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1. Introduction

Researchers view new technology ventures as engines of creative destruction that engender economic growth (Beckman et al., 2012; Bhidé, 2000; Delmar et al., 2011). In the United States, the rate of new firm formation in the high-tech sector has been larger than that in the private sector on average, and between 1980 and 2010 the contribution of new high-tech firms to overall job creation increased (Hathaway, 2013).

Many entrepreneurial opportunities originate in established companies (Burton et al., 2002; Gompers et al., 2005; Liu et al., 2010), and often spin-offs are a means for exploiting opportunities unfamiliar to the parent organization (Bruneel et al., 2013; Chesbrough, 2003; Festel, 2013; Kirchberger and Pohl, 2016). For example, 31.6% to 47.2% of total technology start-up funding in the United States is spawned by existing firms to pursue unfamiliar, high-risk technology projects or business opportunities that fall outside the parent company's core business (Auerswald and Branscomb, 2003).

Most studies on entrepreneurship suggest that the start-ups result from an individual choice that depends on characteristics such as self-efficacy (Markman et al., 2002), human capital (Parker, 2011), skill composition (Lazear, 2004), risk propensity (Simons and Astebro, 2010), and taste for variety (Astebro and Thompson, 2011). However, corporate spin-offs are often the result of an organizational process in which the decision to pursue a new business opportunity in a new organization is rooted in the incumbent organization, regardless of whether the new firm is started by the parent firm or its employees (Agarwal et al., 2004; Freeman 1986; Klepper and Sleeper, 2005; Sørensen and Fassiotto, 2011).

In the context of corporate spin-offs we investigate the antecedents of technological spin-offs - that is, new ventures founded with technological knowledge and employees transferred from an incumbent firm to an independent new company (Bruneel et al., 2013; Fryges and Wright, 2014).

There exist several factors that trigger the formation of a spin-off and the literature on spinoffs as an organizational process has developed along two main lines of research. One stream of the literature points to the inertia and bureaucracy of incumbent organizations as a source of employee frustration (Dobrev and Barnett, 2005; Elfenbein et al, 2010; Erikkson and Kuhn, 2006; Sørensen, 2007). It is difficult for the organization to assess the quality and value of new ideas, as in the case of technologies or business opportunities unfamiliar to the organization (Burgelman, 1983; Chesbrough, 2003; Shimizu, 2012). Project rejection or disagreement about the value of new ideas or the strategic direction a firm should take may lead to frustration and prompt employees to leave the organization to pursue their ideas in a new firm (Gompers et al. 2005; Cassiman and Ueda, 2006; Klepper and Thompson, 2010). Prior studies on spinoffs as the result of inertia, bureaucracy and disagreement rely primarily on organizational size and age as proxies for unobservable features of parent organizations, such as the extent of bureaucracy (Dobrev and Barnett, 2005; Elfenbein et al, 2010; Erikkson and Kuhn, 2006; Sørensen, 2007).

Another stream of the literature views incumbent organizations as hotbeds of creative activity and entrepreneurial opportunities (Chatterji, 2009). Spin-offs may leverage the technological and market-related knowledge that their founders inherited from the parent firms to produce product variants that the parent firms do not find profitable. More successful incumbent firms, firms with superior technology and a wider range of products are more likely to spawn spinoffs (Agrawal et al. 2004). The R&D activities of incumbent firms then may lead to more product variants and market opportunities that incumbent firms may find not profitable and industry outsiders may not be able to identify (Klepper and Sleeper 2005). Studies in this research line have found that it is not knowledge abundance per se that generates entry opportunities for spin-offs, but it is the non-use of knowledge by incumbent firms that leads to spin-offs. Incumbent firms may be unable or unwilling to use their technological know-how if they do not possess the needed complementary assets - e.g., market know-how (Agarwal et al., 2004; Gambardella et al., 2014). Studies on spinoffs as the result of a genealogical knowledge-based process have relied primarily on proxies for incumbent knowledge such as patent stock, new product commercialization and production experience as predictors of spinoff formation (e.g., Agarwal et al, 2004; Klepper and Sleeper, 2005).

While both streams of research have greatly advanced the knowledge of spin-off antecedents, what are the micro-organizational settings that generate new technological or business opportunities and affect the formation of a new firm are questions that remains largely unexplored. Studies relying on firm size and age as proxies for bureaucratization cannot capture the substantial differences in the degree of bureaucratization and the delegation of authority that may exist across firms of similar size and age. Similarly, incumbent firms with a comparable technological know-how may generate a different rate of spin-off formation as a consequence of different organization of innovative labor and freedom to explore granted to inventors.

Drawing from prior theoretical and empirical work on entrepreneurial decisions as an organizational process (Bruneel et al., 2013; Burgelman, 1983; Chesbrough, 2003; Dess and Lumpkin, 2005; Lumpkin and Dess, 1996; Sharma and Chrisman, 1999; Stevenson and Jarillo, 1990), this study aims to answer the research question by empirically investigating the role of two key dimensions of the incumbent organization in the formation of a technological spin-off: work autonomy and teamwork in the inventive activity.

Our interest in work autonomy and teamwork is motivated by their recognized importance in innovative and entrepreneurial activities. Autonomy, described as “the freedom granted to individuals and teams who can exercise their creativity and champion promising ideas” (Lumpkin and Dess, 1996, p. 140), is a key dimension of entrepreneurial orientation, defined as “an approach to decision making that draws on entrepreneurial skills and capabilities” (Lumpkin et al. 2009: 48). The engineers and scientists responsible for inventing and commercializing significant technological innovations, or corporate technical entrepreneurs, are strongly motivated by the possibility of working in project teams with capable people and by the freedom to allocate time and select research areas (Marvel et al., 2007).

Studies of organizational creativity (Amabile, 1997; Woodman et al., 1993; Zhang and Bartol, 2010), job design in knowledge-intensive activities (Baron, 2010; Cohen and Bailey, 1997; Humphrey et al., 2007), and entrepreneurial orientation (e.g., Lumpkin and Dess, 1996; Marvel et al., 2007) dig deeper into key organizational conditions, such as teamwork and the freedom to act independently, that spur creativity and entrepreneurship. However, these studies do not explain when new business opportunities generated in established organizations are exploited within the same organization or through the creation of new legal entities. Specifically, extant research on creativity and entrepreneurial decision making does not adequately explore how the nature of inventive outcomes, the characteristics of incumbent organizations, and the features of the external environment "affect the decision to exploit an invention internally or externally" (Shepherd et al., 2015, p. 15).

The empirical analysis draws on a large-scale survey of inventors of European Patent Office (EPO) patents located in the United States, Europe, Japan, and Israel. The unit of analysis is the patent–employer combination at risk of spawning a new patent-based firm. We focus on spin-offs started by the parent firm or an employee (an inventor) in accord with the employer. This empirical setting is ideal to examine technology entrepreneurship for two reasons. First, patented inventions are subject to much less heterogeneity than technological opportunities in general because they must meet common examination standards. The focus on invention and the inventive process reduces the unobserved heterogeneity problems that plague previous studies whose unit of analysis is the industry or the firm (e.g., Eckhardt and Shane, 2011; Shane, 2001a). Second, we control for characteristics of organizations, patents, and technology environments.

We organize the reminder of the paper as follows: Section 2 reviews the existing literature and elucidates the research hypotheses. Section 3 describes the data and defines the variables. Section 4 presents the results of the econometric analysis. Section 5 concludes with a brief discussion of the results and suggestion for further research.

2. Literature review and hypotheses

2.1. Definition of a technology spin-off

The large number of new firms spawned by incumbent organizations has attracted the attention of various streams of research which propose several, somehow overlapping definitions of spin-offs. We investigate spinoffs spawned by business organizations, i.e. corporate spin-offs. Drawing upon previous research (Beckman et al., 2012; Chesbrough, 2003; Fryges and Wright, 2014; Parhankangas and Arenius, 2003), we focus on technology spin-offs, defined as new business formations based on technological knowledge originally developed in an incumbent firm and then transferred to a separate legal entity (Kirchberger and Pohl, 2016). Technological knowledge (as well as other types of knowledge) can be transferred in informal ways, such as knowledge inherited from the founders' earlier work experience, in formal ways, such as licensing and IPR transfer (Fryges and Wright, 2014; Woolley, 2017) or in both ways – when, in addition to the transfer of IPR, the spinoff involves the mobility of employees from the parent firm to the new venture. Fryges and Wright (2014) distinguish two types of corporate spinoffs – spin-offs initiated by former employees who decided to leave the parent to establish their own business ("entrepreneurial spinoffs") and spin-offs" initiated by the parent firm. In the case of assisted spinoffs, either the inventor who developed the technology or other employees (e.g., experienced managers) may be appointed to head the spin-off.

Especially when technology transfer take place in formal way – e.g. patented inventions, the parent firm plays a key role in both "entrepreneurial spinoffs" and "assisted spinoffs" because it controls the key resource upon which the new venture is formed. Even in the case of entrepreneurial spin-offs, the parent organization decides whether it is more profitable to pursue a particular invention through a spinoff rather than, for example, internal development and commercialization. In these circumstances the parent organization may lack the complementary assets needed to exploit the technology in the product market and the spin-off could help "exploit opportunities in unfamiliar markets or technologies" (Bruneel et al., 2013: 943), which may become a source of future growth (Bruneel et al., 2013; Chesbrough 2003). The role of the employer in the case of "entrepreneurial spinoffs" is consistent with the definition of spinoff as "creation of a new entity by an employee who therefore leaves the company, while being helped by its employer" (Ferrary, 2008: 607). The corporate entrepreneurship literature has considered spin-offs as a form of corporate venturing, that is 'the set of organizational systems, processes and practices that focus on creating businesses in existing or new fields, markets or industries – using internal or external means" (e.g., Narayanan et al., 2009: 59).

To sum up, our paper focuses on technological spin-offs as an organizational process, where the parent organization plays always an important role as a source of knowledge and as the owner of IPR transferred to a new venture.

2.2. Work autonomy and spin-offs

Research on work design describes autonomy as a multidimensional construct involving employees' discretion in scheduling and pacing their work activities (i.e., work scheduling autonomy), selecting the methods necessary to accomplish their work (i.e., work methods autonomy), and setting goals (i.e., discretion and control over goals) (Breaugh, 1985). Studies have found that a high level of goal autonomy is positively associated with job performance (Humphrey et al., 2007), strategic effectiveness (Haas, 2010), and organizational learning (McGrath, 2001).

Work autonomy is also a fundamental dimension of entrepreneurial orientation (Dess and Lumpkin, 2005; Lumpkin et al. 2009). The entrepreneurship literature distinguishes structural autonomy from strategic or goal autonomy (Lumpkin et al., 2009). The former consists of discretion with respect to the means of problem solving (e.g., work hours, work procedures, time to complete a task) within given resource constraints (Bailyn, 1985). The latter reflects "the independent action of an individual or a team in bringing forth an idea or a vision and carrying it through to completion" (Lumpkin and Dess, 1996, p. 140).

Structural autonomy

Established organizations grant autonomy to their employees to foster innovation and search for (or create) new business opportunities. Autonomy as a driver of innovation is particularly important in our empirical setting. Compared with other employees, inventors are largely driven by intrinsic motivations and therefore should prefer autonomy and a free working environment more than other incentives, such as social status or higher income. Cognitive psychologists define intrinsically motivated people as those who are driven by a "deep interest and involvement in the work, by curiosity, enjoyment, or a personal sense of challenge" (Amabile, 1997, p. 44). Firms grant autonomy to their employees primarily because autonomy stimulates creativity (Amabile, 1997; Woodman et al., 1993; Zhang and Bartol, 2010) and fosters radical innovations (Lassen et al., 2006). Other studies show that intrinsic motivation to innovate spurs scientists' and engineers' inventive efforts and productivity (Sauermann and Cohen, 2010). Work autonomy in general increases creativity and task performance of intrinsically motivated individuals who develop breakthrough innovations in established firms (Marvel et al., 2007).

