Firms that rely primarily on trade marks tend to introduce less radical, non-product innovations – innovations more typically associated with smaller firms.

Block et al. (2015) identifies four types of trade marking SMEs: First, there are trade marking sceptics, i.e., those SMEs that use trade marks without a reason for doing so; second, there are trade marking SMEs that are marketing focused; third, there are trade marking SMEs that are both marketing focused and protection focused; and fourth, there are trade marking advocates i.e., SMEs that use trade marks for marketing, protection and exchange reasons. Marketing focused SMEs exhibit a desire to improve their image. The use of trade marks to do this (e.g., through brand building or creating customer loyalty) enables a firm to sell larger quantities or charge higher prices for their products (Greenhalgh and Rogers 2008; Srinivasan et al. 2008; Jensen et al. 2008). The marketing motive for using trade marks is particularly relevant to small firms because the strategies small firms pursue are restricted by their limited resources – trade mark use allows small firms to pursue a differentiation strategy (Blind et al. 2006). The protection motive for trade mark use involves the protection of marketing assets or brands, and marketing assets or brands are among a firm's most valuable assets. The exchange motive for trade mark use relates to the firm's likelihood of accessing finance, or licensing and collaboration opportunities from external partners. A small firm's use of trade marks signals innovativeness (Greenhalgh and Rogers 2006) and market orientation (Srinivasan et al. 2008) to investors, increasing the firm's chance of accessing extra finance or engaging in licensing or collaboration activities. The licensing of trade marks to other firms may be particularly important for smaller firms, as they may be unable to commercialise their own innovations due to their limited resources and capabilities (Thomä and Bizer 2013). In a study of Swiss SMEs, Keupp et al. (2009) ask firms about their reasons for using trade marks. 67.2 per cent of firms said that they used trade marks as a protection method, followed by 42.0 per cent indicating that they used trade marks for advertising impact. Flikkema et al. (2014) examine trade mark applications made by SMEs in the Benelux countries. Firms indicated that they used trade marks to help prevent imitation, to protect IP, to protect corporate image, and as a marketing tool to help stimulate sales.

Evidence suggests that smaller firms with prior IP protection activities are more likely to grow than those without (EPO/EUIPO 2019). Drawing on a dataset matching demographic information on European manufacturing SMEs with data for patents, trade marks and registered designs during the 2005-2010 period, the EPO/EUIPO (2019) finds SMEs that filed at least one IP right were 21 per cent more likely to experience a subsequent growth period. Furthermore, SMEs in high-tech industries were 110 per cent more likely to experience high growth if they filed one or more European patents. In low-tech industries, where patenting is relatively infrequent, SMEs were 172 per cent more likely to experience high growth if they filed one or more European patents. In a recent update to the EPO/EUIPO (2019) study, a strong correlation between the ownership of IP protection and indicators of SME success is confirmed (EPO/EUIPO 2021). Revenue per employee in SMEs that own IP protection is, on average, 68 per cent higher than in SMEs that do not own IP protection. In large firms, revenue per employee is 18 per cent higher in firms that own IP protection (EPO/EUIPO 2021).

In addition to the positive growth effect coming from patent use, prior trade mark use is found to be a predictor of high growth in consumer-oriented industries EPO/EUIPO (2019). SMEs that held bundles of IP protection that included trade marks systematically outperformed those that held other bundles of protection or firms that held single IP protection methods. This finding suggests trade marks are the basic building block of effective IP protection bundles (EPO/EUIPO 2019). SMEs that adopted a broad IP strategy, combining a range of IP protection methods, were 33 per cent more likely to experience periods of high growth (EPO/EUIPO 2019). Despite the positive performance effects of trade marks in small firms, an IPO study (IPO 2018b) reports that large firms are more aware than small firms of the products that can be protected by trade marks. Small firms are said to lack the knowledge and capabilities to use trade marks, causing them to underestimate their value. Survey evidence in the study suggests that 25.5 per cent of innovating small firms did not perceive trade marks to be important compared with 16.7 per cent of large firms.

Brem et al. (2017) use data for 2,873 Spanish manufacturing and service firms to examine how trade mark use affects firm turnover. Findings suggest that trade mark use has a positive effect on the performance of small firms but not that of medium firms. In addition, the relationship between trade mark use and firm performance is found to be stronger for small and medium-sized enterprises (SMEs) in less knowledge-intensive service industries than for firms in general. Results also indicate a positive relationship between registered design use and SME firm performance. Support is stronger for SMEs in medium-high and medium-low technology manufacturing industries than for firms in general. Munari and Santoni (2010) use data for 425 Italian manufacturing SMEs to examine how registered design use affects performance. Results show that firms that use patents, trade marks and registered designs experience higher performance levels than firms that do not.

As in the general case above (H2a), it is reasonable to expect that trade mark use will have a positive effect on small firms' ability to create value from innovation. We expect the magnitude of this positive effect to be greater than that for firms more generally, given that the evidence suggests trade marks are accessible to small firms, widely used by small firms, and popular during the early stages of a firm's life (i.e., when a firm is typically small). Furthermore, we expect to see a mutually reinforcing effect from the combined use of trade marks and patents/registered designs in small firms, with the resulting positive effect being larger in small firms than in the more general case above (H2b). This suggests:

H2c: The magnitude of the direct positive effect of trade marks on the ability to create value from an innovation in small firms is larger than that for firms more generally.

H2d: The magnitude of the mutually reinforcing effect of trade marks and patents/registered designs on the ability to create value from an innovation in small firms is larger than that for firms more generally.

3. DATA AND METHODS

3.1 Data

Our analysis is based on two matched data sources: UK Intellectual Property Office (IPO) data detailing patents granted, trade marks registered and designs registered in the UK during the 1995-2018 period; and, data from the UK Innovation Survey (UKIS) covering the 2012-2018 (UKIS 9-UKIS 11) period.

UK Intellectual Property Office (IPO) data

The patent data covers patents granted by the IPO during the 1995-2018 period. Each record includes the patent application number, the name and address of the applicant, the company reference number (CRN, obtained from FAME data /Companies House records), the date the patent was granted, the date of the most recent renewal payment and the year of protection provided by the most recent renewal payment (renewal fees are required for the 5th-20th year of protection). The trade mark data details trade marks registered in the UK between 1995 and 2018. Each record includes the published trade mark number (be it a standard, certification or collective trade mark), the CRN, the year of registration and the next renewal date (renewal is necessary every 10 years), and the trade mark class (goods, service or ‘complex’ – trade marks that relate to both goods and services). IPO registered design data covers designs registered in the UK during the 1997 to 2018 period. Each record includes the design number, the applicant’s name, the CRN, the date of registration, the number of registration renewals that have been made (the first renewal takes place 5 years after the initial registration, with a maximum of four renewals being permitted, providing 25 years of protection in total), and the date the next renewal is due (dates in the past indicate lapsed registrations).

UK Innovation Survey (UKIS)

Conducted every two years, the UKIS represents the main source of innovation data in the UK. It is used widely across Government to help improve policy and by the research community for understanding the innovation landscape. Based upon a core questionnaire developed by the European Commission (Eurostat) and Member States, the UKIS forms part of a wider innovation survey covering European countries – the European Union Community Innovation Survey. Background and motivation for the surveys can be found in the Organisation for Economic Co-operation and Development’s (OECD) Oslo manual (OECD, 2005), along with a description of the type of questions and definitions used. In the UK, the Office for National Statistics (ONS) – the UK official government statistical office – manages the administration of and data collection for the UKIS. The sampling frame is taken from the Inter-departmental Business Register (IDBR), a UK-Government compiled register of all UK businesses based on tax and payroll records.

Conducted by means of a postal questionnaire and follow-up telephone interviews, the UKIS is statistically representative of the 12 regions of the UK, most industrial sectors and all sizes of firms with more than 10 employees. Providing detailed information on firms’ innovation activity as well as an insight into the objectives of this innovation activity and firms’ external innovation connections, survey questions relate to firm size and structure, customer base, firm product and process innovation activity, the sources of innovation, perceived barriers to innovation, the levels of public support and basic economic information about the firm. The surveys are non-compulsory and, for the three waves analysed here, achieved a 51 per cent response rate in 2014 (UKIS 9), 43 per cent response rate in 2016 (UKIS 10) and 45 per cent response rate in 2018 (UKIS 11).

Data-matching process

From the IPO data, we derived the number of live patents, trade marks and registered designs associated with each business (CRN) for each year during the 1995-2018 period. This exercise identified firms with 102,641 separate CRNs which had held IP protection during this period. These IP protection histories for each CRN were then imported into the ESRC Secure Data Service (SDS) to allow CRNs to be matched to the enterprise reference numbers – entrefs – which provide the link to other administrative datasets, including the UKIS. Of the CRNs provided, it proved possible to match 79,327 with entrefs. Pseudo-CRNs were retained in the matching file to assist with the relatively rare situations where either a single entref was matched with multiple CRNs or a single CRN was matched with multiple entrefs. In these more complex situations, we assume that patents, trade marks and registered designs linked to shared entrefs or Pseudo-CRNs are available to all enterprise units (defined by their enterprise reference numbers) within that group. Pseudo-CRNs were then used to aggregate IP protection holdings and create a set of unique IP protection histories for all unique entrefs. The resulting data file contains IP protection histories for 76,033 unique enterprise units.

The matched dataset links the IP protection histories with the UKIS (2012-2018), allowing us to explore the relationship between IP protection holdings and innovation output indicators. Data in each of the UKIS waves covers a three-year period (UKIS 9 – 2012 to 2014; UKIS 10 – 2014 to 2016; and UKIS 11 – 2016 to 2018). The IP protection histories relate to single years, and therefore the matching process is not straightforward. Rather than having a single IP protection stock for a matched entref in one particular wave of the UKIS data, two IP protection stocks are assigned – the IP protection stock at the start of the period and the IP protection stock at the end of the period. For example, an entref in the UKIS 9 data (covering innovation in 2012-14) has a starting IP protection stock equal to its IP protection holding in 2012, and an ending IP protection stock equal to its IP protection holding in 2015 – the time of the UKIS survey.

Variable definitions are given in Annex 1, and pairwise correlation coefficients[11] are given in Annex 2. Descriptive statistics (the number of observations, the mean and the standard

[11] Pairwise correlation coefficients are reported rather than standard correlation coefficients because the standard correlation coefficient calculation drops all observations when missing values are present, and this results in missing correlation coefficients amongst our variables.

deviation) for all firms, small firms and large firms are given in Table 1, while those for different sectors in the small-firm group are given in Annex 3.

3.1.1 Dependent variables

Our analysis includes four dependent variables derived from the UKIS data. Two dependent variables relate to innovation propensity and two relate to value creation from innovation. In the two innovation propensity models, the first dependent variable is a binary variable used to examine firms that engaged solely in new-to-the-firm (NTF) product/service innovation[12]. Firms that did not engage in product/service innovation – termed non-innovators here – are assigned a value of 0, and firms that undertook produce/service innovation that was new to the firm are assigned a value of 1. Those firms that engaged in new-to-the-market (NTM) product/service innovation (either solely or in combination with NTF product/service innovation) are excluded from the analysis. This allows the model to identify the impact of IP protection on NTF product/service innovation. The descriptive statistics in Table 1 show that 17 per cent of firms in the estimation sample engaged solely in NTF product/service innovation.

The second binary dependent variable is used to examine firms that engaged in NTM product/service innovation. The reference group of firms here i.e., those firms taking the value 0, includes non-innovators and firms that engaged solely in NTF product/service innovation. This second dependent variable is set equal to 1 if the firm engaged in NTM product/service innovation, either solely or in combination with NTF product/service innovation. This allows the model to identify the impact of IP protection on NTM product/service innovation in firms that engage in NTM product/service innovation, either solely or in conjunction with NTF product/service innovation. The descriptive statistics in Table 1 indicate that 10 per cent of the estimation sample engaged in NTM product/service innovation (either solely or in combination with NTF product/service innovation).

To investigate how IP protection influences firms' ability to create value from innovation, two further dependent variables are constructed that relate to a firm's turnover attributable to innovation. The UKIS data includes firms' estimates of the percentage of turnover (in the final year of the survey period) that came from products/services that were NTF and products/services that were NTM during the survey period. Viewed as an indicator of innovation output (Becker et al. 2016; Roper et al. 2017), these data illustrate a firm's ability

[12] Referred to as goods and services innovation in UKIS.

to introduce new products/services to the market, as well as the commercial success of a firm's innovations (Roper et al. 2017). Our third dependent variable uses firms' estimates of the percentage of business turnover from products/services that were NTF. In line with the NTF innovation propensity model discussed above, we exclude firms that undertook NTM product/service innovation from the analysis. This allows the model to identify the impact of IP protection on the percentage of business turnover from NTF product/service innovation in firms that engage, solely, in innovation of this type. Across our estimation sample, on average, 2.04 per cent of business turnover came from NTF product/service innovation in firms that engaged only in NTF product/service innovation (Table 1).

Our fourth dependent variable uses firms' estimates of the percentage of business turnover from NTM product/service innovation. This allows the model to identify the impact of IP protection on the percentage of business turnover from NTM product/service innovation in firms that engage in NTM product/service innovation, either solely or in combination with NTF product/service innovation. Across our estimation sample, on average, 4.97 per cent of business turnover came from NTM product/service innovation (Table 1).

3.1.2 Independent variables

We focus on three key independent variables: firms' live stocks of patents, trade marks and registered designs. Firms' live stocks of these IP protection methods are determined when the IP histories data is matched with the UKIS data. In our empirical analysis, the independent variables are defined as the logarithm of firms' live patent, trade mark and registered design stocks at the beginning of the UKIS survey period[13].

3.1.3 Control variables

In addition to our dependent and independent variables, we include a set of control variables in the empirical analysis which previous studies have shown to impact firm innovation and innovation returns. As well as using IP protection in the form of formal knowledge protection methods (e.g., patents, trade marks and registered designs), firms can incorporate more informal or strategic knowledge protection methods into their innovation strategies to help capture returns (Laursen and Salter 2005; Greenhalgh and Rogers 2007). Informal knowledge protection methods are non-statutory methods and are not based directly on regulated structures and statutory enforcement possibilities

[13] The logarithm of each IP protection stock is used, rather than the actual value, to address the non-linear effect an additional unit of each protection mechanism is expected to have on the dependent variable.

(Hurmelinna-Laukkanen 2014)[14]; examples of informal methods include secrecy, complexity of design and lead-time on competitors. Literature suggests that informal methods are more widely used by firms than formal methods (e.g., Hall et. al. 2014; Freel and Robson 2017), with much of the survey-based literature (e.g., Levin et al. 1987 and Cohen et al. 2000) suggesting that firms rely heavily on informal methods such as lead time and secrecy. Other studies (e.g., Arundel 2001 and Laursen and Salter 2005), also find a preference for informal methods. Firms' choice of knowledge protection method – be it formal or informal – has been found to differ across industrial sectors (Levin et al. 1987; Cohen et al. 2000), across firms of different sizes (Lopez 2009; Hall et al. 2014) and across innovations of varying degrees of novelty (Hanel 2005). The presence of tacit or codified knowledge, product or process technologies, and firm resources and capabilities all help determine whether or not a firm uses formal IP protection or a more informal, strategic option. The UKIS asks firms about the proportion of their innovations during the three-year period that were protected by strategically using speed-to-market to gain lead-time advantages on competitors, protected through complexly designed products and services, and protected through the use of secrecy (including the use of non-disclosure agreements). The 2012-2014 UKIS asked firms to choose between six options, ranging from 'none' (not used) to 'over 90 per cent'. The 2014-2016 and 2016-2018 surveys asked firms to choose between just four options, including 'none' (not used), 'low' (less than 40 per cent), 'medium' (40-90 per cent) and 'high' (over 90 per cent). Using these data, we create three dummy variables, designed to represent the extent to which firms use the three informal or strategic knowledge protection methods. The three newly-created control variables are set equal to 0 if the firm indicated that it did not use, or had low use of the informal protection method (less than 40 per cent of innovations during the period were protected by the informal method), and set equal to 1 if the firm indicated that it had medium or high use of the informal protection method (more than 40 per cent of innovations during the period were protected by the informal method). Across our estimation sample, 9 per cent of firms used lead-time (or speed-to-market) to protect more than 40 per cent of their innovations. The percentage was higher for complexity and secrecy – 15 per cent of firms and 14 per cent of firms, respectively (Table 1).

