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When Do Start-ups Patent Their Inventions? Evidence from a Broad Approach

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Abstract:
Patents are no longer merely protective; other factors are becoming prominent in explaining when start-ups patent their inventions. This study uses data from 220 start-ups from different industries to evaluate the role of size, location, collaboration partners and financial means in patenting activity. Our results show a quadratic effect of size on patenting likelihood for start-ups, and patenting level reaches a tipping point for medium-sized start-ups. The findings also show that patenting likelihood is higher, regardless of the industry, when: (i) start-ups are located in international clusters or near other start-ups; (ii) start-ups collaborate with specialized research institutes; and (iii) start-ups are financed through crowdfunding campaigns. Location in co-working spaces seems, however, to be associated with lower patenting likelihood. These results help to illustrate the context in which start-ups value patents as protection instruments vs. as strategic resources to achieve other goals, such as reputation, or access to networks or financial capital. Analysing the reasons why start-ups patent is crucial due to the growing relevance these companies gain when they introduce innovations in the current economy.

Keywords: Start-ups, patents, location, collaboration, financing
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Introduction

Nowadays, start-ups can be seen as engines of innovation and entrepreneurship (Calcagnini et al. 2016; Colombelli 2016). Scholars and policymakers are working to understand the variables that explain start-ups' growth and success (Chatterji et al. 2019; Czarnitzki and Delanote 2013; Nuscheler, Engelen, and Zahra 2019), business models (Zimmerman and Zeitz 2002), and strategic decisions (Islam, Fremeth, and Marcus 2018; Pe'er and Keil 2013).

Among the main strategic decisions start-ups make, the decision to patent an invention has received considerable attention in research (see e. g. Helmers and Rogers 2011; Mann and Sager 2007). A wide range of reasons beyond the traditional core protective motive have been identified (Blind et al. 2006; Ernst, Conley, and Omland 2016; Großmann, Filipović, and Lazina 2016; Holgersson 2013; Long 2002). Patents are fundamentally a protection instrument to prevent imitation and dangerous knowledge spillovers. They have traditionally been used to measure innovative performance. However, patents have also become a strategic resource that start-ups can use for different purposes. Understanding strategic motives to patent may shed valuable light on other key issues related to local environment or collaboration strategies.

To date, studies in this field have been performed on specific industries and analyse only a limited group of related variables. Most papers are limited to single industries, such as biotechnology and software start-ups (see, e. g. Helmers and Rogers 2011; Mann and Sager 2007), or to the link between venture capital and patents (see, e. g. Zhou et al. 2016). Scholars consistently omit a broader approach that would include how other variables explain patenting likelihood in start-ups, regardless of industry. In response to this limitation in existing research, our study addresses the following question: Is it possible to find a set of common conditions or contexts in which start-ups value patents as a strategic resource, regardless of their activity or industry? To answer this question, we examine a wide range of different conditions or frameworks in which start-ups have considered the value of patenting the results of their work.

This study uses a logistic regression to test various hypotheses on size, location strategy, collaboration partners, and financial means. To do so, we collected data from 220 Spanish start-ups in different economic sectors. Firstly, we tested the quadratic effect of size on patenting likelihood for start-ups. Secondly, we tested how location near horizontal agents and international clusters leads start-ups to register patents. Thirdly, we compared

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the role of collaboration with upstream and downstream vertical collaborators. Finally, we tested how business angels, venture capital, and crowdfunding campaigns can explain patenting likelihood in start-ups.

Our study contributes to the start-up literature by providing evidence for the contexts in which start-ups develop higher patenting likelihood for their inventions. Drawing on prior literature, our study identifies a set of contexts in which start-ups find additional value in patenting their inventions. Firstly, patents could be used as a strategic resource in the early stage of growth, when the enterprise's bundle of resources and capabilities is limited. Secondly, start-ups continue to use patents with the core intention of protection when the firms are located near other start-ups and collaborate with research institutes. Third, reputation can motivate start-ups to patent when they locate in international clusters. Finally, a patent can be considered as an instrument to distinguish one start-up from others when it is pursued to attract financial capital, mainly in crowdfunding campaigns.

Literature Review and Hypotheses

A review of the literature shows that the main areas of interest in research on start-ups attempt to explain start-up growth (see, e. g. Baum, Calabrese, and Silverman 2000) and survival (see, e. g. Pe'er and Keil 2013). To increase understanding of how to achieve these desirable outcomes, scholars have analysed key issues such as location strategy, alliances, venture capital, and patents in start-ups. Most empirical studies have been developed in high-tech industries (mainly biotechnology or software start-ups).

In analysing location strategy, the literature has attempted to explain the conditions under which start-ups take advantage of locating in clusters. Small size seems to lead start-ups to locate in clusters to compensate for their lack of resources (Pe'er and Keil 2013). Studies demonstrate, however, that start-ups need a solid bundle of resources and capabilities to exploit the opportunities that clusters provide (Almeida, Dokko, and Rosenkopf 2003). Delerue and Lejeune (2012) find that human capital and its capabilities are essential if start-ups are to create valuable alliances in international clusters. Locating in clusters thus poses significant challenges for start-ups, while subjecting them to significant levels of rivalry that result in high failure rates (Pe'er and Keil 2013).

Since Shan, Walker, and Kogut (1994) analysed the role collaboration plays in understanding innovative performance in biotechnological start-ups, alliances have been a core issue in understanding start-up success. Alliances between start-ups and universities have received the most attention (Calcagnini et al. 2016; Wang and Shapira 2012), demonstrating that start-ups view universities as a source of up-to-date information (Baum, Calabrese, and Silverman 2000; Okamuro, Kato, and Honjo 2011), as well as a stimulating context in which to find mentorship for their entrepreneurial projects (Guerrero and Urbano 2014; Shah and Pahnke 2014). Lynskey (2004) indicates that greater university–industry collaboration promotes innovation in technology-based start-up firms. Horizontal alliances (with other start-ups in the same industry) and vertical alliances (with universities, research institutes and firms) are strong options for obtaining complementary resources such as scientific knowledge, infrastructure, distribution channels, or customers portfolios (Baum and Silverman 2004; Doblinger, Surana, and Diaz Anadon 2019; Paradkar, Knight, and Hansen 2015).

Like collaboration, the influence of venture capital on start-up success has been researched intensively. Beyond the financial function of venture capital, studies have analysed how venture capital develops active involvement in start-up management (Dutta and Folta 2016), producing a wide range of effects. On the one hand, venture capital provides various benefits to reputation and contact networks (Davila, Foster, and Gupta 2003) and effective coaching to achieve growth and profitability (Baum and Silverman 2004; Hellmann and Puri 2000). On the other, venture capital usually triggers radical turnarounds in the start-ups backed, eventually producing leadership changes inside the start-up (Banerjee and Cole 2012). For these reasons, the literature establishes that start-ups backed by venture capital can come to differ significantly from start-ups supported by other financial means.

Finally, some scholars have analysed the role of patenting in the growth and survival of start-ups. Some controversial issues (e. g. cost, bureaucracy, and effort) question the real value start-ups attribute to patents. Initial empirical studies focused on explaining whether patenting has significant and positive effects compared to non-patenting in start-ups. These studies provide strong evidence that patenting is a source of advantage for start-ups. For instance, Mann and Sager (2007) demonstrate that patents help software start-ups to compete and stabilize in a volatile industry. Similarly, Helmers and Rogers (2011) prove that patenting correlates with lower likelihood of failure and positive asset growth in high-tech start-ups; patenting definitely helps start-ups to grow faster than non-patenting. In addition, Banerjee and Cole (2012) confirm that achieving the first patent can serve as an inflection point in the life of the start-up and translate into low likelihood of leadership change due to stakeholders' decisions. More recently, Haeussler, Harhoff, and Mueller (2014) demonstrate that information generated in the course of the patenting process could facilitate additional matters, such as venture

capital investors' decisions. Patents are thus considered as an endorsement of the start-up's management. As the literature consistently provides significant evidence highlighting the value of patents for start-ups, we propose a set of hypotheses to explain the context surrounding start-ups that patent their inventions.