In the inventive setting, like other creative or knowledge-intensive activities, structural autonomy represents the minimum level of freedom needed to motivate inventors and stimulate their creativity. However, this type of autonomy does not entail significant discretion and control over goals, which are important to foster exploration and favor entrepreneurial orientation of inventors. Thus, entrepreneurial opportunities discovered or generated under conditions of structural autonomy are likely to fall within the organization's scope of existing knowledge and business activities.

Moreover, previous studies suggest that working in flat organizational structures, with few layers, produces job satisfaction and reduces the inventors' incentive to leave their organization to join an entrepreneurial start-up (Marvel et al., 2007).

Thus, the combination of job satisfaction and limited freedom to explore the technological and business space produced by structural autonomy leads to the following hypothesis:

Hypothesis 1. Inventions developed by individuals or teams that are given structural autonomy are less likely to be exploited through a technology spin-off.

Strategic autonomy

The implications of autonomy for corporate spinoffs are likely different when employees enjoy strategic autonomy rather than structural autonomy. Strategic autonomy introduces individuals and teams to higher levels of decision making and allow them to explore business opportunities outside the established chain of command and current corporate strategy (Burgelman, 1983).

When facing rapid change firms have to explore novel, unfamiliar technologies or business landscapes. Highly explorative search in turn prompts organizations to grant strategic autonomy to individual employees or teams—that is, organization should "not specify goals, talent allocations, or lines of authority" (McGrath, 2001, p. 120). Because of technological and market uncertainty, closely monitoring employees to hold them accountable for failure to attain an expected level of performance does not generate the "requisite variety" needed to foster innovation (Chesbrough, 2003).

Encouraging independent action leads to experimenting with many different technologies and business ideas and may decrease coordination among autonomous teams or "create inefficiencies, such as duplication of effort and wasting of resources on projects with questionable feasibility" (Dess and Lumpkin, 2005, p. 150). Strategic autonomy may also stimulate individuals to act in their own self-interest, thus lowering the overall value of new ideas to the employer organization (Shimizu, 2012). Furthermore, teams that enjoy a high level of autonomy to explore new landscapes run a high risk of remaining isolated from the rest of the organization (Haas, 2010). Finally, high levels of exploration and strategic autonomy may lead to the discovery (or creation) of new business opportunities that do not fit the current businesses of the organization. Projects more distant from the core business are likely to call for a greater resource commitment (Ioannou, 2014), and thus corporate selection mechanisms should be activated to preserve the consistency of corporate strategy (Burgelman, 1983) or avoid a situation in which new promising ideas remain frustrated by internal resource allocation systems and organizational routines (Chesbrough, 2003; Nelson and Winter, 1982).

Empirical studies show that established firms are often unwilling or unable to pursue innovations that challenge their current ways of doing business or to evaluate entrepreneurial opportunities that fall outside their core business (Gompers et al., 2005). Established firms may rationally choose to exploit only opportunities close to their core business (Cassiman and Ueda, 2006) and refuse to support initiatives that fall outside the purview of employees assigned tasks (Hellmann, 2007). While inventions leading to business opportunities that fall into noncore areas are often abandoned, established organizations may have incentives to allow or pursue these business opportunities through a spin-off. In these conditions, spin-offs may be beneficial to the parent's performance because they release resources such as funding, human capital, and managerial attention and therefore help the parent organization maintain "corporate coherence" (Ioannou, 2014). Moreover, spinoffs can be used by established firms as a strategic practice to avoid internal resistance to innovation (Lumpkin and Dess, 1996) and to foster creativity by offering inventors an economic incentive (through the status of shareholder) and a symbolic incentive (through the status of entrepreneur) to produce marketable technologies (Ferrary, 2008). Thus, established firms can rely on the reactivity and organizational flexibility of spinoffs to explore opportunities in unfamiliar markets or technologies (Bruneel et al., 2013).

To sum up, while established firms grant autonomy primarily to motivate inventors to innovate, strategic autonomy may spur exploration and technological discoveries that are a poor fit with the core businesses, while also nurturing the development of entrepreneurial skills of inventors. This increases the likelihood of an innovation being pursued through a spin-off. These considerations lead to the following testable hypothesis:

Hypothesis 2. Inventions developed by individuals or teams that are given strategic autonomy are more likely to be exploited through a technology spin-off.

2.3. Teamwork

While autonomy granted to inventors may reflect an organizational attempt at undertaking explorative search to face rapid technical change, the organization of inventive effort as an individual endeavor or as a teamwork may vary with the complexity of the underlying technology or the strategic importance of a specific inventive target. For these reasons, the decision whether to rely on a teamwork organization rather than an individual inventor implies a shift from the macro-organizational level (the company) to the micro-organizational level (the invention).

Teams represent sets of individuals who carry out interdependent tasks (rather than individual design), share responsibility for outcomes, and act as a social entity embedded in one or more larger social systems, such as a business unit or a company (Cohen and Bailey, 1997). Teamwork is associated with cooperation among coworkers, interaction, communication, and integration (McDonough, 2000). An inventive team can be considered a project team that carries out multiple activities that typically require collaboration and feedback among members (Cohen and Bailey, 1997). A wealth of job design and human resources management literature has investigated the organization of teams (e.g., group cohesiveness, diversity, communication) and its implications for the performance (e.g., productivity, innovation) of established organizations (Cohen and Bailey, 1997). As discussed before, individual inventors and inventor teams may enjoy different levels of autonomy and organizations aiming to foster creativity and innovation.

However, how the inventive output of teamwork will be exploited by an incumbent organization – internally, in new products or services or externally, via a spinoff, remains a largely unexplored research area. This is a relevant gap given the large diffusion of teamwork in inventive activities.

Teamwork can provide the opportunity to learn from experienced coworkers on how to organize and mobilize the resources needed to found a new firm (Nanda and Sørensen, 2010). Moreover, interactions among members expose teammates to a broader set of competencies and experiences. Cross-functional teams then are likely to nurture a balanced and varied set of skills in employees by broadly defining jobs and roles (Lazear, 2004). In this respect, teamwork and collaboration among coworkers favor formal and informal socialization processes that can provide employees with skills important for exploring new business opportunities and fostering entrepreneurship (Sørensen and Fassiotto, 2011). While these effects are generally important for teamwork, they are probably less relevant in the case of inventive teams, where skills vary across scientific and technical fields more than across functional activities (see for example Petre, 2004, for a discussion of cases of multi-disciplinary engineering teams). Thus, compared with other employees, inventors have limited opportunities to develop the balanced and varied set of skills typical of entrepreneurs (Lazear, 2005). Moreover, teamwork and the joint effort of various co-inventors may signal a strong commitment of the organization to the invention and a high expected value of this invention, which should reduce the probability of a spin-off. Furthermore, the notions of "teamwork" and "coworkers" imply that complex inventive activities require cooperation among people with multiple skill sets. Complementarities among coworkers and the organization-specific knowledge developed through their interactions cannot be easily transferred to a new venture. Tacit knowledge is not only embedded in human capital but also rooted in organizational routines at the team and firm levels (Hitt et al., 2001; Kogut and Zander 1992; Nelson and Winter, 1982; Teece, 1986). While employees may leave and appropriate the human capital component of organizational knowledge, they cannot easily appropriate and transfer organizational routines to a new organization. The socialization process fostered by these complementarities and interactions among coworkers may also discourage exploration and hamper the formation of new ventures if it strengthens the commitment to core norms and shared values (e.g., Sørensen, 2002).

This discussion suggests that, besides limited entrepreneurial capital accumulation effects, teamwork generates various effects related to organizational complexity, idiosyncratic and tacit knowledge, and socialization, which reduce the likelihood of a spin-off. Overall, the multiplicity of these latter effects is likely to dominate the entrepreneurial capital effect, generate a high level of embeddedness of team members in the existing organization, and reduce the likelihood of external venturing through a spin-off. We test then the following hypothesis:

Hypothesis 3. Inventions developed through teamwork are less likely to be exploited through a technology spin-off.

3. Methods

3.1. Data and Sample

In line with extant contributions in the entrepreneurship literature (Fuller and Rothaermel, 2012; Gambardella et al., 2014; Markman et al., 2002), we rely on patent application and use to create a sample of technology spin-offs. Specifically, we use data from the PatVal-EU II, PatVal-US, and PatVal-JP surveys conducted between 2010 and 2011 as part of the INNOS&T project (Torrisi et al., 2016). These surveys collect data on the characteristics of invention processes that lead to EPO patents, inventor biographies and motivations for research, patent value, commercialization, and other issues. Inventors in 20 European countries, Israel, the United States, and Japan were contacted and surveyed, using a harmonized questionnaire across all regions. The sample was drawn at the level of patent applications, with priority dates between 2003 and 2005. We chose 2005 as an upper bound because international (Patent Cooperation Treaty [PCT]) filings enter the regional phase only 30 months after the priority date. Choosing patent applications with later priority dates would have led to biases due to censored PCT filings. After sampling the patents, we chose one inventor listed on the patent document at random. For the full-scale survey, inventors received a letter asking them to fill out an online questionnaire. We received 23,044 responses, for a 20% response rate.

We matched survey data with information from various sources. Specifically, from EPASYS (the EPO's administrative database) and PATSTAT (the EPO Worldwide Patent Statistical Database), we retrieved data on the number of inventors, the name and type of applicant (i.e., business organization, individual, not-for-profit organization), the number of forward citations, the technological class of the patent, the overall number of patents in the focal technological class, and their applicants. From COMPUSTAT, Amadeus, and LexisNexis databases, we retrieved firm-level data to identify the ultimate owner of the organizations in our sample. Furthermore, we collected data on the number of employees and the founding year of the company to double-check information gathered through the survey and to integrate missing values.

To eliminate sources of undesirable heterogeneity that can undermine the test of our hypotheses, we imposed five restrictions. First, we bound the analysis to inventors who defined their employment status at the time of the invention as "employee." Therefore, we excluded 4,620 observations for which the inventor reported that he or she was self-employed, a student, unemployed, or retired or did not answer. Second, given our focus on the organizational context of business organizations, we selected only inventor-employees who were affiliated with (employed by) a business organization: 1,447 observations did not match this condition. Third, we limited our attention to inventor-employees whose age was between 18 and 65 years at the time of the invention: we excluded 3,456 observations in line with the age threshold or because the inventor's age was not available. Fourth, we removed from our analysis situations in which the patent applicant (i.e., the owner of the intellectual property) was a third party with no linkages to the employer organization and excluded 849 observations. Fifth, a question in The PatVal survey asks the inventor: "Has this patent been used by any of the inventors or applicants to found a new company?” Drawing from the answers to this question we excluded 801 cases with missing values.

After applying these filters, we were left with 11,871 observations. Due to missing values in the variables described below and used in the econometric analysis, the final sample comprises 10,279 observations.