[14] Although not based directly upon statutory enforcement possibilities, informal knowledge protection methods may have associated legal contracts alongside them e.g., firm using secrecy may require employees to sign non-disclosure agreements.

In addition to the three informal protection control variables, we include further control variables to reflect a firm's characteristics, capabilities and resource base (Griliches 1992; Love and Roper 1999). Firm size influences a firm's propensity to innovate (Laursen et al. 2013). Here, we include employment (expressed as a logarithm) to reflect a firm's size and the scale of its resources. Employee skills allow firms to successfully harness the performance benefits of innovation (Leiponen 2005; Hewitt-Dundas 2006), and we reflect this through the inclusion of two variables – the proportion of a firm's employees that hold a degree or higher qualification in (a) a science or engineering subject, and (b) other subjects. Across our sample, 8.1 per cent of employees are science graduates and 11.8 per cent of employees have a degree from another discipline (Table 1). A firm's exporting behaviour is linked to innovative activity through both competition and learning effects (Love and Roper 2015). We include a binary (0/1) variable to indicate whether or not the firm exported during the survey period. In our sample, 29 per cent of firms engaged in exporting (Table 1). Innovation outputs are positively related to internally generated knowledge coming from in-house R&D (Love and Roper 2001; Love and Roper 2005) and knowledge sourced from external partners. Two binary (0/1) variables are included to indicate whether or not the firm reported (a) internal R&D expenditure and (b) external R&D expenditure during the survey period. Across our estimation sample, 23 per cent of firms invested in internal R&D, whereas 7 per cent of firms invested in some form of external R&D (Table 1). The extent of a firm's interactive knowledge search has been used extensively in studies of the determinants of innovation (e.g., Laursen and Salter 2006; Becker et al. 2016), and is measured here by a variable indicating the extent or breadth of the firm's innovation co-operation. The UKIS asks firms if they co-operated on any innovation activity. Firms are asked specifically about co-operation that may have taken place with seven particular co-operation partners (e.g., competitors or other businesses within the industry, universities or other higher education institutions and government or public research institutes). Following Laursen and Salter (2006) and Becker et al. (2016), firms' binary (0/1) responses for each of the seven co-operation partners are summed to create a count indicator having a minimum value of 0 and a maximum value of 7. On average, firms in our sample have approximately one co-operation partner (1.24 in Table 1). In keeping with Becker et al. (2016), several variables reflecting innovation-related investments are included in the analysis. Binary (0/1) variables indicating whether a firm invested in advanced machinery and equipment, whether training for innovative activities took place within a firm, whether a firm acquired knowledge from other businesses or organisations, whether a firm made investments into the market introduction of its innovations, and whether a firm invested in design activities are all included in our analysis.

In our sample, some 31 per cent, 20 per cent, 5 per cent, 12 per cent and 14 per cent of firms, respectively, engaged in these innovation-related investments (Table 1).

We also include UKIS wave dummies in our analysis to control for any temporal effects on the dependent variables, as well as sector dummies (at the 2-digit level) to allow for sectoral heterogeneity i.e., different innovation intensities across industries (Levin et al. 1987; Cohen et al. 2000)[15].

3.2 Estimation methods

Models are estimated in which the firm is the unit of analysis, and where our four dependent variables are related to patents, trade marks, registered designs and a series of control variables. Each model also includes three IP protection interaction variables (patents-trade marks, patents-registered designs and trade marks-registered designs) to capture the potential for reinforcing effects across the three IP protection variables. In addition to calculating standard model coefficients, we also calculate average marginal effects[16]. These average marginal effects capture any reinforcing effects and indicate the overall effect on the dependent variable. We adopt two empirical approaches to estimate our models, each reflecting the nature of the dependent variables being investigated. A probit model is used to examine how each IP protection method influences firstly, NTF product/service innovation, (excluding firms that engaged in NTM product/service innovation from the analysis), and secondly, NTM product/service innovation. Using the maximum-likelihood method, the probit estimation procedure models the probability that the dependent variable will be equal to one i.e., it models the probability that the type of product/service innovation being examined will take place. Next, an Ordinary Least Squares (OLS) regression model is used to examine how IP protection methods influence the proportion of business turnover from firstly, NTF product/service innovation, and secondly, the proportion of business turnover from NTM product/service innovation.

In addition to our four baseline models covering all firms in the UKIS 9-UKIS 11 pooled dataset, we estimate the four models for small firms and large firms. Furthermore, we also estimate the four models for manufacturing firms, service firms, high-tech/knowledge-intensive firms and low-tech/less knowledge-intensive firms within the baseline, small-firm and large-firm datasets. It is also important to note that, given the pooled cross-sectional

[15] Some sectors are not included in the analysis (e.g., agriculture, forestry and Fishing) as the UKIS only covers sections B-N of the Standard Industrial Classification (SIC) 2007.
[16] The average marginal effect is calculated using individual observation derivatives.

nature of our data, the regression results we obtain are indicative of association rather than causation.

4. RESULTS

4.1 IP protection and innovation propensity

Regression results for the models that investigate how patents, trade marks and registered designs influence NTF and NTM innovation propensity for all firms, small firms and large firms are reported in Table 2. The key results are as follows:

- **Patents** - Across all firms, an increase in the stock of patents at the beginning of the UKIS period (ceteris paribus) has an unanticipated, significant, negative effect on the propensity to engage in NTF product/service innovation during the survey period. We observe a similar result in both the small-firm and large-firm models, although that for large firms is less significant. In all three models, however, higher patent stocks at the beginning of the UKIS period (ceteris paribus) have an insignificant effect on the propensity to engage in NTM innovation (Table 2).

- **Trade marks** - Across all firms, an increase in the stock of trade marks (ceteris paribus) has an insignificant effect on the propensity to engage in both NTF and NTM innovation. However, in small firms, there is a significant, negative effect on the propensity for NTF product/service innovation, and in large firms, there is a significant, positive effect on the propensity for NTM product/service innovation.

- **Registered designs** - Across all firms, an increase in the stock of registered designs (ceteris paribus) has a significant, positive effect on the propensity for NTM product/service innovation. We observe a similar result in small firms, but see no significant effect in large firms.

These results provide support for H1a in terms of registered designs only, i.e., registered designs increase the propensity to innovate of all firms. However, our results contradict H1c because this positive registered design effect is equally significant in smaller firms, and larger in magnitude.

Interaction effects reflecting the combined impacts of the IP protection measures are also estimated (Table 2). The key results are as follows:

- **Patent/registered design interaction** - This coefficient is positive and significant in the NTM innovation models for both small firms and large firms. For a given stock of registered designs, the positive interaction effect offsets the negative effect of higher patent stocks on the propensity for NTM innovation. The multiplicative nature of the interaction variables means that the offsetting effect is stronger in firms with larger registered design stocks. Conversely, for a given stock of patents, the positive interaction term reinforces the positive registered design effect, with the reinforcing effect being stronger in firms with higher patent stocks. In the small-firm NTM innovation model, both the registered design coefficient and the patent/registered design interaction coefficient are positive and statistically significant, suggesting a positive link between registered design use and the propensity for NTM innovation in small firms, with this positive link being strengthened by the combined use of registered designs and patents.

- **Other interactions** - Of the other interaction variables included in the models (Table 2), the patent/trade mark interaction is significant for NTF innovation in the all-firm and large-firm model. All other interactions prove to be insignificant.

The small-firm and large-firm results provide partial support for H1b, supporting the view that patents and registered designs have a mutually reinforcing effect on a firm's propensity to innovate. These effects prove to be more significant in smaller firms, contradicting H1d that suggests weaker effects in small firms.

In addition to the standard model coefficients, we estimate the average marginal effect of each IP protection method (the calculation of which includes the IP protection interactions) to give an indication of the scale of each IP effect. The key results are as follows:

- **Patents** - On average, a one per cent increase in a firm's patent stock is associated with a 0.11 per cent fall in the propensity for NTF innovation across all firms, a 0.19 per cent fall in the propensity for NTF innovation in small firms, and a 0.06 per cent fall in the propensity for NTM innovation in large firms.

- **Trade marks** - On average, a one per cent increase in a firm's trade mark stock is associated with a 0.02 per cent fall in the propensity for NTF innovation in small firms, and a 0.01 per cent increase in the propensity for NTM innovation in large firms.

- **Registered designs** - On average, a one per cent increase in a firm's registered design stock is associated with a 0.03 per cent increase in the propensity for NTM innovation across all firms and a 0.05 per cent increase in the propensity for NTM innovation in small firms.

Further analysis of the marginal effects of each of the IP variables is included in Annex 8.

4.2 IP protection and creating value from innovation

Regression results for firms' ability to create value from NTF innovation and NTM innovation are included in Table 3. The key results are:

- **Patents** - Across all firms, an increase in the stock of patents (ceteris paribus) has a significant, negative effect on the proportion of firm sales from NTF product/service innovation. We observe a similar result in the small-firm model, although the corresponding coefficient in the large-firm model is insignificant.

- **Trade marks** - Across all firms, an increase in the stock of trade marks (ceteris paribus) has a significant, negative effect on both the proportion of firm sales from NTF and NTM product/service innovation. We observe a similar result in the small-firm models, but the level of statistical significance is lower. In the large-firm models, coefficients are insignificant.

- **Registered designs** - Across all firms, small firms and large firms, an increase in the stock of registered designs (ceteris paribus) has an insignificant effect on both the proportion of firm sales from NTF and NTM product/service innovation.

These results provide no support for H2a or H2c and the direct positive contribution of trade marks to firms' ability to generate value from innovation.

Interaction effects for the three IP protection methods are also estimated (Table 3):

- **Patent/trade mark** - This interaction coefficient is positive and significant for the proportion of sales from NTF innovation across all firms and in large firms. For a given stock of trade marks, the positive coefficient suggests that the interaction effect offsets the negative effect of higher patent stocks on the proportion of sales from NTF innovation. This offsetting effect is stronger in firms with larger trade mark stocks.

- **Patent/registered design** - This interaction coefficient is negative and significant for the proportion of sales from NTF innovation across all firms and in large firms. For a given stock of registered designs, the negative interaction effect reinforces the negative effect of higher patent stocks on the proportion of sales from NTF innovation in both of these models. The multiplicative nature of the interaction variables means that the reinforcing effect is stronger in firms with larger registered design stocks.

- **Registered design/trade mark** - This interaction coefficient is positive in all six models, however, significant in just one – the proportion of sales from NTM innovation across all firms. The registered design/trade mark interaction coefficient is positive, suggesting that for a given stock of registered designs, the interaction effect offsets the negative effect of trade mark stocks on a firm's proportion of sales from NTM innovation. The multiplicative nature of the interaction variables means that the offsetting effect is stronger in firms with larger registered design stocks.

Despite many interaction effects proving to be weak, we do find some support for H2b in that trade marks and patents/registered designs have a mutually reinforcing effect on a firm's ability to create value from an innovation (shown by the positive and significant interaction effects between patents and trade marks and registered designs and trade marks). However, we find no support for H2d, which hypothesises that the magnitude of the mutually reinforcing effect of trade marks and patents/registered designs on the ability to create value from an innovation in small firms is larger than that for firms more generally.

As with the probability-of-innovation models, we also estimate the average marginal effect of each IP protection method, the calculation of which includes the IP protection interactions discussed above:

- **Patents** - On average, a one per cent increase in a firm's patent stock is associated with a 1.76 per cent fall in the proportion of a firm's sales from NTF innovation across all firms and a 4.07 per cent fall in the proportion of a firm's sales from NTF innovation in the small-firm model.

- **Trade marks** - On average, across all firms, a one per cent increase in a firm's trade mark stock is associated with a 0.44 per cent fall and a 0.82 per cent fall in the proportion of a firm's sales from NTF and NTM innovation, respectively. In the small-firm model, a one per cent increase in a firm's trade mark stock is associated with a 0.62 per cent fall and a 1.07 per cent fall in the proportion of a firm's sales from NTF and NTM innovation, respectively.

- **Registered designs -** In all six models, the average marginal effect of registered design stocks is insignificant.

Further analysis of the marginal effects of each of the IP variables is included in Annex 8.

4.3 Other influences on innovation propensity and value creation

Model control variables indicate that informal knowledge protection methods are important for firms' innovation. More specifically, lead time is particularly important for NTM innovation in small firms (Table 2). However, the results suggest that lead time is not associated with the proportion of sales from innovations (Table 3). Complexity of design is important for all innovation in small and large firms, as well as the proportion of sales from NTM innovation in both small and large firms (Table 3). Secrecy is important for NTM innovation in small and large firms, but more significant in small firms. Furthermore, we find secrecy to be significant for the proportion of sales from NTM innovation in small firms, but not in large firms.

The proportion of graduate employees in a firm is typically important for innovation, with the proportion of science graduates highly significant for NTM innovation in both small and large firms (Table 2). The results also suggest science graduates to be more significant for the proportion of sales from NTM innovation in small firms than in large firms (Table 3). Internal R&D is highly significant for innovation in small and large firms, and significant for the proportion of sales from innovations in small firms, but not in large firms. External R&D is important for the proportion of sales from NTM innovation in both small and large firms (Table 3). Investment in design and training is important for all innovation in small and large firms (Table 2), with design investment being significant for both the proportion of sales from NTF innovation and from NTM innovation in small firms. In large firms, design investment is only significant for the proportion of sales from NTM innovation (Table 3). Engagement in exporting is highly significant for NTM innovation in small firms, however, insignificant in large firms (Table 2). Across all models, we find no significant effect of exporting on the proportion of sales from innovation (Table 3).

5. FOCUSING ON SMALL FIRMS

In this section, we consider the impacts of IP protection on the propensity to innovate and create value for different types of small firms, estimating models for small manufacturing firms and service firms, and small high-tech/knowledge-intensive firms and low-tech/less knowledge-intensive firms (Tables 4 and 5). In terms of small firms' propensity to innovate, the main direct effects of IP protection measures are as follows (Table 4):

- **Patents** - The highly significant, negative effect of patent stocks on the propensity for NTF innovation in small firms is driven by both manufacturing and service firms, although the negative effect of patent stocks is stronger in the manufacturing sector.

- **Trade marks** - The significant, negative effect of trade mark stocks on the propensity for NTF innovation in small firms is not observed in the sectoral or technology breakdown. However, we do observe a significant, positive effect of trade mark stocks on the propensity for NTM innovation in low-tech/less knowledge-intensive firms.

- **Registered designs** - The significant, positive effect of registered designs on the propensity for NTM innovation in small firms is driven by service sector and low-tech/less knowledge-intensive firms – both groups experiencing significant, positive effects on the propensity for NTM innovation following an increase in the stock of registered designs.

As before, we also estimate the interaction effects between IP protection measures on the propensity for innovation (Table 4):

- **Patent/trade mark** - This interaction coefficient is insignificant in both the NTF and NTM innovation models for small firms (Table 2), however, the sectoral results show the patent/trade mark interaction variable to be significant in both the propensity for NTF and NTM innovation models across manufacturing firms (Table 4). This suggests that, for a given stock of trade marks, the positive interaction effect offsets the negative effect of higher patent stocks on the propensity for NTF and NTM innovation in manufacturing firms, with this offsetting effect being stronger in manufacturing firms with higher trade mark stocks.

- **Patent/registered design** - This interaction coefficient is positive and significant in the small-firm propensity for NTM innovation model (Table 2). Results for the sectoral analysis (Table 4) suggest that this is driven by low-tech/less knowledge-intensive firms. For a given stock of registered designs, the positive interaction effect offsets the negative effect of higher patent stocks on the propensity for NTM innovation, with this offsetting effect being stronger in low-tech/less knowledge-intensive small firms with larger registered design stocks.

- **Registered design/trade mark -** This interaction coefficient is insignificant for both innovation types in the small-firm model (Table 2). However, the small-firm sectoral regression results in Table 4 indicate a significant, negative effect from the registered design/trade mark variable on NTM innovation in service firms. For a given stock of trade marks, the negative interaction effect offsets any positive effect from registered design stocks on the propensity for NTM innovation in small service firms, with this offsetting effect being stronger in firms with larger trade mark stocks.

