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Abstract

Using a large, longitudinal panel (2004-2011) of USA start-ups this paper shows the extent to which IP types (e.g. trademarks, patents, copyrights, outward licensing) enhance multidimensional performance. An ordered probit analysis (with random effects), corrected for sample selection bias, estimates performance to derive the following conclusions. First, trademarks and out-licensing IP types increase a firm's chances of being a high performer, confirming the importance of certain forms of IP protection for start-ups. Second, patenting significantly reduces the chances of being a high performer, suggesting patenting has limited performance benefits for start-ups. Third, few performance synergies exist in the *joint* use of IP types, suggesting that strong complementarities among IP types are limited. While out-licensing patents *and* out-licensing copyrights certainly increase performance, out-licensing patents *and* out-licensing trademarks actually diminish it. Further, registering more trademarks *and* outlicensing more trademarks also diminishes performance, suggesting start-up firms should keep trademarks in-house.

Keywords: Performance, firm start-ups, intellectual property, out-licensing, complementarities

JEL Codes: C55, D22, L25, O34

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1. Introduction

This paper assesses whether start-ups which seek protection for their intellectual capital achieve higher performance, building on earlier works by Agostini et al. (2016), Maresch et al. (2016), Suh and Hwang (2010) and Peña (2002). Specifically, it examines how IP types influence their chances of being a high, medium or low performer. Intellectual capital such as skills, knowledge and creativity, rooted in products and/or services, are a potential source of competitive advantage for many entrepreneurs (Fisher et al., 2013). Deriving benefits from intellectual capital, by creating intellectual property (IP), may be achieved through legal rights, like copyrights, registered trademarks and patents (Greenhalgh and Rogers, 2007). Start-ups with intellectual capital may protect it either by obtaining such legal rights, or by exploiting their IP through special contracts such as 'out-licensing' (Motohashi, 2008). Shapira and Wang (2009) find that the initial stock of intellectual property is a key influence on the development trajectory of start-ups, arguing that most rely on a core technology, only using additional R&D to make minor product/service adjustments. However, evidence shows that few start-ups seek legal rights to protect their own intellectual property (Leiponen and Byma, 2009). Instead, most rely on informal mechanisms such as trade secrecy, faster lead times, or being first to market (Hanel, 2008; Laursen and Salter, 2005; González-Álvarez and Nieto-Antolín, 2007). These mechanisms are less costly and less complex. This paper explores whether start-up firms, with more costly and complex legal protections for their IP types, achieve greater performance.

As many start-ups choose not to formally protect their intellectual property, research tends to focus on large firms (Sydler et al., 2014; Riahi-Belkaoui, 2003) and on patenting (Agostini et al., 2015; Sandner and Block, 2011; Artz et al., 2010). Exceptionally, Hsu and Ziedonis (2013) examined patenting by small entrepreneurial firms seeking venture capital. Zhou et al. (2016) extend this research to trademarks and patenting (and their potential synergies, or otherwise, in venture capital funding). While Thomä and Bizer (2013), and Kitching and Blackburn (1998), examine how small firms use IP to protect intellectual capital, others examine the effect of patenting (Leiponen and Byma, 2009; Helmers and Rogers, 2011), trademarks (Block et al., 2015) and licensing (Motohashi, 2008) on the performance of new start-ups. No study comprehensively examines the effect of a portfolio of IP types on small firm start-up performance. To illustrate, while Agostini et al. (2016) recently focussed on IP use in Italian SMEs, they limit their study to just *two* different IP types (viz. patents and trademarks). In addition, few studies consider the impact of the *joint* use of intellectual property types on performance, and their associational characteristics (e.g. in terms of complements and substitutes), and none appear to apply these investigations to a large sample of start-ups. In comprehensively assessing whether start-ups who solely or jointly use legal protections for a wide range of IP types achieve rewards in terms of higher performance, we bridge this research gap in the literature.

It is important to explore the relation between firm performance and: (i) a broad *range* of IP types; and (ii) their potential *synergies*, arising from the joint use of IP types. This is because the strength of individual appropriation methods may derive largely from how a portfolio of IP types is developed. Thus, exploitation of their joint, rather than just their solo, characteristics will create the synergies that lead to enhanced performance (Bosworth and Webster, 2006). While a patent certainly signals technological advance within a firm and potential innovativeness (Ayerbe et al., 2014), this is far from being a guarantee of commercial success, let alone an indicator of likely implementation of the technology. On the other hand, trademarks signal something more solid, performance wise e.g. suggesting wider market access, and a marketing capability which is a good match for emerging products (Block et al., 2015). Thus, their impact on performance is likely to be greater for start-ups, and their joint use is arguably synergistic given that patents focus on product development alone, whereas trademarks focus more on market developments for 'oven ready' products. Insights of this nature have important implications for both the practical management of a portfolio of IP, and the strategic recommendations of enterprise development agencies, who advise start-ups on the management of their IP portfolio.

The originality of this paper rests on our comprehensive exploration of: (1) how the *full set* of IP types impact on small firm start-up performance; (2) how their *joint use* affects small firm start-up performance building on studies proposing such synergistic effects (Thomä and Bizer, 2013; Amara et al., 2008); and (3) how, using econometrics, a multi-dimensional measure of *Performance* helps us understand better the impact that IP types have on overall start-up performance. Existing studies largely focus on single dimensional measures of performance such as sales (Agostini et al., 2016; Suh and Hwang, 2010). The use of such multi-dimensional performance indicators to capture more fully business success in small firms, has been explored successfully by Power and Reid (2015). Further development of broader measures, in IP studies, has only recently been undertaken e.g. Maresch et al. (2016). We explore how IP types affect start-up performance using the eight-year Kauffman panel[1] dataset of start-ups in the USA, with

about 2,000 to 5,000 firms in each year, giving us about 24,000 observations. It is a rich data source containing measures of diverse intellectual property types (including patents, trademarks and copyrights and out- licensing) and a set of control variables (including sectors and size) for inclusion in estimation. Econometric estimation was by an ordered probit, with random effects corrected for sample selection bias. Interaction terms between IP types were included to capture the influence of the joint use of IP types on the overall performance of a sample of US firm start-ups.
Briefly, this paper is structured as follows: Section 2 shows how our research arose from extant works and states our key hypotheses. Section 3 explains the modelling (e.g. data, variables, performance measurement, and econometrics). Section 4 reports on empirical results (e.g. marginal effects, interactions). Section 5 summarises the findings and their limitations, implications for practice and policy, and potential for further development.

2. Literature

Theories about the relationship between IP types and firm performance often espouse the resource-based view of the firm. This suggests that creating and maintaining strategic resources and capabilities fosters above average performance (Peteraf, 1993; Wernerfelt, 1984). To retain competitive advantage, resources must be valuable, rare, and difficult to copy (Barney, 1991). Knowledge is the firm's main resource satisfying these attributes. Assets related to knowledge are called intellectual capital (Subramaniam and Youndt, 2005; Teece, 2002), and Edvinsson and Malone (1997) split this threefold into: human capital, structural (organizational) capital and relational (customer) capital. Structural capital includes intellectual property like patents, copyrights, licenses, etc. Grant (1996) and Nonaka (1994) show how these impact on performance (especially in start-ups). Research by Neuhäusler (2012) shows that small firms underinvest in formal means of protecting IP and knowledge assets; and asks if such mechanisms yield below average performance, concluding 'yes': they have little advantage over informal methods, like trade secrecy.

2.1 Patenting

Offensively, firms patent to protect their inventions against imitation (Blind et al., 2006). Defensively, firms patent to prevent rivals leapfrogging them. Patents are also sources of licencing income, useful for international expansion, and enhance the firm's technological image/reputation (Blind and

Thumm, 2004). Unfortunately, these benefits adhere more to large firms rather than start-ups. Torrisi et al. (2016) found that small firms were less likely to patent or to inward license, than large firms. Further, small firms face higher fixed cost of patenting, and receive lower benefits, compared to large firms, through being disadvantaged in enforcing legal rights (Blind et al., 2006). Thus, patenting is likely to have a negative effect on the performance of small firm. For them, informal mechanisms of IP protection are typically used alternatively, and to better effect (Kitching and Blackburn, 1998). Given findings of a negative (Hall et al., 2007) or insignificant performance impact (Artz et al., 2010; Suh and Hwang, 2010) of patents on small firms, we hypothesize (*H1*), that start-ups suffer a negative effect upon performance from using patents.

H1: As start-ups increase their holdings of patents, they are likely to experience a reduction in performance.

2.2 Trademarks

Trademarks protect brands rather than inventions. They signal products quality and help consumers to differentiate between the products of a company and their rivals (Besen and Raskind, 1991; Landes and Posner, 1987). The prominence of trademarks is evident in the vast number of trademark applications. SMEs are more likely to engage in trademarking than large firms (Rogers et al., 2007; Greenhalgh and Rogers, 2010). They differentiate products in niche markets, thus strengthening branding (Block et al., 2015). It is also less costly (and less complex) to register trademarks, which arguably signal quality to equity funders, and foster partnerships and strategic alliances (Motohashi, 2008; Block et al., 2015).