3.2. Measures

3.2.1. Dependent variable

We operationalize the dependent variable, TECHNOLOGY SPINOFF, as a dichotomous variable which equals 1 if the patented invention has been used to establish a technology spin-off, and 0 otherwise. The procedure to identify technology spin-offs unfolds in five steps, as described below, and is based on both survey data and information gathered from external sources (e.g., the U.S. Securities and Exchange Commission’s EDGAR system, Bureau van Dijk’s ORBIS, LexisNexis, The Internet Archive, Company Check, DueDil, LinkedIn, ZoomInfo).

First, as mentioned in the previous section, the survey asked the inventors whether the patent was used by any of the inventors or applicants to found a new company: 254 inventors gave an affirmative answer to this question. When this condition was met, inventors were asked to specify the name of the new firm and its location. Based on useful answers to this question and knowing the name of the employer organization (as reported by the inventor) we exclude 70 observations for which the inventor did not report the new company name or did not report the name of the employer organization at the time of the invention or reported the same name for the parent company and the new firm. We are left with 184 cases which may involve a technology spinoff.

Second, we retrieved information about the founding year of the new firm from external sources, and assess the coherence between the year of founding and the priority year of the patent application (as a proxy for the time of completion of the inventive process) and require that the new firm was founded after or in the priority year of the patent. We were unable to recover the founding year of 8 new firms and discarded 18 additional observations for which the inventors reported a founding year four or more years before the priority of the patent. The remaining 158 cases may qualify as a technology spinoff.

Third, inspection of external sources revealed that in 8 cases the founding process did not involve a new legal entity. These observations refer to name change of existing organizations, the establishment of an industry consortium, the launch of a new trademark and divestments of old established business units of the incumbent firm. These observations were eliminated from the working sample.

Fourth, in line with previous research that defines spin-offs as independent new legal entities (Helfat and Lieberman, 2002), we excluded from the sample 24 cases of wholly owned subsidiaries.

Finally, we assessed whether a transfer of human resources from the parent company took place. We relied on two survey questions asking the inventors: (1) who founded the new company (e.g., you yourself, other co-inventors, (one of) the applicant(s), others); (2) who retains an ownership stake in the new company (e.g., partially owned by the inventor; partially owned by the applicant; independent (no participation of the applicant/owner of the patent or the inventors). We also examined the career biographies of the top management team and press releases of the new firms to establish linkages with the parent organizations and the patented inventions. For 13 of the new firms, there was no transfer of employees between the two organizations and no involvement of the parent company in the establishment.

As a result, we determined that 113 observations pertain to a technology spin-off. In 45 per cent of cases the spin-off was initiated by the parent company. For the remaining cases, we do not have clear-cut evidence to say that the parent company initiated the process. However, in 92 cases at least one of the inventors of the focal patent was actively involved in the founding process and in 69 cases the inventor involved was the one participating to the PatVal survey.

Furthermore, we could determine that the parent company always supported the foundation of the new firm by agreeing on the use of the patent (through licensing or other contractual agreements) or the transfer of the patent ownership to the spin-off.

3.2.2. Explanatory variables

Work autonomy. The PatVal surveys asked inventors to rate their autonomy or the autonomy of their team from 0 (“no autonomy”) to 5 (“very high”) with respect to the following dimensions: (1) selection of tasks or projects to carry out, (2) flexibility of working hours, and (3) allocation of working time among different tasks or projects. We use the score assigned by the focal inventor to the first item to define the variable STRATEGIC AUTONOMY; this variable is used to test Hypothesis 1. We use the average (rounded to the nearest integer) of the scores assigned by the focal inventor to the second and third items to create the variable STRUCTURAL AUTONOMY; this variable is used to test Hypothesis 2.

Teamwork. We use the variable TEAMWORK to test Hypothesis 3. This variable equals 1 if the organization of inventive activities is described by the inventor as being a result of teamwork and 0 if it is a result of individual work.

3.2.3. Control variables

We control for various factors at the organizational level, the patent and technology level, and the inventor level.

Organization level. As mentioned before, earlier research (Bruneel et al. 2013; Fryges and Wright, 2014) suggests that main reason for a parent company to support a corporate spinoff is to pursue opportunities in new technologies and markets that do not fit its core business. In these circumstances, the parent firm may lack the complementary assets needed to transform the technological opportunities into a source of growth in unfamiliar markets (Bruneel et al., 2013; Chesbrough 2003). In the regression analysis, we control for the parent firm’s endowment of complementary assets that engender the exploitation of the patented invention in the downstream market, Specifically, we rely on a question in the PatVal survey that asks inventors to rate their agreement (1 = "completely disagree," and 5 = "completely agree") with the following statement: "The organization had all the resources to turn the invention into something economically valuable (e.g., a new product, process or [something] else)." The variable COMPLEMENTARY ASSETS equals the inventor's corresponding score.

Building on external sources of knowledge is often crucially important for a firm inventive activity. While nurturing the relationship with external partners, the parent company creates favorable conditions for employees to recognize new business opportunities and mobilize resources required for the launch of a new venture (Dobrev and Barnett, 2005; Gompers et al., 2005; Sørensen and Fassiotto, 2011). To control for the effect of collaboration with external actors, we created three dummy variables equal to 1 if, during the inventive activity, the parent organization undertook, respectively, formal or informal collaborations with (1) buyers and suppliers along the value chain ($COLLABORATION_{VERTICAL}$), (2) competing firms or other business organizations ($COLLABORATION_{HORIZONTAL}$), or (3) universities or other public or private research organizations ($COLLABORATION_{RESEARCH}$).

To account for the role of incumbent firm size as a determinant of spin-off formation (Dobrev and Barnett, 2005; Elfenbein et al, 2010; Erikkson and Kuhn, 2006; Sørensen, 2007), we included a set of dummy variables (FIRM SIZE) that account for different size classes of the inventors' employer (measured as the number of employees). The baseline category comprises firms with more than 5,000 employees, which represent 63.5% of observations in our sample.

We use a set of 6 dummy variables to control for the industry of the parent firm. We have adopted the US Standard Industry Classification (SIC) and, based on its primary 3-digit SIC code, assigned each firm to one of the following macro-sectors: MINING & CONSTRUCTION; MANUFACTURING; TRANSPORTATION & COMMUNICATION; WHOLESALE & RETAIL TRADE; FINANCE & INSURANCE; SERVICES. Most sample organizations (83.8%)

operate in a manufacturing sector, while the second largest group (6.2%) comprises firms operate in industries such as business services, engineering and research&development.

Finally, we control for the localization of the organization where the patent was developed by means of four macro-geographical dummy variables: EUROPE (which represents the reference category in the regression models); UNITED STATES, UK, IRELAND, ISRAEL and JAPAN.

Patent & Technology level. A large body of the literature (Shane, 2001a, b; Stuart and Sorenson, 2003) indicates that differences in technological opportunities and across technological regimes influence the formation of technological start-ups. Accordingly, we control for the following patent technological classes: ELECTRICAL ENGINEERING, INSTRUMENTS, CHEMISTRY, PROCESS ENGINEERING, MECHANICAL ENGINEERING, and CONSUMPTION & CONSTRUCTION. Besides, we include the degree of technological concentration measured by the top 10 patentees' share of patents in the 30 technological classes assigned to patents (OST30_CONCENTRATION).

We also control for the characteristics of the patented invention. To account for patent value (Shane, 2001a), we consider two covariates. First, STRATEGIC STAKE which measures the share of forward self-citations to the patented invention, as a proxy of the patentee's strategic stake in the focal technology (Somaya, 2003). Second, the variable CLAIMS counts the number of claims in the focal patent and indicates the applicant's intended scope of the patent protection (Sampat, 2010).

Moreover, we include the variable COINVENTORS, which measures (on a logarithmic scale) the number of inventors listed in the patent document. Previous studies on employee mobility and entrepreneurship have used this variable to account for R&D effort and potential collaboration among knowledge workers (Gambardella et al., 2014; Palomeras and Melero, 2010).

We also factored into the model the variable GOVERNMENT FUNDS that equals 1 if financing from national or international (e.g., European Union) governments supported the research leading to the invention, and 0 otherwise. The participation in publicly-funded research projects often entails the collaboration with other parties. As discussed before, collaboration may help inventors to identify new technological and business opportunities outside the employer's core business and establish professional links that may help the formation of a new firm (Dobrev and Barnett, 2005; Gompers et al., 2005; Sørensen and Fassiotto, 2011)

In our robustness checks we further explore the mechanisms through which teamwork is correlated with the likelihood of a spin-off. To this end, we use a proxy for the multi-disciplinarity of research underlying the patented invention. More precisely, we counted the number of different technology areas the EPO office assigns to each patent. Specifically, we construct the binary variable TECH_BREADTH, which equals 1 if the number of eight-digit International Patent Classification (IPC) codes assigned to the patent is higher than the median computed for the entire sample (i.e., 2) and 0 if otherwise.

Inventor level. In the section on robustness checks we accounted for the following inventor characteristics. First, general human capital is an individual trait that previous studies (Eriksson and Khun, 2006; Parker, 2011) have shown to be positively associated with new venture activity. Drawing on these contributions, we control for this feature through the variable AGE, which reports the age (on a logarithmic scale) of the inventor at the time of the invention. *Second,* we use R&D experience (RESEARCH EXPERIENCE) as a measure of job specialization, which indicates a skill profile distinct from entrepreneurs (Lazear, 2004, 2005). We compute this variable as the difference (on a logarithmic scale) between the year of the patented invention and the year the inventor began engaging in research activities. Third, we consider a measure of taste for entrepreneurship (Astebro and Thompson, 2011; Bhidé, 2000)—namely, an inventor's RISK PROPENSITY—which is assessed on an 11-point scale, ranging from "completely unwilling to take risks" (0) to "completely willing to take risks" (10). Finally, the variable MANAGERIAL STATUS, which measures (on a logarithmic scale) the number of individuals reporting to the inventor at the time of the invention (Sauermann and Cohen, 2010).

Table 1 provides descriptive statistics for variables used in the econometric analysis.

Insert Table 1 Here

3.3. Estimation Method

We carried out a multivariate regression analysis based on a logit estimator because TECHNOLOGY SPINOFF is a dichotomous variable (Greene, 2003). The regression model takes the form Prob(TECHNOLOGY SPINOFF = 1|x) = $\Delta(x'\beta + z'\gamma)$, where Δ is the cumulative function of the logistic distribution; *x* is a set of characteristics of the inventive process leading to a specific invention and other features of the overall workplace; and *z* is a vector of controls at the patent, inventor, and employer levels. In addition, β and γ are the vectors of parameters to be estimated. We use sampling weights in estimations to control for both coverage bias and nonresponse bias.

4. Results

Before analysis, we examined the variables for the presence of multicollinearity. The pairwise correlation coefficients reported in Table 2, suggest that collinearity does not represent a major concern in our setting. Both the variance inflation factor (VIF) and the condition number for the model in Column 3 of Table 3 are below the critical thresholds (i.e., 10 for VIF and 15 for the condition number) (Belsley et al., 1980). The average VIF is equal to 1.35 (the maximum VIF = 2.38), and the condition number is 4.12. It is also worth noting that since the phenomenon under scrutiny involves rare events, the magnitude of the marginal effects presented in Table 3 is small, in absolute terms; this finding is in line with earlier studies that display marginal effects (e.g., Braguinsky et al., 2012; Elfenbein et al., 2010).

4.1. Main results

Table 3 reports the average marginal effects (AMEs) for explanatory variables in the estimated models. The first column in Table 3 shows the results for a baseline model in which only controls are factored. Columns 2–3 progressively add the explanatory variables measuring structural and strategic autonomy (model 2) and teamwork (model 3). Columns 4–6 refer to robustness checks.

