Paper to be presented at
the DRUID16 20th Anniversary Conference
Copenhagen, June 13-15, 2016

# Leveraging radical acquired technologies to innovate: The moderating effect of star scientists and upstream strategic alliances

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## Abstract

In the present research, we investigate the impact exerted by the radicalness of acquired technologies on the acquiring firms' subsequent innovativeness. However, besides acquiring technologies, firms may also decide to make and/or ally to source new knowledge and develop technical solutions. Thereby, we analyze how the above relationship is dependent on the employment of star scientists to develop new technologies in-house and the establishment of upstream strategic alliances to co-create them with partners, hence referring to the make and ally knowledge sourcing modes, respectively. We tested our hypotheses on a sample of 6,208 USPTO patented technologies acquired by 350 biotechnology firms over the period 1980-2012. Results reveal that the radicalness of acquired technologies exhibits an inverted U-shaped effect on the extent to which acquiring firms exploit these technological solutions for innovating. This relationship is in turn negatively moderated by both the employment of star scientists and establishment of upstream alliances.

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## ABSTRACT

In the present research, we investigate the impact exerted by the radicalness of acquired technologies on the acquiring firms' subsequent innovativeness. However, besides acquiring technologies, firms may also decide to make and/or ally to source new knowledge and develop technical solutions. Thereby, we analyze how the above relationship is dependent on the employment of star scientists to develop new technologies in-house and the establishment of upstream strategic alliances to co-create them with partners, hence referring to the make and ally knowledge sourcing modes, respectively. We tested our hypotheses on a sample of 6,208 USPTO patented technologies acquired by 350 biotechnology firms over the period 1980–2012. Results reveal that the radicalness of acquired technologies exhibits an inverted U-shaped effect on the extent to which acquiring firms exploit these technological solutions for innovating. This relationship is in turn negatively moderated by both the employment of star scientists and establishment of upstream alliances.



**Keywords:** technology acquisition, radical technologies, star scientists, upstream alliances, biotech industry.

## INTRODUCTION

In the current competitive scenario, firms are increasingly accelerating the pace of innovation in order to get higher returns and achieve technology leadership (Laursen et al., 2010; Leone and Reichstein, 2012). Nevertheless, due to the growing complexity of the industrial ecosystem, internal R&D departments are not anymore sufficient to timely innovate for generating a sustainable competitive advantage (Chesbrough, 2003). Accordingly, firms may speed up their innovation processes by accessing more and diversified sources of knowledge (Vanhaverbeke et al., 2002), hence integrating their in-house R&D activities with externally developed knowledge (Cassiman and Veugelers, 2006; Ceccagnoli et al., 2014). In particular, sourcing externally developed technologies has been emerging as a key strategy for innovating firms (Arora and Gambardella, 2010; Chesbrough, 2003; Natalicchio et al., 2014), especially in those sectors characterized by science-intensity and rapid technological change, since it allows firms to diminish the costs and risks of the innovation process, reduces the time to market, and makes possible to access latest technological developments (Tsai et al., 2011). Thereby, participating in markets for technologies, as arenas in which patented technical solutions are exchanged for a price (Conti et al., 2013), offers organizations the opportunity to acquire technologies, which may be then internally integrated to foster innovativeness (Arora and Gambardella, 2010; Ceccagnoli et al., 2014). This open innovation strategy is obtaining increasing significance, as highlighted by the Organisation for Economic Co-operation and Development (OECD), reporting that the value of intellectual property market transactions had been averagely growing by 10.1 percent per year from 2000 to 2011 (OECD, 2014). With this regard, the acquisition of external technologies, rather than their in-licensing, assumes a particular relevance (Somaya, 2012). Indeed, companies may be interested in acquiring patents that create significant market opportunities and, thus, establish future competitive advantages through their subsequent exploitation (Tsai and Wang, 2008). In fact, in-licensing patents may expose companies to imitation and infringement risks, since it may be difficult to define and enforce licensing contracts that assign the exclusive use of the technology (Hill, 1992), while protection is significantly relevant for those patents deemed as paramount for the acquiring firm's competitive strategies (Blind et al., 2006). In addition, licensing agreements may be exposed to the grant-back clause, which gives the licensor "the rights to all subsequent technology advances or improvements introduced by the licensee, based on the licensed technology" (Leone and Reichstein, 2012, p. 968), hence reducing the acquiring firm's opportunity to build a sustainable competitive advantage. Accordingly, firms may decide to acquire the property rights of these crucial patents, in order to reinforce their market position and get full control on their use (Mudambi and Tallman, 2010).