We conclude that the effect of trademarks on performance is likely to be positive (Sandner and Block, 2011; Greenhalgh and Rogers, 2012). In support, Srinivasan et al. (2008), Jensen et al. (2008) and Helmers and Rogers (2010) find that small firms' trademarks reduce their exit rate. Therefore, H2 holds that, for start-ups, a positive relationship exists between trademarking and performance.

H2: As start-ups increase their holdings of trademarks they are likely to experience improved performance.

2.3 Copyrights

Copyrights enable the firm to protect and benefit from creative work. Registering is easy, though enforcement is expensive. Bainbridge (1999) argued that fighting a copyright breach was legally complicated, both nationally and internationally. Though copyrighting is widespread, Greenhalgh and Rogers (2007) reported little reliable evidence that copyrighting brings value to the firm. Most research is at the industry, rather than the firm level, and emphasises *enforcing* copyrights rather than *valuing* them (Dickson and Coles, 2000). Suh and Hwang (2010) investigated the effect of IP rights on the performance of software firms in South Korea, and found that copyrighting, compared to patenting, had a more positive effect on firm performance. Thus, H3 suggests a positive relationship between copyrights and small firm performance.

H3: As start-ups increase their holdings of copyrights, they are likely to experience improved performance.

Licensing

Unfortunately, there has been little research on open sourcing, and particularly out-licensing (Mortara and Minshell, 2011). In out-licensing IP, firms benefit from both royalty payments and other non-pecuniary benefits (e.g. access to knowledge, co-licensing). The ‘desorptive’ (rather than ‘absorptive’) capacity has also been examined (Müller-Seitz, 2012; Bianchi et al., 2011), mainly in a large firm context, but to a degree in start-ups. To illustrate, Motohashi (2008) explored the economic effects of out-licensing through two effects: revenue (+) and rent dissipation (-). The former arises from exploiting IP. The latter from increased product competition. Arguably, rent dissipation is lesser for smaller firms, as their lesser market power increases their appetite for out-licensing.

Out-licensing deals are clinched in recognition of the significant value in a firm’s IP (Hu et al., 2014). They are motivated, in smaller firms, by a lack of resources to exploit their value. Motohashi (2008) finds that start-ups and smaller firms license more, to compensate for their lack of complementary assets for appropriating economic rent via R&D. Pereira et al. (2015) argues that gaining revenue from licensing makes an attractive business model for start-ups. It enables them to develop foreign markets quickly at lower costs and with greater revenue. While Pereira et al. (2015) found no evidence of a positive impact of out-licensing patents on sales growth, for US High Tech start-ups (a sub sample of the Kauffman firm survey between 2004 and 2010), they found it was a key component in building a patent portfolio for offensive and defensive reasons (e.g. blocking competitors, increasing bargaining power in cross-licensing agreements).

Motohashi (2008) and Pereira et al. (2015) focussed on out-licensing *patents* rather than out-licensing *other forms* of IP (e.g. copyrights and trademarks). Block et al. (2015) focussed on trademarks and argued that capital rationed and resource-constrained smaller firms also benefitted from out-licensing trademarks: by extending their reach to foreign markets and to other regions where they are not currently trading. They also argued that trademark registration was an important precursor to franchising and found that trade market exchanges were important to SMEs who were trademark advocates. While out-licensing copyrights is now commonplace (de Laat, 2005), compared to twenty years ago, there has been little exploration of the performance benefits of this, as it has accrued to small start-up firms. However as indicated above, Suh and Hwang (2010) found positive revenue effects from copyrights, as opposed to patenting, for software firms. Such positive revenue effects may be extended to out-licensing copyrights.
Given the above, a positive relationship between out-licensing IP types and performance is postulated in H4.

H4: Start-ups who engage in out-licensing IP types achieve greater performance.

2.4 Complementarities

Jacobsen et al. (2005) argued that the value of knowledge assets lay in their combined, rather than individual, characteristics. Working together effectively creates synergies. Capturing less-novel aspects of new product varieties (e.g. reputable source, quality design) registered trademarks complement legal protection provided by patents (and copyrights, for software development) which are only awarded for new inventions (or code) with industrial application (Greenhalgh and Longland, 2005). Trademarks assist in the market exploitation of innovations rather than by the actual innovations themselves. This is how the synergy of intangibles creates a competitive advantage (Roos et al., 2001). It explains why the *range* of IP forms is so important to our research. Cassiman and Veugelers (2006) also discuss the synergies between different elements of IP (e.g. trade secrecy, and legal protections). They find that internal R&D, and external knowledge acquisition, are also complementary innovation activities. However, they argue that the degree of complementarity is sensitive to other features of the firm's strategic environment, such as firm size, marketing and manufacturing capacities, competition, the level and type of innovation and R&D (Thomä and Bizer, 2013). Given these sensitivities, Motohashi (2008) has suggested that revenue-based synergies for high tech start-ups exist: from out-licensing these forms of IP protections to larger firms, who have the capacity to exploit them.

While there is some evidence of complementarities between IP rights in both large (Greenhalgh et al., 2003; Loundes and Rogers, 2003) and small firms (Amara et al., 2008), no study (of which we are aware) examines whether these synergies lead to improvements in performance. This neglect, which we aim to rectify in our research, is particularly true of micro-firms and start-ups. Greenhalgh et al. (2003) found for UK manufacturing firms, and Loundes and Rogers (2003) for Australian firms, evidence of a dependence between patenting and registered trademarks. Further, Amara et al. (2008), for a sample of Canadian Knowledge-Intensive Business Services (KIBS), found that trademarks complemented, rather than substituted for, patents and copyrights. Thomä and Bizer (2013) found that the *joint use* of trademarks and patents (or trademarks and copyrights) was effective in improving performance, for a sample of innovative small start-ups of 5-49 employees. We therefore seek to explore whether the *joint use* of formal IP types leads to improvements in performance, through hypothesis H5.

H5: Greater complementarities between IP types are likely to raise the performance of start-ups.

Extending the above, we explore complementarities in the *joint use* of IP types and the out-licensing of these forms of IP, as well as the *joint use* of out-licensing of different forms of IP types. We do this as out-licensing IP, in itself, is a legal protection and can have positive revenue consequences for small firms and start-ups. Papageorgiadis et al. (2016) found that copyright and trademark enforcement strength had a highly significant effect on licensing, and on motivating increased levels of unaffiliated licensing. Creating a patent portfolio generates opportunities for licensing these patents (Pereira et al., 2015) and the out-licensing of patents may also present opportunities to out-license both trademarks and copyrights. The performance benefits of these complementarities have not yet been explored fully to date, for either large or small firms.

3.Modelling and Data

3.1 Modelling

The starting point of our modelling is the construction of a 'performance indicator' viz. a function that captures the multidimensional nature of performance in a start-up. This indicator is expressed thus: $y \equiv \Phi(\boldsymbol{Z})$ where $\boldsymbol{Z} = (z_1, z_2, \ldots . z_n)$ is a vector of variables which are commonly used to measure performance: like sales, profitability etc. $\Phi(.)$ is defined in a complex way. It is basically a lexicographic, data-reduction algorithm, using data quartiles to 'boil down' the information given by eight familiar performance variables into a simple one-dimensional ordered variable (see Subsection 3.3). This becomes the dependent variable in our econometric model, where y is now assigned values of $(1, 2, 3)$, to be interpreted as low, medium and high performance respectively.

Consider how such a performance indicator is explained by our intellectual property types. At its simplest:
Performance (y) = F (IP Types, Controls; Random Variables)
(1)

Expression (1) can be expressed in symbols as follows:
$y = F(\boldsymbol{IP}, \boldsymbol{X}; \boldsymbol{R})$ where the symbols have the following definitions
(2)

IP is a vector which contains four types of intellectual property (IP), namely: patent (P); copyright (C), trademark (T) and out-licensing of IP types (LO_i) as above.

X is a vector of control variables, like ownership, incorporation, sector, etc.

R is a vector of key random variables pertaining to estimation of an ordered probit model, with random effects, and an adjustment for sample selection bias (e.g. random variables ε, v as set out in end note 5).