Size and Patents in Start-ups

Over the years, scholars have studied extensively the relationship between firm size and innovation outcomes (see, e. g. Audretsch and Vivarelli 1996). Scholars show similar interest in explaining innovation outcomes in start-ups (see, e. g. Almeida, Dokko, and Rosenkopf 2003; Czarnitzki and Delanote 2013). Based on Schumpeter's premise that innovation is more frequent in larger firms, the first empirical studies of start-ups proved positive relationships between size and innovative results (see, e. g. Shan, Walker, and Kogut 1994). Many of these works measured innovative results through patents to demonstrate that propensity to this protection strategy increases with size (see, e. g. Arundel and Kabla 1998; Shan, Walker, and Kogut 1994).

Patents registered by start-ups reflect not only innovation results but also strategic decisions related to other incentives (Blind et al. 2006; Helmers and Rogers 2011). Several arguments have been proposed to explain why start-ups patent their inventions: attracting investors (Hsu and Ziedonis 2013; Mann and Sager 2007) or alliance partners (Colombo, Grilli, and Piva 2006; Ernst, Conley, and Omland 2016), selling licenses to achieve income from prior inventions (Ernst, Conley, and Omland 2016; Graham and Sichelman 2008) and gaining reputation relative to stakeholders (DeCarolis and Deeds 1999; Cohen et al. 2002). In addition to truly innovative performance and the goal of protection, many factors emerge throughout the literature to explain the patenting likelihood of start-ups.

Start-up size may initially have a positive influence on the number of patents registered. Firstly, small start-ups are likely to focus almost exclusively on core research and other technical activities to define initial innovation outcomes (Colombo, Grilli, and Piva 2006). When start-ups begin to grow, they have more resources to innovate and more linkages to access valuable external knowledge (Almeida, Dokko, and Rosenkopf 2003; Furlan 2019). Such conditions ensure a good level of innovation in start-ups' first stage of growth, resulting in significant patenting activity. At higher levels, however, start-up size can negatively affect patenting likelihood. First, innovation productivity can be damaged when a firm must attend to other functions in the value chain, such as production, coordination, commercialization, or distribution (Colombo, Grilli, and Piva 2006). Second, start-up growth reflects a good level of resources, which reduces incentives to register patents for reasons other than mere protection.

In sum, increase in start-up size may be positively related to number of patents registered, as the effect of additional resources and incentives protects inventions through patents. At a certain point, however, the relationship between size and patents becomes negative due to lower innovative results and lower incentives to patent.

H1: *An inverted U-shaped relationship exists between start-ups' size and their patenting likelihood.*

Location Strategy and Patents in Start-ups

Innovation activity is usually located in specific geographic areas, commonly known as clusters. Location in clusters and other co-location strategies have traditionally been related to higher levels of innovation in start-ups (Brenner and Greif 2006; Calcagnini et al. 2016; Colombelli 2016; DeCarolis and Deeds 1999) and other firms (Blind and Grupp 1999). Looy, Debackere, and Andries (2003) determine that geographical clustering (with the presence of universities, knowledge centres, established firms and high-tech start-ups, and the availability of venture capital) is a critical ingredient in boosting regional innovation and economic success. For decades, many empirical studies provided solid evidence of the advantages of working near other innovation partners to achieve complementary assets (see, e. g. Colombo, Grilli, and Piva 2006). More recently, however, scholars have highlighted the dark side of working side by side with other innovation players (see, e. g. Allen et al. 2016; Pe'er and Keil 2013).

Traditionally, research has concentrated on highlighting the advantages that start-ups exploit by locating near other innovation players. Among other benefits, location provides the opportunity to create informal ties to seize knowledge spillovers (Brenner and Greif 2006; Colombelli 2016; Henderson and Cockburn 1996), offsets liabilities associated with newness (McCann and Folta 2011), increases communication between firms (Allen et al. 2016), provides a valuable context in which to capture talent and skilled employees (Pe'er and Keil 2013) and promotes employee mobility to ensure regular knowledge flow between various agents (Colombo et al. 2017; DeCarolis and Deeds 1999). These advantages can generate important innovative results that translate into patents. Some studies highlight the challenge that co-location strategy poses to surviving extreme levels

of rivalry, and not all start-ups have the resources required to face this difficult context (Pe'er and Keil 2013). Under such conditions, start-ups must develop intense patenting activity to protect their inventions (Mann and Sager 2007), in addition to achieving innovative performance.

Location near other actors can thus be associated with higher patenting likelihood for inventions developed by start-ups, due either to truly superior innovation performance or to protection decisions. We can argue, however, that proximity to specific actors leads to more intense patenting activity. Specifically, working near horizontal agents, such as other start-ups, or locating in co-working centres where creative teams are developing similar projects in the same industry (Spreitzer, Garrett, and Bacevice 2015) may increase the possibility of registering patents. While this horizontal tie can provide many opportunities to innovate, prospective employee mobility poses a greater need to protect innovative advances through patents.

H2: *Patenting likelihood is more intense when start-ups are located near other horizontal agents.*

H2(a): *Patenting likelihood is more intense when start-ups are located near other start-ups.*

H2(b): *Patenting likelihood is more intense when start-ups are located in co-working spaces/centres.*

H2(c): *Patenting likelihood is more intense when start-ups are located in clusters.*

While the contextual factor of locating near horizontal agents increases patenting likelihood, patents can also be seen as instruments to achieve reputation when start-ups choose to locate in clusters, especially at international level. Local clusters aside, start-ups locate in international clusters to access prestigious collaborators. Some studies show, however, that mere location in international clusters does not enhance the likelihood of creating international alliances, due to high rivalry in these geographic locations (see, e. g. Delerue and Lejeune 2012). Recent empirical evidence consistently attributes a major cause of start-up failure in international clusters to lack of resources to compete in these contexts (Pe'er and Keil 2013). Patents can compensate for such lack of resources, serving as an objective signal of technological performance to help start-ups stand out among rivals. Strategic motives such as reputation and access to international markets (Blind et al. 2006) explain why start-ups develop intense willingness to patent their inventions when they decide to locate in international clusters.

H3: *Locating in clusters increases the patenting likelihood when start-ups compete at international level.*

Collaboration Partners and Patents in Start-ups

In addition to reaping benefits by co-locating near other related agents, start-ups may collaborate with other partners due to lack of certain resources (De Meyer 1999), promoting regular interaction and creating more formal ties (Paradkar, Knight, and Hansen 2015). The search for complementary assets and complex knowledge explains the collaboration between start-ups and vertical partners (Colombo, Grilli, and Piva 2006; Baum and Silverman 2004), even when they are not co-located (Brenner and Greif 2006). Baum, Calabrese, and Silverman (2000) distinguish between upstream alliances (with universities and research institutes) and downstream alliances (with manufacturing, marketing or consulting companies).

Although vertical collaborations pose multiple opportunities for start-ups as drivers of innovation and entrepreneurial activities (Calcagnini et al. 2016), such alliances should be also seen as sources of threats and risk that constitute an additional reason to patent in order to guard against opportunistic behaviour (Jolink and Niesten 2016). Collaboration activities with these vertical partners frequently increase likelihood of unintended and dangerous knowledge spillovers that can be reduced through patents (Blind et al. 2006). Yet such knowledge spillovers are not equally common in every collaborative situation (Sorenson, Rivkin, and Fleming 2006). We thus argue that collaboration with vertical agents is not always related to more intense patenting likelihood.