So far, academic studies have largely investigated the technology acquisition process, by mainly focusing on the characteristics of the supply and demand side (e.g., Arora and Gambardella, 2010; Ceccagnoli and Jiang, 2013), as well as on the industry's main features (e.g., Arora et al., 2001). Nevertheless, only scant attention has been deserved to the main characteristics of the acquired technologies, especially referring to how these characteristics may influence the acquiring firm's capability to further innovate (e.g., Wang et al., 2013). Thereby, in the attempt to shed new light on this issue, in the present study we focus upon a specific characteristic, as the radical nature of the acquired technology. Specifically, a radical technology is deemed as "something novel, that it has distinctive features missing in previously observed inventions." (Dahlin and Behrens, 2005, p. 724). Our choice is justified by the fact that radical technologies are particularly relevant to sustain innovativeness (Phene et al., 2006), since these generate new trajectories of development (Dosi, 1982) and consequently may promote further waves of innovation within companies (Ahuja and Lampert, 2001). Therefore, radical technologies constitute the basis to generate technological progress and ensure competitive advantage (Ahuja and Lampert, 2001; Dahlin and Behrens, 2005), despite may present high integration and exploitation costs, mainly due to the lack of ad hoc complementary assets and resources (Teece, 1986; Wu et al., 2014). However, acquiring technologies is just one of the strategies that firms may adopt to generate new knowledge to innovate.

Indeed, previous studies suggested that knowledge is the most strategically significant resource for organizations, accounting for the great part of the value added and supporting the sustainability of their competitive advantage (Grant, 1996). Thus, managers are charged with the paramount task of sustaining the competitive advantage by choosing how to organize the firm to efficiently source the knowledge and develop the capabilities needed to feed the internal innovation processes (Nickerson and Zenger, 2004). The extant literature identifies three prototypical modes according which firms can source knowledge, such as make, buy, and ally (Carayannopoulos and Auster, 2010; Mudambi and Tallman, 2010). Specifically, in the make mode firms develop knowledge through their internal resources; in the buy mode firms use markets and contracts to acquire knowledge; and in the ally mode firms establish formal agreements with allied partners to co-create knowledge (Mudambi and Tallman, 2010). However, these modes are not mutually exclusive, since firms may combine them by adopting concurrent knowledge sourcing (Jacobides and Billinger, 2006; Parmigiani and Mitchell, 2009). Actually, the high complexity and dynamism of the current scenario (Parmigiani, 2007) often lead firms to simultaneously make, buy, or ally to acquire novel resources (Jacobides and Billinger, 2006; Parmigiani and Mitchell, 2009). Therefore, as a consequence, firms may also choose to internally develop new technologies and/or co-create new technical solutions with external partners (Gulati, 1998). With this regard, the employment and retention of star scientists (e.g., Rothaermel and Hess, 2007; Zucker et al., 1998) and the establishment of upstream strategic alliances (e.g., Hess and Rothaermel, 2011; Lavie and Rosenkopf, 2006), respectively, have been proved to act as fundamental antecedents for innovation, by providing the firms with a variety of knowledge generation opportunities (Hess and Rothaermel, 2011). This is especially true in science-based industries, as biotechnology, where for 10–15 years star scientists represented the main repositories of discoveries and technological advancements (Zucker et al., 1998) and the race for innovation forces firms to cooperate at an increasing rate with other actors on a number of research activities for integrating external competencies and resources to innovate (Tzabbar et al., 2013). In particular, star scientists, identified as those individuals who have demonstrated superior levels of productivity and visibility within the scientific community (Hess and Rothaermel, 2011; Kehoe and Tzabbar, 2015; Lacetera et al., 2004), allow firms to cope with uncertainty, complexity, and rapid technological changes, by providing the access to key knowledge and hence sustaining technology shifts. Differently, upstream alliances are used by firms for the purpose of exploring new technological opportunities and generating new knowledge through R&D collaboration with other organizations (Koza and Lewin, 1998). Hence, upstream alliances are distinguished from downstream alliances, which are instead characterized by the merging of existing competencies related to exploitative activities, as manufacturing, marketing, and commercialization, to create synergies among partners (Koza and