Expressing (2) explicitly in terms of our key objects of interest, IP types, we get:
$y = F(P, T, C, LO_i; \boldsymbol{X}, \boldsymbol{R})$ (3)
where we expect $\partial y/\partial P > 0$, $\partial y/\partial T > 0$, $\partial y/\partial C > 0$ and $\partial y/\partial LO_i > 0$ in accordance with H_1, H_2, H_3 and H_4.
Equation (3) can be refined further by recognising the potential associative relationships between IP types. Formally we are extending our performance model, *Performance* (y) $= F(P, C, T, LO_i, X)$ to capture potential

complementarities by including interaction terms between, for instance, patents and copyrights *(PC)*, copyrights and trademarks *(CT)* and patents and trademarks *(PT)* or between out-licensing of IP types (LO_i) where i is an index for three types of IP denoted (P, C, T). We also examine interaction effects for out-licensing different forms of IP (LO_{ij}) where i and j ($i \neq j$) are different forms of IP. Taking these nuances into account, the model specification becomes:

Performance (y) $= F(P, C, T, LO_i, LO_{ij}, PC, CT, PT, LO_P P, LO_C C, LO_T T, X)$ (4)

For example, if a start-up is sufficiently technology aware, it might find that patenting (P) is associated with 'out-licensing patents' (LO_P) to recognise potential complementarities between P and LO_P where IP type i is denoted as P for patents in this instance. This would be indicated by $k(P, LO_P)$, for which P and LO_P may vary positively in some systematic way viz. $\partial P/\partial LO_P > 0$. Such effects as $k(.)$ are considered in our econometric modelling, often specified in multiplicative forms. All the plausible associative relationships among IP types referred to in Section 2 and equation (4) can be fleshed out as follows:

$y = F\,(P, T, C, LO_i; LO_{ii}, f\,(P, T), g\,(P, C), h\,(T, C), k(P, LO_P), l(C, LO_C), m(T, LO_T); \boldsymbol{X}, \boldsymbol{R})$

(5)

in which the associative relationships are functions $g(.)$, $h(.)$, $k(.)$, $l(.)$ and $m(.)$. Equations (3) and (5) are estimated by an econometric technique suitable for panel estimation (described in 3.4 below), on our Kauffman data-set (described next in 3.2).

3.2 Data

The study uses data gathered on firms between 2005 and 2012 from the longitudinal Kauffman Firm Survey covering the first 8 years of business operations from 2004 to 2011. All new businesses (including franchises) started in 2004 in the USA (save branches or subsidiaries of existing businesses) were included in the sampling frame. The initial frame of approximately 238,000 start-ups in 2004 was provided by Dun & Bradstreet. They identified new firm start-ups from diverse sources (e.g. credit bureaus, state offices, credit card and shipping companies). The total sample frame of 32,469 firms consisted of three strata of 3,869 high tech, 7,574 medium tech and 21,026 non-tech, start-up firms which were sampled using sequential random sampling until data was gathered on approximately 5,000 firms.

The Kauffman data were collected by self-administered web survey and Computer-Assisted Telephone Interviewing (CATI). There was extensive question pretesting and piloting (N=400) of the final survey instrument and Mathematica's quality assurance methods were employed in processing the data (DesRoches et al., 2013). Response burden and common method bias (Podsakoff et al., 2012) was reduced by asking respondents to confirm information provided in previous interviews and collecting new data only when a change had occurred. Questions were factual in nature and thus were less likely to be affected by common method bias. This freedom from bias was confirmed by Harman's single factor test of the regressors included in estimation[2]. Table 1 provides information on survey rounds. It shows that in the base year of 2004, 4,928 surveys were completed. This represented a 43% response rate when sampling weights were applied (Ballou et al., 2008). These firms were then tracked annually through to the final (eighth) year in 2011. The respondent numbers fell year-by-year due to attrition, refusals, change of contact and businesses exits. We constructed an 'unbalanced panel', tracking all surviving businesses. This yielded a panel database of 25,542 observations. It provided vital information on: (a) multiple dimensions of performance (e.g. profit, sales); and (b) the wide range of IP (e.g. patents, copyright, trademarks, out-licensing). Using firms' exit data we corrected our model for sample selection bias. This is discussed further in Sections 3 and 4. The key variables used in the econometric modelling are described and defined in Table 2.

Table 1 Kauffman Firm Survey

Survey Round	**Data Collection**	**Information Gathered for**	**Completed Interviews**	**Survivors to the next survey Round**	**Non survivors at end of survey round**
Baseline survey (Year 0)	July 2005 – July 2006	2004	4,928	4,625	303
First Follow Up (Year 1)	June 2006 – Jan 2007	2005	3,998	4,068	346
Second Follow Up (Year 2)	May – Dec 2007	2006	3,390	3,598	338
Third Follow Up (Year 3)	June – July 2008	2007	2,915	3,203	429
Fourth Follow Up (Year 4)	June – July 2009	2008	2,606	2,811	320
Fifth Follow Up (Year 5)	May – Nov 2010	2009	2,408	2,591	296
Sixth Follow Up (Year 6)	May – Nov 2011	2010	2,126	2,300	295
Seventh Follow Up (Year 7)	May - Dec 2012	2011	2,046	2,046	-

Source: Adapted from DesRoches et al. (2013).

Note. 4928 firms completed the baseline survey which gathered data for the year 2004. When the first follow-up survey occurred only 4625 firms are known to have survived and 303 firms had ceased to trade in the meantime. Of the 4625 surviving start-ups firms 3998 completed interviews in the first follow-up, the difference being survey attrition etc. After the first follow-up 4,068 firms are known to have survived to the second follow up out of the

4,928 firms originally interviewed. A further 346 firms had ceased to trade. In the second follow-up, 3390 surviving start-ups completed interviews. After the second follow-up 3,598 firms are known to have survived to the third follow up; 338 ceased to trade and 2,915 start-ups were interviewed in this third follow-up. We hope the above explanation assists in interpreting the information in Table 1.

Table 2 Variable Definitions and Summary Statistics (Panel Estimates)

Variable	Definition	N	Mean	SD	Min	Max
Size	A count of all full-time and part-time employees excluding contract workers and the business owner(s)	24,429	2.9367	6.1482	0	61
Debt	Includes total debt of the owner operators and total debt of the business (bank and non-bank debt sources). It is captured on an ordered scale where 0=$0; 1= less than $500; 2=$501-$1,000; 3=$1,001- $2,000; 4=$2,000-$5,000; 5=$5,001 to $10,000; 6=$10,001 to $25,000; 7=$25,001 to $100,000; 8 =$100,001 to $1,000,000; and 9=greater than $1,000,000.	24,483	2.8857	3.1711	0	9
Team of owners	=1 if a business with more than one owner; = 0 otherwise	24,660	0.3811	0.4856	0	1
Purchased	=1 if the business operates out of premises which the business purchased; = 0 otherwise	24,650	0.0643	0.2453	0	1
Incorporated	=1 if the business is incorporated; = 0 otherwise	24,650	0.6475	0.4777	0	1
Total equity of owners	Includes total equity of the owner operators. It is captured on an ordered scale where 0=$0; 1= less than $500; 2=$501-$1,000; 3=$1,001- $2,000; 4=$2,000-$5,000; 5=$5,001 to $10,000; 6=$10,001 to $25,000; 7=$25,001 to $100,000; 8 =$100,001 to $1,000,000; and 9=greater than $1,000,000.	24,387	2.1494	2.8010	0	9
Service	=1 if a business sells a service ; = 0 otherwise	24,570	0.8610	0.3459	0	1
Product	=1 if a business sells a product; = 0 otherwise	24,567	0.4861	0.4998	0	1
PhD	Count of owners with PhD degree	25,542	0.0945	0.3608	0	6
Expenditure on R&D	=1 if the business spent money on research and development of new products and services during calendar; = 0 otherwise.	24,343	0.1890	0.3915	0	1
High tech	=1 if 28 Chemicals and allied products, 35 Industrial machinery and equipment, 36 Electrical and electronic equipment or 38 Instruments and related products; = 0 otherwise	25,542	0.1281	0.3342	0	1
Patents	Count of patents of the business	24,335	0.1717	1.9919	0	100
Copyrights	Count of copyrights of the business	24,058	1.4881	12.2427	0	250
Trademarks	Count of registered trademarks of the business	23,987	0.2809	1.4617	0	100

Out-licensing patents	=1 out-licensing patents; = 0 otherwise	25,542	0.0039	0.0642	0	1
Out-licensing copyrights	=1 out-licensing copyrights; = 0 otherwise	25,542	0.0129	0.1127	0	1
Out-licensing trademarks	=1 out-licensing trademarks; = 0 otherwise	25,542	0.0084	0.0914	0	1
Manufacturing	= 1 Manufacturing; 0 = otherwise	25,513	0.1444	0.3415	0	1
Construction	= 1 Construction; 0 = otherwise	25,513	0.0796	0.2707	0	1
Wholesale Retail	= 1 Wholesale and Retail; 0 = otherwise	25,513	0.1436	0.3507	0	1
Low Knowledge IS	= 1 Low KIS ; 0 = otherwise	25,513	0.2383	0.4261	0	1
Knowledge IS	= 1 Knowledge Information Services; 0 = otherwise	25,513	0.3828	0.4861	0	1
Other	= 1 Other; 0 = otherwise	25,513	0.0113	0.1058	0	1
Year	Year that the data was collected for.	25,542	2006	2.259	2004	2011
North East	= 1 North East; 0 = otherwise	24,369	0.1618	0.4377	0	1
Mid-West	= 1 Mid-West; 0 = otherwise	24,369	0.2566	0.4367	0	1
South	= 1 South 0 = otherwise	24,369	0.3228	0.4680	0	1
West	= 1 West; 0 = otherwise	24,369	0.2588	0.4380	0	1
Composite Performance Indicator	=1 low performer (lower quartile); = 2 medium performer (interquartile range); =3 high performer	25,542	2.005	0.7985	1	3
Perceived Competitive Advantage	=1 perceived a competitive advantage; =0 otherwise	24,492	0.5928	0.4913	0	1
$Assets_t$	Total Assets in year t	24,330	268K	481K	0	2000K
$Sales_t$	Total Revenue in year t	23,870	332K	552K	0	2000K
Return on $Equity_t$	$Profit_t$ divided by total equity in year t	23,597	2.5092	65.36	2196	2665
$Profit_t$	Net income in year t	23,621	32,038	282K	-2000K	2000K
Rate of $profitability_t$	$Profit_{t/}$ $Assets_t$	21,931	0.5937	29.19	-733	2196
Survival	=1 firms that survived to the next period; =0 otherwise	25,542	0.9089	0.2877	0	1