Insert Tables 2 and 3 Here

In what follows we present the results reported under Model 3 in Table 3. Hypothesis 1 posits a negative association between structural autonomy and the probability of using the patent in a technology spin-offs. The results show that granting inventors/teams the freedom to set the pacing of their jobs and allocate their working time across tasks is negatively associated with the probability of using the patented invention to establish a new venture. The estimated AME implies that a unitary increase in the level of STRUCTURAL AUTONOMY reduces the probability of a technology spin-off by 0.3%. In this case, a hypothetical shift from the 5^{th} to the 95^{th} percentile of STRUCTURAL AUTONOMY implies a decline of 1% (p = .075) in the probability of a technology spin-off.

The results show that granting inventors/teams the freedom to select the projects they work on increases the likelihood of a technology spin-off, thus lending support to Hypothesis 2. The estimated AME suggests that a unitary increase in the level of STRATEGIC AUTONOMY increases the probability of a technology spin-off by 0.3%. Furthermore, a hypothetical shift from the 5^{th} to the 95^{th} percentile of STRATEGIC AUTONOMY implies a 1.2% increase (p = .000) in the probability of a technology spin-off.

With respect to the predictions in Hypothesis 3, the estimated effect of TEAMWORK shows that the likelihood of a spin-off is reduced by 0.6% for inventions developed in teams. The effect of teamwork remains significant when controlling for complementary assets, which suggests that teamwork measures a dimension not fully captured by the resource endowment of the organization.

The marginal effects of some control variables deserve attention. At the organization level, we find that the presence of complementary resources to make the invention commercially valuable (COMPLEMENTARY ASSETS) reduces the probability of a spin-off by 0.4%. In this case, a hypothetical shift from the 5th to the 95th percentile of COMPLEMENTARY ASSETS implies a 2% decrease (p = .000) in the probability of a technology spin-off. Collaboration with competitors and other firms ($\text{COLLABORATION}_{\text{HORIZONTAL}}$) and collaboration with universities and other research centers ($\text{COLLABORATION}_{\text{RESEARCH}}$) both increase the probability of a spin-off by almost 1 percentage point. In contrast, collaborating with suppliers or customers ($\text{COLLABORATION}_{\text{VERTICAL}}$) is not associated with an increased likelihood of a technology spin-off. In line with previous studies (e.g., Elfenbein et al 2010; Sørensen, 2007), we find a negative association between employer size and the probability of spawning a new venture. Compared with the baseline size category (5,000 employees and more), all size dummies are positive and significant. In unreported regressions, we control for the age of the employer organization and find that younger employers (firms that are less than five years old) are more likely to spawn a spin-off than older employer firms. Finally, the estimated effects of industry dummies reveal that only parent firms operating in service industries experience a significantly higher probability (1.4%) of spawning a technology spinoff with respect to the reference category of manufacturing firms.

The patentee's strategic stake in the focal technology is not significant. However, the number of claims, another proxy for the expected economic value of the patent, and the number of co-inventors of the patent are positively associated with the likelihood of observing a technology spinoff, albeit their effect is significant only at the 10% level. The results in Table 3 corroborate the idea that differences across technological regimes influence the exploitation of patented inventions by technology spinoff. In particular, as compared to the reference category ELECTRICAL ENGINEERING (e.g., Audiovisual, Information Technology, Semiconductors), the probability of observing a technology spinoff is 0.7 lower if the patent belongs to the technical field CHEMISTRY (e.g., Polymers, Pharmaceuticals, Petrochemicals) or PROCESS ENGINEERING (e.g., Textiles, Printing, Process-machines).

4.2. Robustness checks

We carried out various exclusion tests to check the robustness of our results and rule out alternative explanations.

To further explore the mechanisms through which teamwork is correlated with the likelihood of a spin-off we relied on TECH_BREADTH as a proxy for the multidisciplinarity of the research underlying the patented invention. The results under Model 4 in Table 3 show that TECH_BREADTH does not enter significantly in the technology spin-off equation. Moreover, although patents resulting from teamwork have a larger number of technology areas than patents developed by individual inventors (t = -5.64, *p* = .000), the multidisciplinarity underpinning the patented invention does not affect the association between teamwork and spin-offs.

Next, we assess how the inclusion of inventor characteristics in the model affects the relationship between the main explanatory variables and TECHNOLOGY SPINOFF. We estimate two equations. In the first specification (Model 5), we consider all technology spinoffs: Qualitative evidence for the cases in our sample suggests that even when the inventor is not among the founders, he/she may have contributed to get the spawning process started, or may occupy managerial positions in the new firm (see Table 4). In the second specification (Model 6), we restrict the set of technology spinoffs only to observations where the survey inventor was actively involved in the establishment of the new venture.

Results under both specifications suggest that accounting for inventor-level characteristics does not undermine the effects of the main variables in our analysis. Moreover, the effects estimated for inventor-level variables are very similar under models 5 and 6. Specifically, Inventor age (AGE) has a positive effect on the likelihood of founding a new venture. The magnitude of this effect is noteworthy: a one standard deviation increase (9.2 years) above the sample mean of inventor age implies a 0.3% increase in the likelihood of a spin-off. In contrast, inventor research experience (RESEARCH EXPERIENCE) is negatively associated with the probability of spin-offs. A one standard deviation increase above the mean of research experience (9.6 years) implies a 0.2% decrease in the likelihood of a spin-off. The results also confirm that RISK PROPENSITY is positively related to inventors' spin-offs. A one standard deviation increase (2.3) above the sample average of risk propensity is associated with a 0.5% increase in the likelihood of a spin-off.

It is possible that the perception of strategic autonomy reflects the position of inventors in the organization. Inventors with managerial roles may have developed a superior ability to explore new business opportunities and an entrepreneurial attitude. To exclude this alternative explanation, we entered in the regression model the variable MANAGERIAL STATUS. This variable is weakly correlated with strategic autonomy (Pearson = 0.19). In addition, estimates reported under model 6 show that this variable does not enter significantly in the technological spin-off equation, while the marginal effect of strategic autonomy remains stable. This suggests that the organizational position of the inventor does not affect the association between strategic autonomy and spinoff.

The positive impact of strategic autonomy could arise because of sorting processes that cause inventors with individual characteristics, such as taste for independence or risk propensity, to self-select into jobs with high levels of autonomy, which pave the way for subsequent entrepreneurship. Sørensen (2007) notes that people may sort into organizations depending on both observable and unobservable characteristics. Our estimates control for various observable individual characteristics, such as RISK PROPENSITY. In our sample, the average score of RISK PROPENSITY among inventors with the highest level of strategic autonomy is 7.7, a significantly higher score (t = -21.120, p = .000) than that observed for those with no autonomy (6.1). To evaluate whether this dispositional trait drives the effect of strategic autonomy on the likelihood of a spin-off, we compute the marginal effect of STRATEGIC AUTONOMY at different levels of RISK PROPENSITY: the 10th (score = 4), 50th (score = 7), and 90th (score = 10) percentiles of the risk propensity distribution. The corresponding marginal effects for STRATEGIC AUTONOMY are, respectively, 0.1% (p = .057), 0.2% (p = .009), and 0.4% (p = .006). The effect of strategic autonomy increases with risk propensity; thus, we cannot rule out that a sorting effect is at work. However, the significant and positive effect of STRATEGIC AUTONOMY for inventors with a risk propensity below or at the median confirms that the effect of autonomy is not entirely driven by risk propensity.

We cannot analyze sorting on unobservable individual characteristics, which would require a longitudinal data set. However, the richness of data on observable individual characteristics such as RISK PROPENSITY makes our results robust to heterogeneity generated by endogenous sorting by inventors. In addition, although it is theoretically possible that future entrepreneurs self-select into firms that are characterized by a high likelihood of spin-offs, in practice this implies assuming substantial foresight from the inventor who anticipates future entrepreneurship. Our analysis also focuses on new ventures whose founding is favored or allowed by an established organization. Thus, sorting on individual characteristics is less important here than in studies on employee entrepreneurship (e.g., Gambardella et al., 2014).

In unreported regressions, we further check the robustness of results presented in this paper. First, we have adopted the approach developed in (King and Zeng, 2001) to handle the rareness of positive outcomes in the dependent variable and estimated the full model with controls at the individual levels. Results, available upon request from the authors, are the same as those reported in Table 3. Second, we restricted the test of our hypotheses to the sample of used patents; that is, we dropped from the analysis patents that, at the time of the survey, had not been used internally (e.g., in a new product) or externally (e.g., licensed, sold). We also estimated a Heckman probit model to account for potential selection bias. The results are similar to those reported in the paper and are available on request.

4.3. Spin-offs as a vehicle of exploration: a qualitative examination

We hypothesize that the positive association between strategic autonomy and the likelihood of a technology spin-off is explained by an exploration mechanism. However, we cannot measure it directly because the survey does not provide information about the nature of business opportunities explored during the inventive process. Nevertheless, we can make inferences from the spin-off activity: if exploration drives the formation of spin-offs, many of these start-ups should be established to pursue market opportunities not exploited by the parent company. Furthermore, and more important, the relationship between the business activity of the spin-off and the market in which the parent firm is active should change with the level of strategic autonomy.

We collected data on industries in which both spin-offs and their parent companies operate by searching several data sets (e.g., Amadeus, ORBIS, Osiris, Zephyr, LexisNexis). We found information about primary and secondary Standard Industrial Classification (SIC) codes at the four-digit level of aggregation for all parent–spin-off dyads. For 80.6% of the cases, the industries of the parent firm and the spin-off do not match.[1] Therefore, in the majority of cases, spin-offs in our data set exploit technological opportunities outside the core business of their parent company. In addition, the share of spin-offs not operating in the same industry as the parent company is smaller (73%) when the inventor/team strategic autonomy is low (below or equal to the sample median), as compared with the ratio (85%) observed for inventors/teams that are given high levels of strategic autonomy.

We also compare the 4-digit industries of parent firms and new ventures operating as wholly owned subsidiaries, which were excluded from our sample, and find a mismatch in 45.5% of the cases - a significantly smaller share compared with that of technology spinoffs.

[1] Often, the parent firm is present in two or more industries. In these cases, we compared all industry codes of the parent with the industry of the spin-off. When we found a match at the four-digit SIC level, we scrutinized more carefully the activity of the spin-off to determine whether it focuses on a market niche not occupied by the parent.

Table 4 shows the business activity of 22 parent–spin-off dyads that we randomly selected from the data set.[2] In 8 of the 22 cases, the level of strategic autonomy granted to the inventors/teams at the time of the invention is below the sample mean (3.1); in the remaining cases, the level of strategic autonomy is above the mean. The share of patents developed under conditions of high strategic autonomy in these 22 cases is similar to that of the full sample (65%). Table 4 also compares the core industry of the parent firm and the spin-off at the four-digit level of aggregation. In 4 of the 22 cases (18%), the industry of the spin-off matches that of the parent, which is in line with the share of matches in the full sample (approximately 20%). Furthermore, the share of no-match cases is much higher when inventors report a high level of strategic autonomy (93%) than when inventors report a low level of strategic autonomy (63%). In only 4 of the 22 cases (18%) does the sector of the spin-off match that of the parent at the two-digit SIC level.