The average marginal effects for each IP protection method in the small-firm sectoral models (Table 4), which include the IP protection interactions, indicate that:

- **Patents -** On average, a one per cent increase in small-firm patent stock is associated with a 5.30 per cent fall in the propensity for NTF innovation in small manufacturing firms, a 0.20 per cent fall in the propensity for NTF innovation in small service firms, and a 0.11 per cent fall in the propensity for NTM innovation in small low-tech/less knowledge-intensive firms.

- **Trade marks -** On average, a one per cent increase in small-firm trade mark stock is associated with a 0.02 per cent increase in the propensity for NTM innovation in small low-tech/less knowledge-intensive firms.

- **Registered designs -** On average, a one per cent increase in small-firm registered design stock is associated with a 0.05 per cent increase in the propensity for NTM innovation in small service firms and a 0.04 per cent increase in the propensity for NTM innovation in small low-tech/less knowledge-intensive firms.

For comparison purposes, the IP protection average marginal effects for all firms and large firms are shown in Annexes 4-5. The most notable difference between these results and those of small firms is the effect of trade marks on the propensity for innovation in large firms. Here, we see a significant, positive effect of trade mark stocks on the propensity for NTM innovation in large manufacturing firms and a significant, positive effect of trade mark stocks on the propensity for NTM innovation in large high-tech/knowledge-intensive firms.

Estimating small-firm models for the relationship between firms' IP protection stocks and value creation (Table 5) suggests:

- **Patents** - The significant negative effect of patents on the proportion of sales from NTF innovation in the small-firm regression (Table 3) is driven by service firms, high-tech/knowledge-intensive firms and low-tech/less knowledge-intensive firms (Table 5). Patents are insignificant for the proportion of sales from NTM innovation in the small-firm model (Table 3), but the sectoral breakdown indicates that the effect is positive and significant in small manufacturing firms (Table 5). In small low-tech/less knowledge-intensive firms, however, the effect of patent stocks on sales from NTM innovation is negative and significant (Table 5).

- **Trade marks** - The significant, negative effect of trade marks on the proportion of sales from NTF and NTM innovation in small firms (Table 3) is driven by manufacturing and high-tech/knowledge-intensive small firms (Table 5).

- **Registered designs** - The insignificant effect of registered design stocks on the proportion of sales from NTF and NTM innovation in small firms (Table 3) is reflected across all of the small-firm sectoral models, with the exception of the NTM model for small service firms.

Interaction terms between IP protection measures are also included in the models relating to the proportion of small firms' sales derived from NTF and NTM innovation:

- **Patent/trade mark** - The patent/trade mark interaction coefficients in the models examining the proportion of sales from NTF and NTM innovation are insignificant for small firms (Table 3). However, in the small-firm sectoral models, the patent/trade mark interaction coefficient is positive and significant in all four NTF innovation models (Table 5).

- **Patent/registered design** – The patent/registered design interaction coefficients in the small-firm model (Table 3) are insignificant for both the proportion of sales from NTF and NTM innovation. The sectoral models for small firms indicate that the same is true for small manufacturing firms, small service firms and small high-tech/knowledge-intensive firms, but not for small low-tech/less knowledge-intensive firms (Table 5). In this latter group, the patent/registered design interaction term has a significant, positive effect on both the proportion of sales from NTF and NTM innovation.

- **Registered design/trade mark** – The registered design/trade mark interaction coefficients are insignificant for both the NTF and NTM models for small firms (Table 3). However, the small-firm sectoral regression results in Table 5 show that the registered design/trade mark variable has a significant, negative effect on the proportion of sales from NTF innovation in small manufacturing firms, and a significant, positive effect on the proportion of sales from NTM innovation in small manufacturing firms.

The average marginal effects for each IP protection method in the small-firm sectoral models (Table 5), which include the IP protection interactions, suggest similar sign patterns and significance levels to the standard coefficients.

- **Patents** - On average, a one per cent increase in patent stocks is associated with a 16.56 per cent rise in the proportion of sales from NTM innovation in small manufacturing firms and a 6.78 per cent fall in the proportion of sales from NTM innovation in low-tech/less knowledge-intensive firms. In small service firms and small low-tech/less knowledge-intensive firms, on average, a one per cent increase in the stock of patents is associated with a 6.57 per cent and a 5.28 per cent fall in the proportion of sales from NTF innovation, respectively.

- **Trade marks** - In small manufacturing firms and small low-tech/less knowledge-intensive firms, on average, a one per cent increase in the stock of trade marks is associated with a 1.26 per cent and 1.18 per cent fall in the proportion of sales from NTF innovation, respectively. In addition, in small manufacturing firms and small low-tech/less knowledge-intensive firms, on average, a one per cent increase in the stock of trade marks is associated with a 2.24 per cent and 1.97 per cent fall in the proportion of sales from NTM innovation, respectively.

- **Registered designs** - In small service firms, on average, a one per cent increase in the stock of registered designs is associated with a 2.23 per cent fall in the proportion of sales from NTM innovation.

For comparison purposes, the IP protection average marginal effects across all firms and in large firms are shown in Annexes 6-7. Notable differences between small and large firms include the insignificance of patent stocks for the proportion of sales from NTM innovation in large manufacturing firms, the absence of significant, negative associations between trade mark stocks and the proportion of sales from innovations in large manufacturing firms, and the significant, negative association between registered design stocks and the proportion of sales from innovations in large high-tech/knowledge-intensive firms, which are not present in the small-firm models.

6. DISCUSSION AND CONCLUSIONS

Previous analyses have suggested the potential for formal IP protection mechanisms – patents, trade marks and registered designs – to contribute to firms' innovation activity both individually and in combination. UK evidence is limited however, particularly in the context of smaller firms. In this paper we therefore explore the impact of formal IP protection instruments on two different but interlinked aspects of firm-level innovation. We consider two research questions:

- How do formal IP protection instruments influence the propensity that a firm will introduce new-to-the-market or new-to-the-firm innovation? This involves the combination of knowledge to develop a new market offering. Here, patents and registered designs – both indicators of past investments in knowledge and creativity – may play an important role.

- How do formal IP protection instruments enable firms to create value from their innovations? This relates to appropriability and firms' ability to capture the economic value of the innovations they make. Here, each IP protection instrument may play a role, but trade marks may be particularly important in protecting firms' ability to capture value.

Our analysis combines population data on registered IP provided by the IPO with survey data on firms' innovation activity taken from the UK Innovation Survey. Measurement of IP protection variables is undertaken a year prior to the observation period for innovation and value creation from innovation eliminating any potential for reverse causality.

In terms of the propensity to innovate, our analysis suggests that, across all firms and in small firms, a firm's stock of registered designs is positively related to the propensity for NTM product/service innovation. Patents and trade marks have no statistically robust direct effect on the propensity for NTM product/service innovation in small firms. Nevertheless, an increase in patent stocks has a statistically significant, negative effect on the probability of NTF innovation in small firms and across firms more generally. One explanation for this is that firms with a large number of patents are likely to operate in an industry where there are competing firms that also own a large number of patents, and in this case, the opportunity for NTF innovation (i.e., innovation that leads to a product or service that is already present in the marketplace) is low due to the high costs associated with gaining access to other firms' patented technologies. Such a situation may give rise to patent thickets, for example, holding up innovation and reducing competition within markets. Despite the insignificant effect of patents on NTM product/service innovation, however, we do find an indirect effect, with patents enhancing the impact of registered designs on the propensity to undertake NTM product/service innovation in small firms. There is no similar indirect effect from trade marks in this stage of the innovation process.

To measure firms' ability to create value from innovation, we use a standard measure – the proportion of firms' sales derived from innovative products. In considering firms' returns to innovation, results suggest that, across all firms and in small firms, a firm's stock of trade marks is negatively related to the proportion of its turnover coming from innovation. This is perhaps due to established products benefitting more than innovative products from firms' trade marks. Patents have no significant, positive direct or indirect effect on the proportion of sales from NTM innovation, but across all firms, registered designs do have significant indirect positive benefits on trade marks.

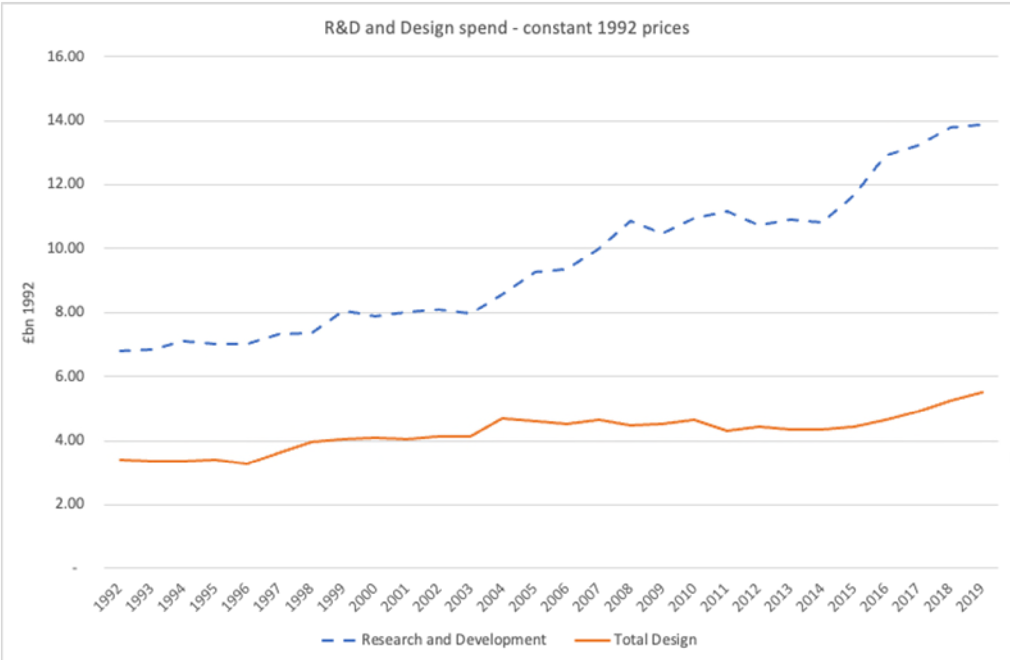
In summary, our analysis suggests that registered designs combined with patents promote the propensity for NTM product/service innovation. To some extent, trade marks combined with registered designs also boost the returns to NTM innovation by protecting a firm's market-oriented capabilities. The analysis in Annex 8 shows that both effects prove rather similar for small firms as they are for the general population of businesses. Each IP protection instrument therefore plays a role in supporting innovation, although registered designs play a complementary role, enhancing both the impact of patents on the propensity for NTM innovation and trade marks in terms of value creation. Without registered designs, both effects are weaker or not observed. Registered designs therefore play a critical role in 'unlocking' the potential for firms' IP to contribute to innovation and subsequent value creation. Despite this, empirical studies of the role of design in driving innovation and firm performance remain rare, and as a consequence, 'the true contribution of design to economic development is grossly underestimated' (Gershman et al. 2020: 244), and the suggestion of Hobday et al. (2012) that, 'the methods and measurement techniques used in innovation could address the contribution of design in much more detail and reveal the ways in which design creates value across the industrial and service sectors' remains largely unanswered.

The Government's vision is for the UK to be a global hub for innovation by 2035 (Innovate UK, 2021). As part of its mission to help the Government achieve this vision, Innovate UK set out five strategic themes and six strong foundations in its 'plan for action' over the 2021-

2025 period (Innovate UK 2021). Design features as one of the six strong foundations, being described as an essential foundation of effective innovation (Innovate UK 2021: 48). In an earlier report, Innovate UK (2020: 25) suggest four factors that may be restricting design investment in UK firms: insufficient investment in design; difficulty accessing design talent; poor management of design processes and a lack of strategic design leadership. And, recent data confirms that design investment in the UK has lagged R&D spend over the last decade, actually declining as a proportion of all intangible investment. In 2019, design spend by UK firms was £9.6bn compared to £24.0bn on R&D, and in real terms, while business R&D spending has risen in recent years, design spending has remained relatively flat (Figure 1). Future analysis could usefully therefore examine the determinants of design investment, engagement and registration in UK firms and sectors as well as the barriers to engagement.

Limitations to our study also suggest potential directions for future research. First, our analysis is purely quantitative and understanding the potentially complex relationships between formal IP protection mechanisms and their contribution to value creation is likely also to require a more in-depth qualitative approach. Second, our IP protection stock measures have a number of limitations: older patents/trade marks/registered designs may not relate to current innovations; patents/trade marks/registered designs in the stock may not have led to any innovations or have been commercialised – some innovations take longer to commercialise than others. This suggests that the choice of lag in our analysis is crucial and will vary across firms and industries; patent/trade mark/registered design stocks do not necessarily reflect quality; and innovation in some industries is reflected by a larger number of patents than in others. Third, we do not control for other types of innovation in our empirical models. Whether or not a firm engages in other types of innovation (e.g., process or organisational innovation) may affect its propensity to carry out product/service innovation. Fourth, we focus on innovation from the individual firm's perspective, and do not consider innovation from a societal point of view (i.e., we do not consider how IP protection affects the total amount of innovation in the economy). Fifth, to date our study relates to the pre-pandemic period and extending the analysis to include more recent years seems an obvious development. This matters because changes in digital adoption and the role of digital technologies in innovation may have changed during the pandemic and this, in turn, may have altered the design-to-value-creation linkage. Finally, we only consider the within-firm contribution of design. Arguably, design, like innovation itself, may create significant positive spillovers, and estimating these wider social benefits may provide a profitable avenue for future analysis. Examining the determinants of, barriers to, and wider benefits of design investment and protection through registration will provide a better understanding of the benefits of design in driving innovation and value creation, and may help to raise the profile of design as a public policy issue, identifying specific support needs, and ensuring that public-sector support for design no longer remains ‘meager’ relative to that for R&D (Rosenfeld 2018).

Figure 1: Real business design and R&D spending (1992 prices)



Source: Authors’ analysis. ONS time series from ‘Experimental estimates of investment in intangible assets in the UK, 1997 to 2019’ (Published 1st December 2021), deflated using GDP deflator.