Upstream alliances increase the danger of knowledge spillovers for start-ups, as specific knowledge can flow easily between the two parties (Sorenson, Rivkin, and Fleming 2006). A major reason firms enter into such exploratory alliances is to expand their collection of distinctive capabilities (Colombo, Grilli, and Piva 2006; Cho and Lee 2016; Ernst, Conley, and Omland 2016), a goal that frequently requires sharing technological know-how generated through significant R&D effort (Calcagnini et al. 2016). For the partners involved, patents can ensure retrieval of the knowledge spilled (Leiponen and Byma 2009). In signing downstream alliances, in contrast, start-ups pursue other complementary assets, such as a well-known brand, low-cost manufacturing capacity, or a specialized distribution channel (Colombo, Grilli, and Piva 2006). In such exploitative alliances, the likelihood of dangerous spillovers is small, due to the technological and strategic distance between the two parties (Baum, Calabrese, and Silverman 2000; Sorenson, Rivkin, and Fleming 2006).

H4: *Patenting likelihood is more intense when start-ups collaborate with upstream partners (universities and research institutes) than with downstream partners.*

Financial Means and Patents in Start-ups

An additional factor explaining when start-ups patent is their financing strategy at any given time. The survival, growth, and success of a start-up depend largely on its capacity to secure financial support through external means (Greenberg 2013). In other words, financial resources are one of the most valuable complementary assets that start-ups must obtain (Colombo et al. 2017). Saridakis, Mole, and Hay (2013) show that being financially constrained at start-up is related to higher vulnerability to external forces and higher likelihood to exit the industry. Different options for obtaining financial resources – such as venture capital, business angels, and crowdfunding – may affect patenting likelihood differently in start-ups (Ahlers et al. 2015). Although scholars have paid more attention to the link between venture capital and patents (Dutta and Folta 2016; Haeussler, Harhoff, and Mueller 2014; Holgersson 2013; Islam, Fremeth, and Marcus 2018; Mann and Sager 2007; Smith and Cordina 2015; Zhou et al. 2016), this study includes additional financial instruments, such as business angels and crowdfunding, as possible influences on patenting activity in start-ups.

Some studies demonstrate that venture capital triggers a wide variety of effects in the management of start-ups (Hellmann and Puri 2000; Looy, Debackere, and Andries 2003). For Davila, Foster, and Gupta (2003), venture capital leads start-ups to increase their number of employees in the months both prior to the venture capital round and after the event. In general terms, venture-backed start-ups benefit from additional advantages (technical resources, reputation, networking, or specialized coaching), while also facing significant changes in their boards and governance. Seizing venture capital opportunities could also affect patenting likelihood in start-ups. Before the round is completed, start-ups can patent their previous inventions to obtain resources with liquidation value, which in uncertain conditions can attract the interest of venture capitalists (Ahlers et al. 2015; Cassar 2004; Mann and Sager 2007). Since venture capitalists view ability to patent as a potential indication of future survival, start-ups may be strongly motivated to patent in order to attract these investors (Smith and Cordina 2015). Moreover, once the investment has been made, registration of additional patents can mitigate venture capitalists' risks by safeguarding knowledge and intellectual property within the firm (Holgersson 2013).

Other theoretical arguments in the specialized literature may, however, suggest that business angels affect the patenting activity of start-ups differently than does venture capital. Firstly, business angels usually invest in start-ups in the early stage (as seed capital), providing less-formal financial means before start-ups have been able to develop inventions to be patented (Cassar 2004). It is thus difficult for start-ups to use patents to attract the interest of business angels. Secondly, due to their more relaxed governance approach and long-term horizon for investments, business angels do not usually force the innovation process to obtain additional patents as financial payoffs (Dutta and Folta 2016). Further, since business angels usually invest in a particular industry where they have gained some experience, they are limited in their ability to provide an extensive network of contacts or sophisticated knowledge to boost the innovation process of the start-ups in which they invest (Vanacker, Collewaert, and Paeleman 2013).

In addition to venture capital and business angels, crowdfunding has recently emerged as a novel way for start-ups to raise capital from a relatively large number of individuals without financial intermediaries (Calic and Mosakowski 2016). Scholarly interest has focused on explaining the variables that ensure the venture's success in obtaining crowdfunding. To date, scholars agree on the essential role that quality signals play in attracting 'the crowd' in crowdfunding projects (Mollick 2014). Ahlers et al. (2015) present evidence that successful crowdfunding projects are based on credible signals that highlight the quality of the start-up. Patents thus clearly fulfil the criterion of serving as a signal to differentiate between competing start-ups (Cohen and Lemley 2001; Long 2002). In other words, we can expect start-ups facing a crowdfunding project to make great efforts to patent their inventions as an objective way to signal their quality. Stanko and Henard (2016) recently demonstrated that start-ups can develop subsequent innovation projects once the crowdfunding campaign is complete, seizing valuable feedback from early adopters who become crowdfunders. Start-ups can achieve additional innovations that translate into new patents from these crowdfunding projects.

According to these theoretical arguments, we formulate the following hypotheses:

H5: *Patenting likelihood can vary depending on the financial means used by start-ups.*

H5(a): *Patenting likelihood is more intense when start-ups are financed through venture capital.*

H5(b): *Patenting likelihood is less intense when start-ups are financed through business angels.*

H5(c): *Patenting likelihood is more intense when start-ups are financed through crowdfunding.*

Research Approach

Data Source and Procedures

We used a questionnaire survey method to collect data from Spanish start-ups. The study population was obtained from *Start-upxplore*, a global platform to connect start-ups, investors, and seed accelerators in an entrepreneurial ecosystem. The platform currently acts independently and represents the unique overall record of start-ups in Spain. At the time of data collection (2017), *Start-upxplore* included 7928 start-ups as the basis for the target population.

The questionnaire was distributed via email to the population of start-ups. After repeated reminders, 220 anonymous, complete responses were returned. The sample contains start-ups with distinct characteristics from diverse industries, sectors and locations in Spain. Once the data were exported from the Google database, the responses were coded to enable numerical analysis of the variables. Statistical analysis program SPSS (version 22) was used for the quantitative and regression analyses.

Measures

Table 1 contains the distribution of start-ups in the sample, classified by age, size, and sector. Sector classification is based on the Venture Economics Industry Codes (VEIC). Many scholars have used the VEIC schema to categorize start-ups in different industries (see, e. g. Mann and Sager 2007). Table 2 shows the study variables, with their main descriptors and statistical measures. These variables were obtained from specific items in the questionnaire. In most cases, items were recorded in such a way that higher values represented higher levels on the different scales.

Table 1: Distribution of start-ups by age, size, and sector.

Variable distribution	Start-ups in the sample (%)
Age	
Less than 1 year	11.8
1–2 years	26.4
2–4 years	39.5
More than 5 years	22.3
Size	
1–5 employees	60.9
6–10 employees	16.4
11–15 employees	8.2
More than 15 employees	14.5
Sector	
Sector 1: Communications and media, computer- and other electronics-related[1]	40.0
Sector 2: Biotechnology, pharmacology and medical/health-related[2]	6.4
Sector 3: Energy-related[3]	3.2
Sector 4: Consumer-related[*]	19.5
Sector 5: Industrial products[†]	5.9
Sector 6: Other services and manufacturing[a]	25.0

[1]Sector 1 regroups three main categories: Communications and Media (VEIC 1000), Computer-Related (VEIC 2000) and Other Electronics-Related (VEIC 3000).
[2]Sector 2 regroups two main categories: Biotechnology and Pharmacology (VEIC 4000), and Medical/Health-Related (VEIC 5000).
[3]Sector 3 refers to Energy-Related (VEIC 6000).
[*]Sector 4 refers to Consumer-Related (VEIC 7000).
[†]Sector 5 refers to Industrial Products (VEIC 8000).
[a]Sector 6 refers to Other Services and Manufacturing (VEIC 9000). It may include start-ups in industries related to Transportation, Financial Services, Agriculture, Forestry, Fishing and Animal Husbandry, Mining and Minerals (non-energy related), Construction and Building Products, Utilities and Related Firms, and Other Products and Services.