Lewin, 1998; Rothaermel and Deeds, 2004). Specifically, establishing upstream alliances is a particularly relevant strategy in those sectors characterized by science-intensity and rapid development, since it may timely provide valuable and novel knowledge that otherwise would not be available to the innovating firms (Powell et al., 1996). In turn, these three strategies are interdependent and may reciprocally influence their processes and routines. Therefore, the presence of star scientists and the establishment of upstream alliances may influence the firms' capability to innovate by leveraging radical acquired technologies. Accordingly, this paper aims at analyzing the relationship between the radicalness of the acquired technologies and the extent to which acquiring firms exploit these technologies in order to stimulate their internal innovation processes. Furthermore, we also investigate the moderating effects exerted on the above relationship by both the presence of star scientists within the acquiring firms' internal R&D departments and their portfolio of upstream strategic alliances, hence offering a multilevel perspective of the innovation process. Indeed, innovation is a multilevel phenomenon, thus investigating the linkages among multiple levels of analysis, as individuals, firms, and alliances, may provide a richer and sharper perspective on its dynamics (Gupta et al., 2007).

Our analysis is conducted on a sample of 6,208 patented technologies assigned by the U.S. Patent and Trademark Office (USPTO) and acquired by 350 biotechnology firms over the period 1980–2012. Results reveal that the radicalness of acquired patents exerts an inverted U-shaped effect on the extent to which firms exploit these technologies for developing proprietary innovative solutions. In addition, this effect is negatively moderated by both the employment of star scientists and establishment of upstream alliances.

The remainder of the paper is structured as follows. In the next section, we review the theoretical background and develop the hypotheses. Afterwards, we present the research methodology and outline the results. Finally, the last section concludes the paper by discussing the results and main implications, as well as describing the limitations of the paper that may spur further research.

## THEORY AND HYPOTHESES

The high degree of competitiveness characterizing the current environment is leading firms to cope with increasing costs, time constraints, and innovation complexity (Vanhaverbeke et al., 2002). In this scenario, firms cannot longer rely solely on their internal R&D activities (Ceccagnoli et al., 2014; Chesbrough, 2003), but they tend more and more to acquire externally developed technologies for enhancing the effectiveness of their internal innovation processes (Arora and Gambardella, 2010; Ceccagnoli et al., 2014; Chesbrough, 2003; Conti et al., 2013) and renewing their knowledge base (Eisenhardt and Martin, 2000). In particular, the characteristics of the acquired technologies may sensitively impact on their use to sustain the acquiring firm's internal R&D activities. In fact, technological solutions may differ across a number of various dimensions, as radicalness, scientific content, and scope (e.g., Dahlin and Behrens, 2005; Fleming and Sorenson, 2004), which have been proven to influence how firms understand, assimilate, and exploit them (Wang et al., 2013). Specifically, according to the extant literature, one of the most relevant technology characteristic is represented by the radical nature (e.g., Rosenkopf and Nerkar, 2001), since radical technologies may generate competitive advantage for firms and have a significant impact on the industrial ecosystem and the competitive environment (Tushman and Anderson, 1986). Radical technologies rely upon novel knowledge bases (Hill and Rothaermel, 2003) and significantly differ from both prior and current technological solutions (Dahlin and Behrens, 2005). In the biotechnology sector, a clear example is represented by the so called "Oncomouse", engineered by Harvard University. The Oncomouse was the first genetically modified mouse, endowed with recombinant oncogenes, to be used in cancer research (Murray, 2010). The Oncomouse was also the first animal patented at the USPTO and it spurred a massive stream of further technological development; in fact, nowadays, this patent has received more than 600 citations by other related patented inventions. Radical technologies are thus characterized by novelty and uniqueness (Dahlin and Behrens, 2005) and contribute to create new trajectories of technological development (Dosi, 1982) that, in turn, generate a discontinuity with the past (Ahuja and Lampert, 2001; Phene et al., 2006; Trajtenberg, 1990) and may sustain firms in corporate reinvention, business growth, and new business development (Burgelman, 1983). Therefore, radical technologies may represent rare, valuable, and inimitable sources of competitive advantage (Barney, 1991), offering firms with the opportunity to maintain and enhance a position of technology leadership in specific markets. In other words, radical technologies serve as an antecedent for subsequent technological progress (Ahuja and Lampert, 2001), by opening up new possibilities coming along with the Schumpeterian process of creative destruction (Dahlin and Behrens, 2005).