Insert Table 4 Here

Overall, the qualitative analysis shows that the spin-offs do not compete with the parent in the same market and that patents developed in inventive settings characterized by high levels of strategic autonomy are more likely to be exploited by spin-offs in markets in which the parent is not present. This qualitative evidence offers additional support for the idea that the association between strategic autonomy and the likelihood of a spin-off is explained by exploratory search and discovery (or generation) of business opportunities outside the parent firm domain. Finally, Table 4 illustrates the role of inventors in the founding and management of spin-offs. In the majority of cases, inventors or co-inventors of the focal patent are involved in the spin-off as founders (65%) and occupy a top management position in the new venture.

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[2] Confidentiality agreements with survey participants prevent us from disclosing any information that would allow identification of the individual inventors or their employers at the time of the survey.

5. Discussion and conclusions

5.1. Implications for research

This paper offers novel findings on the role of organizational characteristics of firms in the formation of technology spin-offs. The convergence between organizational literature and entrepreneurship studies is only recent (Sørensen and Fassiotto, 2011), and little theory and empirical analysis exist on the impact of organizational dimensions, such as work autonomy and teamwork, on the probability that a technology developed in a firm is transferred to a spin-off firm. Although many previous studies have focused on size as a proxy for organizational characteristics of the parent, our findings indicate the importance of a finer-grained examination of the organizational context beyond firm size.

Our findings are in line with previous work on corporate entrepreneurship, defined as a "process whereby an individual or a group of individuals, in association with an existing organization, create a new organization" (Sharma and Chrisman, 1999, p. 18). The literature highlights various reasons for spin-offs, such as the lack of complementary assets, the discovery of new business opportunities that are misaligned with the firm's strategic goals (Cassiman and Ueda, 2006), and the underutilization of valuable knowledge (Agarwal et al., 2004; Gambardella et al., 2014).

We contribute to this literature by showing how the organization of innovative activities of established firms can facilitate or inhibit inter-organization knowledge transfer through spinoff (Agarwal et al. 2010). More precisely, we advance the theory of corporate spin-off by showing that the association between work autonomy and spin-offs varies with the type of autonomy granted to inventors (i.e., structural autonomy vs. strategic autonomy). We theorize and show empirically that patents developed by inventors who enjoy a higher level of strategic autonomy are more likely to be used by spin-offs as a way to explore business opportunities in sectors where the parent is not present. Since the survey does not tell about the exploration of business opportunities during the inventive process, we rely on external sources of data to compare the business activity of spin-offs with that of their parent firms. Our findings are consistent with our theorizing and suggest that strategic autonomy leads inventors to scanning business landscapes unfamiliar to the employer organization and spurs firms to exploit the resulting business opportunities through spinoffs.

We also hypothesize and show empirically that teamwork organization of inventive activities—likely targeting more complex innovations and generating organization-specific nontransferable knowledge—is negatively associated with the probability of a technology spin-off. This result suggests that the idiosyncratic and tacit knowledge effect associated with teamwork outweighs social and entrepreneurial capital accumulation effects.

Unlike prior studies that focus on spin-offs as a process driven by employees' decisions to enter into entrepreneurship to exploit opportunities not exploited by the employer (e.g., Agarwal et al., 2004; Klepper and Sleeper, 2005), we concentrate on spin-offs as a form of corporate entrepreneurship, that is as a way for incumbent organizations to experiment and "exploit opportunities in unfamiliar markets or technologies" (Bruneel et al. 2013: 943). In our analysis, the parent organization always plays a key role in the formation of a spin-off. Even when the inventor or other employees took the initiative, in our setting the spinoff formation results from the collaboration between the employee and the employer, who (in over 80% of cases) has invested its own money in the R&D leading to the invention and owns the patented invention. The employer organization then makes a decision about whether it is more profitable to pursue a particular invention through a spinoff rather than abandon it or exploiting it alternatively – e.g., through the development and commercialization of new products. Although we do not directly observe the reasons why an incumbent organization initiates or agrees to transfer its proprietary technology to a new firm, the decision to rely on a spin-off reveals that the incumbent organization considers this option as a way to extract value from its R&D investments and to create opportunities for future growth (Bruneel et al, 2013; Ferrary, 2008; Fryges and Wright, 2014).

Thus, this study advances the understanding of corporate entrepreneurship and external corporate venturing (e.g., Narayanan et al., 2009; Zahra et al. 2007; Larraneta et al., 2016) by showing that spin-offs and the organization of inventive activities are different dimensions of the same process of exploration of technological and business opportunities.

Although we cannot establish an absolute causality, the significant association of teamwork and autonomy with spinoff formation supports our conjecture. This association, which is robust to several controls at the firm, the patent, the technology and the individual level, indicates that the hypothesized mechanisms that connect teamwork and autonomy with spinoff provide a plausible explanation of the spin-off phenomenon.

Work autonomy and teamwork are key notions in organizational creativity and innovation management studies (Amabile, 1997; Sauerman and Cohen, 2000; Woodman et al., 1993; Zhang and Bartol, 2010). We contribute to this stream of research by discussing the mechanisms through which both factors affect spin-off formation, an issue that remains underdeveloped in previous works on creativity and innovation management. Building on this stream of research, we claim that teamwork probably entails organizational investment of resources in complex inventions. Teamwork implies interactions among individuals specializing in interdependent tasks. These interactions give rise to organization-specific, tacit knowledge which cannot be more easily transferred to a separate new venture, compared with individual work. Moreover, we contribute to this stream of research, by showing that different types of autonomy generate different effects on the likelihood of spin-off – with strategic autonomy spurring exploration of new technological and business opportunities that the incumbent firm may find convenient to pursue by external venturing.

We also contribute to the literature on job design and entrepreneurship (e.g., Baron, 2010; Cohen and Bailey, 1997; Hayton, 2005) by showing that job design of knowledge-intensive work is part of a broader strategic process that involves decisions about whether to exploit commercially a technology through internal or external venturing. Specifically, our study suggests that established organizations aiming to experiment with technologies likely give more autonomy to their inventors and rely on spinoffs to pursue new business opportunities that cannot be easily exploited within their core business. Our findings also hold when focusing on spin-offs founded by the survey inventor with the support of the parent organization, which transfers of its proprietary technology to the spin-off. Interestingly, while inventor's age (a measure of work experience) and risk tolerance enters positively the spin-off equation, R&D experience enters with a negative sign. This result suggests that though work experience is generally useful for entering into entrepreneurship, probably because over time inventors get involved in a wider set of activities and develop multiple skills, R&D-specific experience reveals a specialized working professional profile that, according to the jack-of-all-trades theory of entrepreneurship (Lazear, 2004), predicts a lower propensity to start a new firm.

5.2. Implications for practice

In addition to a better understanding of the origin of technological spin-offs, our findings can help established firms make more efficient use of their knowledge and elaborate effective human capital management policies. Established organizations would benefit from identifying the conditions that can encourage or prevent the creation of spin-offs. For example, firms that pursue more exploratory search and grant high levels of strategic autonomy will likely discover business opportunities outside their core business, which it would be better to pursue by external venturing to exploit the advantages of this option – e.g., flexibility and speed, compared with internal venturing. As Williamson (1975, pp. 205–206) hypothesizes, "independent investors and small firms (perhaps new entrants) in an industry" are a more efficient mechanism for new product development and market testing than large enterprises. In contrast, firms that focus on less exploratory search, which requires limited strategic autonomy, are more likely to generate entrepreneurial ideas that can be exploited through internal venturing.

In addition, our findings on individual characteristics in the analysis of spin-offs founded by the survey inventor may help an established firm identify which employees are more likely to exploit the opportunities the firm is not willing or able to pursue through internal venturing. We find that, in addition to the hypothesized effects of teamwork and autonomy, some inventor characteristics, such as age (a proxy for work experience) and risk propensity are correlated with the likelihood of a spin-off, controlling for the organizational role. This evidence suggests that in their decision whether to initiate or support a technology spin-off established companies take into account some characteristics of inventors as potential founders of spinoffs along with the characteristics of the technology and the business opportunities. Spin-offs are a potentially important way to use inventions, a large proportion of which would otherwise remain unused by the patent owner because of, for example, a lack of complementary assets needed to translate an invention into a useful innovation or the inefficiencies of the market for technology, which can hamper the trade of patents. Compared with licensing or patent sale, spin-offs are less affected by the functioning of the market for technology. The founder or the sponsor of the new venture is either the inventor or the employer at which the invention was developed, which moderates the information asymmetry problem that plagues technology markets and favors technology transfer.

5.3. Limitations and further research

Our analysis controls for a large number of observable individual traits that may affect inventors sorting into organizational contexts characterized by teamwork and greater working autonomy as well as their likelihood to found a spin-off. The cross-sectional nature of our data set and the absence of multiple observations for the same inventor do not allow deal with sorting on unobservable fixed effects. However, our data account for sorting on finer-grained observable dispositional traits (e.g., risk propensity) that were not available in previous work based on longitudinal data sets (e.g., Dobrev and Barnett, 2005; Sørensen, 2007). Further research on the effect of organizational context on entrepreneurship would benefit from the availability of a richer set of longitudinal data on individual characteristics and inventor mobility across different firms.

The association between organizational characteristics and the probability of a spin-off raises the question whether firms decide their job design after or along with the strategy of technology exploitation (e.g., internal or external venturing). To stimulate innovation, firms need to incentivize inventors (through teamwork and autonomy), and in turn, these incentives (e.g., strategic autonomy) can affect the type of business opportunities created by the invention. Even if we cannot totally exclude reverse causality because of the cross-sectional nature of the data, spin-offs are rare events and thus the extent to which firms account for the possibility of a spin-off in their job design and R&D management decisions is not clear. Although in theory firms may grant autonomy to prevent employee mobility or to favor external corporate venturing, extant research shows there is no evidence of a significant association between autonomy and turnover intention (Humphrey et al., 2007). This suggests that R&D management decisions aim to foster knowledge creation, rather than governing corporate venturing, in the first place. In addition, because of the uncertainty intrinsic to R&D, when key R&D management and job design decisions (e.g., how much autonomy should be granted to inventors) are made, it is difficult for a firm to predict the nature of the inventive outcome and anticipate whether it should be pursued through external or internal venturing. Furthermore, a large share of spin-offs in our sample were founded by the survey inventor and in these cases unlikely the spin-off was planned by the parent organization at the time of invention (Ioannou, 2014). When the spin-off was initiated by the parent firm, it is possible that it has carefully planned the spin-off along with the level of autonomy it granted to inventors. To moderate the potential reverse causality we made sure that teamwork and autonomy are predetermined with respect to the date of spin-off foundation. In sum, even if reverse causality cannot be entirely ruled out, our findings are useful to corporate entrepreneurship theory and business practice because they show that firms must lay the groundwork for such events by identifying the right employees and providing them with an organizational environment that fosters innovation and exploration of new business opportunities. To the best of our knowledge, this is the first attempt at digging deep into the association between the organization of the inventive activity and spin-off formation. Future research may benefit from longitudinal data that would be more appropriate to deal with causality.

Our analysis points out some noteworthy mechanisms that affect the formation of a spin-off. Although we do not directly observe these mediating mechanisms, previous studies show that our measures (e.g., autonomy) are associated with such mechanisms (e.g., job satisfaction, entrepreneurial orientation). Our qualitative analysis suggests that strategic autonomy is associated with the distance between the parent and the spin-off businesses. Further research should investigate these mechanisms in greater depth, especially those that link autonomy to exploration of new technological and business opportunities and spin-off formation. Another worthwhile avenue for further research on post-entry performance is about the association between spin-off's growth, the organizational contexts that originated the spinoff – e.g. the level of strategic autonomy of their founders and the distance between the parent's core business and the spin-off's business activities at the time of foundation. Understanding the drivers of post-entry performance, along with the antecedents, has important implications for both research and practice.