NAICS[3] sectors from 11 to 92 were represented. In the base-year (2004), % representation included: construction (7.9%), manufacturing (14.6%), wholesale and retailers (15.1%), low knowledge services (24.3%), with knowledge intensive services (36.9%) being strongly represented in the sample. By 2011 even more firms were in knowledge intensive services (41.1%). Marginally fewer survived in the other sectors, including: construction (7.4%), manufacturing (13.2%), wholesale and retailers (13.7%), low knowledge services (23.4%). All four census-bureau designated regions of the USA were represented. Percentages (% 2004, % 2011) were as follows: Northeast (15.6%, 17.5%), Midwest (25.1%, 26.1%), South (33.7%, 31.6%) and West (25.6%, 24.9%). The average employee size of the businesses at start-up was 1.68 (3.83), standard deviation in parentheses. Thus, these businesses were small at start-up. Judged against a wide variety of size measures, the firms in our sample are a good reflection of the population of small entrepreneurial firms in the USA, (Statistics of U.S. Businesses, US Census Bureau).

1.3 Key Variables

The key independent variables in this paper are defined in Table 2. This table lists relevant IP and control variables. The performance (*y*) variable – see equation (1) above has a composition which is explained in Table 3. In that table, eight components of *y* are given (e.g. assets, sales, RoE, etc.), as are their upper quartiles (P75), for each year. This variable (*y*), is explained first, in terms of its construction, in this section. The explanation of the independent variables (**IP**, **X**) follows.

Table 3: Dimensions of Composite Performance Indicator

	Year							
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Dimensions (*d*)	**P75**	**P75**	**P75**	**P75**	**P75**	**P75**	**P75**	**P75**
Perceived Competitive Advantage	1	1	1	1	1	1	1	1
$Assets_t$	62.5K	550K	550K	550K	550K	550K	550K	550K
Size	2	3	3	3	3	3	3	4
$Sales_t$	62.5K	550K	550K	550K	550K	550K	550K	550K
Return on $Equity_t$	28%	100%	100%	100%	100%	100%	100%	100%
$Profit_t$	4K	62.5K	62.5K	62.5K	62.5K	17.5K	17.5K	17.5K
Rate of $profitability_t$	12%	53%	100%	100%	50%	100%	100%	100%
Survival	1	1	1	1	1	1	1	1
Composite Performance Indicator	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Low Performer – P*25*	1	1	1	1	1	1	1	1
Medium Performer - Interquartile range	2-3	2	2-3	2-4	2-3	2-3	2-4	2-3
High Performer – *P75*	4+	3+	4+	5+	4+	4+	5+	4+

Note:

P75 refers to the upper quartile range; P25 refers to the lower quartile range.

Firms with upper quartile performance on dimension *d* in year *t* received a score of '1' for that dimension in year *t*. The scores for each firm on each performance dimension *d* in year *t* were summated to obtain the composite performance indicator for a firm in year *t*. The ranges for low (P25), medium (interquartile range) and high (P75) overall performance based on the composite performance indicator are also presented by year.

Performance (*y*)

Following Maresch et al. (2016) our performance indicator (*y*) used several performance dimensions. Using modern multidimensional conceptions of performance (Chen et al., 2012; Epstein and Manzoni, 2002; Chrisman et al., 1998), the indicator (*y*) compounds the effects of eight elements which include: (a) assets, headcount, sales, return on equity, profit, profitability (measured as continuous variables); and (b) survival and perceived competitive advantage (measured as binary variables). Table 3 details these eight dimensions; and Table 2 defines these dimensions and presents summary statistics on these variables.

To obtain our performance indicator, we assess the performance of each start-up firm on each dimensions *d* in year *t*, relative to the distribution of performance of all start-up firms in the sample on each dimension in year *t*, thereby accounting for the relative nature and multidimensional nature of performance (Kay, 1993). We use the 75th percentile values on each dimension of performance for start-up firms presented in Table 3 by year to identify the upper boundary classification for high performance on that dimension *d* in year *t*. Firms who were classified as 'high performers' (defined as upper quartile performance) on dimension *d* in year *t* received a score of '1' for that dimension in year *t*. The scores for each firm on each performance dimension in year *t* were then summed to obtain the composite performance indicator for a firm in year *t*. Highest performers *across all eight* dimensions in a given year *t* received a total performance score of '8' for that year (i.e. achieved upper quartile performance on all dimensions). At the other end of the continuum the lowest performers *across all eight* dimensions in a given year *t* (i.e. failed to achieve upper quartile performance on any dimension) received a total performance score of '0' for that year (i.e. failed to achieve upper quartile performance on any dimension)[4]. Our three-category ordered performance indicator (y) adopted in econometric estimation (viz. ordered probit panel estimation) was constructed from the composite performance indicators of firms in year *t*. The distribution (lower, inter and upper quartile range) of these composite performance indicators for all firms in year *t* are also provided in Table 3. Firms achieving a composite performance score in the upper quartile range in year *t* were coded as '3' for high performers in year *t*. Similarly, firms with composite performance scores within the 'inter', and 'lower', quartile ranges in year *t* were coded as '2' and '1' in that year respectively for medium and low performers.
This approach is supported by academics like Richard et al. (2009) who favour multidimensional measures of organizational performance over

accounting and financial dimensions. Santos and Brito (2012) too advocate this approach. From a practitioner standpoint, they advised looking at all elements of performance, before evaluating decisions and actions.

*Intellectual Capital (**IP**)*

The full range of IP types, including patents, trademarks and copyrights and outward licensing, is incorporated into the analysis. Patents, trademarks and copyrights are measured similarly. They are approximated here by a business reported count of these individual legal property rights owned by the business. We do not have data on forward or backward citations of patents (Frietsch et al., 2014) but having data on other sources of intellectual property rights is useful in the context of start-ups as it captures more of the innovative performance of small firms (Mendonça et al., 2004). Few studies incorporate all three of these measures of structural intellectual capital. Less than 4% of the sample interviewed in any year possessed patents. Less than 10% had registered copyrights and less than 14% had registered trademarks. The low proportion of start-ups investing in legal rights to protect their intellectual capital is not uncommon. Neuhäusler (2012) found in a large-scale survey of patenting firms in Germany that only 7.4% stressed the importance of formal appropriation methods. It suggests that business owners are more inclined to allocate scarce resources to developing new products and processes rather than protecting existing products, (Kitching and Blackburn, 1998). Business owners are not predisposed to obtain and enforce formal and registrable rights. About a fifth of our firms who acquired copyrights or trademarks in any year also had patents; but almost sixty percent of those who had copyrights also had trademarks in any year, because these legal property rights are easier and cheaper, to register.

The out-licensing activities of start-ups are also captured in our data. The out-licensing of patents (LO_P), trademarks (LO_T) and copyrights (LO_C) are all used in our modelling. Rather than an intensity measure, these measures are binary (1/0) in nature. Incorporating licensing activities into our analysis adds a realistic dimension to the range of IP types that start-ups can adopt to manage and apply knowledge-based assets that they own. Two percent or less of the sample interviewed in any year engaged in outlicensing their intellectual capital. For the whole dataset, less than 6% engaged in out-licensing. These are rare events for most firms in our sample.

*Control Variables (**X**)*

In our statistical estimation, we control for firm employee size, the ownership structure, the financial and human capital resources, its business and innovation strategy as well as industry and regional differences. These measures are explained briefly below, and further information is available in Tables 2 and 3.

Size. Firm size is captured by the number of employees (excluding owners and contract workers).

Ownership. The ownership structure of the firm is controlled for in two ways. A dummy variable taking on the value of '1' for incorporated and '0' otherwise is included to account for the legal form of the business similar to Reid and Smith (2000). A dummy variable taking on the value of '1' for multiple owner firms and '0' otherwise was included to control for founding team performance benefits like Delmar and Shane (2006).

Finance. We control for the financial resources of the firm to exploit the firm's IP. Our debt measure includes personal debt of the owner operators which may inhibit their ability to borrow additional finance to fund growth. The level of formal equity finance invested by the owner operators of the business is also included.

Business and Innovation Strategy: Following Leitner and Güldenberg (2010) in emphasising dual strategies, involving several elements (e.g. cost, service), we used two measures. A dummy variable called 'Product' is equal to '1' if the firm sold a product and '0' otherwise. A further dummy variable defined similarly called 'Service' is included to account for potential dual strategies. As Parker et al. (2010) find dynamic strategies are more successful than static ones, we capture this by including a dummy variable indicating whether the firm had any expenditure on R&D in a particular year.