However, we expect that building upon radical acquired technologies holds up to a certain threshold, since an excessive radicalness poses increasing challenges for the acquiring firms, which may encounter difficulties in adapting to the new changed technological paradigm and leveraging it to innovate (Tushman and Anderson, 1986). In particular, internally exploiting radical technologies requires different capabilities respect to the core competences retained by firms (Tushman and Anderson, 1986). Thereby, firms may lack the suitable competencies and resources to support the technological change derived from the acquisition and adoption of highly radical technologies. Indeed, firms' strategic decision to innovate by relying upon external technologies is influenced by their existing complementary assets (Teece, 1986), which may prevent firms from embracing the transition towards novel technological trajectories significantly breaking with their current set of resources (Wu et al., 2014). Additionally, previous scholarly research highlighted the necessity of developing absorptive capacity to increase firms' ability to innovate on the basis of externally acquired knowledge (Cohen and Levinthal, 1990; Zahra and George, 2002). In fact, absorptive capacity is a crucial capability for firms acquiring external technologies (Cohen and Levinthal, 1990), since it allows them to effectively evaluate and exploit these technical solutions (Laursen et al., 2010). In particular, the more is the acquired knowledge novel and different respect to the acquiring firm's knowledge base, as in the case of highly radical technology, the more absorption efforts and costs are needed to effectively assimilate and integrate the acquired technology (Phene et al., 2006). Thereby, firms may lack a sufficient degree of absorptive capacity for sustaining the integration of the acquired highly radical technologies within their internal innovation process. Hence, on the basis of the above reasoning, we expect that:

*H1: The radicalness of the acquired technology will exhibit an inverted U-shaped effect on the extent to which the acquiring firm exploits it for developing technological innovations.*

As previously discussed, knowledge is the most relevant resource for firms, being paramount for their competitiveness (Grant, 1996). Nevertheless, firms may often lack the knowledge resources needed to keep or establish competitive advantage, thus they are called to acquire them by choosing among three prototypical sourcing modes, such as make, buy, and ally (Mudambi and Tallman, 2010). Within this framework, the acquisition of external technologies belongs to the buy mode of sourcing knowledge (Cassiman and Veugelers, 2006). However, the choice among the sourcing modes depends on different factors, as the specific characteristics of the needed knowledge and the capabilities of the focal firm (see Carayannopoulos and Auster, 2010). Consequently, firms may concurrently adopt different strategies referring to the make, buy, and ally sourcing modes, in order to efficiently acquire the knowledge needed to sustain their innovation processes (Jacobides and Billinger, 2006; Parmigiani and Mitchell, 2009).  Therefore, firms' capability to innovate by exploiting acquired technologies may be affected by other interdependent strategic approaches. Indeed, organizations may concurrently nurture their innovativeness by leveraging their key employees, representing a strategy within the make sourcing mode, or collaborate with external partners in the new knowledge creation process, through the engagement in upstream strategic alliances, belonging to the ally mode (Hess and Rothaermel, 2011; Jacobides and Billinger, 2006; Parmigiani and Mitchell, 2009). Moreover, sourcing knowledge by concurrently make, buy, and ally is particularly valuable in science-intensive industries, as the case of biotechnology (Powell et al., 1996), where a number of companies, such as the case of Amgen and Genzyme, often tend to simultaneously enlarge their knowledge base by acquiring external technologies, exploiting the competences of their key employees, and allying with other organizations.