Table 1: Descriptive statistics

	All firms (baseline)			Small firms			Large firms		
	Obs (N)	Mean	Std Dev.	Obs (N)	Mean	Std Dev.	Obs (N)	Mean	Std Dev.
New-to-the-firm (NTF) product/service innovator (0/1)	20,231	0.17	0.37	8,990	0.16	0.37	4,250	0.19	0.39
New-to-the-market (NTM) product/service innovator (0/1)	22,903	0.10	0.30	10,062	0.10	0.29	4,817	0.13	0.33
New-to-the-firm (NTF) innovation success (%)	20,222	2.04	9.57	8,984	2.08	9.80	4,250	1.80	9.05
New-to-the-firm-and-market (NTM) innovation success (%)	22,889	4.97	15.47	10,051	5.10	15.88	4,817	3.85	12.60
Patents (log)	22,903	0.002	0.05	10,062	0.001	0.04	4,817	0.01	0.14
Trade marks (log)	22,903	0.13	0.49	10,062	0.07	0.33	4,817	0.78	1.28
Registered designs (log)	22,903	0.01	0.13	10,062	0.004	0.09	4,817	0.06	0.35
Lead time (0/1)	22,903	0.09	0.29	10,062	0.09	0.28	4,817	0.13	0.34
Complexity (0/1)	22,903	0.15	0.36	10,062	0.14	0.35	4,817	0.21	0.41
Secrecy (0/1)	22,903	0.14	0.34	10,062	0.13	0.33	4,817	0.22	0.41
Employment (log)	22,903	3.31	0.90	10,062	2.96	0.43	4,817	6.32	0.77
Science graduates (%)	22,903	8.06	18.47	10,062	7.69	18.53	4,817	9.75	17.71
Other graduates (%)	22,903	11.84	21.52	10,062	11.38	21.56	4,817	14.19	20.02
Design-engaged firm (0/1)	22,903	0.14	0.35	10,062	0.13	0.34	4,817	0.18	0.38
Training-engaged firm (0/1)	22,903	0.20	0.40	10,062	0.19	0.40	4,817	0.23	0.42
Exporting firm (0/1)	22,903	0.29	0.46	10,062	0.26	0.44	4,817	0.43	0.50
Int R&D (0/1)	22,903	0.23	0.42	10,062	0.21	0.41	4,817	0.35	0.48
Ext R&D (0/1)	22,903	0.07	0.25	10,062	0.06	0.25	4,817	0.11	0.31
Innovation partners (0 to 7)	22,903	1.24	2.08	10,062	1.20	2.07	4,817	1.72	2.30
Innovation partners (squared) (0 to 49)	22,903	5.88	12.90	10,062	5.72	12.85	4,817	8.24	14.61
Acquisition of existing knowledge (0/1)	22,903	0.05	0.21	10,062	0.05	0.21	4,817	0.06	0.24
Market introduction of innovation (0/1)	22,903	0.12	0.33	10,062	0.12	0.33	4,817	0.15	0.35
Acquisition of advanced machinery (0/1)	22,903	0.31	0.46	10,062	0.30	0.46	4,817	0.35	0.48

Table 2: The probability of NTF and NTM product/service innovation – all firms, small firms and large firms, probit models

	All firms (baseline)		Small firms		Large firms	
	NTF	NTM	NTF	NTM	NTF	NTM
Standard coefficients						
Patents (log)	-0.645***	-0.066	-1.089***	-0.296	-0.439**	-0.541
	(0.231)	(0.219)	(0.412)	(0.510)	(0.219)	(0.338)
Trade marks (log)	-0.026	0.007	-0.108*	0.055	0.024	0.059*
	(0.030)	(0.030)	(0.064)	(0.056)	(0.025)	(0.034)
Registered designs (log)	-0.062	0.265**	0.099	0.481**	0.025	0.006
	(0.259)	(0.121)	(0.464)	(0.195)	(0.128)	(0.143)
Patent-trade mark (log)	0.374**	0.116	0.255	0.195	0.414***	0.014
	(0.156)	(0.123)	(0.206)	(0.306)	(0.131)	(0.162)
Patent-registered designs (log)	-0.184	0.190	0.000	3.877***	-1.375*	0.604**
	(0.740)	(0.239)	(.)	(1.416)	(0.780)	(0.277)
Registered designs-trade mark (log)	0.020	-0.020	-0.272	-0.085	0.031	0.040
	(0.073)	(0.035)	(0.225)	(0.108)	(0.035)	(0.035)
Lead time (0/1)	0.044	0.281***	0.067	0.329***	0.044	0.095
	(0.082)	(0.065)	(0.102)	(0.083)	(0.104)	(0.086)
Complexity (0/1)	0.235***	0.240***	0.224**	0.213**	0.170*	0.320***
	(0.076)	(0.068)	(0.097)	(0.087)	(0.095)	(0.085)
Secrecy (0/1)	0.004	0.163***	0.007	0.187***	0.055	0.136*
	(0.067)	(0.055)	(0.087)	(0.071)	(0.084)	(0.078)
Employment (log)	-0.004	-0.058***	0.109	-0.071	-0.018	0.006
	(0.018)	(0.018)	(0.072)	(0.059)	(0.037)	(0.045)
Science graduates (%)	0.001	0.003***	0.002	0.004***	-0.003*	0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Other graduates (%)	0.002**	0.002**	0.002*	0.002*	0.003**	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Design-engaged firm (0/1)	0.424***	0.298***	0.421***	0.278***	0.356***	0.195***
	(0.062)	(0.052)	(0.077)	(0.065)	(0.079)	(0.074)
Training-engaged firm (0/1)	0.438***	0.137***	0.449***	0.165***	0.317***	0.160**
	(0.084)	(0.052)	(0.098)	(0.064)	(0.070)	(0.073)
Exporting firm (0/1)	0.071	0.324***	0.086	0.344***	-0.023	0.086
	(0.050)	(0.047)	(0.062)	(0.057)	(0.068)	(0.084)
Int R&D (0/1)	0.485***	0.569***	0.493***	0.560***	0.354***	0.408***
	(0.105)	(0.059)	(0.130)	(0.073)	(0.069)	(0.081)
Ext R&D (0/1)	-0.124	0.075	-0.166	0.098	-0.092	0.047
	(0.079)	(0.061)	(0.102)	(0.077)	(0.094)	(0.083)
Innovation partners (0 to 7)	0.399***	0.267***	0.414***	0.262***	0.362***	0.342***
	(0.040)	(0.035)	(0.049)	(0.044)	(0.042)	(0.058)
Innovation partners (squared) (0 to 49)	-0.048***	-0.029***	-0.050***	-0.029***	-0.044***	-0.037***
	(0.006)	(0.005)	(0.007)	(0.006)	(0.006)	(0.008)
Acquisition of existing knowledge (0/1)	0.026	0.062	0.063	0.049	0.024	-0.038
	(0.088)	(0.089)	(0.109)	(0.113)	(0.126)	(0.103)
Market introduction of innovation (0/1)	0.445***	0.473***	0.466***	0.459***	0.515***	0.560***
	(0.100)	(0.063)	(0.119)	(0.078)	(0.091)	(0.095)
Acquisition of advanced machinery (0/1)	0.392***	0.147***	0.405***	0.171***	0.354***	0.106
	(0.063)	(0.049)	(0.076)	(0.060)	(0.061)	(0.072)
Average marginal effects						
Patents (log)	-0.106***	-0.004	-0.185***	-0.025	-0.035	-0.063**

	(0.038)	(0.022)	(0.069)	(0.051)	(0.038)	(0.030)
Trade marks (log)	-0.005	0.001	-0.019*	0.006	0.006	0.009*
	(0.005)	(0.003)	(0.011)	(0.006)	(0.005)	(0.005)
Registered designs (log)	-0.011	0.030**	0.014	0.051**	0.008	0.008
	(0.044)	(0.013)	(0.078)	(0.020)	(0.022)	(0.015)
N	20207	22869	8950	10018	4214	4780
Chi-squared	2155.277	2461.306	1403.028	1648.801	882.766	891.666
p	0.000	0.000	0.000	0.000	0.000	0.000
bic	1.90e+05	1.36e+05	1.52e+05	1.05e+05	7334.079	5817.655

Table 3: Proportion of sales from NTF and NTM innovation – all firms, small firms and large firms, OLS models

	All firms		Small firms		Large firms	
	NTF	NTM	NTF	NTM	NTF	NTM
Standard coefficients						
Patents (log)	-1.907*	2.326	-4.254*	2.252	-1.124	-1.303
	(0.979)	(4.035)	(2.199)	(9.999)	(0.892)	(1.459)
Trade marks (log)	-0.440***	-0.822***	-0.619*	-1.071**	-0.115	-0.259
	(0.157)	(0.231)	(0.322)	(0.470)	(0.132)	(0.169)
Registered designs (log)	-0.293	-1.271	0.845	-0.704	-0.039	-0.210
	(0.931)	(0.925)	(1.816)	(1.519)	(0.679)	(0.912)
Patent-trade mark (log)	1.338***	-0.611	2.740	-2.729	1.200**	0.610
	(0.414)	(1.970)	(2.069)	(4.932)	(0.506)	(0.686)
Patent-registered designs (log)	-1.485**	0.275	4.613	7.153	-6.435***	-0.969
	(0.606)	(2.167)	(6.002)	(7.075)	(2.404)	(1.712)
Registered designs-trade mark (log)	0.069	0.464*	-0.285	0.674	0.100	0.244
	(0.248)	(0.256)	(0.675)	(0.820)	(0.155)	(0.235)
Lead time (0/1)	-0.683	1.516	-1.023	1.446	-0.036	-0.622
	(1.050)	(1.046)	(1.361)	(1.342)	(0.689)	(0.892)
Complexity (0/1)	1.943	3.358***	2.094	3.892***	1.135	3.395***
	(1.389)	(1.167)	(1.800)	(1.500)	(0.740)	(0.929)
Secrecy (0/1)	0.881	2.115***	1.490	2.354**	-0.452	0.230
	(0.753)	(0.807)	(1.002)	(1.047)	(0.551)	(0.680)
Employment (log)	-0.384***	-1.084***	-0.656**	-1.578***	0.041	-0.153
	(0.100)	(0.131)	(0.310)	(0.412)	(0.219)	(0.265)
Science graduates (%)	0.002	0.053***	-0.000	0.057***	-0.016	0.024*
	(0.008)	(0.013)	(0.009)	(0.016)	(0.010)	(0.015)
Other graduates (%)	0.011	0.021**	0.012	0.021**	0.006	0.017
	(0.007)	(0.008)	(0.008)	(0.010)	(0.008)	(0.010)
Design-engaged firm (0/1)	1.769***	3.772***	1.701**	3.893***	0.849	2.220***
	(0.625)	(0.721)	(0.798)	(0.915)	(0.757)	(0.841)
Training-engaged firm (0/1)	0.833*	0.950*	0.703	0.845	1.216**	2.306***
	(0.437)	(0.556)	(0.531)	(0.678)	(0.567)	(0.709)
Exporting firm (0/1)	-0.304	0.054	-0.347	-0.026	-0.032	-0.483
	(0.246)	(0.381)	(0.301)	(0.468)	(0.353)	(0.460)
Int R&D (0/1)	1.822***	4.148***	2.075***	4.707***	-0.002	0.402
	(0.518)	(0.639)	(0.680)	(0.827)	(0.543)	(0.601)
Ext R&D (0/1)	1.104	2.820***	1.278	2.850**	1.113	1.817*
	(0.872)	(0.978)	(1.163)	(1.258)	(0.912)	(0.961)
Innovation partners (0 to 7)	0.992***	1.293***	1.118***	1.419***	0.810**	0.811**
	(0.305)	(0.371)	(0.377)	(0.460)	(0.327)	(0.361)
Innovation partners (squared) (0 to 49)	-0.091**	-0.101*	-0.106*	-0.119*	-0.095*	-0.088
	(0.046)	(0.056)	(0.056)	(0.069)	(0.049)	(0.055)
Acquisition of existing knowledge (0/1)	0.168	0.224	0.463	0.322	0.682	-1.188
	(0.803)	(1.026)	(1.002)	(1.266)	(1.147)	(1.146)
Market introduction of innovation (0/1)	2.295**	3.675***	2.527**	3.893***	2.814***	3.784***
	(0.927)	(0.899)	(1.133)	(1.105)	(0.835)	(0.845)
Acquisition of advanced machinery (0/1)	0.701*	1.498***	0.718	1.664***	1.227***	1.599***
	(0.400)	(0.453)	(0.496)	(0.553)	(0.383)	(0.468)
Constant	1.208	2.095*	1.970	3.424*	-1.535	-2.105
	(1.024)	(1.233)	(1.447)	(1.784)	(1.450)	(1.962)

Average marginal effects						
Patents (log)	-1.764*	2.248	-4.071*	2.084	-0.552	-0.884
	(0.957)	(3.808)	(2.220)	(9.662)	(0.833)	(1.149)
Trade marks (log)	-0.438***	-0.819***	-0.619*	-1.071**	-0.099	-0.239
	(0.157)	(0.230)	(0.321)	(0.469)	(0.130)	(0.166)
Registered designs (log)	-0.287	-1.210	0.829	-0.648	-0.029	-0.028
	(0.905)	(0.898)	(1.776)	(1.483)	(0.585)	(0.792)
N	20226	22893	8984	10051	4252	4819
R squared	0.089	0.209	0.097	0.221	0.070	0.146
bic	1.48e+05	1.86e+05	66225.683	82255.414	31088.626	37954.582

Table 4: The probability of NTF and NTM product innovation across sectors – small firms, probit models

Small firms	Manufacturing firms		Service firms		High-tech/ Knowledge intensive firms		Low-tech/ less knowledge intensive firms	
	NTF	NTM	NTF	NTM	NTF	NTM	NTF	NTM
Standard coefficients								
Patents (log)	-30.399***	-1.071	-1.220**	-0.442	-0.687	-0.165	0.000	-1.321***
	(1.616)	(0.658)	(0.475)	(0.697)	(0.704)	(0.844)	(.)	(0.405)
Trade marks (log)	-0.176	-0.168	-0.075	0.097	-0.120	-0.093	-0.107	0.167**
	(0.156)	(0.159)	(0.069)	(0.059)	(0.106)	(0.094)	(0.081)	(0.067)
Registered designs (log)	0.103	-0.043	-0.809	0.606**	0.000	0.690	0.260	0.475**
	(0.468)	(0.410)	(0.841)	(0.239)	(.)	(0.461)	(0.533)	(0.203)
Patent-trade mark (log)	35.262***	1.824***	0.000	0.000	0.000	0.740	0.000	0.400
	(1.932)	(0.567)	(.)	(.)	(.)	(0.844)	(.)	(0.259)
Patent-registered designs (log)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.154***
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(1.485)
Registered designs-trade mark (log)	0.000	0.000	-0.040	-0.486**	0.000	-0.040	-0.375	-0.152
	(.)	(.)	(0.265)	(0.240)	(.)	(0.260)	(0.234)	(0.157)
Lead time (0/1)	0.017	0.209	0.049	0.363***	-0.105	0.478***	0.202	0.166
	(0.187)	(0.162)	(0.120)	(0.095)	(0.134)	(0.097)	(0.145)	(0.134)
Complexity (0/1)	-0.121	-0.005	0.321***	0.273***	0.225	0.119	0.196	0.295**
	(0.172)	(0.163)	(0.112)	(0.100)	(0.141)	(0.097)	(0.126)	(0.130)
Secrecy (0/1)	0.380**	0.264*	-0.067	0.181**	0.001	0.198**	0.056	0.197*
	(0.180)	(0.151)	(0.099)	(0.079)	(0.113)	(0.092)	(0.128)	(0.107)
Employment (log)	0.106	-0.066	0.110	-0.068	0.047	-0.153*	0.152	-0.010
	(0.129)	(0.137)	(0.080)	(0.066)	(0.072)	(0.082)	(0.099)	(0.082)
Science graduates (%)	-0.004	-0.003	0.002	0.004***	0.001	0.002	0.006**	0.008**
	(0.006)	(0.004)	(0.002)	(0.002)	(0.002)	(0.001)	(0.003)	(0.003)
Other graduates (%)	0.010***	0.007**	0.001	0.002	0.001	0.001	0.003	0.003*
	(0.004)	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Design-engaged firm (0/1)	0.455***	0.295**	0.433***	0.269***	0.364***	0.318***	0.465***	0.245**
	(0.171)	(0.142)	(0.084)	(0.073)	(0.098)	(0.080)	(0.107)	(0.100)
Training-engaged firm (0/1)	0.200	-0.027	0.475***	0.203***	0.339***	0.054	0.506***	0.268***
	(0.142)	(0.133)	(0.109)	(0.072)	(0.081)	(0.080)	(0.136)	(0.092)
Exporting firm (0/1)	-0.100	0.405***	0.123*	0.324***	0.040	0.351***	0.144	0.362***
	(0.130)	(0.128)	(0.070)	(0.064)	(0.075)	(0.080)	(0.094)	(0.081)
Int R&D (0/1)	0.260	0.761***	0.534***	0.504***	0.406***	0.715***	0.580***	0.444***
	(0.160)	(0.157)	(0.147)	(0.081)	(0.091)	(0.094)	(0.191)	(0.102)
Ext R&D (0/1)	-0.072	0.153	-0.173	0.108	0.059	0.168*	-0.407**	0.067
	(0.241)	(0.164)	(0.115)	(0.087)	(0.123)	(0.092)	(0.160)	(0.125)