Human Capital. A count of founders with PhDs captures the human intellectual capital in start-ups. The degree of human capital drives the knowledge and skills applied to solve business problems (Galende and Gonzalez, 1999).

Industry. A dummy variable 'Hightech' coded as '1' for firms in industries that are considered as high tech based on the Bureau of Labour Statistics definition, USA and '0' otherwise is used to control for the industrial variance of R&D. We also control for sectoral differences (see Table 2).

Location. We include four regional dummies to capture the four broad census bureau regions in the USA.

3.4 Estimation Methods

Given the ordinal nature of our performance indicator, we used an ordered probit technique (with random effects) to estimate equations (3) and (5) above with an adjustment for sample selection bias.[5] The ordinal dependent variable represented by digits 1, 2, 3 representing low, medium and high performance, according to our performance index Φ **(Z)** is described in detail above. Computations were undertaken using Stata software (oprobit, manuals Stata 14). Huber-White (Robust) Sandwich estimation of the variance covariance matrix was applied to produce consistent estimates when the disturbances are not identically distributed over the panels or there is serial correlation in ε_{it}. The adjustment for sample selection bias was undertaken adopting the methods of Wooldridge (1995) and Vella (1998) to correct for this form of bias in a panel estimation. Sample selection bias is expected to exist, as the measures of performance and IP are only observed for surviving firms. Non-surviving firms drop out of the sample (see Table 1). This correction involved the calculation of the inverse Mills ratio (λ) in year t from binary probit estimations of the probability of firm survival (s=1) in year *t* against independent variables: size, organisation, resources, strategy, location and sector variables. Appendix Table A1 presents the probit estimates of the survival equation for each year of the panel estimations. The calculated Mills ratio across all the years was included as an additional regressor in ordered panel probit estimations of equations (3) and (5) to correct the estimates for sample selection bias. Vella (1998) provides a further description of this approach.

4. Results

Table 4 presents the results of the ordered panel probit estimations, corrected for sample selection bias. The data in Column I show the significance and sign of mechanisms for protecting IP for the reduced equation (3). Columns II to IV include the effects of complementarities through the use of interaction effects to estimate equation (5). These interaction effects are added in stages. Column II tests whether complementarities between different ways of protecting IP affect start-up performance *(y)*. Here, the joint impact on performance of more patents and trademarks (PT) is examined, and also similar impacts for the joint use of, copyrights and trademarks (CT), and of patents and copyrights (PC). Column III tests the impact on performance of complementarities between the different mechanisms for protecting IP, and of outlicensing these IP types (LO_PP, LO_CC, LO_TT). Finally, Column IV explores complementarities between different forms of out-licensing IP, using cross products LO_{ij}. The Wald test (joint test of $\beta_i = 0$ for all i) indicates high significance [Prob. value<0.0001], for all the estimates in Columns I to IV. The associated marginal effects are in Table 5, for the estimates of Column IV of Table 4. Likelihood ratio tests show this extended model to be preferred to the reduced model (of Table 4 Column I): [LR (3) statistic= 12.71, Prob. value > χ^2 = 0.0053].

Table 4: Estimates from Panel Ordered Probit Estimation Corrected for Sample Selection

VARIABLES	(I)	(II)	(III)	(IV)
Size	0.0922***	0.0921***	0.0920***	0.0924***
	(0.0057)	(0.0057)	(0.0057)	(0.0057)
Debt	-0.0078*	-0.0077*	-0.0077*	-0.0077*
	(0.0041)	(0.0041)	(0.0041)	(0.0041)
Team of owners	6.77e-06	-4.28e-05	-1.08e-05	-1.16e-04
	(0.0333)	(0.0334)	(0.0333)	(0.0333)
Purchased	0.318***	0.319***	0.319***	0.318***
	(0.0589)	(0.0589)	(0.0589)	(0.0590)
Incorporated	0.302***	0.302***	0.301***	0.301***
	(0.0371)	(0.0371)	(0.0371)	(0.0371)
Total equity of owners	-0.0497***	-0.0497***	-0.0497***	-0.0497***
	(0.0041)	(0.0041)	(0.0041)	(0.0041)
Service	-0.0162	-0.0152	-0.0143	-0.0151
	(0.0428)	(0.0429)	(0.0429)	(0.0429)
Product	0.1130***	0.1120***	0.1110***	0.1100***
	(0.0291)	(0.0291)	(0.0291)	(0.0291)
% with PHD	0.112***	0.112***	0.112***	0.114***
	(0.0423)	(0.0424)	(0.0423)	(0.0421)
Expenditure on R&D	0.163***	0.162***	0.161***	0.161***
	(0.0314)	(0.0314)	(0.0315)	(0.0315)
High tech	-0.0262	-0.0271	-0.0275	-0.0269
	(0.0491)	(0.0492)	(0.0492)	(0.0492)
Patents	-0.0120**	-0.0124**	-0.0117*	-0.0119**
	(0.0055)	(0.0060)	(0.0060)	(0.0061)
Copyrights	0.0012	0.0014	0.0015	0.0014
	(0.0009)	(0.0010)	(0.0010)	(0.0010)
Trademarks	0.0251***	0.0323**	0.0385***	0.0367***
	(0.0071)	(0.0127)	(0.0137)	(0.0136)
Out-licensing Patents	0.1660	0.1570	0.2560	0.5020*
	(0.2050)	(0.2050)	(0.2280)	(0.2580)
Out-licensing Copyrights	0.2690***	0.2710***	0.2720**	0.3060**
	(0.1010)	(0.1020)	(0.1150)	(0.1250)
Out-licensing Trademarks	0.1630	0.1590	0.3050**	0.5780***
	(0.1310)	(0.1320)	(0.1540)	(0.1580)
Patents × Trademarks		0.0002	0.0002	0.0002
		(0.0005)	(0.0005)	(0.0005)
Patents × Copyrights		1.18e-05	1.06e-05	9.75e-05
		(0.0001)	(0.0001)	(0.0001)
Trademarks × Copyrights		-0.0004	-0.0005	-0.0005
		(0.0005)	(0.0005)	(0.0005)
Patents × Out-licensing Patents			-0.0139	-0.0159
			(0.0110)	(0.0106)
Copyrights × Out-licensing			-7.63e-05	-1.84e-05

Copyrights				
			(0.0022)	(0.0022)
Trademarks × Out-licensing Trademarks			-0.0534**	-0.0506*
			(0.0272)	(0.0295)
Out-licensing Patents × Out-licensing Copyrights				0.9110**
				(0.4350)
Out-licensing Patents×Out-licensing Trademarks				-1.435***
				(0.4300)
Out-licensing Copyrights×Out-licensing Trademarks				-0.4120
				(0.2900)
Construction	0.1000	0.1020	0.1030	0.1000
	(0.0692)	(0.0693)	(0.0693)	(0.0693)
Wholesale Retail	0.2860***	0.2860***	0.2870***	0.2840***
	(0.0584)	(0.0584)	(0.0584)	(0.0585)
Low Knowledge IS	0.0832	0.0840	0.0847	0.0822
	(0.0553)	(0.0554)	(0.0554)	(0.0554)
Knowledge IS	0.0921*	0.0929*	0.0938*	0.0897*
	(0.0522)	(0.0523)	(0.0523)	(0.0523)
Other	0.0443	0.0451	0.0458	0.0432
	(0.181)	(0.181)	(0.182)	(0.182)
Mills	-7.895***	-7.892***	-7.890***	-7.887***
	(0.3010)	(0.3010)	(0.3010)	(0.3010)
Constant				
Cut1	-1.222***	-1.219***	-1.217***	-1.221***
	(0.0910)	(0.0911)	(0.0911)	(0.0911)
Cut2	0.1970**	0.2000**	0.2020**	0.1980**
	(0.0909)	(0.0909)	(0.0910)	(0.0910)
Sigma	0.8740***	0.8740***	0.8750***	0.8760***
	(0.0335)	(0.0335)	(0.0336)	(0.0336)
Observations	22,463	22,463	22,463	22,463
Number of firms	4,869	4,869	4,869	4,869
χ^2	2315	3740	2829	2814
Prob > χ^2	0.0001	0.0001	0.0001	0.0001

Note: Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Estimates include regional controls and fixed year effects. Manufacturing is the reference category.