Table 2: Measures of variables.

Variable	Definition	Measurement
Dependent variable		
Patent	Binary variable to record whether the start-up has registered any patent to protect its inventions.	This variable takes the value 1 if the start-up has patented its inventions and 0 if the start-up has not patented its inventions.
Independent variables		
Location	Degree of start-up's proximity to: (a) other start-ups, (b) co-working spaces/centres or (c) clusters.	Five-point Likert scale ranging from "null or very low" to "very high" proximity.
Collaboration	The extent to which a start-up cooperates and works with other partners that typically shape the innovation ecosystem: (a) universities, (b) research institutes, (c) other start-ups, (d) large companies, (e) SMEs and (f) public administrations.	Five-point Likert scale ranging from "null or very low" to "very high" collaboration.
Financing	Extent to which a start-up is backed through each of the different means of funding. Backing options considered in the study were: (a) venture capital, (b) business angels' investments and (c) crowdfunding.	Five-point Likert scale ranging from "null or very low" to "very high" financing intensity.
Control variables		
Age	Number of years since the start-up was established.	Four categories ranging from 1 to 4, as follows: '1' for less than 1 year, '2' for 1–2 years, '3' for 2–4 years, and '4' for more than 5 years.
Scope	Refers to the geographical reach of start-up activities.	Four categories ranging from 1–4 as follows: '1' for local, '2' for national, '3' for international and '4' for global scope.
Size	Number of employees reported by start-up at moment of data collection.	Four categories ranging from 1–4 as follows: '1' for 1–5 employees, '2' for 6–10 employees, '3' for 11–15 employees and '4' for more than 15 employees.

Dependent Variable: Patent

Prior research has commonly used patents as indicators of innovation output (Allen et al. 2016; Doblinger, Surana, and Diaz Anadon 2019; Brenner and Greif 2006; Shan, Walker, and Kogut 1994). Although it could be argued both that not all innovations are patented and that not all patented inventions become innovations,

patents represent one of the few reliable variables available over time. Further, given the cross-sectional nature of our survey, start-ups might not register comparable numbers of patents due to the idiosyncrasies of each sector. According to Soh and Subramanian (2014), not all firms have the same propensity to patent their inventions, and patents may be limited to specific technological areas. We thus define the dependent variable as a binary variable, asking start-ups whether or not they have registered any patent to protect their inventions. The variable 'patent' takes the value 1 if a start-up has actually registered a patent.

Independent Variables and Control Variables

Table 2 details the methods employed to measure the set of independent variables: location, collaboration, and means of financing. Our study also considered three control variables: age, scope, and size. We argue the role of age as a control variable due to the common influence of age and size on the number of patent applications (Allen et al. 2016). We controlled for firm-size effect as a typical influence explaining innovation output according to prior literature (Allen et al. 2016; Shan, Walker, and Kogut 1994).

Results

Table 3 represents the main descriptive statistics and Table 4 the correlations among the variables. Based on the mode values in Table 3, the most common features of the start-ups included in the sample are: age 2–4 years old, national scope, having 1–5 employees, preference for being located near other start-ups, being financed by business angels, and having mainly collaborated with other start-ups, large firms and SMEs, and public administration.

Table 3: Descriptive statistics.

Variable	Mean	Median	Mode	SD	Min.	Max.
1. Patent	0.26	0	0	0.44	0	1
2. Age[1]	2.72	3	3	0.94	1	4
3. Scope[2]	2.90	3	2	0.83	1	4
4. Size[3]	1.76	1	1	1.11	1	4
5. Loc. Start-ups	3.27	4	5	1.54	1	5
6. Loc. Co-working	2.98	3	1	1.61	1	5
7. Loc. Clusters	2.92	3	1	1.55	1	5
8. Co. Universities	2.46	2	1	1.48	1	5
9. Co. Research Institutes	1.78	1	1	1.19	1	5
10. Co. Start-ups	3.04	3	3	1.29	1	5
11. Co. Large Companies	2.61	3	3	1.30	1	5
12. Co. SMEs	2.97	3	3	1.26	1	5
13. Co. Public Administration	2.32	2	1	1.30	1	5
14. F. Venture Capital	2.08	1	1	1.55	1	5
15. F. Business Angels	3.06	3	5	1.66	1	5
16. F. Crowdfunding	1.33	1	1	0.96	1	5

[1]Age ranges from 1 to 4 as follows: 1 = less than 1 year, 2 = 1–2 years, 3 = 2–4 years, 4 = more than 5 years.
[2]Scope ranges from 1 to 4 as follows: 1 = local, 2 = national, 3 = international, 4 = global.
[3]Size ranges from 1 to 4 as follows: 1 = 1–5 employees, 2 = 6–10 employees, 3 = 11–15 employees, 4 = more than 15 employees.

Table 4: Correlations among variables.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Patent															
2. Age	0.02														
3. Scope	0.20**	0.10													
4. Size	0.15*	0.31**	0.11												
5. Loc. Start-ups	0.12	−0.14*	−0.01	−0.09											
6. Loc. Co-working	−0.04	−0.15*	−0.07	−0.11	0.74**										
7. Loc. Clusters	0.13	−0.02	0.08	0.00	0.64**	0.53**									
8. Co. Universities	0.30**	0.10	0.10	0.17**	0.16*	0.07	0.15*								
9. Co. Research Institutes	0.41**	0.04	0.11	0.08	0.27**	0.13	0.27**	0.56**							
10. Co. Start-ups	0.06	0.04	0.01	−0.03	0.43**	0.30**	0.28**	0.18**	0.26**						
11. Co. Large Companies	0.13*	0.22**	0.13	0.31**	0.09	0.10	0.18**	0.15*	0.14*	0.22**					
12. Co. SMEs	0.11	0.09	0.05	0.08	0.10	0.11	0.12	0.27**	0.19**	0.28**	0.50**				
13. Co. Public Administration	0.25**	−0.02	0.07	0.13	0.23**	0.11	0.26**	0.40**	0.50**	0.19**	0.26**	0.28**			
14. F. Venture Capital	0.15*	−0.02	0.09	0.37**	0.10	0.06	0.13	0.17*	0.21**	0.09	0.16*	0.06	0.29**		
15. F. Business Angels	−0.03	−0.06	0.09	−0.12	0.20**	0.13*	0.23**	0.04	0.09	0.12	−0.05	0.10	0.11	0.16*	
16. F. Crowdfunding	0.23**	−0.03	0.02	0.05	0.07	0.03	0.08	0.12	0.15*	0.13*	0.06	−0.02	0.08	0.10	0.02

$N = 220$
* $p < 0.05$
** $p < 0.01$

Table 5 reports the logit estimation results to test our hypotheses. A logistic regression model was adopted due to choice of a binary-dependent variable. Using this statistical method, we estimate how a set of independent variables explains the likelihood that the dependent variable takes the value 1 (Hilbe 2009; Hosmer and Lemeshow 2000). This statistical methodology has been employed in other empirical studies in the field, in which scholars analyse when a company registers patents or sells licenses to these patents (see, e. g. Colombo, Grilli, and Piva 2006).

Table 5: Logit regression models on patent.