Our analysis focuses on technological spin-offs but it can generalize to other spin-offs formation, in particular spin-offs in knowledge-based activities, where creativity and innovation are important for the incumbent firms' innovativeness and competitiveness. However, to what extent our findings could be generalized to other types of spinoffs such as "necessity spinoffs" triggered by adverse events such as restructuring or acquisition that lead to spawn mature, low-tech activities like technical assistance or manufacturing of noncritical components, is up for testing in future research.

References

Agarwal, R., Echambadi, R., Franco, A.M., & Sarkar, MB. (2004). Knowledge transfer through inheritance: spin-out generation, development, and survival. *The Academy of Management Journal*, 47(4), 501–522.

Agarwal, R., Audretsch, D., & Sarkar, MB. (2010). Knowledge spillovers and strategic entrepreneurship. *Strategic Entrepreneurship Journal*, 4(4), 271-283.

Amabile, T.M. (1997). Motivating creativity in organizations: on doing what you love and loving what you do. *California Management Review*, 40(1), 39–58.

Astebro, T., & Thompson, P. (2011). Entrepreneurs, jacks of all trades or hobos? *Research Policy*, 40(5), 637–649.

Auerswald, P.E., & Branscomb, L.M. (2003). Start-ups and spin-offs: collective entrepreneurship between invention and innovation. In D.H. Hart (ed.), *The emergence of entrepreneurship policy* (pp. 61–91). New York: Cambridge University Press.

Bailyn, L. (1985). Autonomy in the industrial R&D lab. *Human Resource Management,* 24(2), 129–146.

Baron, R.A. (2010). Job design and entrepreneurship: why closer connections = mutual gains. *Journal of Organizational Behavior*, 31(2-3), 370–378.

Beckman, C., Eisenhardt, K., Kotha, S., Meyer, A., & Rajagopalan, N. (2012). Technology entrepreneurship. *Strategic Entrepreneurship Journal*, 6(2), 89-93.

Belsley, D.A., Kuh, E., & Welsch, R.E. (1980). Regression diagnostics: identifying influential data and sources of collinearity. New York: John Wiley & Sons.

Bhidé, A.V. (2000). The origin and evolution of new businesses. New York: Oxford University Press.

Braguinsky, S., Klepper, S., & Ohyama, A. (2012). High-tech entrepreneurship. *Journal of Law and Economics*, 55(4): 869-900.

Breaugh, J.A. (1985). The measurement of work autonomy. *Human Relations,* 38(6), 551–570.

Bruneel, J., Van de Velde, E., & Clarysse, B. (2013). Impact of the type of corporate spin-off on growth. *Entrepreneurship Theory and Practice,* 37(4), 943–959.

Burgelman, R.A. (1983). A process model of internal corporate venturing in the diversified major firm. *Administrative Science Quarterly,* 28(2), 223–244.

Burton, M.D., Sørensen, J.B., & Beckman, C.M. (2002). Coming from good stock: career histories and new venture formation. In M. Lounsbury (ed.), *Research in the sociology of organizations* (vol. 19, pp. 229–262). Bingley, UK: Emerald Publishing.

Cassiman, B., & Ueda, M. (2006). Optimal project rejection and new firm start-ups. *Management Science*, 52(2), 262–275.

Chatterji, A.K. (2009). Spawned with a silver spoon? Entrepreneurial performance and innovation in the medical device industry. *Strategic Management Journal*, 30: 185-206.

Chesbrough, H. (2003). The governance and performance of Xerox's technology spin-off companies. *Research Policy*, 32(3): 403–421.

Cohen, S.G., & Bailey, D.E. (1997). What makes teams work: group effectiveness research from the shop floor to the executive suite. *Journal of Management*, 23(3), 239–290.

Delmar, F., Wennberg, K., & Hellerstedt, K. (2011). Endogenous growth through knowledge spillovers in entrepreneurship: an empirical test. *Strategic Entrepreneurship Journal*, 5(3), 199-226.

Dess, G.G., & Lumpkin, G.T. (2005). The role of entrepreneurial orientation in stimulating effective corporate entrepreneurship. *Academy of Management Executive*, 19(1), 147–156.

Dobrev, S.D., & Barnett, W.P. (2005). Organizational roles and transition to entrepreneurship. *Academy of Management Journal*, 48(3), 433–449.

Eckhardt, J.T., & Shane, S.A. (2011). Industry changes in technology and complementary assets and the creation of high-growth firms. *Journal of Business Venturing*, 26(4), 412–430.

Elfenbein, D.W., Hamilton, B.H., & Zenger, T.R. (2010). The small firm effect and the entrepreneurial spawning of scientists and engineers. *Management Science,* 56(4), 659–681.

Erikkson, T., & Kuhn, J.M. (2006). Firm spin-offs in Denmark 1981–2000: patterns of entry and exit. *International Journal of Industrial Organization*, 24(5), 1021–1040.

Ferrary, M. (2008). Strategic spin-off: a new incentive contract for managing R&D researchers. *Journal of Technology Transfer,* 33(6), 600-618.

Festel, G. (2013). Academic spin-offs, corporate spin-outs and company internal start-ups as technology transfer approach. *Journal of Technology Transfer*, 38(4), 454-470.

Freeman, J. (1986). Entrepreneurs as organizational products: semiconductor firms and venture capital firms. In G. Libecap (ed.), *Advances in the study of entrepreneurship, innovation, and economic growth* (vol. 1, pp. 33–58). Greenwich, CT: JAI Press.

Fryges, H. & Wright. M. (2014). The origin of spin-offs: a typology of corporate and academic spin-offs. Small Busimess Economics 43(2):245–259.

Fuller, A.W., & Rothaelmer, F.T. (2012). When stars shine: the effects of faculty founders on new technology ventures. *Strategic Entrepreneurship Journal*, 6(3), 220–235.

Gambardella, A., Ganco, M., & Honoré, F. (2014). Using what you know: patented knowledge in incumbent firms and employee entrepreneurship. *Organization Science*, 26(2), 456–474.

Gompers, P., Lerner, J., & Scharfstein, D. (2005). Entrepreneurial spawning: public corporations and the genesis of new ventures, 1986 to 1999. *Journal of Finance*, 60(2), 577–614.

Greene, W.H. (2003). Econometric analysis (5th ed.). Upper Saddle River, NJ: Prentice Hall.

Haas, M.R. (2010). The double-edge swords of autonomy and external knowledge: analyzing team effectiveness in a multinational organization. *Academy of Management Journal*, 53(5), 989–1008.

Hathaway, I. (2013). Tech starts: high-technology business formation and job creation in the United States. Kauffman Foundation Research Series: Firm Formation and Economic Growth.

Hayton, J.C. (2005). Promoting corporate entrepreneurship through human resource management practices: A review of empirical research. *Human Resource Management Review*, 15(1): 21-41.

Helfat, C.E., & Lieberman, M.B. (2002). The birth of capabilities: market entry and the importance of pre-history. *Industrial and Corporate Change*, 11(4): 725-760.

Hellmann, T. (2007). When do employees become entrepreneurs? *Management Science*, 53(6), 919–933.

Hitt, M.A., Bierman, L., Shimizu, K., & Kochhar, R. (2001). Direct and moderating effects of human capital on strategy and performance in professional service firms: a resource-based perspective. *Academy of Management Journal*, 44(1), 13–28.

Humphrey, S.E., Nahrgang, J.D., & Morgeson, F.P. (2007). Integrating motivational, social, and contextual work design features: a meta-analytic summary and theoretical extension of the work design literature. *Journal of Applied Psychology*. 92(5), 1332–1356.

Ioannou, I. (2014). When do spinouts enhance parent firm performance? evidence from the U.S. automobile industry, 1890–1986. *Organization Science*, 25(2), 529–551.

Kirchberger, M.A., & Pohl, L. (2016). Technology commercialization: a literature review of success factors and antecedents across different contexts. *Journal of Technology Transfer*, 41(5), 1077-1112.

Klepper, S., & Sleeper, S. (2005). Entry by spinoffs. *Management Science*, 51(8), 1291–1306.

Klepper, S., & Thompson, P. (2010). Disagreements and intra-industry spinoffs. *International Journal of Industrial Organization*, 28: 526-530.

King, G., Zeng, L. (2001). Logistic regression in rare events data. *Political Analysis*, 9(2): 137-163.

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

Larraneta, B., Galán González, J.L., & Aguilar, R. (2016). Early efforts to develop absorptive capacity and their performance implications: differences among corporate and independent. *Journal of Technology Transfer*, doi:10.1007/s10961-016-9488-1.

Lassen, A.H., Gertsen, F., & Riss, J.O. (2006). The nexus of corporate entrepreneurship and radical innovation. *Creativity and Innovation Management*, 15(4), 359–372.

Lazear, E.P. (2004). Balanced skills and entrepreneurship. *American Economic Review*, 94(2), 208–211.

Lazear, E.P. (2005). Entrepreneurship. *Journal of Labour Economics*, 23(4), 649–680.

Lumpkin, G.T., Cogliser, C.C., & Schneider, D.R. (2009). Understanding and measuring autonomy: an entrepreneurial orientation perspective. *Entrepreneurship Theory and Practice*, 33(1), 47–69.

Lumpkin, G.T., & Dess, G.G. (1996). Clarifying the entrepreneurial orientation construct and linking it to performance. *Academy of Management Review*, 21(1), 135–172.

Liu, X. Wright, M., Filatotchev, I., Dai, O., & Lu, J. (2010). Human mobility and international knowledge spillovers: evidence from high-tech small and medium enterprises in an emerging market. *Strategic Entrepreneurship Journal*, 4(4), 340-355.

Markman, G.D, Balkin, D.B., & Baron, R.A. (2002). Inventors and new venture formation: the effect of general self-efficacy and regretful thinking. *Entrepreneurship Theory and Practice*, 27(2), 149–165.

Marvel, M.R., Griffin, A., Hebda, J., & Vojak, B. (2007). Examining the technical corporate entrepreneurs' motivation: voices from the field. *Entrepreneurship Theory and Practice*, 31(5), 753–768.

McDonough, E.F., III. (2000). Investigation of factors contributing to the success of cross-functional teams. *Journal of Product Innovation Management*, 17(3), 221–235.

McGrath, R.G. (2001). Exploratory learning, innovative capacity and managerial oversight. *Academy of Management Journal*, 44(1), 118–131.

Nanda, R., & Sørensen, J.B. (2010). Workplace peers and entrepreneurship. *Management Science*, 56(7), 1116–1126.

Narayanan, V.K., Yang, Y., & Zahra, S.A. (2009). Corporate venturing and value creation: a review and proposed framework. *Research Policy*, 38 (1), 58–76.

Nelson, R.R., & Winter, S.G. (1982). An evolutionary theory of economic change. Cambridge, MA: Harvard University Press.

Palomeras, N., Melero, E. (2010). Markets for inventors: Learning-by-hiring as a driver of mobility. *Management Science* 56 (5), 881–895.

Parhankangas, A., & Arenius, P. (2003). From a corporate venture to an independent company: a base for a taxonomy for corporate spin-off firms. *Research Policy*, 32 (3), 463–481.

Parker, S.C. (2011). Intrapreneurship or entrepreneurship? *Journal of Business Venturing*, 26(1), 19–34.

Petre, M. (2004). How expert engineering teams use disciplines of innovation. *Design Studies*, 25 (5), 477-493.