Table 5: Marginal Effects from Panel Ordered Probit Estimation Corrected for Sample Selection

VARIABLES	I Low Performers	II Medium Performers	III High Performers
Patents	0.0044**	-0.0014**	-0.0029*
	(0.0022)	(0.0007)	(0.0015)
Copyrights	-0.0005	0.0002	0.0004
	(0.0004)	(0.0001)	(0.0002)
Trademarks	-0.0134***	0.0044***	0.0090***
	(0.0050)	(0.0017)	(0.0033)
Out-licensing Patents	-0.1580**	0.0068	0.1510*
	(0.0670)	(0.0246)	(0.0912)
Out-licensing Copyrights	-0.1030***	0.0175***	0.0855**
	(0.0381)	(0.0025)	(0.0391)
Out-licensing Trademarks	-0.1780***	-0.0010	0.1790***
	(0.0384)	(0.0200)	(0.0578)
Patents × Trademarks	-8.79e-05	2.90e-05	5.90e-05
	(0.0002)	(5.64e-05)	(0.0001)
Patents × Copyrights	-3.55e-05	1.17e-05	2.38e-05
	(4.73e-05)	(1.56e-05)	(3.18e-05)
Trademarks × Copyrights	0.0002	-5.67e-05	-0.0001
	(0.0002)	(5.70e-05)	(1.16 e-05)
Patents × Out-licensing Patents	0.0058	-0.0019	-0.0039
	(0.0039)	(0.0013)	(0.0026)
Copyrights×Out-licensing Copyrights	6.70e-05	-2.21e-05	-4.49e-05
	(0.0008)	(0.0003)	(0.0005)
Trademarks × Out-licensing Trademarks	0.0184*	-0.0061*	-0.0123*
	(0.0107)	(0.0036)	(0.0072)
Out-licensing Patents ×Out-licensing Copyrights	-0.2440***	-0.0630	0.3070*
	(0.0711)	(0.1020)	(0.1730)
Out-licensing Patents ×Out-licensing Trademarks	0.5090***	-0.3550***	-0.1540***
	(0.1040)	(0.0946)	(0.0102)
Out-licensing Copyrights ×Out-licensing Trademarks	0.1590	-0.0787	-0.0807*
	(0.116)	(0.0723)	(0.0434)
Wald χ^2 (42)			2813.62
Prob > χ^2			0.0001
Observations			22,463
Number of firms			4,869

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
The estimation included controls and fixed year effects. Manufacturing is the reference category.

4.1 Intellectual Property Rights and Performance

Looking at Table 4 Columns I-IV we find that the coefficient on patents is always *negative* and *significant* indicating that patenting by small firm start-ups has a negative effect, supporting H1. This finding highlights the difficulties start-ups face in protecting IP, by patenting. High performing firm start-ups are less likely to favour this form of IP. On evidence elsewhere (Hall et al., 2013; Heger and Zaby, 2013; Kitching and Blackburn, 1998) the full costs of patenting, including enforcement, often outweigh potential revenue benefits - particularly for dynamic start-ups. Both Agostini et al. (2016) and Suh and Hwang (2010) found patent counts did not raise sales. However, in Suh and Hwang (2010), for South Korean software firms, a positive association between use of copyrighting and performance was found. However, we do not find support for this in our US data (see Table 4, Columns I-IV), so there is no support for hypothesis H3 across all variants of the estimates. It seems that for US start-ups holding copyrights does not immediately improve performance. This finding is sensitive to the inclusion of lagged copyrights, as discussed in Section 4.3.

By contrast, we do find evidence of performance benefit from trademarking (Table 4, Columns I-IV), supporting previous studies like Sandner and Block (2011) and Block et al. (2014). It seems that variables involving strong legal protection (e.g. registered trademarks and out-licensed copyrights) do raise overall performance as the coefficients of these measures are positive and significant. Both contractual arrangements for managing IP, and registered trademarks, are more heavily used by high performing start-ups, supporting hypotheses H2 and H4. Thus, it seems that IP protection which supports market access and development is more likely to raise performance. Out-licensing patents or out-licensing trademarks only yield higher performance when complementarities from out-licensing IP types are controlled for, see Table 4 Columns III and IV; and Column IV only for patents. Positive coefficients on these regressors are significant. Plausibly, there are diminished rent dissipation effects (Motohashi, 2008) here, with positive consequences for performance, supporting hypothesis H4.

The observed differences in Table 4 carry over to Table 5 for the *range* of IP types, in that, for example, the trademark and out-licensing variables have positive and significant marginal effects on performance for medium and high performers (with high performers only for out-licensing trademarks and out-licensing patents), but negative and significant marginal effects for low performers. Consider the marginal effects for low, medium and high performers, presented in Columns I, II and III respectively of Table 5. We find that medium and high performers generally experience negative and significant marginal effects on patents. In contrast, we find that low performing start-ups (perhaps inadvertently) adopt the opposite strategy, apparently over-investing in patent rights, rather than using other forms of IP protection like trademarks, and consequently missing out on the associated performance reward from the latter. However, the magnitude of the marginal effects on patenting for low performers and high performers is not particularly high (+0.004 or +0.4%; -0.003 or -0.3% respectively). This low magnitude perhaps reflects the low propensity of start-ups and firms generally to patent in any case. According to Maresch et al. (2016) patenting only pays off if the innovating firms go head-to-head with competitors, and get to market quickly with their new product. The magnitude of the marginal effects for high performers are greater for trademarks (0.009 or 0.9%), out-licensing patents (0.151 or 15%), out-licensing copyrights (0.086 or 8.6%) and out-licensing trademarks (0.179 or 18%). These kinds of small odds improvement could be attractive to start-ups, particularly in the case of out-licensing patents and trademarks. However as indicated below, these improvements can be negated if IP protection within the firm's portfolio is not managed carefully.

By contrast, low performers may be characterised as the 'living dead'. Most widely known IP types (save patenting) used by disadvantaged start-ups have a negative impact on performance (Column I, Table 5). Further, looking at control variables (Column I, Table 5) we see firm growth is disadvantaged (e.g. smaller in size), and the corporate form compromised (less likely to be incorporated), with little appetite present for improving corporate performance (e.g. in terms of more skilled staff and more R&D, both of which seem to signal diminished performance). This contrasts markedly with medium and high performers, who are more dynamic and motivated to improve corporate performance e.g. investing more in growth, skilled staff, R&D, and premises, (see Columns II and III, Table 5). This suggest a coherent empirical model of start-up performance, in which low performers (bottom quartile) do appear to behave differently from medium and high performers (upper three quartiles). This increases our confidence in our estimates as we turn to examine the relation between the joint use of IP and firm performance, as captured by hypothesis H5.

4.2 Complementarities in the joint use of IP and Performance

Examining the panel ordered probit estimates presented in Table 4 Columns II-IV, we find limited evidence for H5 (that complementarities between IP types boost start-ups performance). Interestingly, beyond complementary effects, we also found substitutive effects. Initially we found that the interaction terms *Patents×Trademarks*, *Patents×Copyrights* and *Copyrights×Trademarks*, capturing the joint influence of having higher numbers of these IP types, were not significant in the estimates (see Column II, Table 4). They did not add any additional explanatory power [LR (3) statistic= 2.99, Prob. value > χ^2 = 0.3924]. The situation changes slightly when out-licensing is considered in interaction variables (LO_{ij}). Complementarities between IP types and measures of out-licensing are captured in the estimates of Table 4 Column III by interaction terms *Patents×Out-licensing Patents*, *Copyrights×Out-licensing Copyrights*, *Trademarks×Out-licensing Trademarks*. Here, there was a negative and significant coefficient only on the interaction term *Trademarks× Out-licensing Trademarks.* This indicates that the probability of being a high performing start-up, with a relatively higher number of trademarks, or being a high performing start-up, that engages in out-licensing trademarks (which is now significant), is lowered if the start-up *jointly* has higher trademarks *and* engages in out-licensing these trademarks. Rather than being a revenue-based synergy, this joint effect is dissipating rents. It indicates that start-ups whose main differentiating factor is trademarks should hold these in-house. If the start-up's main differentiating factor is out-licensing trademarks it should reduce this activity, as its number of registered trademarks increases. Finally, complementarities between different forms of out-licensing are also included in the estimates, as presented (in Table 4 Column IV) by interaction terms *Out-licensing Patents×Out-licensing Copyrights*, *Out-licensing Patents×Out-licensing Trademarks* and *Out-licensing Copyrights×Out-licensing Trademarks.* As indicated above, this variant of equation (5) adds significant additional explanatory power. The coefficient on *Out-licensing Patents×Out-licensing Copyrights* was positive and significant, supporting H5, indicating that the joint strategy of out-licensing patents and copyrights is rent generating, and fares better than the rent dissipating effect of out-licensing patents and trademarks. The coefficient on the latter interaction term *Out-licensing Patents×Out-licensing Trademarks* was negative and significant. For high performers, the magnitude of the positive marginal effect of *Out-licensing Patents×Out-licensing Copyrights* was sizeable (0.307 or 30%) which indicates a strong complementarity in engaging in this IP management strategy (Table 5, Column III). The magnitude of the rent dissipating effect is high also for *Out-licensing Patents×Out-licensing Trademarks*, arguably reducing the rent generated from the solo use of both of these strategies (Table 5, Column III). It seems that high performers choose to license-out patents and copyrights but not trademarks. As suggested above, these may be better kept in-house. This is also borne out by the robustness tests below.