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Control variables						
Age	−0.10	−0.14	−0.13	−0.11	−0.10	−0.10
	(0.18)	(0.18)	(0.19)	(0.19)	(0.21)	(0.21)
Scope	0.56**	0.64**	0.58**	−0.41	−0.52	−0.47
	(0.20)	(0.21)	(0.21)	(0.46)	(0.50)	(0.50)
Size	0.28*	2.57**	2.37**	2.48**	2.28*	2.48*
	(0.14)	(0.89)	(0.91)	(0.93)	(1.03)	(1.06)
Predictors						
Size-squared		−0.47**	−0.43*	−0.45*	−0.44*	−0.47*
		(0.18)	(0.18)	(0.19)	(0.21)	(0.22)
Loc. Start-ups			0.43*	0.46*	0.41+	0.35+
			(0.17)	(0.18)	(0.21)	(0.21)
Loc. Co-working			−0.38*	−0.41*	−0.37*	−0.39*
			(0.16)	(0.16)	(0.18)	(0.19)
Loc. Cluster			−0.13	−0.88*	−1.00*	−1.01*
			(0.14)	(0.45)	(0.50)	(0.51)
Scope x Loc. Cluster				0.32*	0.34*	0.35*
				(0.14)	(0.15)	(0.16)
Co. Universities					0.14	0.13
					(0.15)	(0.15)
Co. Research Institutes					0.64**	0.61**
					(0.20)	(0.19)
Co. Start-ups					−0.25	
					(0.17)	
Co. Large Companies					0.11	
					(0.18)	
Co. SMEs					0.03	
					(0.18)	
Co. Public Administration					0.00	
					(0.17)	
F. Venture Capital						0.01
						(0.14)
F. Business Angels						−0.19
						(0.13)
F. Crowdfunding						0.48**
						(0.18)
Constant	−2.93***	−5.08***	−5.51*	−2.61	−2.96	−3.54+
	(0.75)	(1.15)	(1.28)	(1.71)	(1.87)	(1.88)
N	220	220	220	220	220	220
Chi square	12.85**	19.65***	30.12***	35.83***	61.37***	69.05***
Hosmer and Lemeshow Test	12.08	11.93	5.37	6.40	6.43	6.22
−2 Log likelihood	240.96	234.15	223.68	217.98	192.44	184.75
Pseudo R^2 (McFadden's R^2)	0.05	0.08	0.12	0.14	0.24	0.27
Pseudo R^2 (Nagelkerke's R^2)	0.08	0.12	0.19	0.22	0.36	0.39

Note. Standard errors in parentheses.
Hosmer and Lemeshow test presents p-values above the significance level of 5 %.
$^{+}p < 0.10$.
$^{*}p < 0.05$.
$^{**}p < 0.01$.
$^{***}p < 0.001$.

Model 1 is the baseline model, with constant and control variables only. All of these variables have a positive and statistically significant influence on the dependent variable except the variable age. Models 2–6 examine the effects of the explanatory variables on the dependent variable. Model 2 includes the U-shaped impact of start-up size. Models 3 and 4 represent the effects of location, and Model 5 treats the influence of collaboration on the dependent variable. Finally, Model 6 includes financing variables.

Based on the results of Model 2, the variable "size squared" holds the expected negative coefficient and is statistically significant (−0.47, $p < 0.01$). Subsequent models (Models 3–6) maintain the U-shaped relationship. We thus confirm the first condition to prove the quadratic effect of size on patenting activity. Further, to improve confirmation of this quadratic effect, we estimate both linear and curvilinear regressions and compare the results (Table 6). The quadratic regression is more significant than the linear estimation, showing a positive and negative coefficient for each side of the curve, respectively. This evidence supports Hypothesis 1. Figure 1 represents graphically the role of both the linear estimation and the quadratic regression of size in explaining the dependent variable. The maximum is reached when variable size takes the value 2.75. As this value is between 2 and 3, patenting likelihood reaches a tipping point for medium-sized start-ups, that is, for start-ups with 6–10 employees and 11–15 employees.

Table 6: Linear and curvilinear regression of size and patent.

Equation	Summary of the model			Estimations		
	R^2	F	Sign.	Constant	b1	b2
Linear	0.022	4.809	0.029	0.160**	0.059*	
Quadratic	0.044	4.985	0.008	–0.167	0.441*	–0.080*

* $p < 0.05$.
** $p < 0.01$.

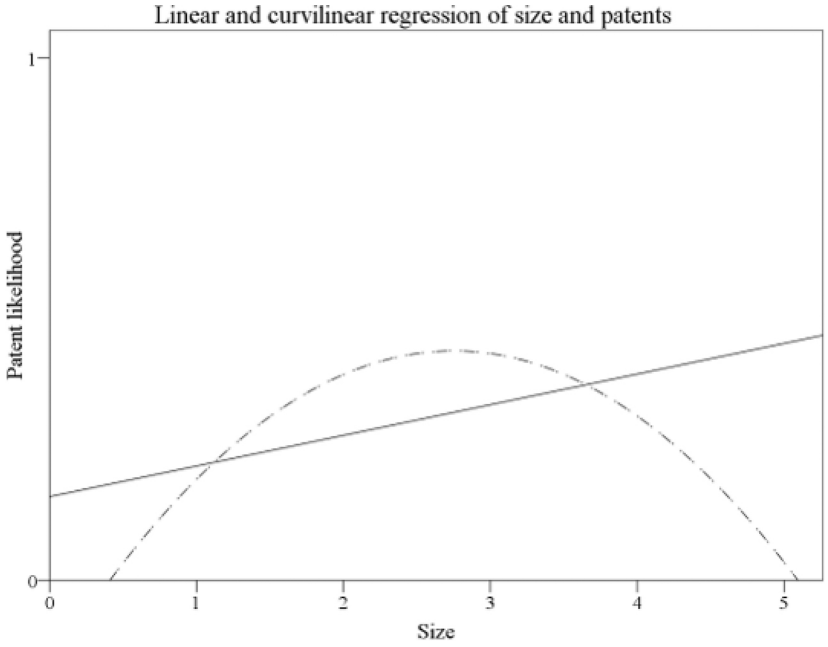

Figure 1: Linear and curvilinear regression of size and patents. Note: Figure 1 is based on the linear and quadratic estimations in Table 5.

Hypothesis 2 is tested in Model 3. The coefficient 'location near start-ups' is positively and statistically significant (0.43, $p < 0.02$). Hypothesis 2a thus states that likelihood of patenting is greater when start-ups are located near other start-ups. Hypotheses 2b and 2c relate this idea to location in co-working spaces/centres and clusters. Contradicting Hypotheses 2b and 2c, Model 2 reports a negative and statistically significant relationship if the start-up is located near co-working spaces (−0.38, $p < 0.01$) and no significance if the start-up is located in clusters (0.13, $p < 0.35$). Hence, our data only partially support Hypothesis 2.

To test Hypothesis 3, Model 4 reports a negative and statistically significant relationship when start-ups are located in clusters (−0.88, $p < 0.05$). On introducing the interaction effect between scope and location in cluster, however, we obtain a positive and significant coefficient (0.32, $p < 0.05$). The interaction effect reverses

the initial negative relationship between location in clusters and patents, resulting in a positive relationship when the scope of the start-up activity is extended from local to global. Therefore, Hypothesis 3 is supported.

Model 5 tests Hypothesis 4, showing that collaboration with research institutes has a positive and significant coefficient (0.64, $p < 0.01$). No significance was found, however, for the coefficient collaboration with universities. Nor were collaboration variables related to downstream partners statistically significant. Since only research institutes have a significant impact on the dependent variable, collaboration with most downstream partners has no statistical significance, partially supporting Hypothesis 4.

Hypothesis 5 is tested through Model 6. Hypotheses 5a and 5b refer to venture-backed start-ups and start-ups financed through business angels, respectively. Both coefficients have the expected signs: positive in the case of venture capital and negative in the case of business angels. Neither is statistically significant. Hypothesis 5c shows that crowdfunding has a positive and significant coefficient (0.30, $p < 0.001$). The global Hypothesis 5 is thus only partially supported, as Model 6 supports Hypothesis 5c but not Hypotheses 5a and 5b.

Figure 2 sums up the results of the model tested.