Innovation partners (0 to 7)	0.594***	0.216**	0.383***	0.266***	0.419***	0.247***	0.413***	0.259***
	(0.090)	(0.092)	(0.054)	(0.049)	(0.053)	(0.055)	(0.066)	(0.062)
Innovation partners (squared) (0 to 49)	-0.079***	-0.027**	-0.046***	-0.029***	-0.054***	-0.027***	-0.049***	-0.028***
	(0.014)	(0.013)	(0.008)	(0.007)	(0.008)	(0.008)	(0.010)	(0.009)
Acquisition of existing knowledge (0/1)	-0.573*	-0.030	0.186	0.068	0.039	-0.178	0.074	0.223
	(0.306)	(0.199)	(0.116)	(0.126)	(0.134)	(0.119)	(0.162)	(0.159)
Market introduction of innovation (0/1)	0.380**	0.526***	0.511***	0.442***	0.661***	0.461***	0.369**	0.433***
	(0.173)	(0.152)	(0.136)	(0.088)	(0.122)	(0.094)	(0.163)	(0.113)
Acquisition of advanced machinery (0/1)	0.519***	0.267**	0.397***	0.160**	0.447***	0.026	0.406***	0.295***
	(0.124)	(0.129)	(0.086)	(0.068)	(0.079)	(0.083)	(0.102)	(0.085)
Average marginal effects								
Patents (log)	-5.302***	-0.129	-0.204**	-0.044	-0.131	-0.009	0.000	-0.107***
	(0.410)	(0.096)	(0.080)	(0.069)	(0.135)	(0.104)	(.)	(0.034)
Trade marks (log)	-0.035	-0.026	-0.013	0.009	-0.023	-0.013	-0.018	0.015**
	(0.031)	(0.025)	(0.012)	(0.006)	(0.020)	(0.013)	(0.013)	(0.006)
Registered designs (log)	0.020	-0.007	-0.136	0.054**	0.000	0.095	0.038	0.041**
	(0.093)	(0.065)	(0.139)	(0.023)	(.)	(0.061)	(0.085)	(0.017)
N	1088	1305	7836	8681	3832	4476	5109	5542
Chi-squared	1870.510	277.561	1195.336	1415.521	687.129	949.035	771.263	716.543
p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
bic	19987.368	19325.508	1.30e+05	84291.211	54629.287	46317.730	96019.102	57285.150

Table 5: Proportion of sales from NTF and NTM innovation across sectors – small firms, OLS models

Small firms	Manufacturing firms		Service firms		High-tech/ Knowledge intensive firms		Low-tech/ less knowledge intensive firms	
	NTF	NTM	NTF	NTM	NTF	NTM	NTF	NTM
Standard coefficients								
Patents (log)	-12.925	17.964**	-6.678***	0.545	-10.776***	11.644	-5.377***	-6.841***
	(17.525)	(8.962)	(1.449)	(12.474)	(2.542)	(22.830)	(1.230)	(2.354)
Trade marks (log)	-1.329*	-2.277**	-0.451	-0.798	-1.214**	-1.969**	-0.372	-0.573
	(0.682)	(0.999)	(0.357)	(0.519)	(0.511)	(0.888)	(0.407)	(0.532)
Registered designs (log)	0.708	0.081	-2.456	-2.276*	0.696	-1.396	0.987	-0.202
	(1.437)	(2.460)	(2.215)	(1.333)	(0.778)	(3.815)	(2.138)	(1.638)
Patent-trade mark (log)	64.336*	-12.467*	1.837***	-1.851	92.943***	-7.955	1.262**	-0.013
	(34.955)	(6.432)	(0.595)	(4.500)	(4.639)	(20.810)	(0.490)	(2.200)
Patent-registered designs (log)	0.000	4.568	0.000	7.325	0.000	0.000	9.041***	11.028*
	(.)	(9.544)	(.)	(7.786)	(.)	(.)	(2.573)	(6.601)
Registered designs-trade mark (log)	-51.912*	4.010**	0.764	0.635	-9.621***	3.288	-0.382	0.188
	(29.812)	(1.933)	(0.870)	(0.775)	(2.730)	(2.305)	(0.786)	(0.880)
Lead time (0/1)	0.612	1.676	-1.556	1.491	-3.381	1.227	1.231	1.818
	(1.838)	(1.874)	(1.669)	(1.633)	(2.144)	(2.154)	(1.400)	(1.547)
Complexity (0/1)	-1.447	-0.474	3.004	4.851***	3.722	5.265*	0.442	2.605**
	(1.718)	(1.876)	(2.196)	(1.815)	(3.440)	(2.691)	(1.088)	(1.329)
Secrecy (0/1)	4.270*	3.503	0.912	2.117*	1.321	2.884*	1.588	1.675
	(2.258)	(2.179)	(1.090)	(1.181)	(1.728)	(1.648)	(1.089)	(1.307)
Employment (log)	-1.625*	-3.359***	-0.568*	-1.279***	-1.005*	-2.468***	-0.467	-1.163**
	(0.978)	(1.094)	(0.326)	(0.444)	(0.578)	(0.767)	(0.346)	(0.461)
Science graduates (%)	-0.038	0.023	0.000	0.056***	-0.008	0.030*	0.018	0.126***
	(0.044)	(0.056)	(0.010)	(0.017)	(0.010)	(0.016)	(0.020)	(0.042)
Other graduates (%)	0.075	0.085**	0.009	0.016	0.002	0.012	0.025*	0.025
	(0.054)	(0.041)	(0.008)	(0.010)	(0.010)	(0.012)	(0.015)	(0.016)
Design-engaged firm (0/1)	2.440**	3.492**	1.605*	4.021***	1.952	3.947***	1.568	3.724***
	(1.100)	(1.600)	(0.908)	(1.045)	(1.261)	(1.458)	(1.062)	(1.172)
Training-engaged firm (0/1)	3.291**	3.489**	0.284	0.363	0.085	-0.463	1.025	1.645**
	(1.478)	(1.636)	(0.561)	(0.739)	(0.898)	(1.131)	(0.660)	(0.824)
Exporting firm (0/1)	0.125	0.570	-0.372	-0.058	-0.684	-0.351	0.004	0.349
	(0.711)	(1.007)	(0.332)	(0.530)	(0.548)	(0.838)	(0.332)	(0.522)
Int R&D (0/1)	0.938	3.679**	2.361***	4.973***	2.103**	4.937***	2.274**	4.438***
	(0.918)	(1.506)	(0.775)	(0.939)	(0.967)	(1.214)	(0.918)	(1.073)
Ext R&D (0/1)	3.342	3.818	1.077	2.754*	2.575	2.840	-0.310	2.684
	(2.615)	(2.583)	(1.290)	(1.424)	(1.763)	(1.874)	(1.546)	(1.707)
Innovation partners (0 to 7)	1.113	1.219	1.072**	1.435***	1.159**	1.711**	1.059**	1.266**
	(0.712)	(0.930)	(0.420)	(0.515)	(0.584)	(0.747)	(0.473)	(0.569)

Innovation partners (squared) (0 to 49)	-0.159	-0.136	-0.092	-0.115	-0.101	-0.139	-0.105	-0.107
	(0.102)	(0.136)	(0.063)	(0.077)	(0.087)	(0.112)	(0.071)	(0.085)
Acquisition of existing knowledge (0/1)	-4.694**	1.171	1.292	0.439	1.738	-0.324	-0.554	1.080
	(2.376)	(2.955)	(1.096)	(1.398)	(1.591)	(1.888)	(1.283)	(1.698)
Market introduction of innovation (0/1)	1.967	1.653	2.589**	4.205***	3.817	5.354***	1.769**	2.716**
	(1.602)	(1.627)	(1.289)	(1.267)	(2.589)	(2.058)	(0.870)	(1.105)
Acquisition of advanced machinery (0/1)	1.138	2.564**	0.639	1.510**	0.070	1.422	1.162**	1.981***
	(0.979)	(1.226)	(0.551)	(0.612)	(0.904)	(1.000)	(0.491)	(0.611)
Constant	101.428***	102.590***	1.723	2.527	2.390	2.865	1.053	2.120
	(2.652)	(3.609)	(1.485)	(1.853)	(2.461)	(2.775)	(1.468)	(1.852)
Average marginal effects								
Patents (log)	-7.270	16.557**	-6.573***	0.442	-3.840	10.971	-5.277***	-6.784***
	(15.819)	(8.330)	(1.421)	(12.174)	(2.388)	(21.183)	(1.205)	(2.255)
Trade marks (log)	-1.259*	-2.242**	-0.449	-0.798	-1.179**	-1.968**	-0.373	-0.572
	(0.681)	(0.991)	(0.357)	(0.519)	(0.510)	(0.887)	(0.406)	(0.531)
Registered designs (log)	0.594	0.564	-2.412	-2.228*	-0.022	-1.118	0.969	-0.178
	(1.436)	(2.356)	(2.168)	(1.305)	(0.700)	(3.729)	(2.095)	(1.600)
N	1097	1316	7887	8735	3842	4481	5142	5570
R squared	0.198	0.243	0.092	0.225	0.103	0.219	0.099	0.212
bic	8258.130	10987.370	58057.515	71366.729	30063.684	38825.009	36271.746	43493.403

Annex 1: Variable definitions

Variable	Definition
NTF Product/service innovator (0/1)	Firms introducing a new or improved product or service which is new to the firm (NTF)
NTM Product/service innovator (0/1)	Firms introducing a new or improved product or service which is new to the market (NTM)
NTF innovation success (%)	Proportion of firm's turnover coming from innovation which is new to the firm
NTM innovation success (%)	Proportion of firm's turnover coming from innovation which is new-to-the-market
Patents (log)	Patent count at the start of the period (CIS wave)
Trade marks (log)	Trade mark count at the start of the period (CIS wave)
Registered designs (log)	Registered design count at the start of the period (CIS wave)
Lead time (0/1)	Firms using lead time to protect innovations
Complexity (0/1)	Firms using complexity to protect innovations
Secrecy (0/1)	Firms using Secrecy to protect innovations
Int R&D (0/1)	Firms undertaking in-house R&D
Ext R&D (0/1)	Firms undertaking external R&D
Employment (log)	Employment at the end of the survey period
Science graduates (%)	Proportion of the workforce that are science or engineering graduates
Other graduates (%)	Proportion of the workforce that are graduates in subjects other than science or engineering
Exporting firm (0/1)	Firms that are exporting
Innovation partners (0 to 7)	Number of innovation partners
Innovation partners (squared) (0 to 49)	Number of innovation partners squared
Design-engaged firm (0/1)	Firms investing in design
Training-engaged firm (0/1)	Firms investing in training related to innovation
Acquisition of existing knowledge (0/1)	Firms investing in external knowledge acquisition related to innovation
Acquisition of market intelligence (0/1)	Firms investing in the acquisition of market intelligence related to innovation
Acquisition of advanced machinery (0/1)	Firms investing in the acquisition of machinery related to innovation

Annex 2: Correlation matrix, N=22,903

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1 Product/service innovator (0/1)	1.00																							
2 New-to-the-firm (NTF) product/service innovator (0/1)	0.58	1.00																						
3 New-to-the-market (NTM) product/service innovator (0/1)	0.96	.	1.00																					
4 New-to-the-firm (NTF) innovation success (%)	0.44	.	0.44	1.00																				
5 New-to-the-market (NTM) innovation success (%)	0.51	0.43	0.47	0.92	1.00																			
6 Patents (log)	0.03	0.04	0.02	0.01	0.02	1.00																		
7 Trade marks (log)	0.13	0.12	0.08	0.01	0.03	0.07	1.00																	
8 Registered designs (log)	0.08	0.09	0.03	0.00	0.02	0.07	0.31	1.00																
9 Lead time (0/1)	0.30	0.31	0.19	0.11	0.24	0.05	0.10	0.03	1.00															
10 Complexity (0/1)	0.39	0.37	0.26	0.16	0.29	0.05	0.10	0.05	0.63	1.00														
11 Secrecy (0/1)	0.36	0.35	0.23	0.14	0.28	0.05	0.13	0.05	0.47	0.59	1.00													
12 Employment (log)	0.04	0.02	0.03	-0.02	-0.05	0.04	0.34	0.09	0.04	0.05	0.07	1.00												
13 Science graduates (%)	0.18	0.20	0.09	0.07	0.20	0.03	0.04	0.01	0.19	0.26	0.31	0.01	1.00											
14 Other graduates (%)	0.10	0.07	0.07	0.05	0.08	0.00	0.06	0.01	0.07	0.09	0.12	0.04	0.19	1.00										
15 Design-engaged firm (0/1)	0.41	0.34	0.31	0.17	0.27	0.04	0.13	0.09	0.27	0.33	0.33	0.04	0.15	0.06	1.00									
16 Training-engaged firm (0/1)	0.36	0.25	0.30	0.16	0.23	0.01	0.05	0.03	0.23	0.28	0.26	0.03	0.18	0.09	0.32	1.00								
17 Exporting firm (0/1)	0.23	0.24	0.13	0.06	0.14	0.06	0.21	0.10	0.21	0.28	0.29	0.10	0.26	0.15	0.23	0.12	1.00							
18 Int R&D (0/1)	0.50	0.42	0.35	0.19	0.32	0.06	0.18	0.08	0.36	0.47	0.47	0.10	0.28	0.10	0.46	0.37	0.33	1.00						
19 Ext R&D (0/1)	0.27	0.24	0.19	0.12	0.21	0.04	0.10	0.05	0.20	0.25	0.26	0.05	0.15	0.07	0.28	0.25	0.15	0.40	1.00					
20 Innovation partners (0 to 7)	0.42	0.32	0.31	0.18	0.28	0.04	0.11	0.04	0.33	0.40	0.41	0.07	0.24	0.10	0.32	0.39	0.17	0.43	0.30	1.00				
21 Innovation partners (squared) (0 to 49)	0.32	0.25	0.22	0.14	0.23	0.04	0.08	0.03	0.28	0.32	0.34	0.06	0.21	0.09	0.24	0.32	0.11	0.32	0.25	0.95	1.00			
22 Acquisition of existing knowledge (0/1)	0.20	0.18	0.14	0.08	0.13	0.04	0.07	0.05	0.15	0.17	0.20	0.01	0.12	0.06	0.22	0.22	0.11	0.25	0.30	0.24	0.21	1.00		
23 Market introduction of innovation (0/1)	0.34	0.30	0.26	0.14	0.22	0.03	0.12	0.06	0.24	0.27	0.23	0.02	0.11	0.05	0.36	0.29	0.17	0.33	0.24	0.25	0.18	0.20	1.00	
24 Acquisition of advanced machinery (0/1)	0.32	0.21	0.27	0.14	0.20	0.02	0.05	0.02	0.21	0.26	0.23	0.03	0.11	0.02	0.26	0.36	0.13	0.31	0.22	0.35	0.26	0.18	0.30	1.00

Annex 3: Descriptive statistics – small firms

	Manufacturing firms			Service firms			High-tech/ Knowledge-intensive firms			Low-tech/Less knowledge-intensive firms		
	Obs (N)	Mean	Std Dev.	Obs (N)	Mean	Std Dev.	Obs (N)	Mean	Std Dev.	Obs (N)	Mean	Std Dev.
New-to-the-firm (NTF) product/service innovator (0/1)	1,098	0.21	0.41	7,892	0.16	0.36	3,843	0.20	0.40	5,147	0.15	0.35
New-to-the-market (NTM) product/service innovator (0/1)	1,318	0.16	0.37	8,744	0.09	0.28	4,486	0.14	0.35	5,576	0.07	0.26
New-to-the-firm (NTF) innovation success (%)	1,097	2.65	10.10	7,887	2.01	9.76	3,842	2.87	12.24	5,142	1.70	8.31
New-to-the-market (NTM) innovation success (%)	1,316	6.32	15.99	8,735	4.92	15.86	4,481	7.42	20.04	5,570	3.87	12.99
Patents (log)	1,318	0.002	0.05	8,744	0.001	0.04	4,486	0.001	0.03	5,576	0.002	0.04
Trade marks (log)	1,318	0.12	0.37	8,744	0.07	0.32	4,486	0.08	0.33	5,576	0.07	0.33
Registered designs (log)	1,318	0.01	0.15	8,744	0.003	0.08	4,486	0.002	0.06	5,576	0.01	0.11
Lead time (0/1)	1,318	0.16	0.36	8,744	0.08	0.27	4,486	0.13	0.34	5,576	0.07	0.25
Complexity (0/1)	1,318	0.25	0.43	8,744	0.13	0.33	4,486	0.22	0.41	5,576	0.10	0.30
Secrecy (0/1)	1,318	0.22	0.41	8,744	0.11	0.32	4,486	0.22	0.42	5,576	0.07	0.26
Employment (log)	1,318	3.04	0.44	8,744	2.95	0.43	4,486	2.96	0.44	5,576	2.96	0.43
Science graduates (%)	1,318	5.27	12.18	8,744	8.03	19.25	4,486	16.54	26.67	5,576	3.00	9.22
Other graduates (%)	1,318	6.16	14.48	8,744	12.13	22.29	4,486	19.84	26.81	5,576	6.90	16.50
Design-engaged firm (0/1)	1,318	0.23	0.42	8,744	0.12	0.33	4,486	0.18	0.39	5,576	0.11	0.31
Training-engaged firm (0/1)	1,318	0.20	0.40	8,744	0.19	0.39	4,486	0.24	0.43	5,576	0.17	0.37
Exporting firm (0/1)	1,318	0.49	0.50	8,744	0.23	0.42	4,486	0.38	0.49	5,576	0.20	0.40
Int R&D (0/1)	1,318	0.34	0.48	8,744	0.19	0.40	4,486	0.32	0.47	5,576	0.16	0.36
Ext R&D (0/1)	1,318	0.10	0.30	8,744	0.06	0.23	4,486	0.09	0.29	5,576	0.05	0.22
Innovation partners (0 to 7)	1,318	1.38	2.04	8,744	1.17	2.07	4,486	1.44	2.17	5,576	1.07	2.01
Innovation partners (squared) (0 to 49)	1,318	6.09	12.49	8,744	5.67	12.90	4,486	6.77	13.36	5,576	5.17	12.54
Acquisition of existing knowledge (0/1)	1,318	0.06	0.24	8,744	0.04	0.20	4,486	0.06	0.24	5,576	0.04	0.19
Market introduction of innovation (0/1)	1,318	0.17	0.37	8,744	0.11	0.32	4,486	0.15	0.35	5,576	0.11	0.31
Acquisition of advanced machinery (0/1)	1,318	0.42	0.49	8,744	0.29	0.45	4,486	0.32	0.47	5,576	0.30	0.46