Sampat, B.N. (2010). When Do Applicants Search for Prior Art? *The Journal of Law and Economics* 53 (2): 399–416.

Sauermann, H., & Cohen, W.M. (2010). What makes them tick? Employees motives and firm innovation. *Management Science*, 56(12), 2134–2153.

Shane, S. (2001a). Technological opportunities and new firm creation. *Management Science*, 47(2), 205–220.

Shane, S. (2001b). Technology regimes and new firm formation. *Management Science*, 47(9), 1173–1190.

Sharma, P., & Chrisman, J.J. (1999). Toward a reconciliation of the definitional issues in the field of corporate entrepreneurship. *Entrepreneurship Theory and Practice*, 23(3), 11–27.

Shepherd, D.A., Williams, T.A., & Patzelt, H. (2015). Thinking about entrepreneurial decision making: review and research agenda. *Journal of Management*, 41(1), 11–46.

Shimizu, K. (2012). Risks of corporate entrepreneurship: autonomy and agency issues. *Organization Science*, 23(1), 194–206.

Simons, K.L., & Astebro, T. (2010). Entrepreneurs seeking gains: profit motives and risk aversion in inventors' commercialization decision. *Journal of Economics & Management Strategy*, 19(4), 863–888.

Somaya, D. (2003). Strategic determinants of decisions not to settle patent litigation. *Strategic Management Journal*, 24(1), 17–38.

Sørensen, J.B. (2002). The strength of corporate culture and the reliability of firm performance. *Administrative Science Quarterly*, 47(1), 70–91.

Sørensen, J.B. (2007). Bureaucracy and entrepreneurship: workplace effects on entrepreneurial entry. *Administrative Science Quarterly*, 52(3), 387–412.

Sørensen, J.B., & Fassiotto, M.A. (2011). Organizations as fonts of entrepreneurship. *Organization Science*, 22(5), 1322–1331.

Stevenson, H.H., & Jarillo, J.C. (1990). A paradigm of entrepreneurship: entrepreneurial management. *Strategic Management Journal*, 11, 17–27.

Stuart, T.E., & Sorenson, O. (2003). The geography of opportunity: spatial heterogeneity in founding rates and the performance of biotechnology firms. *Research Policy*, 32(2), 229–253.

Teece, D.J. (1986). Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. *Research Policy*, 15(6), 285–305.

Torrisi, S., Gambardella, G., Giuri, P. Harhoff, D., Hoisl, K., & Mariani, M. 2016. Used, blocking and sleeping patents: Empirical evidence from a large-scale inventor survey. *Research Policy*, 45(7): 1374-1385.

Williamson, O.E. (1975). Markets and hierarchies: antitrust analysis and implications. New York: The Free Press.

Woodman, R.W., Sawyer, J.E., & Griffin, R.W. (1993). Toward a theory of organizational creativity. *Academy of Management Review*, 18(2), 293–321.

Woolley, J.L. (2017). Origins and outcomes: the role of spin-off founders and intellectual property in high-technology venture outcomes. *Academy of Management Discoveries*, 3(1): 64-90.

Zahra, S.A., Van de Velde, E., Larraneta, B. (2007). Knowledge conversion capability and the performance of corporate and university spin-offs. *Industrial and Corporate Change*, 16(4): 569-608.

Zhang, X., & Bartol, K.M. (2010). Linking empowering leadership and employee creativity: the influence of psychological empowerment, intrinsic motivation, and creative process engagement. *Academy of Management Journal*, 53(1), 107–128.

Table 1. Descriptive statistics

Variable	Mean	SD	Min	Max
Dependent variable				
TECHNOLOGY SPINOFF	0.010	0.100	0	1
Organization of inventive activities				
STRUCTURAL AUTONOMY	4.156	0.999	1	5
STRATEGIC AUTONOMY	3.090	1.396	1	5
TEAMWORK	0.695	0.460	0	1
Employer characteristics				
COMPLEMENTARY ASSETS	3.578	1.309	1	5
$\text{COLLABORATION}_{\text{VERTICAL}}$	0.394	0.489	0	1
$\text{COLLABORATION}_{\text{HORIZONTAL}}$	0.122	0.327	0	1
$\text{COLLABORATION}_{\text{RESEARCH}}$	0.162	0.368	0	1
$\text{FIRM SIZE}_{1–19}$	0.023	0.150	0	1
$\text{FIRM SIZE}_{20–99}$	0.054	0.225	0	1
$\text{FIRM SIZE}_{100–999}$	0.136	0.343	0	1
$\text{FIRM SIZE}_{1,000–4,999}$	0.139	0.346	0	1
$\text{FIRM SIZE}_{>=5,000}$	0.649	0.477	0	1
MINING & CONSTRUCTION	0.019	0.137	0	1
MANUFACTURING	0.839	0.368	0	1
TRANSPORT & COMMUNICATION	0.022	0.148	0	1
WHOLESALE & RETAIL TRADE	0.035	0.183	0	1
FINANCE & INSURANCE	0.023	0.150	0	1
SERVICES	0.062	0.241	0	1
EUROPE [(a)]	0.568	0.495	0	1
UNITED STATES	0.046	0.208	0	1
UK, IRELAND, ISRAEL	0.169	0.375	0	1
JAPAN	0.218	0.413	0	1
Patent and technology characteristics				
STRATEGIC STAKE (log)	0.280	0.510	0	3.784
CLAIMS (log)	2.671	0.580	0	5.236
COINVENTORS (log)	0.770	0.609	0	3.871
GOVERNMENT FUNDS	0.060	0.237	0	1
ELECTRICAL ENGINEERING	0.255	0.436	0	1
INSTRUMENTS	0.150	0.357	0	1
CHEMISTRY	0.196	0.397	0	1
PROCESS ENGINEERING	0.133	0.339	0	1
MECHANICAL ENGINEERING	0.206	0.405	0	1
CONSUMPTION & CONSTRUCTION	0.061	0.238	0	1
OST30_CONCENTRATION	0.118	0.061	0.033	0.260
TECH_BREADTH	0.410	0.492	0	1
Inventor characteristics				
AGE (log)	3.738	0.217	2.890	4.174
RESEARCH EXPERIENCE (log)	2.582	0.748	0	4.190
RISK PROPENSITY	6.807	2.308	1	11
MANAGERIAL STATUS (log) [(b)]	1.132	1.173	0	5.525

Note: Descriptive statistics refer to 10,279 observations with complete data for all variables used in the baseline specification of the econometric models.

[(a)]The dummy variable EUROPE comprises the following countries: Denmark, Finland, Norway, Sweden, Belgium, Luxemburg, the Netherlands, France, Germany, Austria, Switzerland, Czech Republic, Hungary, Poland, Slovenia, Spain, Italy, and Greece..

[(b)] Descriptive statistics are computed over 9,706 observations without missing values.

Table 2. Correlations matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	TECHNOLOGY SPINOFF																		
2	STRUCTURAL AUTONOMY	0.00																	
3	STRATEGIC AUTONOMY	0.05*	0.36*																
4	TEAMWORK	-0.03*	0.02*	-0.03*															
5	COMPLEMENTARY ASSETS	-0.06*	0.13*	0.07*	0.06*														
6	COLLABORATION$_{VERTICAL}$	0.01	0.04*	0.07*	0.11*	0.06*													
7	COLLABORATION$_{HORIZONTAL}$	0.04*	0.04*	0.06*	0.07*	-0.02*	0.24*												
8	COLLABORATION$_{RESEARCH}$	0.05*	0.02*	0.09*	0.11*	-0.05*	0.19*	0.23*											
9	FIRM SIZE$_{1–19}$	0.13*	0.05*	0.10*	-0.03*	-0.06*	0.03*	0.04*	0.06*										
10	FIRM SIZE$_{20–99}$	0.05*	0.04*	0.08*	-0.05*	-0.01	0.04*	0.03*	0.06*	-0.04*									
11	FIRM SIZE$_{100–999}$	0.01	-0.02	0.05*	-0.03*	0.03*	0.07*	0.02	0.03*	-0.06*	-0.09*								
12	FIRM SIZE$_{1,000–4,999}$	-0.01	-0.04*	0.00	0.00	0.00	0.01	-0.01	-0.01	-0.06*	-0.10*	-0.16*							
13	MINING & CONSTRUCTION	0.02*	-0.01	0.03*	-0.01	-0.02	0.03*	0.02	0.00	0.00	0.00	0.01	0.00						
14	TRANSPORT & COMMUNICAT.	0.02	0.00	0.01	-0.01	-0.04*	-0.01	-0.01	-0.01	0.00	0.00	-0.03*	-0.05*	-0.02*					
15	WHOLESALE & RETAIL TRADE	0.00	0.00	0.02	-0.02	0.01	0.03*	0.00	0.00	0.08*	0.08*	0.04*	0.02	-0.03*	-0.03*				
16	FINANCE & INSURANCE	0.01	0.01	0.01	-0.01	0.02*	0.03*	0.00	0.00	0.02	0.04*	0.05*	0.02*	-0.02*	-0.02*	-0.03*			
17	SERVICES	0.10*	0.04*	0.05*	-0.02	-0.03*	0.00	0.02	0.03*	0.18*	0.14*	0.02*	-0.02	-0.04*	-0.04*	-0.05*	-0.04*		
18	UK, IRELAND, ISRAEL	0.05*	0.00	0.05*	-0.02*	0.03*	0.00	0.03*	0.03*	0.08*	0.07*	0.03*	-0.01	0.00	0.00	0.00	0.00	0.04*	
19	UNITED STATES	0.03*	0.06*	0.11*	0.01	0.07*	0.02	0.00	0.03*	0.06*	0.03*	-0.02*	-0.04*	0.00	-0.03*	0.00	-0.04*	0.10*	-0.10*
20	JAPAN	-0.05*	-0.17*	-0.05*	0.04*	-0.17*	-0.07*	-0.05*	-0.01	-0.07*	-0.11*	-0.11*	0.11*	-0.01	-0.03*	-0.05*	-0.08*	-0.06*	-0.12*
21	STRATEGIC STAKES	-0.02*	0.01	0.01	0.06*	0.05*	-0.04*	-0.01	0.01	-0.02	-0.04*	-0.06*	0.00	-0.01	-0.05*	-0.01	-0.04*	0.00	-0.01
22	CLAIMS	0.05*	0.07*	0.07*	0.04*	0.02*	0.00	0.03*	0.07*	0.06*	0.05*	0.02	-0.03*	0.00	0.01	0.02	0.00	0.10*	0.09*
23	COINVENTORS	-0.01	-0.01	-0.04*	0.43*	0.04*	0.01	0.04*	0.09*	-0.03*	-0.06*	-0.09*	-0.01	-0.01	0.00	-0.03*	-0.02*	0.01	-0.04*
24	GOVERNMENT FUNDS	0.02	0.02	0.03*	0.04*	-0.06*	0.05*	0.08*	0.20*	0.07*	0.09*	0.03*	-0.02	0.01	-0.01	0.00	0.00	0.03*	-0.01
25	INSTRUMENTS	0.02	-0.03*	0.00	-0.02	-0.02	0.02*	0.01	0.07*	0.05*	0.05*	0.02	0.01	-0.02	-0.02	0.02*	-0.01	-0.01	0.04*
26	CHEMISTRY	-0.01	0.03*	0.05*	0.11*	0.02	-0.08*	-0.01	0.07*	0.01	-0.01	-0.02*	0.02*	0.03*	-0.06*	0.00	-0.02*	-0.04*	-0.01
27	PROCESS ENGINEERING	-0.01	0.00	0.03*	-0.02	0.02*	0.07*	0.03*	-0.02*	-0.01	0.00	0.07*	0.04*	0.03*	-0.01	0.03*	0.00	-0.05*	-0.02*
28	MECHANICAL ENGINEERING	-0.02*	-0.04*	-0.08*	-0.03*	0.01	0.07*	-0.01	-0.06*	-0.03*	-0.02	-0.02	-0.03*	-0.03*	-0.06*	-0.02*	0.06*	-0.05*	-0.02*
29	CONSUM. & CONSTRUCT.	0.02	0.00	0.05*	-0.01	0.04*	0.06*	0.02*	-0.03*	0.02*	0.02	0.09*	0.05*	0.08*	-0.02*	0.01	0.02	0.00	0.00
30	OST30_CONCENTRATION	-0.01	0.05*	-0.03*	0.00	-0.07*	-0.14*	-0.03*	-0.01	-0.04*	-0.04*	-0.12*	-0.07*	-0.07*	0.13*	-0.05*	-0.06*	0.08*	0.01
31	AGE	0.03*	0.07*	0.18*	-0.06*	0.09*	0.07*	0.06*	0.05*	0.04*	0.04*	0.04*	-0.02*	0.03*	-0.02*	0.01	0.03*	0.00	0.03*
32	RESEARCH EXPERIENCE	-0.01	0.06*	0.10*	-0.02	0.05*	0.00	0.04*	0.04*	-0.02	-0.01	-0.02	-0.01	0.01	-0.05*	0.00	0.00	-0.01	0.01
33	RISK PROPENSITY	0.05*	0.11*	0.23*	-0.03*	0.08*	0.08*	0.07*	0.07*	0.08*	0.09*	0.03*	-0.01	0.01	-0.01	0.03*	0.00	0.04*	0.02*
34	MANAGERIAL STATUS	0.01	0.09*	0.19*	0.11*	0.06*	0.07*	0.07*	0.07*	0.00	0.06*	0.07*	0.02*	0.01	-0.01	0.02	0.02	0.01	0.01