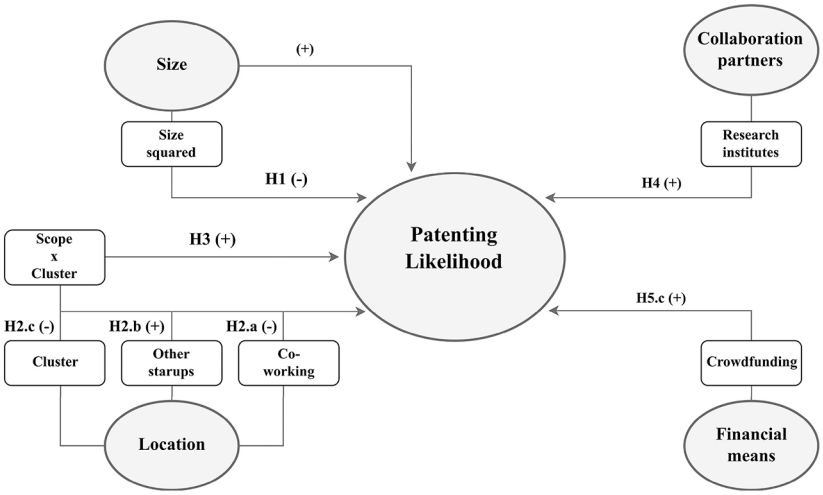

Figure 2: Summary of the model tested. Notes: Figure 2 is based on the logit estimates for Model 6 in Table 4. Each arrow specifies the positive and negative relationships between variables on patenting likelihood for signs of coefficients obtained in the model tested.

Finally, Table 4 displays additional information on the models' goodness of fit. Chi-square tests enable us to determine whether the models are globally significant (with $p < 0.001$ in most), while the Hosmer and Lemeshow tests produce p-values above the significance level (5 %), leading us to conclude that the models seem to fit well. Moreover, the pseudo R^2s suggest that the final Model 6 fits best. In addition, to assess problems of multicollinearity among the variables analysed, we checked all variance-inflation factors (VIF) and condition indexes. All VIFs are under 3.15 – well below the cut-off threshold of 10. Moreover, the average of the set of VIF values is 1.54, suggesting little risk of multicollinearity.

Discussion

This study was conducted to test a wide range of variables that may contribute to patenting activity of start-ups in different activity sectors. We evaluated the role of size, location, collaboration partners, and financial means together to determine the conditions under which start-ups decide to patent their inventions. The results could extend understanding of strategic motives to patent beyond mere protective interest.

First, we analysed the influence of control variables that might explain when a start-up patents its inventions. Age does not seem to be a critical factor in the model estimated, although some empirical studies demonstrate that older firms build a larger technology base protected by several patents over time (see, e. g. Peeters and de la Potterie 2006). Our finding may be explained by the different positive and negative ways that age can influence patenting simultaneously (Almeida, Dokko, and Rosenkopf 2003), which could end up producing an overall non-significant effect in our results. In contrast, as expected, patenting likelihood increases if start-ups extend their scope of activity to international or global level. Like the prior literature, our study confirms that patents are closely related to specific contexts (Helmers and Rogers 2011; Mann and Sager 2007; Shan, Walker, and Kogut 1994).

Firstly, we established and tested the quadratic effect of size on the possibility of registering patents in start-ups. The findings support the conclusion that start-up size is positively related to patents in the first stage

of growth. Once a tipping point is reached, however, the relationship becomes negative. This effect can be explained by decreasing innovative performance or minor strategic incentives to patent. Firstly, larger size forces the start-up to focus on coordination and management activities that do not contribute directly to generating new patents. Secondly, when size and tangible assets are small, start-ups feel motivated to patent to signal their technological and innovative potential. Their efforts are thus devoted to registering patents in the early stage of growth. Once a considerable size is reached, start-ups work to achieve other strategic objectives related to key collaborations or financial resources.

Secondly, we tested the role of location in the patenting likelihood of start-ups. Based on related literature, we established that the probability is greater when start-ups are located near other horizontal agents and international clusters. Firstly, the findings support that being located near other start-ups increases patenting likelihood. Working side by side may create a positive context to enhance innovation but may also indicate that employee mobility forces start-ups to develop intense activity to register patents in order to protect their inventions from prospective knowledge spillovers. Secondly, although we hypothesized the same relationship for location of co-working centres and clusters, our results shows that this location strategy negatively influences patenting likelihood in start-ups. This surprising finding provides additional insights into which variables can determine whether start-ups patent. The results on co-working centres may be explained by a working culture in these spaces based on rules such as trust, rapport and collegiality, which promote open knowledge flow, influencing patenting activity in the direction opposite to that expected (Spreitzer, Garrett, and Bacevice 2015). Our findings thus show that work environment can influence willingness to patent, regardless of who is located near the start-up.

As to location in clusters, we established that the international scope of start-ups can moderate the relationship between location in clusters and patenting likelihood. Initially, our results showed a significant negative relationship among clusters and patent likelihood in start-ups. This relationship could be explained by the fact that the benefits of agglomeration are not distributed symmetrically among firms in the cluster. According to McCann and Folta (2011), patenting activity is associated with younger firms and firms that possess higher knowledge stocks. Despite this negative relationship, we found that the sign of this relationship is reversed once start-ups compete in international clusters. The findings thus provide information about the importance of patents to achieving reputation in these competitive contexts, where lack of resources can hinder success in achieving key international collaborations. Finally, patents can compensate for this lack of resources by providing objective reputational signals of the innovative potential of start-ups located in international clusters.

Thirdly, we hypothesized and tested the influence of upstream vertical collaborators on patenting activity. The results support the conclusion that collaboration with research institutes increases patenting likelihood in start-ups, but our results do not show evidence of collaboration with other upstream vertical agents, such as universities. Firstly, the significant influence of collaborations with research institutes highlights the importance of knowledge spillovers to specialized partners with low technological distance, a danger limited through patents. Secondly, our results suggest differences in the intentions of start-ups when collaborating with research institutions and universities. Finally, our findings are useful to confirm that patenting activity is not an important goal in signing exploitative alliances with downstream vertical partners such as large companies, SMEs and public administration. Consistent with our results, Leiponen and Byma (2009) found that small firms that collaborate with horizontal partners tend to prefer speed to protecting innovations through patents.

Ultimately, we argue theoretically and test empirically how different financial means influence patenting likelihood in start-ups. Firstly, although the literature presents solid arguments for the connection between venture capital and patents in start-ups, our results do not support this relationship between the two variables, when we also consider crowdfunding in the model. No other study to date compares the relative weight of these financial factors on patenting activity. Then, our results show that crowdfunding becomes the most important source of financing in explaining when start-ups patent their inventions (venture capital loses relative importance). Our results are thus consistent with some arguments developed in other studies (Dutta and Folta 2016; Smith and Cordina 2015), which argue that venture capital investors may use patents as a signal when deciding to invest (Holgersson 2013; Zhou et al. 2016) but that being backed by venture capital does not necessarily lead start-ups to register additional patents once the investment decision is made. This finding can be explained by venture capital investors' tendency to focus on helping the start-up define its business model to generate market value rather than on boosting or promoting the start-up's technical capabilities to register new patents (Smith and Cordina 2015). Our study shows instead that crowdfunding campaigns may strengthen patenting activity. We thus confirm the findings of other recent articles that highlight crowdfunding's potential to boost the innovation process or increase the need of protection (see Stanko and Henard 2016). Firstly, start-ups may patent to attract any kind of investor and signal their technological potential; however, crowdfunding campaigns can provide additional opportunities to trigger subsequent innovation processes, which will translate into in higher patenting likelihood. Frequently, early adopters of a new technology become crowdfunders who get involved by providing feedback for subsequent versions of technological applications. In addition to providing finan-

cial resources, crowdfunding thus presents the opportunity to boost innovation through lead-users, increasing patenting likelihood in the start-up. On the other hand, the need to protection will be higher when new technical projects are shared to many crowdfunders. Finally, although we expected a lower influence of business angels on patents, our results suggest no influence at all. The flexible governance approach of business angels and the long-term duration of their investments do not exert great influence on the innovation process (Dutta and Folta 2016). Moreover, Conti, Thursby, and Rothaermel (2013) demonstrate that patents have no signalling value for business angels. Similarly, Croce, Tenca, and Ughetto (2017) find that a start-up is more likely to be rejected at the screening stage of business angels' investments due to the characteristics of the entrepreneurial and management team than to lack of innovativeness. These issues may relegate registering of patents to second place when the start-up is backed by angel investors.