Annex 4: The probability of NTF and NTM product innovation across sectors – all firms, probit models, marginal effects

All firms	Manufacturing firms		Service firms		High-tech/ Knowledge intensive firms		Low-tech/ less knowledge intensive firms	
	NTF	NTM	NTF	NTM	NTF	NTM	NTF	NTM
Average marginal effects								
Patents (log)	0.025	0.053	-0.158***	-0.026	-0.072	-0.006	-0.188***	0.002
	(0.049)	(0.048)	(0.058)	(0.033)	(0.052)	(0.034)	(0.058)	(0.032)
Trade marks (log)	0.008	-0.003	-0.006	0.002	-0.004	-0.001	-0.006	0.002
	(0.011)	(0.008)	(0.006)	(0.004)	(0.010)	(0.006)	(0.007)	(0.004)
Registered designs (log)	0.023	0.032	-0.092*	0.032**	-0.081*	0.036	0.014	0.028**
	(0.054)	(0.028)	(0.053)	(0.015)	(0.044)	(0.031)	(0.054)	(0.013)
N	2977	3852	17197	18967	9037	10573	11167	12296

Annex 5: The probability of NTF and NTM product innovation across sectors – large firms, probit models, marginal effects

Large firms	Manufacturing firms		Service firms		High-tech/ Knowledge intensive firms		Low-tech/ less knowledge intensive firms	
	NTF	NTM	NTF	NTM	NTF	NTM	NTF	NTM
Average marginal effects								
Patents (log)	0.000	-0.176*	-0.015	-0.029	-0.045	-0.002	0.000	-0.009
	(.)	(0.103)	(0.063)	(0.031)	(0.039)	(0.031)	(.)	(0.036)
Trade marks (log)	0.019	0.019**	0.003	0.007	0.008	0.026***	0.006	-0.002
	(0.012)	(0.009)	(0.006)	(0.006)	(0.009)	(0.005)	(0.006)	(0.007)
Registered designs (log)	0.039	0.017	-0.061	0.016	-0.045	0.002	0.011	0.015
	(0.034)	(0.030)	(0.065)	(0.025)	(0.050)	(0.033)	(0.029)	(0.016)
N	652	905	3494	3810	2009	2285	2200	2483

Annex 6: Proportion of sales from NTF and NTM innovation across sectors – all firms, OLS models, marginal effects

All firms	Manufacturing firms		Service firms		High-tech/ Knowledge intensive firms		Low-tech/ less knowledge intensive firms	
	NTF	NTM	NTF	NTM	NTF	NTM	NTF	NTM
Average marginal effects								
Patents (log)	3.343	7.290	-4.240***	-0.010	-1.815	5.656	-2.743***	-4.164**
	(2.683)	(4.483)	(0.874)	(5.910)	(1.414)	(5.762)	(1.035)	(1.766)
Trade marks (log)	-0.413	-0.607*	-0.361*	-0.735**	-0.727***	-1.187***	-0.320*	-0.648**
	(0.256)	(0.338)	(0.187)	(0.287)	(0.272)	(0.438)	(0.192)	(0.265)
Registered designs (log)	0.232	-0.083	-1.720**	-1.916*	-1.290	-2.216	0.348	-0.562
	(0.916)	(1.234)	(0.725)	(0.999)	(0.836)	(1.716)	(1.243)	(1.024)
N	2995	3884	17231	19009	9052	10593	11174	12300

Annex 7: Proportion of sales from NTF and NTM innovation across sectors – large firms, OLS models, marginal effects

Large firms	Manufacturing firms		Service firms		High-tech/ Knowledge intensive firms		Low-tech/ less knowledge intensive firms	
	NTF	NTM	NTF	NTM	NTF	NTM	NTF	NTM
Average marginal effects								
Patents (log)	-0.126	-1.102	-1.652***	-1.203	-0.480	-0.474	-1.816***	-2.969***
	(1.791)	(1.828)	(0.550)	(1.949)	(1.093)	(1.690)	(0.577)	(1.061)
Trade marks (log)	-0.047	0.090	-0.115	-0.335*	-0.105	0.165	-0.029	-0.372**
	(0.291)	(0.345)	(0.148)	(0.186)	(0.279)	(0.319)	(0.134)	(0.187)
Registered designs (log)	-0.249	-0.200	-0.021	1.486	-2.087**	-3.422*	0.805	1.439
	(0.672)	(0.977)	(1.522)	(1.882)	(1.010)	(1.806)	(0.748)	(0.921)
N	678	927	3574	3892	2019	2312	2233	2507

Annex 8: Average marginal effects of IP protection – an extended analysis

To explore the average marginal effects of the IP protection methods further, we examine how elasticities vary as firms' stocks of one other IP protection method change. To highlight similarities and differences between average marginal effects in small firms and firms more generally, we compare results for the all-firm (baseline) group with those for the small-firm group.

To calculate the average marginal effects reported in Tables 2-5, the derivative for each observation is evaluated, and the average of these values is determined. Here, we calculate the marginal effect of each IP protection method in the same way, whilst specifying representative values for one other IP protection method. The range of representative values chosen is determined by the sample being analysed. For example, to calculate the marginal effect of patent stocks at representative values of registered design stocks in a small-firm sample, the range of values for registered design stocks is chosen so as to include at least ninety-nine per cent of small firms in the estimation.

In this study, we hypothesise that patents and registered designs have a direct effect on a firm's propensity to innovate (H1a above), and that both patents and registered designs have a mutually reinforcing effect on a firm's propensity to innovate (H1b). In relation to small firms, we hypothesise that these effects are weaker than in firms more generally (H1c and H1d). The results in Table 2 suggest that patent stocks have no significant effect on the probability of NTM innovation across all firms and small firms, leading us to reject this part of hypothesis H1a. However, registered design stocks have a significant, positive effect on the probability of NTM innovation across all firms and small firms, with a slightly stronger effect in small firms, supporting the registered design part of hypothesis H1a. We investigate the potentially reinforcing effect of patent stocks and registered design stocks on the probability of NTM innovation by calculating the marginal effect of patent stocks (or registered design stocks), whilst specifying representative values of registered design stocks (or patent stocks). Although not hypothesised, we also investigate the possibility that firms' trade mark stocks may reinforce the patent stock and registered design stock effects on NTM innovation. We plot the elasticities for patent stocks and registered design stocks against representative values of another IP protection method, and present the charts in Figure A1. Blue lines represent elasticities, and the grey and green lines represent the 95 per cent confidence intervals around these estimates. The elasticities for patent stocks increase with representative values of registered design stocks and trade mark stocks. The confidence intervals suggest that in small firms, patent stock elasticities are significant for representative values of registered designs, and across all firms and in small firms, registered design stock elasticities are significant at low patent stock levels, becoming insignificant as patent stocks increase (Figure A1: a(ii), b(i) and b(ii)). The results provide evidence of the mutually reinforcing effect of patents and registered designs on NTM innovation, especially in small firms. Consequently, we cannot reject H1b, but we are able to reject H1d. In addition, the analysis suggests a positive relationship between trade mark stocks and patent stock elasticities (indicating a potential reinforcing effect), but estimates are insignificant (Figure A1: c(i) and c(ii)). In contrast, results suggest that trade mark stocks do not reinforce registered design elasticities, indeed, elasticities fall as firms' trade mark stocks increase – although estimates are insignificant (Figure A1: d(i) and d(ii)).

Furthermore, we hypothesise that trade marks have a direct positive effect on a firm's ability to profit from an innovation during the commercialisation or exploitation stage of the innovation process (H2a). Moreover, we suggest that trade mark stocks combined with patent or registered design stocks have a mutually reinforcing effect on a firm's ability to profit from an innovation (H2b). In relation to small firms, we hypothesise that the direct positive effect of trade marks on a firm's ability to profit from innovation is larger in small firms than in firms more generally (H2c), and that any mutually reinforcing effect of trade marks and patents or registered designs is also larger in small firms (H2d). Regression results in Table 4 suggest that there is no direct positive effect of trade mark stocks on the proportion of a firm's sales from innovation (NTF or NTM). Indeed, coefficients are negative and significant across small firms and all firms in general, leading to the rejection of hypotheses H2a and H2c. We explore the potentially reinforcing effect of patent stocks and registered design stocks on the proportion of sales from innovation by calculating the marginal effect of trade mark stocks, whilst specifying representative values of patent stocks or registered design stocks. The trade mark stock elasticities are plotted against representative values for patent stocks and registered design stocks and presented in Figure A2. The trade mark stock elasticities are negative and fall as representative values of patent stocks increase (Figure A2: a(i) and a(ii)), providing evidence against H2b and H2d. The charts depicting trade mark stock elasticities at representative values of registered design stocks (Figure A2: b(i) and b(ii)), show trade mark stock elasticities increasing as the registered design stock increases. Despite elasticities being negative and significant at low registered design stock values, there is evidence to suggest that larger registered design stocks are associated with less negative trade mark elasticities. As registered design stocks become larger, the trade mark stock elasticities in small firms eventually turn positive, although estimates are not statistically significant. These results provide evidence of the mutually reinforcing effect of trade marks and registered designs during the commercialisation stage of the innovation process.

Figure A1: Average marginal effects of IP protection – NTM product/service innovation

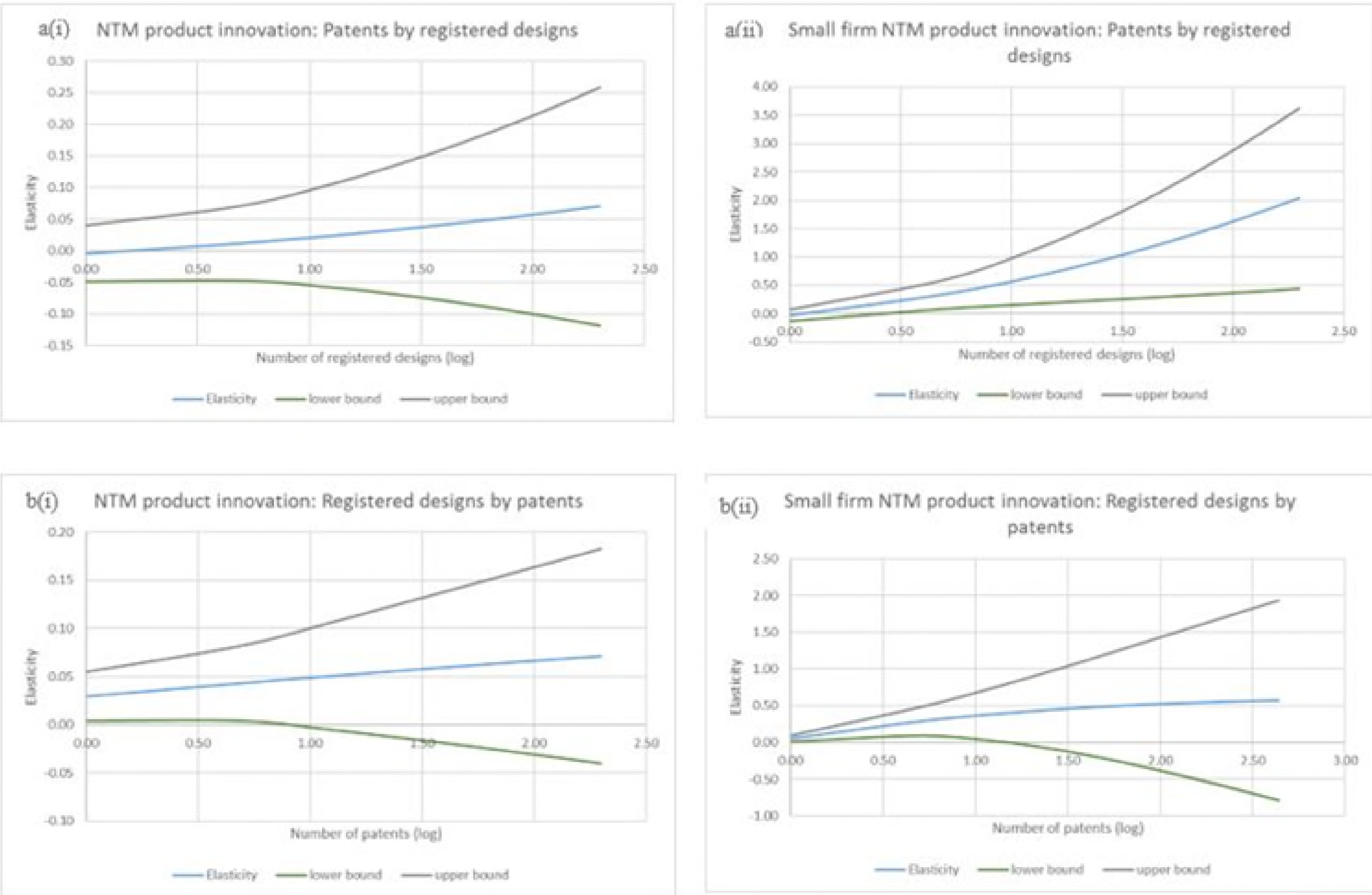


Figure A1 (continued): Average marginal effects of IP protection – NTM product/service innovation