4.3 Robustness

The Appendix presents our preferred estimates of Column IV Table 4 when one-period lagged IP types$_{(t-1)}$, staggered to lagged IP types$_{(t-4)}$ are included in the estimation of equation (5). This examines whether the effects identified above persist (Columns I-V, Table A2). Briefly, we note that trademark effects persist for up to three time-periods. The negative and significant effect of patents do persist for two time-periods. Lagged patents have significant and positive effects when two to four lags are incorporated into the model. This suggests that if start-ups can survive for 3 years, they may still reap the rewards of patenting further down the line. Further, registered *Copyrights* becomes positive and significant when lagged copyrights are included in the model. This supports H3, and studies like Suh and Hwang (2010), though none of the lagged values of copyrights are themselves significant. The effect of out-licensing copyrights or trademarks is positive and significant as above when one lag of this variable is included in the estimation. We find that complementary and substitutive effects generally persist when lagged IP types are incorporated in estimates. There is additional support for H5, with positive and significant coefficients on *Patents×Trademarks* and *Patents×Copyrights* when lagged IP types are included in the estimator. This supports extant evidence of synergies between trademarks and patents cf. Thomä and Bizer (2013), Amara et al. (2008) and Loundes and Rogers (2003). We also trialled three-way interaction terms for *Copyrights×Trademarks×Copyrights* and *Out-licensing copyrights×Out-licensing patents×Out-licensing trademarks* in estimates of an expanded equation (5). These three-way interaction terms were insignificant and failed to add explanatory power [6].

5. Discussion

Our work suggests that a better appreciation of the performance benefits of diverse IP types, beyond patenting, would be beneficial to the early stages of start-ups, in terms of research methods and of practice. While studies (Griliches et al., 1991; Artz et al., 2010; Suh and Hwang, 2010) have suggested that specific IP types (e.g. patenting) are of dubious performance advantage in certain contexts (e.g. in start-ups) this has not led, so far, to a more general investigation of the performance implications of the full range of IP types, such as we have conducted. Taking up this research challenge, our study shows that for a wider range of IP types (e.g. including registered trademarks and out-licensing) their use is indeed associated with better performance in start-ups. In enterprise mentoring, these potential benefits can be highlighted, so start-ups can manage their IP types to better effect. Whilst it is thought that, in theory, complementarities might exist between intellectual property types, we only find evidence of performance benefits in start-ups when lagged IP types are incorporated into the model. Therefore empirically, it may require taking a more evolutionary perspective on start-ups, over longer periods of time to detect if any associative benefits of this nature are emerging.

5.1 Implications for theory

The performance advantages of IP types, as major knowledge assets of firms, has been broadly examined theoretically and empirically, for large firms (Sydler et al., 2014) rather than small firm start-ups (Leiponen and Byma, 2009; Helmers and Rogers, 2011). Research on the performance benefits of patenting (Agostini et al. 2015; Artz et al., 2010) often neglect the broader range of alternative IP types we have examined here. Our study fills this research gap through a comprehensive examination of the performance benefits accruing to young firms from holding a range of IP types. This builds on the preliminary work of others like Block et al. (2015) and Motohashi (2008) who have generally used much smaller samples of start-ups, and have typically considered fewer IP types. Our work is therefore a significant generalization of previous work.

Although our evidence on the weak performance gains from patenting for start-ups may seem contrary to some aspects of the research literature, it needs to be borne in mind that much of this literature concerns large, mature firms (Sydler et al., 2014; Riahi-Belkaoui, 2003), rather than the small start-up firms - the focus of our paper. Further, one must interpret evidence cautiously, as apparently solid evidence of patenting's limited impact may not be picked-up in performance measures, in cases where patenting is pre-emptive, Guellec et al. (2012) (e.g. through the use of protective patent thickets, Graevenitz et al. 2013, which aim at diminishing the performance of rivals). Also, our own findings, in this start-up context, suggest performance benefits yielded from IP types may vary by lifecycle stage and firm size. Finally, our findings could differ by sector. To illustrate, patents may be an intrinsic part of the IP strategy of firms in the high technology sector, and in certain cases a grant of patent is a necessary requirement to gaining venture capital funding (Mann and Sager, 2007). For our panel of start-ups, contracting arrangements for selling and protecting the firms IP do seem to yield significant performance benefits. For example, out-licensing at this early stage in the firm's lifecycle, seems important. It may provide a viable route for start-ups to improve performance as markets for IP become well developed in their industry: cf. Padula et al. (2015) who investigate upstream small firms which, as inventors of new technologies, sell this capability, through licensing, to downstream firms which specialise in the implementation of technologies.

5.2 Implications for practice and policy

The findings of this study are of interest to academics in the IP area, but also to other parties, including enterprise development agencies, who stimulate new start-ups with advice and incubation facilities, and venture capitalists, who invest time and money in the growth and development of start-ups. Enterprise development agencies, and venture capitalists, need to advise new entrepreneurs on the potential value of other forms of intellectual property appropriation (e.g. trademarks and outward licensing). In turn, new entrepreneurs need to appreciate that patenting is only of value, performance-wise, if there is significant scope for marketizing its perceived intrinsic value. A patent must be capable of industrial implementation, and the process of bringing it to market is typically complex, risky and expensive. One route by which these risks and complexities can be attenuated by the firm, or even avoided entirely, is by out-licensing the intellectual property; but of course this necessarily sacrifices much of the value, in the case of technology based firms, which then falls in the lap of the licensee, who has both borne the risk, and hazarded the finance, to bring a technology based product to market (Jeong et al., 2013). As alternatives, trade secrecy and trademarking are economical and have the scope, if well managed, to engender greater performance. Given the importance of out-licensing to performance enhancement, educating new entrepreneurs on strategies for leveraging internal IP may be of considerable benefit to the performance of new firm start-ups. On a wider perspective, fostering the development of markets in IP types, by enterprise policy (including dimensions like innovations in law, and business education), may also be a way forward to reducing impediments to the transfer of knowledge in this way.

5.3 Limitations and future research directions

As is usual for empirical work, our research is limited by the data available to us. We only have access to anonymised data, so we cannot access further data on the patents (e.g. citations), copyrights and trademarks, to assess their quality or nature. Though we can certainly observe whether a firm is engaged in outward licensing or not, we lack the information we would like to have on cross-licensing. Further gaps in data, which we would have liked to overcome, include: the number of licenses a firm sells; and the nature of the technologies that they license (e.g. whether licenses are for core, or non-core, technologies). Future work should examine these intricacies to assess their impact on the relationship between intellectual property types and the performance of start-ups. Such work may benefit from a more formal exploration of the performance benefits of a comprehensive range of IP types, and how they vary over the lifecycle of the firm. Developments of this work might explore how such IP configurations differ for the few firms which grow to be large, as opposed to the great majority which remain small.

Notes

1. For details on the Kauffman firm Survey see https://www.kauffman.org/what-we-do/research/kauffman-firm-survey-series.

2. Using unrotated principal axis factoring to assess common method bias, we find that only 26% of the variation is common to one factor when all regressors are included across all 8 years of the panel which is less than the 50% threshold (as recommended in the relevant test protocol) indicating that there is no significant evidence of common method bias and that no remedial measures are required.

3. NAICS stands for the North American Industry Classification System, see https://www.census.gov/eos/www/naics/.

4. In 2011 this minimum value was '1' as firms active in this period were not followed up on in future periods (see Table 1).

5. The ordered probit panel estimation is estimated using maximum likelihood to fit the random effects model of form

$$\Pr(y_{it} > k \mid K, x_{it}, v_i) = \emptyset(x_{it}\beta + v_i - K_k)$$

for i=1,…,n panels, t=1,…n_i, panel level random effects v_i which are independent and identically distributed N(0,σ_v^2), K cutpoints K_1, K_2, K_3,…K_{K-1}, where K is the number of possible outcomes; and ϕ(.) is the standard normal cumulative probability distribution. The probability of observing a high performer from our ordered composite performance indicator y_{it} is as follows:

$$p_{itk} \equiv \Pr(y_{it} = k \mid K, x_{it}, v_i) = Pr\ (K_{k-1} < x_{it}\beta + v_i + \varepsilon_{it} \leq K_k)$$

$$= \Pr(K_{k-1} - x_{it}\beta - v_i < \varepsilon_{it} \leq K_k - x_{it}\beta - v_i)$$

$$= \emptyset\ (K_k - x_{it}\beta - v_i) - \emptyset(K_{k-1} - x_{it}\beta - v_i)$$

where k_0 has values as -∞, and K_K has values as +∞. x_{it} does not contain the constant term as its effects are included in the cut points.