Managerial Implications

While this study advances scholarly knowledge, it is also of value for start-up managers who wish to make decisions about protective strategy and its value. For example, our results highlight that the start-up should invest effort in patenting activity in the early stages in order to capture this activity's value to achieve reputation in international clusters or collaboration agreements (especially with research institutes). Moreover, patents should be seen as a necessary resource when the start-up works near other start-ups but are not crucial when the start-up has decided adopt the philosophy of co-working centres. Finally, managers should consider the role of patents when seeking to attract attention through crowdfunding activities, in which protecting initial inventions with a patent is an indicator of innovation potential, the ability to introduce new products or services regularly in the future.

Limitations and Future Research

Some limitations must be taken into account in analysing the results of this study. Firstly, data were collected at a single point in time. Although theory grounds the argument for causality in the relationships analysed, our results do not explain the direction of this causality and thus limit our findings to correlation between variables. Future research could examine these relationships using longitudinal data. Secondly, most analyses of patents consider the objective number of patents registered in a specific period. However, much heterogeneity exists across industries and firms in both number of patents and motives to pursue innovation (Dutta and Folta 2016). This consideration led us to use a binary variable for patents to measure the effects of the explanatory variables across sectors with greater accuracy. Measuring innovation beyond the use of patents also presents difficulties due to restrictions on objective data. A promising direction for future research would be to analyse patents divided by start-up industry and to use more accurate and realistic measures for innovation outcomes. Thirdly, our survey is limited to Spanish start-ups, making it difficult to generalize the findings. We should bear in mind that governments affect start-up behaviour through different laws to promote entrepreneurship, and results could be different in other countries.

Conclusions

This study examined the variables that influence patenting activity in start-ups. Specifically, we examine the role of size, location, collaboration and financial means in start-ups in different activity sectors of the Spanish economy. According to our findings, the Spanish start-up with the greatest likelihood to patent competes at international level, is not large in size, is located near other start-ups and international clusters, collaborates with research institutes and is financed through crowdfunding campaigns. The results of this study reflect different contexts in which start-ups find diverse motives to patent, beyond mere necessity to protect previous inventions and defend against knowledge spillovers. Patents can be seen as a source of reputation or an objective signal to highlight start-ups' innovative and technological potential in order to attract partners or investors. Due to the lack of resources start-ups face, patents become a strategic resource to obtain and exploit in order to achieve other strategic objectives.

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References

Ahlers, G. K. C., D. Cumming, C. Günther, and D. Schweizer. 2015. "Signaling in Equity Crowdfunding." *Entrepreneurship Theory and Practice* 39 (7): 955–80.

Allen, T. J., P. A. Gloor, A. Fronzetti Colladon, S. L. Woerner, and O. Raz. 2016. "The Power of Reciprocal Knowledge Sharing Relationships for Start-up Success." *Journal of Small Business and Enterprise Development* 23 (3): 636–51.

Almeida, P., G. Dokko, and L. Rosenkopf. 2003. "Start-up Size and the Mechanisms of External Learning: Increasing Opportunity and Decreasing Ability?" *Research Policy, Special Issue on Technology Entrepreneurship* 32 (2): 301–15.

Großmann, A-M, E. Filipović, and L. Lazina. 2016. "The Strategic Use of Patents and Standards for New Product Development Knowledge Transfer." *R&D Management* 46 (2): 312–25.

Arundel, A., and I. Kabla. 1998. "What Percentage of Innovations are Patented? Empirical Estimates for European Firms." *Research Policy* 27 (2): 127–41.

Audretsch, D. B., and M. Vivarelli. 1996. "Firm Size and R&D Spillovers: Evidence from Italy." *Small Business Economics* 8 (3): 249–58.

Banerjee, P. M., and B. M. Cole. 2012. "A study of biotechnology start-ups undergoing leadership change: Antecedents of change and endogenous performance consequences." *Technovation*, 32 (9–10), 568–78.

Baum, J. A. C., T. Calabrese, and B. S. Silverman. 2000. "Don't Go It Alone: Alliance Network Composition and Start-ups' Performance in Canadian Biotechnology." *Strategic Management Journal* 21 (3): 267–94.

Baum, J. A. C., and B. S. Silverman. 2004. "Picking Winners or Building Them? Alliance, Intellectual, and Human Capital as Selection Criteria in Venture Financing and Performance of Biotechnology Start-ups." *Journal of Business Venturing* 19 (3): 411–36.

Blind, K., J. Edler, R. Frietsch, and U. Schmoch. 2006. "Motives to Patent: Empirical Evidence from Germany." *Research Policy* 35 (5): 655–72.

Blind, K., and H. Grupp. 1999. "Interdependencies between the Science and Technology Infrastructure and Innovation Activities in German Regions: Empirical Findings and Policy Consequences." *Research Policy* 28 (5): 451–68.

Brenner, T., and S. Greif. 2006. "The Dependence of Innovativeness on the Local Firm Population: an Empirical Study of German Patents." *Industry and Innovation* 13 (1): 21–39.

Calcagnini, G., I. Favaretto, G. Giombini, F. Perugini, and R. Rombaldoni. 2016. "The Role of Universities in the Location of Innovative Start-ups." *The Journal of Technology Transfer* 41 (4): 670–93.

Calic, G., and E. Mosakowski. 2016. "Kicking off Social Entrepreneurship: How a Sustainability Orientation Influences Crowdfunding Success." *Journal of Management Studies* 53 (5): 738–67.

Cassar, G. 2004. "The Financing of Business Start-ups." *Journal of Business Venturing* 19 (2): 261–83.

Chatterji, A., S. Delecourt, S. Hasan, and R. Koning. 2019. "When Does Advice Impact Startup Performance?" *Strategic Management Journal* 40: 331–56.

Cho, Y., and Y. Lee. 2016. "The Use of IP Profiles in Selecting and Structuring R&D Alliances." *Research-Technology Management* 59 (2): 18–26n.

Cohen, J. E., and M. A. Lemley. 2001. "Patent Scope and Innovation in the Software Industry." *California Law Review* 89 (1): 1–57.

Cohen, W. M., A. Goto, A. Nagata, R. R. Nelson, and J. P. Walsh. 2002. "R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States." *Research Policy* 31 (8–9): 1349–67.

Colombelli, A. 2016. "The Impact of Local Knowledge Bases on the Creation of Innovative Start-ups in Italy." *Small Business Economics* 47: 383–96.

Colombo, L., H. Dawid, M. Piva, and M. Vivarelli. 2017. "Does Easy Start-up Formation Hamper Incumbents' R&D Investment?" *Small Business Economics* 49: 513–31.

Colombo, M. G., L. Grilli, and E. Piva. 2006. "In Search of Complementary Assets: the Determinants of Alliance Formation of High-tech Start-ups." *Research Policy* 35 (8): 1166–99.

Conti, A., M. Thursby, and F. T. Rothaermel. 2013. "Show Me the Right Stuff: Signals for High-tech Start-ups." *Journal of Economics & Management Strategy* 22 (2): 341–64.

Croce, A., F. Tenca, & E. Ughetto. 2017. "How business angel groups work: Rejection criteria in investment evaluation." *International Small Business Journal* 35 (4), 405–26.

Czarnitzki, D., and J. Delanote. 2013. "Young Innovative Companies: the New High-growth Firms?" *Industrial and Corporate Change* 22 (5): 1315–40.

Davila, A., G. Foster, and M. Gupta. 2003. "Venture Capital Financing and the Growth of Start-up Firms." *Journal of Business Venturing* 18 (6): 689–708.