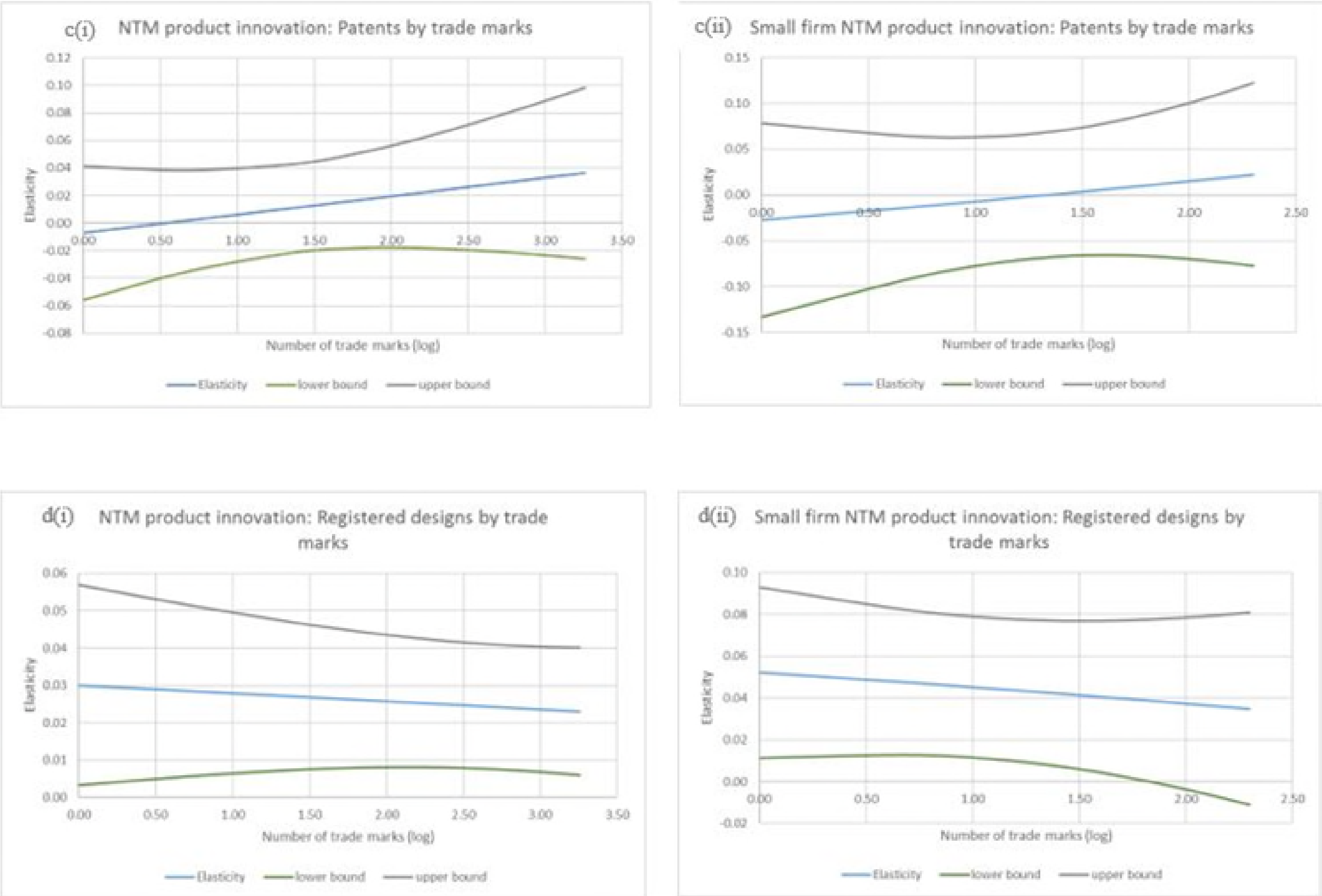
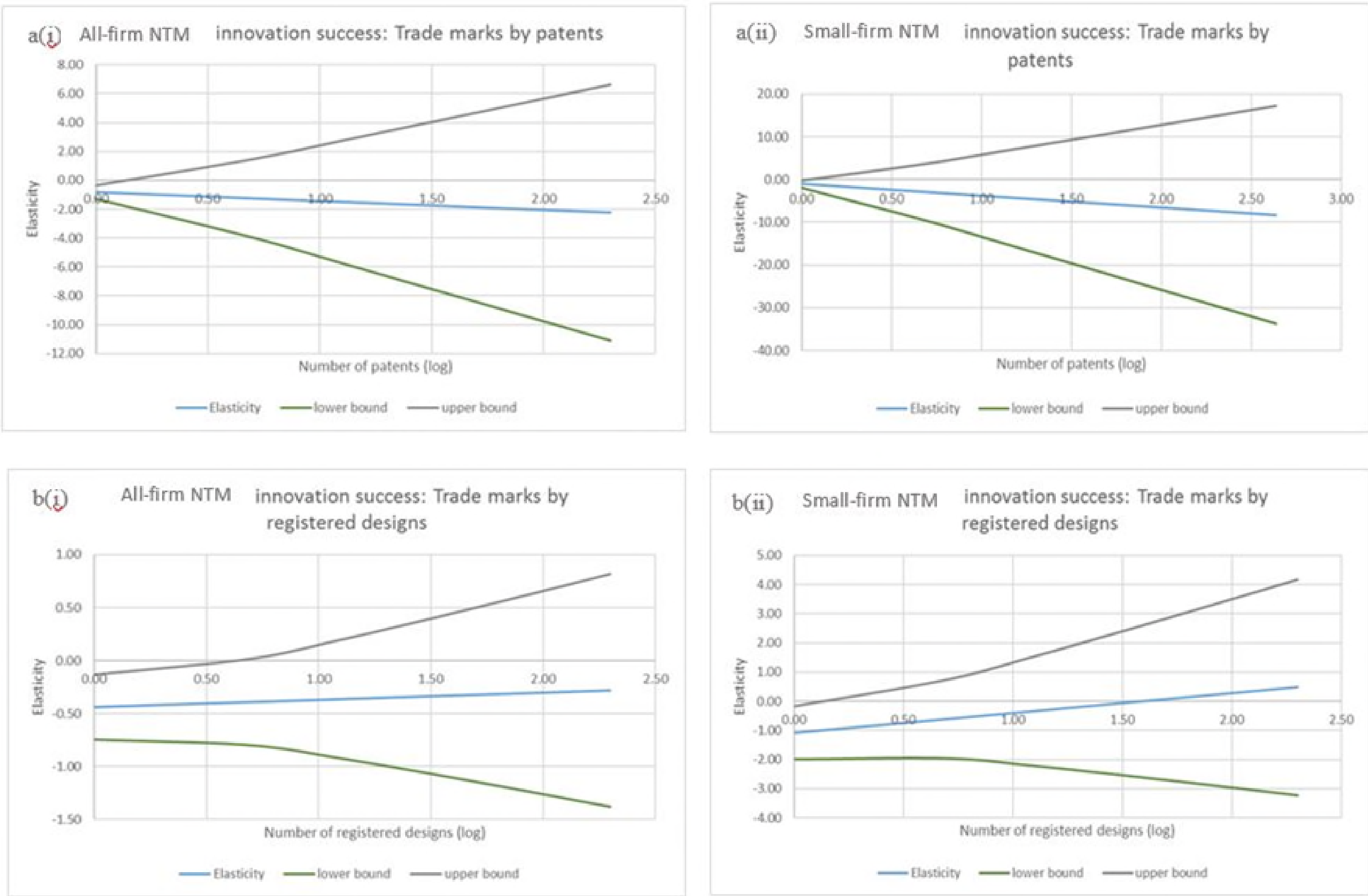


Figure A2: Average marginal effects of IP protection – returns to NTM innovation



REFERENCES

Aaker, D. (2007). Innovation: Brand it or lose it, *California Management Review*, 50, 1, 8-24.

Ahmetoglu, G., Chamorro-Premuzic, T. (2012). Design rights and innovation: a psychometric analysis, in: UK IPO (Ed), *The Development of Design Law: Past and Future*, London, 99-149.

Arora, A. and Athreye, S. (2012). Patent incentives: Returns to patenting and the inducement for research & development, *Intellectual Property Office Research Paper*, (2012/20).

Arora, A., Ceccagnoli, M. and Cohen, W.M. (2008). R&D and the patent premium. *International Journal of Industrial Organization*, 26, 5, 1153-1179.

Arrow, K. (1962). Economic welfare and the allocation of resources for invention, in The Rate and Direction of Inventive Activity, R. Nelson (ed.), *Princeton University Press*, Princeton, US.

Artz, K.W., Norman, P.M., Hatfield, D.E. and Cardinal, L.B. (2010). A longitudinal study of the impact of R&D, patents, and product innovation on firm performance, *Journal of product innovation management*, 27, 5, 725-740.

Arundel, A. (2001). The relative effectiveness of patents and secrecy for appropriation, *Research Policy*, 30, 4, 611-624.

Barney, J.B. (1991). Firm resources and sustained competitive advantage, *Journal of Management*, 32, 99-120.

Bascavusoglu-Moreau, E. and Tether, B.S. (2011). Design economics, Chapter 2: Registered designs & business performance – Exploring the link, IPO Report, 2011/6. Published by The Intellectual Property Office. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/310638/ipresearch-designsreport2-201109.pdf

Becker, B., Roper, S. and Love, J.H. (2016). The effectiveness of regional, national and EU support for innovation in the UK and Spain, *Enterprise Research Centre, Research Paper,* No. 52.

Bessen, J. and Meurer, M.J. (2008). Patent failure: How judges, bureaucrats, and lawyers put innovators at risk, *Princeton and Oxford: Princeton University Press*.

Binks, M.R., and Ennew, C.T. (1996). Growing firms and the credit constraint. *Small Business Economics,* 8,1, 17-25.

Blackburn, R.A. (2003). Small firms, innovation and intellectual property management, in *Intellectual property and innovation management in small firms*, in *R.A. Blackburn (Ed.) Routledge*.

Blind, K., Edler, J., Frietsch, R. and Schmoch, U. (2006). Motives to patent: Empirical evidence from Germany, *Research Policy*, 35, 5, 655-772.

Blind, K., Edler, J., Schmoch, U., Anderson, B., Howells, J., Miles, I., Roberts, J., Green, L., Evangelista, R. and Hipp, C. (2003). Patents in the service industries – Final report, *Fraunhofer Institut fur Systemtechnik und innovationsforschung*, Karlsruhe.

Block, J., Fisch, C. Hahn, A. and Sandner, P. (2015). Why do SMEs file trademarks? Insights from firms in innovative industries, Research Policy 44, 10, 1915-1930.

Brem, A., Nylund, P.A. and Hitchen, E.L. (2017). Open innovation and intellectual property rights: How do SMEs benefit from patents, industrial designs, trade marks and copyrights? *Management Decision*, 55, 6, 1285-1306.

Brouwer, E. and Kleinknecht, A. (1999). Innovative output and a firm's propensity to patent: An exploration of CIS micro data, *Research Policy*, 28, 6, 615-624.

Carter, N.M., Stearns, T.M., Reynolds, P.D., Miller, B.A. (1994). New venture strategies: theory development with an empirical base, *Strat. Manage. J.*, 15, 1, 21-41.

Ceccagnoli, M., Rothaermel, F.T. (2008). Appropriating the returns from innovation, Chapter 1 in G. D. Libecap and M.C. Thursby (eds.), *Advances in the Study of Entrepreneurship, Innovation, and Economic Growth*, Elsevier, 11-34.

Cefis, E. and Marsili, O. (2005). A matter of life and death: innovation and firm survival, *Industrial and Corporate Change*, 14, 6, 1167-1192.

Cohen, W.M. and Levinthal, D.A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35, 128-152.

Cohen, W.M., Nelson, R.R. and Walsh, J.P. (2000). Protecting their intellectual assets: Appropriability conditions and why US manufacturing firms patent (or not), *NBER Working Paper 7552*, National Bureau of Economic Research Inc.

Combe, E. and Pfister, E. (2000). Patents against imitators: An empirical investigation on French data, *Cahiers de la MSE*.

Coombs, R., Narandren, P. and Richards, A. (1996). A literature-based innovation output indicator, *Research policy*, 25, 3, 403-413.

Czarnitzki, D. and Kraft, K. (2004). Innovation indicators and corporate credit ratings: evidence from German firms, *Economics Letters*, 82, 377-384.

De Rassenfosse, G. (2012). How SMEs exploit their intellectual property assets: evidence from survey data, *Small Business Economics*, 39, 2, 437-452.

DeCarolis, D.M., and Deeds, D.L. (1999). The impact of stocks and flows of organizational knowledge on firm performance: An empirical investigation of the biotechnology industry. *Strategic Management Journal*, 20, 10, 953-968.

Dierickx, I., and Cool, K. (1989). Asset stock accumulation and sustainability of competitive advantage. *Management Science*, 35, 1504-1511.

Du, J., Love, J.H. and Roper, S. (2007). The innovation decision, *Technovation*, 27, 12, 744-765.

Economides, N. S. (1988). The economics of trade marks, Trademark Register, 78, 523-539.

EPO/EUIPO (2019) High-growth firms and intellectual property rights. http://documents.epo.org/projects/babylon/eponet.nsf/0/F59459A1E64B62F3C12583FC002FBD93/$FILE/high_growth_firms_study_en.pdf

EPO/EUIPO (2021) Intellectual property rights and firm performance in the European Union. https://euipo.europa.eu/tunnel-web/secure/webdav/guest/document_library/observatory/documents/reports/IPContributionStudy/IPR_firm_performance_in_EU/2021_IP_Rights_and_firm_performance_in_the_EU_en.pdf

EUPTO (2016). Intellectual property (IP) SME scoreboard 2016. https://euipo.europa.eu/tunnel-web/secure/webdav/guest/document_library/observatory/documents/sme_scoreboard_study_2016/sme_scoreboard_study_2016_en.pdf

Flikkema, M., De Man, A., Castaldi, C. (2014). Are trademark counts a valid indicator of innovation? Results of an in-depth study of new Benelux trademarks filed by SMEs. *Ind. Innovation*, 21, 4, 310-331.

Freel, M. and Robson, P.J. (2017). Appropriation strategies and open innovation in SMEs, *International Small Business Journal*, 35, 578-596.

Gershman, M., Thurner, T. W., and Chudaeva, M. (2020). Industrial design for economic growth: Russia’s efforts to improve its manufacturing sector, *Creative Industries Journal*, 13, 3, 244-258.https://doi.org/10.1080/17510694.2019.1707520

Geroski, P., Machin, S., and Van Reenen, J., (1993). The profitability of innovating firms, *Rand Journal of Economics*, 24, 198-211.

Giménez, G. (2018). The impact of the patent system on the social welfare: A critical view, No. ART-2018-105807.

Granstrand, O. (1999). The economics and managements of intellectual property, *Edward Elgar,* Cheltenham.

Grant, R.M. (1996). Toward a knowledge-based theory of the firm. *Strategic Management Journal*, 17, S2, 109-122.

Greenhalgh, C. and Longland, M. (2005). Running to stand still? – The value of R&D, patents and trade marks in innovating manufacturing firms, *International Journal of the Economics of Business,* 12, 3, 307-328.

Greenhalgh, C. and Rogers, M. (2006). The value of innovation: the interaction of competition, R&D and IP, Research Policy, 35, 4, 562-580.

Greenhalgh, C. and Rogers, M. (2007). The value of intellectual property rights to firms and society, *Oxford Review of Economic Policy*, 23, 4, 541-567.

Greenhalgh, C. and Rogers, M. (2008). Intellectual property activity by service sector and manufacturing firms in the UK, 1996–2000. In: *Scarbrough, H. (Ed.), The Evolution of Business Knowledge.* Oxford University Press, 295-318.

Greenhalgh, C. and Rogers, M. (2012). Trade marks and performance in services and manufacturing firms: Evidence of Schumpeterian competition through innovation, *The Australian Economic Review*, 45, 1, 50-76.

Greenhalgh, C., Rogers, M., Schautschick, P. and Sena, V. (2011). Trade mark incentives, IPO Report, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/312078/ipresearch-tmincentives-full-201107.pdf

Griffiths, W.E., Jenson, P.H. and Webster, E. (2005). The effects on firm profits of the stock of intellectual property rights, *Intellectual Property Research Institute of Australia*, *Working Paper No. 05/05*.

Griliches, Z. (1992). The search for research-and-development spillovers, Scandinavian Journal of Economics, 94, S29-S47.

Griliches, Z., Hall, B.H. and Pakes, A. (1991). R&D, patents, and market value revisited: is there a second (technological opportunity) factor? *Economics of Innovation and new technology*, 1, 3, 183-201.

Hall, B.H. (2000). Innovation and market value. In Barrell, R., Mason, G., O'Mahony, M. (Eds.), Productivity, Innovation and Economic Performance. *Cambridge University Press,* Cambridge.

Hall, B.H. and Sena, V. (2017). Appropriability mechanisms, innovation and productivity: Evidence from the UK, *Economics of Innovation and New Technology*, 26, 1-2, 42-62.

Hall, B. H., Helmers, C. and Graevenitz, G. (2016). Patent thickets and first-time patenting: new evidence, *Centre for Economic Policy Research, London*, available at http://voxeu. org/article/patentthickets-and-first-time-patenting-new-evidence

Hall, B.H., Helmers, C., Rogers, M. and Sena, V. (2013). The importance (or not) of patents to UK firms, *Oxford Economic Papers*, 65, 3, 603-629.

Hall, B.H., Helmers, C., Rogers, M. and Sena, V. (2014). The choice between formal and informal intellectual property: *A review, Journal of Economic Literature*, 52, 2, 375-423.

Hall, R. (1992). The strategic analysis of intangible resources, *Strategic Management Journal*, 13, 2, 135-144.