		19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
20	JAPAN	-0.24*														
21	STRATEGIC STAKES	0.11*	0.07*													
22	CLAIMS	0.26*	-0.21*	0.11*												
23	COINVENTORS	0.07*	0.08*	0.16*	0.12*											
24	GOVERNMENT FUNDS	-0.06*	-0.07*	-0.01	0.02	0.03*										
25	INSTRUMENTS	0.06*	0.02*	0.03*	0.04*	-0.02	0.02									
26	CHEMISTRY	0.05*	0.04*	0.13*	0.10*	0.22*	-0.02	-0.21*								
27	PROCESS ENGINEERING	-0.02*	-0.03*	-0.01	-0.03*	-0.04*	-0.01	-0.16*	-0.19*							
28	MECHANICAL ENGINEERING	-0.12*	-0.04*	=-0.06*	-0.15*	-0.09*	0.01	-0.21*	-0.25*	-0.2*						
29	CONSUM. & CONSTRUCT.	-0.04*	-0.07*	=-0.03*	-0.02*	-0.05*	-0.01	-0.11*	-0.13*	-0.1*	-0.13*					
30	OST30_CONCENTRATION	0.05*	0.07*	-0.03*	0.07*	0.01	0.01	-0.16*	-0.04*	-0.26*	-0.18*	-0.30*				
31	AGE	0.20*	-0.22*	-0.01	0.03*	-0.08*	0.00	0.01	0.03*	0.07*	0.00	0.02*	-0.12*			
32	RESEARCH EXPERIENCE	0.11*	-0.07*	0.02*	0.01	-0.03*	0.00	0.01	0.08*	0.03*	-0.02*	-0.04*	-0.04*	0.68*		
33	RISK PROPENSITY	0.20*	-0.10*	0.02*	0.09*	-0.02*	0.02	0.01	0.03*	0.03*	-0.03*	0.02*	-0.05*	0.08*	0.03*	
34	MANAGERIAL STATUS	-0.03*	-0.05*	0.01	0.01	0.03*	0.03*	-0.02	0.06*	0.06*	0.00	0.01	-0.09*	0.30*	0.27*	0.16*

N = 9,706, * $p<0.05$

Table 3. Determinants of technology spin-off (average marginal effects)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
STRUCTURAL AUTONOMY		-0.003**	-0.003**	-0.003**	-0.003**	-0.002**
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
STRATEGIC AUTONOMY		0.003***	0.003***	0.003***	0.003***	0.002***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
TEAMWORK			-0.006**	-0.006**	-0.006**	-0.005**
			(0.003)	(0.003)	(0.003)	(0.002)
COMPLEMENTARY ASSETS	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$COLLABORATION_{VERTICAL}$	-0.002	-0.002	-0.001	-0.002	-0.002	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)
$COLLABORATION_{HORIZONTAL}$	0.008**	0.008**	0.009**	0.009**	0.009**	0.006*
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)
$COLLABORATION_{RESEARCH}$	0.009**	0.008**	0.009**	0.009**	0.010***	0.005
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)
$FIRM\ SIZE_{1–19}$	0.033***	0.029***	0.028***	0.028***	0.024***	0.013**
	(0.011)	(0.010)	(0.010)	(0.010)	(0.009)	(0.005)
$FIRM\ SIZE_{20–99}$	0.012**	0.011**	0.011**	0.011**	0.009**	0.005
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.003)
$FIRM\ SIZE_{100–999}$	0.008**	0.007**	0.007**	0.007**	0.007**	0.003
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)
$FIRM\ SIZE_{1.000–4.999}$	0.007*	0.007	0.007*	0.007*	0.007	0.002
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)
MINING & CONSTRUCTION	0.017*	0.015	0.016	0.015	0.015	0.011
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.008)
TRANSPORT & COMMUNICATION	0.015	0.013	0.013	0.013	0.011	0.008
	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)	(0.007)
WHOLESALE & RETAIL TRADE	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
FINANCE & INSURANCE	0.008	0.008	0.008	0.008	0.008	0.004
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.006)
SERVICES	0.015***	0.014***	0.014***	0.014***	0.015***	0.009**
	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.004)
UK, IRELAND, ISRAEL	0.007	0.007	0.007	0.007	0.008	0.006
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.004)
UNITED STATES	0.002	0.001	0.000	0.000	-0.003	-0.000
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
JAPAN	-0.009***	-0.010***	-0.010***	-0.010***	-0.012***	-0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
STRATEGIC STAKES	-0.004	-0.005	-0.005	-0.005	-0.005	-0.004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
CLAIMS	0.005*	0.004*	0.004*	0.004*	0.004	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
COINVENTORS	0.001	0.001	0.003*	0.003*	0.004**	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
GOVERNMENT FUNDS	-0.005*	-0.005	-0.005	-0.005	-0.005	-0.003
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
INSTRUMENTS	-0.003	-0.004	-0.003	-0.003	-0.003	-0.004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)
CHEMISTRY	-0.007**	-0.007**	-0.007**	-0.007**	-0.007**	-0.007***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
PROCESS ENGINEERING	-0.006**	-0.007**	-0.007**	-0.007**	-0.007**	-0.007***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
MECHANICAL ENGINEERING	-0.006*	-0.006*	-0.006*	-0.006**	-0.006*	-0.005**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
CONSUMPTION & CONSTRUCTION	-0.004	-0.004	-0.004	-0.004	-0.005	-0.004
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)
OST30_CONCENTRATION	-0.043	-0.039	-0.038	-0.039	-0.038	-0.044*
	(0.027)	(0.027)	(0.027)	(0.027)	(0.028)	(0.023)
TECH_BREADTH				0.002		
				(0.002)		
AGE					0.011*	0.010**
					(0.006)	(0.005)
RESEARCH EXPERIENCE					-0.004***	-0.003***
					(0.001)	(0.001)
RISK PROPENSITY					0.002**	0.002***
					(0.001)	(0.001)
MANAGERIAL STATUS					0.000	0.001
					(0.001)	(0.001)
Observations	10,279	10,279	10,279	10,279	9,706	9,663
Pseudo R-squared	0.203	0.214	0.218	0.219	0.232	0.309

Standard errors (robust to intragroup heterogeneity) are in parentheses; *** *p* < .01, ** *p* <.05, * *p* < .10

Table 4. Parent–spin-off industry links and inventors' involvement in the spin-off

Parent business (four-digit SIC code)	Spin-off business (four-digit SIC code)	Spin-off business activity	Strategic autonomy (1="very low," 5="very high")	Inventor(s) is (are) founder(s)	Inventors role in the spin-off
3674	7371	Software application claimed to make an Android device run "ten times faster"	1	Yes	2 co-inventors operate as CEO and CTO
3825	2834	Fast and affordable point-of-care diagnostics for infectious diseases	1	Yes	The inventor operates as CEO
2834	2834	Development and commercialization of novel therapeutics in the areas of thrombosis and hematology	2	Yes	A co-inventor operates as senior VP
6021	6099	Payment network in which multiple banks distribute a single platform for invoice processing and payments	2	No	The inventor operates as Product Management Director
2834	2834	Developing, commercializing treatments targeting gastrointestinal conditions with a high unmet medical need	3	No	The inventor operates as VP early development
2834	2834	Products in the fields of industrial enzymes and strain optimization.	3	No	The parent's president operates as CEO
8730	8732	Discovery of therapeutics for the treatment of cancer through approaches based on noncytotoxic mechanisms	3	Yes	A co-inventor operates as CEO
4899	7371	Market a revolutionary solution for legal peer-to-peer information exchange	3	Yes	The inventor operates as CEO
8731	8731	Novel first-in-class therapies for markets that are underserved by current therapies	4	No	The parent's CEO operates as CSO
3694	3674	Commercialize the market opportunities of electrowetting displays	4	Yes	A co-inventor operates as CTO
4899	2741	Use "'adaptive media" methodologies to monitor customer use of online video to offer personalized advertising	4	Yes	A co-inventor operates as CSO
8731	5084	Comprehensive solutions in water management processes microbiology	4	Yes	The inventor operates as chairman
3841	3845	Completing the development the parent's heart pump technology and introducing this life-saving device to the market	5	No	The inventor operates as a consultant
3711	3751	Design, market, sell the world's most efficient mountain bikes	5	Yes	The inventor operates as technical director
2821	2299	Develop innovative high-technology fabrics and textile systems	5	Yes	2 co-inventors operate as CEO and CDCO
3674	3821	Develops and supplies high-performance integrated camera module technology	5	No	The former CEO of the parent operates as CEO
3674	4899	Wireless medical devices connection via cloud-based solutions that allows device users, health care providers access to biometric information	5	No	The inventor operates as VP global strategy and market development
3679	3842	Automatic disposal syringe injector for the prevention of infections and epidemic diseases transmittal in mass vaccination of farm animals	5	Yes	The inventor is VP of R&D
3714	7379	Tools and information to make decisions about vehicle health and maintenance	5	Yes	The inventor operates as CEO
5191	7389	Self-contained device to be inserted into a book, magazine, or a product and can display video	5	Yes	The inventor operates as CEO
7371	2741	Software platform enabling digital media users to optimize the quality of video content	5	Yes	The inventor operates as VP engineering
3841	8731	Broad-spectrum antiseptic for professional health care use against nosocomial infection	5	Yes	The inventor operates as CEO

Note: CEO, chief executive officer; CTO, chief technology officer; CSO, chief scientific officer, CDCO, chief development and commercialization Officer; VP, vice-president.