De Meyer, A. 1999. "Using Strategic Partnerships to Create a Sustainable Competitive Position for Hi-tech Start-up Firms." *R&D Management* 29 (4): 323–28.

DeCarolis, D. M., and D. L. Deeds. 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.

Delerue, H., and A. Lejeune. 2012. "Internationalization of Biotechnology Start-ups: Geographic Location and Mimetic Behaviour." *International Small Business Journal* 30 (4): 388–405.

Doblinger, C., K. Surana, and L. Diaz Anadon. 2019. "Governments as Partners: the Role of Alliances in U.S. Cleantech Startup Innovation." *Research Policy* 48: 1458–75.

Dutta, S., and T. B. Folta. 2016. "A Comparison of the Effect of Angels and Venture Capitalists on Innovation and Value Creation." *Journal of Business Venturing* 31 (1): 39–54.
Ernst, H., J. Conley, and N. Omland. 2016. "How to Create Commercial Value from Patents: the Role of Patent Management." *R&D Management* 46 (S2): 677–90.
Furlan, A. 2019. "Startup Size and Pre-entry Experience: New Evidence from Italian New Manufacturing Ventures." *Journal of Small Business Management* 57 (2): 679–92.
Graham, S. J. H., and T. Sichelman. 2008. "Why Do Start-ups Patent?" *Berkeley Technology Law Journal* 23 (3): 1063–97.
Greenberg, G. 2013. "Small Firms, Big Patents? Estimating Patent Value Using Data on Israeli Start-ups' Financing Rounds." *European Management Review* 10 (4): 183–96.
Guerrero, M., and D. Urbano. 2014. "Academics' Start-up Intentions and Knowledge Filters: an Individual Perspective of the Knowledge Spillover Theory of Entrepreneurship." *Small Business Economics* 43 (1): 57–74.
Haeussler, C., D. Harhoff, and E. Mueller. 2014. "How Patenting Informs VC Investors: the Case of Biotechnology." *Research Policy* 43 (8): 1286–98.
Hellmann, T., and M. Puri. 2000. "The Interaction between Product Market and Financing Strategy: the Role of Venture Capital." *Review of Financial Studies* 13 (4): 959–84.
Helmers, C., and M. Rogers. 2011. "Does Patenting Help High-tech Start-ups? Research Policy." *Issue Dedicated to Chris Freeman, Founding Editor* 40 (7): 1016–27.
Henderson, R., and I. Cockburn. 1996. "Scale, Scope, and Spillovers: the Determinants of Research Productivity in Drug Discovery." *The Rand Journal of Economics* 27 (1): 32–59.
Hilbe, J. M. 2009. *Logistic Regression Models*. New York: Chapman and Hall.
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.
Hosmer, D. W., and S. Lemeshow. 2000. *Applied Logistic Regression*. New York: John Wiley & Sons.
Hsu, D. H., and R. H. Ziedonis. 2013. "Resources as Dual Sources of Advantage: Implications for Valuing Entrepreneurial-firm Patents." *Strategic Management Journal* 34 (7): 761–81.
Islam, M., A. Fremeth, and A. Marcus. 2018. "Signaling by Early Stage Startups: US Government Research Grants and Venture Capital Funding." *Journal of Business Venturing* 33: 35–51.
Jolink, A., and E. Niesten. 2016. "The Impact of Venture Capital on Governance Decisions in Collaborations with Start-ups." *Small Business Economics* 47 (2): 331–44.
Leiponen, A., and J. Byma. 2009. "If You Cannot Block, You Better Run: Small Firms, Cooperative Innovation, and Appropriation Strategies." *Research Policy* 38 (9): 1478–88.
Long, C. 2002. "Patent Signals." *The University of Chicago Law Review* 69 (2): 625–79.
Looy, B. V., K. Debackere, and P. Andries. 2003. "Policies to Stimulate Regional Innovation Capabilities via University–industry Collaboration: an Analysis and an Assessment." *R&D Management* 33 (2): 209–22.
Lynskey, M. J. 2004. "Determinants of Innovative Activity in Japanese Technology-based Start-up Firms." *International Small Business Journal* 22 (2): 159–96.
Mann, R. J., and T. W. Sager. 2007. "Patents, Venture Capital, and Software Start-ups." *Research Policy* 36 (2): 193–208.
McCann, B. T., and T. B. Folta. 2011. "Performance Differentials within Geographic Clusters." *Journal of Business Venturing* 26 (1): 104–23.
Mollick, E. 2014. "The Dynamics of Crowdfunding: an Exploratory Study." *Journal of Business Venturing* 29 (1): 1–16.
Nuscheler, D., A. Engelen, and S. Zahra. 2019. "The Role of Top Management Teams in Transforming Technology-based New Ventures' Product Introduction into Growth." *Journal of Business Venturing* 34: 122–40.
Okamuro, H., M. Kato, and Y. Honjo. 2011. "Determinants of R&D Cooperation in Japanese Start-ups." *Research Policy* 40 (5): 728–38.
Paradkar, A., J. Knight, and P. Hansen. 2015. "Innovation in Start-ups: Ideas Filling the Void or Ideas Devoid of Resources and Capabilities?" *Technovation* 41–42: 1–10.
Pe'er, A., and T. Keil. 2013. "Are All Start-ups Affected Similarly by Clusters? Agglomeration, Competition, Firm Heterogeneity, and Survival." *Journal of Business Venturing* 28 (3): 354–72.
Peeters, C., and B. V. P. de la Potterie. 2006. "Innovation Strategy and the Patenting Behavior of Firms." *Journal of Evolutionary Economics* 16 (1–2): 109–35.
Saridakis, G., K. Mole, and G. Hay. 2013. "Liquidity Constraints in the First Year of Trading and Firm Performance." *International Small Business Journal* 31 (5): 520–35.
Shah, S. K., and E. C. Pahnke. 2014. "Parting the Ivory Curtain: Understanding How Universities Support a Diverse Set of Start-ups." *The Journal of Technology Transfer* 39 (5): 780–92.
Shan, W., G. Walker, and B. Kogut. 1994. "Interfirm Cooperation and Start-up Innovation in the Biotechnology Industry." *Strategic Management Journal* 15 (5): 387–94.
Smith, J. A., and R. Cordina. 2015. "Patenting and the Early-stage High-technology Investor: Evidence from the Field." *R&D Management* 45 (5): 589–605.
Soh, P-H, and A. M. Subramanian. 2014. "When Do Firms Benefit from University–industry R&D Collaborations? the Implications of Firm R&D Focus on Scientific Research and Technological Recombination." *Journal of Business Venturing* 29 (6): 807–21.
Sorenson, O., J. W. Rivkin, and L. Fleming. 2006. "Complexity, Networks and Knowledge Flow." *Research Policy* 35 (7): 994–1017.
Spreitzer, G., L. Garrett, and P. Bacevice. 2015. "Should Your Company Embrace Coworking?" *MIT Sloan Management Review* 57 (1): 27–29.
Stanko, M. A., and D. H. Henard. 2016. "How Crowdfunding Influences Innovation." *MIT Sloan Management Review* 57 (3): 15–17.
Vanacker, T., V. Collewaert, and I. Paeleman. 2013. "The Relationship between Slack Resources and the Performance of Entrepreneurial Firms: the Role of Venture Capital and Angel Investors." *Journal of Management Studies* 50 (6): 1070–96.
Wang, J., and P. Shapira. 2012. "Partnering with Universities: a Good Choice for Nanotechnology Start-up Firms?" *Small Business Economics* 38 (2): 197–215.

Zhou, H., P. G. Sandner, S. L. Martinelli, and J. H. Block. 2016. "Patents, Trademarks, and Their Complementarity in Venture Capital Funding." *Technovation* 47: 14–22.

Zimmerman, M. A., and G. J. Zeitz. 2002. "Beyond Survival: Achieving New Venture Growth by Building Legitimacy." *Academy of Management Review* 27 (3): 414–31.