6. These estimates are available from the authors on request.

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APPENDIX

Appendix Table A1: Survival Equation Estimates for the Panel Sample Selection Correction

VARIABLES	(I) 2004	(II) 2005	(III) 2006	(IV) 2007	(V) 2008	(VI) 2009	(VII) 2010	(VIII) 2011
Incorporated	0.0935	0.0665	-0.0646	-0.000953	0.0452	0.0338	0.0719	0.0494
	(0.0657)	(0.0732)	(0.0822)	(0.0919)	(0.0937)	(0.0937)	(0.0949)	(0.0307)
Purchased	0.104	0.0527	0.0897	0.182	0.318	0.0643	-0.0247	0.108*
	(0.154)	(0.143)	(0.156)	(0.184)	(0.194)	(0.170)	(0.173)	(0.0611)
Team of owners	0.105	-0.00260	0.164**	-0.00856	0.0425	0.107	0.134	0.0645**
	(0.0685)	(0.0725)	(0.0824)	(0.0932)	(0.0984)	(0.0953)	(0.103)	(0.0316)
Debt	0.0163	0.0065	0.0086	0.0080	-0.0051	0.0355**	0.0349**	0.0111**
	(0.0101)	(0.0106)	(0.0117)	(0.0129)	(0.0130)	(0.0145)	(0.0150)	(0.0045)
Size	0.0199**	0.0235**	0.0106	0.0263**	0.00418	0.00817	0.0113	0.0153***
	(0.0101)	(0.0092)	(0.0089)	(0.0108)	(0.0086)	(0.0108)	(0.0098)	(0.0036)
Competitive Advantage	0.0790	0.245***	0.181**	0.216***	0.243***	0.317***	0.131	0.157***
	(0.0608)	(0.0653)	(0.0735)	(0.0798)	(0.0815)	(0.0846)	(0.0835)	(0.0270)
Service	0.212**	0.253***	0.0652	0.00694	-0.124	0.0820	0.350***	0.132***
	(0.0888)	(0.0937)	(0.109)	(0.128)	(0.128)	(0.136)	(0.126)	(0.0414)
Product	0.0618	-0.0207	-0.0508	-0.0832	-0.0972	0.00270	-0.0774	-0.0291
	(0.0713)	(0.0729)	(0.0858)	(0.0936)	(0.0983)	(0.0975)	(0.101)	(0.0322)
High-tech	-0.0452	0.0849	0.124	-0.0864	0.274*	0.200	-0.0594	0.0499
	(0.0930)	(0.106)	(0.121)	(0.128)	(0.149)	(0.144)	(0.137)	(0.0445)
Constant	1.235***	1.085***	1.458***	1.616***	1.627***	1.485***	1.223***	1.409***
	(0.147)	(0.155)	(0.183)	(0.212)	(0.202)	(0.219)	(0.217)	(0.0678)
Observations	4,724	3,896	3,272	2,703	2,571	2,371	2,099	23,658
χ^2	37.74	51.14	26.95	30.56	35.33	39.96	35.85	152.85
Prob > χ^2	0.0027	0.0000	0.0420	0.0226	0.0056	0.0013	0.0048	0.0163

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; Sectorial and regional dummies included in the estimation
These estimates were used to calculate Mills ratio for the panel sample selection adjustment of estimates of equations (3) and (4) in accordance with Wooldridge (1995) and Vella (1998).

Appendix Table A2: Estimates from Panel Ordered Probit Estimation Corrected for Sample Selection with Lagged IP Types

VARIABLES	(I)	(II)	(III)	(IV)	(V)
Patents	-0.0119**	-0.0180*	-0.0261*	-0.0302	-0.0499
	(0.0061)	(0.0095)	(0.0144)	(0.0218)	(0.0360)
Patents $_{(t-1)}$		-0.0042	-0.0096	-0.0134	0.0116
		(0.0121)	(0.0119)	(0.0124)	(0.0264)
Patents $_{(t-2)}$			0.0276**	0.0231**	0.0433***
			(0.0112)	(0.0109)	(0.0150)
Patents $_{(t-3)}$				0.0215	-0.0002
				(0.0173)	(0.0189)
Patents $_{(t-4)}$					-0.0199
					(0.0239)
Copyrights	0.0014	0.0031**	0.0053***	0.0057**	0.0082**
	(0.0010)	(0.0013)	(0.0017)	(0.0028)	(0.0038)
Copyrights $_{(t-1)}$		-3.16e-05	0.0005	0.0003	-0.0030
		(0.0012)	(0.0015)	(0.0017)	(0.0027)
Copyrights $_{(t-2)}$			-0.0003	0.0006	0.0003
			(0.0015)	(0.0016)	(0.0022)
Copyrights $_{(t-3)}$				-0.0005	-0.0007
				(0.0020)	(0.0024)
Copyrights $_{(t-4)}$					0.0009
					(0.0025)
Trademarks	0.0367***	0.0409**	0.0493**	0.0437	0.0252
	(0.0136)	(0.0191)	(0.0247)	(0.0293)	(0.0406)
Trademarks $_{(t-1)}$		-0.0376**	-0.0491*	-0.0576	-0.0118
		(0.0173)	(0.0252)	(0.0371)	(0.0508)
Trademarks $_{(t-2)}$			-0.0024	-0.0005	0.0041
			(0.0216)	(0.0280)	(0.0388)
Trademarks $_{(t-3)}$				0.0602*	0.0545
				(0.0312)	(0.0372)
Trademarks $_{(t-4)}$					-0.0130
					(0.0418)
Out-licensing Patents	0.5020*	0.5490	0.0045	0.4960	9.4470**
	(0.258)	(0.365)	(0.539)	(0.775)	(4.711)
Out-licensing Patents $_{(t-1)}$		-0.250	0.0790	1.093**	1.217*
		(0.2890)	(0.3960)	(0.4850)	(0.6480)
Out-licensing Patents $_{(t-2)}$			0.3980	-0.5700	0.8460
			(0.3590)	(0.6800)	(0.9850)
Out-licensing Patents $_{(t-3)}$				0.1620	-0.9070*
				(0.3940)	(0.5450)
Out-licensing Patents $_{(t-4)}$					0.8740
					(0.542)
Out-licensing Copyrights	0.3060**	0.3780**	0.1580	-0.0311	-0.1050
	(0.1250)	(0.1510)	(0.1910)	(0.2700)	(0.4380)
Out-licensing Copyrights $_{(t-1)}$		-0.0059	-0.0236	-0.0155	-0.1600
		(0.1390)	(0.1660)	(0.2070)	(0.3330)
Out-licensing Copyrights $_{(t-2)}$			0.1350	-0.0168	-0.0644
			(0.1510)	(0.1890)	(0.2690)
Out-licensing Copyrights $_{(t-3)}$				0.4380**	0.2620
				(0.2110)	(0.2670)
Out-licensing Copyrights $_{(t-4)}$					-0.0409

					(0.3260)
Out-licensing Trademarks	0.5780***	0.5650**	0.4540	0.3130	0.5950
	(0.1580)	(0.2270)	(0.3420)	(0.3630)	(0.6460)
Out-licensing Trademarks $_{(t-1)}$		0.2470	0.0109	-0.6110	-0.7300
		(0.2060)	(0.2730)	(0.3760)	(0.4820)
Out-licensing Trademarks $_{(t-2)}$			-0.0269	0.1240	0.2610
			(0.1960)	(0.2480)	(0.3600)
Out-licensing Trademarks $_{(t-3)}$				-0.1030	-0.4240
				(0.2620)	(0.3570)
Out-licensing Trademarks $_{(t-4)}$					0.6150*
					(0.346)
Patents×Trademarks	0.0002	0.0014**	-0.0013	0.0042	0.0047
	(0.0005)	(0.0007)	(0.0040)	(0.0049)	(0.0064)
Patents×Copyrights	9.75e-05	0.0011***	0.0018*	0.0057**	0.0126
	(0.0001)	(0.0003)	(0.0011)	(0.0023)	(0.0118)
Trademarks× Copyrights	-0.0005	-0.0009	-0.0014**	-0.0013	-0.0008
	(0.0005)	(0.0006)	(0.0007)	(0.0008)	(0.0010)
Patents×Out-licensing Patents	-0.0159	-0.0277	-0.0213	-0.0168	-0.3480
	(0.0106)	(0.0190)	(0.0238)	(0.0962)	(0.2750)
Copyrights×Out-licensing Copyrights	-0.0002	-0.0030	-0.0024	0.0024	0.0062
	(0.0022)	(0.0026)	(0.0032)	(0.0039)	(0.0054)
Trademarks×Out-licensing Trademarks	-0.0506*	-0.0470*	-0.0185	0.0070	0.0225
	(0.0295)	(0.0269)	(0.0484)	(0.0673)	(0.0971)
Out-licensing Patents ×Out-licensing Copyrights	0.9110**	1.4990**	2.0980**	2.3220**	-1.0390
	(0.4350)	(0.6000)	(1.0240)	(1.1210)	(3.5110)
Out-licensing Patents ×Out-licensing Trademarks	-1.4350***	-2.2660***	-2.5430**	-3.2350***	-9.4130***
	(0.4300)	(0.5530)	(1.0320)	(1.0430)	(1.6600)
Out-licensing Copyrights×Out-licensing Trademarks	-0.4120	-0.3210	0.1970	0.1710	0.4110
	(0.2900)	(0.3270)	(0.4920)	(0.5280)	(0.7740)
	(0.0336)	(0.0525)	(0.0693)	(0.0827)	(0.1130)
Observations	22,463	16,652	12,259	8,945	6,386
Number of firms	4,869	4,020	3,271	2,609	2,085
Wald χ^2	2813.62	1813.62	1489.58	1145.28	1927.24
Prob > χ^2	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

The estimations included controls variables and fixed year effects. Manufacturing is the reference category.