Hanel, P. (2005). Current intellectual property protection practices of manufacturing firms in Canada, In *Intellectual Property and Innovation in the Knowledge-Based Economy*, edited by J. Putnam, Ottawa, Canada.

Hargreaves, I. (2011). Digital opportunity: A review of intellectual property and growth. http://www.ipo.gov.uk/ipreview-finalreport.pdf

Hausman, A. (2005). Innovativeness among small businesses: Theory and propositions for future research. *Industrial marketing management*, 34, 8, 773-782.

Helfat, C. (1994). Firm-specificity in corporate applied R&D. *Organisation Science*, 5, 173-184.

Helmers, C., Rogers, M. (2010). Innovation and the survival of new firms in the UK, *Rev. Ind. Org*., 36, 3, 227-248.

Hewitt-Dundas, N. (2006). Resource and capability constraints to innovation in small and large plants, *Small Business Economics*, 26, 257-277.

Hobday, M., Boddington, A. and Grantham, A. (2012). An Innovation Perspective on Design: Part 2, *Design Issues*, 28, 1, 18-29.

Holgersson, M. (2013). Patent management in entrepreneurial SMEs: a literature review and an empirical study of innovation appropriation, patent propensity, and motives, *R&D Management*, 43, 1, 21-36.

Horn, P. M. (2005). The changing nature of innovation, *Research Technology Management*, 48, 28-33.

Hsu, D. and Ziedonis, R. (2008). Patents as quality signal for entrepreneurial ventures, *Academy of Management Best Paper Proceedings*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/310650/ipresearch-designsreport3-201109.pdf

Hurmelinna-Laukkanen, P. (2009). The availability, strength and efficiency of appropriability mechanisms in knowledge creation, *International Journal of Technology Management*, 45, 3/4, 282-290.

Hurmelinna-Laukkanen, P. (2014). Appropriability regimes in the international playground for innovation, *European Journal of International Management*, 8, 6, 621-643.

Hurmelinna-Laukkanen, P. and Puumalainen, K. (2007). Nature and dynamics of appropriability: Strategies for appropriating returns on innovation, *R&D Management*, 37, 2, 95-112.

Innovate UK (2020). Design in innovation strategy, 2020-24. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910246/InnovateUK_DesignStrategy_Web-Enabled.pdf.

Innovate UK (2021). Building the future economy, Plan for action, for UK business innovation, November 2021. https://www.ukri.org/wpcontent/uploads/2021/11/IUK-18112021-Plan-For-Action-for-UK-Business-Innovation_FULL_WEB-FINAL-26.10.21-1.pdf

Innovation Report (2014). *Department for Business Innovation and Skills*, March 2014, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/293635/bis-14-p188-innovation-report-2014-revised.pdf

IPO (2018). Trends at Intellectual Property Office UK 1995-2017, IPO Report, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/741997/IP-Trends-2018.pdf

IPO (2018b). When do firms not use patents and trademarks to protect valuable innovations? Evidence from the SIPU 2015 survey, IPO Report, 2018/01. Published by The Intellectual Property Office. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/744844/SIPU.pdf

IPO (2020). Use of Intellectual Property rights across UK industries, https://www.gov.uk/government/publications/use-of-intellectual-property-rights-across-uk-industries/use-of-intellectual-property-rights-across-uk-industries

Jensen, P. H. and Webster, E. (2009). Another look at the relationship between innovation proxies. *Australian Economic Papers*, 48, 252-269.

Jensen, P.H., Webster, E. and Buddelmeyer, H. (2008). Innovation, technological conditions and new firm survival. *The Economic Record*, 84, 267, 434-448.

Joshi, A. W. and Sharma, S. (2004). Customer knowledge development: Antecedents and impact on new product performance, *Journal of Marketing*, 68, 47-59.

Keupp, M.M., Lhuillery, S., Garcia-Torres, M.A., Raffo, J. (2009). Economic focus study on SMEs and intellectual property in Switzerland. *2nd Report of the IPISME-IP Project*. Swiss Federal Institute of Intellectual Property.

Kitching, J. and Blackburn, R.A. (2003). Innovation, intellectual property and informality, in *Intellectual Property and Innovation Management in Small Firms, R.A. Blackburn (Ed.) Routledge*.

Kogut, B., and Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science*, 3, 3, 383-397.

Krasnikov, A., Mishra, S. and Orozco, D. (2009). Evaluating the financial impact of branding using trade marks: A framework and empirical evidence, Journal of Marketing, 73, 154-166.

Kretschmer, M. and Soetendorp, R., (2001). The strategic use of business method patents: a pilot study of out of court settlements, *Journal of e-Business*, 2, 1, 9-38.

Landes, W. M. and Posner, R. A. (1987). Trademark law: An economic perspective, Journal of Law and Economics, 30, 265–309.

Laursen, K. and Salter, A.J. (2005). My Precious: The role of appropriability strategies in shaping innovative performance, *DRUID working paper*, 05, 02.

Laursen, K. and Salter, A.J. (2006). Open for Innovation: The role of openness in explaining innovation performance among UK manufacturing firms, *Strategic Management*, J.27, 131-150.

Laursen, K., Salter, A.J. and Li, C. (2013). Protection myopia: Managerial views towards intellectual property and the implications for innovative performance, *Paper presented at the 35th DRUID Celebration Conference 2013*, Barcelona, Spain, June 17-19.

Lee, C.Y. (2010). A theory of firm growth: Learning capability, knowledge threshold, and patterns of growth. *Research Policy*, 39, 278-289.

Lee, K.S., Lim, G.H., Tan, S.J. (1999). Dealing with resource disadvantage: generic strategies for SMEs, *Small Bus. Econ*., 12, 4, 299-311.

Leiponen, A. (2005). Skills and innovation, *International Journal of Industrial Organisation*, 23, 303-323.

Leiponen, A. and Byma, J. (2009). If you cannot block, you better run: small firms, cooperative innovation and appropriation strategies, *Research Policy*, 38, 1478-1488.

Leonard-Barton, D. (1992). Core capabilities and core rigidities: a paradox in managing new product development. *Strategic Management Journal*, 13, 111-125.

Levin, R.C., Klevorick, A.K., Nelson, R.R. and Winter, S.G. (1987). Appropriating the returns from industrial research and development, *Brookings Papers on Economic Activity*, 3, 783-820.

Levinthal, D. and March, J. (1993). The myopia of learning. *Strategic Management Journal*, 95-112.

Levitt, B., and March, J. G. (1988). Organizational learning. *Annual Review of Sociology*, 319-340.

Link, A.N., Paton, D. and Siegel, D.S. (2005). An econometric analysis of trends in research joint venture activity, *Managerial and Decision Economics*, 26, 149-158.

Llerena, P. and Millot, V. (2020). Are two better than one? Modelling the complementarity between patents and trademarks across industries. *Industry and Innovation*, 27, 1-2, 52-79.

Lo, S.T. (2011). Strengthening intellectual property rights: Experience from the 1986 Taiwanese patent reforms, *International Journal of Industrial Organization*, 29, 5, 524-536.

Lopez, A. (2009). Innovation and appropriability, empirical evidence and research agenda, in *The Economics of Intellectual Property*, WIPO Publication No. 1012(E).

Love J. H. and Roper, S. (1999). The determinants of innovation: R & D, technology transfer and networking effects, *Review of Industrial Organization*, 15, 43-64.

Love, J.H. and Roper, S. (2001). Location and network effects on innovation success: Evidence for UK, German and Irish manufacturing plants, *Research Policy*, 30, 643-661.

Love, J.H. and Roper, S. (2005). Innovation, productivity and growth: An analysis of Irish data, in *EARIE Annual Congress*, Porto.

Love, J.H. and Roper, S. (2015). SME innovation, exporting and growth: A review of existing evidence. *International Small Business Journal*, 33, 1, 28-48.

Mansfield, E. (1986). Patents and innovation: An empirical study, *Management Science,* 32, 173-81.

Maskus, K.E. (2008). The globalization of intellectual property rights and innovation in services, *Journal of Industry, Competition and Trade*, 8, 247-267.

McDougall, P., Robinson, R.B. (1990). New venture strategies: an empirical identification of eight 'archetypes' of competitive strategies for entry, *Strat. Manage. J.*, 11, 6, 447-467.

Mendonça, S., Santos Pereira, T. and Mira Godinho, M. (2004). Trade marks as an indicator of innovation and industrial change. *Research Policy*, 33, 1385-1404.

Merges, R.P. and Nelson, R.R. (1990). On the complex economics of patent scope, *Columbia Law Review*, 90, 839-916.

Montresor, S., Perani, G. and Vezzani, A. (2014). How do companies 'perceive' their intangibles? New statistical evidence from the INNOBAROMETER 2013, *Technical Report, European Commission, Joint Research Centre, Institute for Prospective Technological Studies*.

Moultrie, J. and Livesey, F. (2011). Design economics, chapter three: Design right case studies, IPO Report, 2011/7. Published by The Intellectual Property Office. Available at:

Munari, F. and Santoni, S. (2010). Exploiting complementarities in IPR mechanisms: The joint use of patents, trade marks and designs by SMEs, *Paper presented at the Strategic Management Society Annual Conference*, Rome, Italy, 9-12 September.

NESTA (2009). Business Growth and Innovation - The wider impact of rapidly-growing firms in UK city-regions, *Research Report,* October 2009. https://media.nesta.org.uk/documents/business_growth_and_innovation.pdf

OECD (2005). Oslo manual guidelines for collecting and interpreting innovation data, *Organisation for Economic Co-operation and Development*, Paris.

OECD (2015). Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264239012-en

OECD/Eurostat (2018), Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris/Eurostat, Luxembourg. https://doi.org/10.1787/9789264304604-en

Olander, H. Hurmelinna-Laukkanen, P and Mähönen, J. (2009). What's small size got to do with it – Protection of intellectual assets in SMEs. *International Journal of Innovation Management*, 13, 3, 349-370.

ONS (2021). Investment in intangible assets in the UK by industry, https://www.ons.gov.uk/economy/economicoutputandproductivity/output/datasets/investmentinintangibleassetsintheukbyindustry

Park, W.G. and Lippoldt, D.C. (2008). Technology transfer and the economic implications of the strengthening of intellectual property rights in developing countries, *OECD Trade Policy Working Papers, No. 62*, OECD Publishing.

Rivette, K.G., and Kline, D. (2000). Rembrandts in the attic: Unlocking the hidden values of patents, *Boston: Harvard Business School Press*.

Rogers, M., Greenhalgh, C., Helmers, C. (2007). An analysis of the association between the use of intellectual property by UK SMEs and subsequent performance. *Report for UK Intellectual Property Office.*

Roper, S. and Hewitt-Dundas, N. (2015). Knowledge stocks, knowledge flows and innovation: Evidence from matched patents and innovation panel data, *Research Policy*, 44, 7, 1327-1340.

Roper, S., Becker, B., Love, J.H. and Bonner K. (2016). Firms' innovation objectives and knowledge acquisition strategies: a comparative analysis, *ERC Research Paper No.38*, February 2016, Enterprise Research Centre.

Roper, S., Du, J. and Love, J.H. (2008). Modelling the innovation value chain, *Research Policy*, 37, 6-7, 961-977.

Roper, S., Hewitt-Dundas, N. and Love, J. H. (2004). An ex ante evaluation framework for the regional benefits of publicly supported R&D projects. *Research Policy*, 33, 487-509.

Roper, S., Love, J.H. and Bonner, K. (2017). Firms' knowledge search and local knowledge externalities in innovation performance, *Research Policy*, 46, 43-56.

Rosenfeld, S.A. (2018). Manufacturing by Design. *Economic Development Quarterly*, 32, 4, 313-325.

Sattler, H. (2003). Appropriability of product innovations: An empirical analysis for Germany', *Research Papers on Marketing and Retailing N. 003*, University of Hamburg.

Scherer, F.M., Herzstein, S.E., Dreyfoos, A., Whitney, W., Bachmann, O., Pesek, P., Scott, C., Kelly, T. and Galvin, J.J. (1959). Patents and the Corporation: A Report on Industrial Technology under Changing Public Policy: Privately Published.

Schmoch, U. (2003). Service marks as novel innovation indicator, *Research Evaluation*, 12, 149-156.

Schumpeter, J. (1942). Capitalism, socialism and democracy, Harper and Row.

Scotchmer, S. (1991). Standing on the shoulders of giants: cumulative research and the patent law*, Journal of Economic Perspectives*, 5, 29-41.

Shapiro, C. (2000). Navigating the patent thicket: Cross licenses, patent pools, and standard setting. *Innovation Policy and the Economy*, 1, 119-150.

Shelanski, H.A. and Klein, P.G. (1995). Empirical research in transaction cost economics: A review and assessment. *Journal of Law, Economics and Organization*, 11, 335-361.

Srinivasan, R., Lilien, G.L., Rangaswamy, A. (2008). Survival of high-tech firms: the effects of diversity of product–market portfolios, patents, and trademarks. *Int. J. Res. Marketing*, 25, 2, 119-128.

Taylor, C.T. and Silberston, Z.A. (1973). The Economic impact of the patent system: A study of the British experience. *Cambridge University Press*: Cambridge.

Teece, D.J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy, *Research Policy*, 15, 285-305.

Teece, D.J. (1998). Capturing value from knowledge assets: The new economy, markets for know-how, and intangible assets, *California Management Review,* 40, 3, 55-79.

Teece, D.J. (2000). Strategies for managing knowledge assets: the role of firm structure and industrial context, *Long Range Planning*, 33, 35-54.

Teece, D.J. and Pisano, G. (1998). The dynamic capabilities of firms: An introduction, in Technology, Organisation and Competitiveness: Perspectives on Industrial and Corporate Change, G. Dosi, D. J. Teece and J. Chytry (Eds.), New York, Oxford University Press Inc., 17-66.

Thomä, J. and Bizer, K. (2013). To protect or not to protect? Modes of appropriability in the small enterprise sector, *Research Policy*, 42, 35-49.

Thrane, S., Blaabjerg, S. and Moller, R.H. (2010). Innovative path dependence: Making sense of product and service innovation in path dependent innovation processes. *Research Policy*, 39, 932-944.

Tidd, J., Bessant, J. and Pavitt, K. (1997). Managing innovation: Integrating technological, market and organizational change, Wiley, Chichester, UK.

TRIPS (1994). Agreement on Trade-Related Aspects of Intellectual Property Rights, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299, 33 I.L.M. 1197 (1994).

Turner, J. (2019). Trade marks and registered designs: Evidence on the links to innovation and business performance, *Enterprise Research Centre, State of the Art Review*, No.19.

Turner, J. and Roper, S. (2020). Understanding the role of IP protection in UK firms' growth, productivity and innovation 1998-2016: Patents, trade marks and registered designs reconsidered, *ERC Research Paper 90*.

Veer, T. and Jell, F. (2012). Contributing to markets for technology? A comparison of patent filing motives of individual inventors, small companies and universities, *Technovation,* 32, 9-10, 513-522.

Wernerfelt, B. (1984). A resource-based view of the firm, *Strategic Management Journal*, 5, 2, 171-180.

West, J. (2006). Does appropriability enable or retard open innovation? in *Open Innovation: Researching a New Paradigm, H. Chesbrough, W. Vanhaverbeke and J. West (eds.*), Oxford University Press.

WIPO (2017). Innovation and Intellectual Property https://www.wipo.int/ip-outreach/en/ipday/2017/innovation_and_intellectual_property.html

WIPO (2021). IP protection: building value and growth for small businesses, March 2021, WIPO Magazine, https://www.wipo.int/wipo_magazine/en/2021/01/article_0003.html

Yale Insights (2015). Are 'patent thickets' smothering innovation? https://insights.som.yale.edu/insights/are-patent-thickets-smothering-innovation

Yoshioka-Kobayashi, T., Fujimotod, T. and Akiikee, A. (2018). The validity of industrial design registrations and design patents as a measurement of "good" product design: A comparative empirical analysis, *World Patent Information*, 53, 14-23.

Centre Manager
Enterprise Research Centre
Warwick Business School
Coventry, CV4 7AL
CentreManager@enterpriseresearch.ac.uk

Centre Manager
Enterprise Research Centre
Aston Business School
Birmingham, B1 7ET
CentreManager@enterpriseresearch.ac.uk

www.enterpriseresearch.ac.uk