Specifically, to capture the strategic use of key employees to innovate, we focus upon the employment of star scientists (Furukawa and Goto, 2006; Hess and Rothaermel, 2011; Rothaermel and Hess, 2007; Zucker et al., 1998), who represent a pivotal asset to sustain the innovative productivity of a firm (Kehoe and Tzabbar, 2015). In fact, star scientists demonstrate high scientific productivity and create linkages with academia, accessing and assimilating the most novel knowledge in the field (Hess and Rothaermel, 2011; Lacetera et al., 2004). Moreover, star scientists also contribute to diffuse valuable knowledge within their organization, with the result of enhancing the innovative capabilities of other employees (Furukawa and Goto, 2006).

Furthermore, firms may source knowledge also by establishing upstream strategic alliances with other organizations, aiming at generating new knowledge and jointly developing innovative solutions with the partners (Gulati, 1998; Koza and Lewin, 1998; Lavie and Rosenkopf, 2006). In fact, upstream alliances make firms able to explore new knowledge opportunities with partners and gain access to external knowledge (Hess and Rothaermel, 2011) and acquire those competences needed to further enlarge their knowledge base (Rothaermel and Deeds, 2004).

In the following, we discuss the impact of both these strategies on the relationship between the radicalness of the acquired technology and the extent to which it is exploited by the acquiring firm to develop related technological solutions.

**Radical acquired technology and internal star scientists**

Star scientists are a critical resource for firms' innovative performance (Furukawa and Goto, 2006; Hess and Rothaermel, 2011; Lacetera et al., 2004; Rothaermel and Hess, 2007; Zucker *et al.*, 1998). Star scientists, in fact, are characterized by a notably high scholarly publication productivity and provide advantages in terms of exploring new knowledge domains, bridging the internal R&D department with external organizations, and offering an useful support in the detection of the most promising technological opportunities (Fleming and Sorenson, 2004; Furukawa and Goto, 2006; Rothaermel and Hess, 2007). Furthermore, star scientists also contribute to build the information and knowledge core of a firm (Rothaermel and Hess, 2007), since they own the expertize and reputation required to influence the direction of the firm's technological and scientific evolution (Higgins et al., 2011).

Nevertheless, previous studies revealed that often internal scientists may suffer from the not-invented here (NIH) syndrome, indicating a socio-psychological negative attitude of employees towards the use of knowledge acquired beyond firms' organizational boundaries (Arora and Gambardella, 2010; Katz and Allen, 1982). This attitude is expected to be more significant for star scientists, since their role is characterized by high "self-involvement and empowerment, which may further boost the tendency to undervalue knowledge coming from others." (de Araújo Burcharth et al., 2014, p. 158) Moreover, we believe that the incidence of the NIH syndrome is crucial for the acquisition and further exploitation of radical technologies, since these are generally grounded in a field requiring competences sensitively different from those owned by the firm's star scientists and in which they have little or few experience (Zucker et al., 2007). Indeed, this may increase the costs of exploiting radical technologies, such that the negative returns of radicalness occur earlier, since researchers' motivation to innovate upon these solutions tends to decrease when the research projects falls outside their competencies (Gambardella et al., 2015). In turn, this rejection is also dependent upon the fact that radical technological solutions often originate from individuals at the margin of a given scientific community, being this the source of different perspectives and heuristics in problem solving (Jeppesen and Lakhani, 2010). Therefore, internal star scientists may tend to resist or, at least, sabotage the use of these technologies due to their disruptive power for the social structure and prestige of scientists' community (Van Maanen and Barely, 1984). Indeed, companies retain star scientists in order to perform explorative activities, solve new problems, and generate novel knowledge and technological solutions (Jong and Slavova, 2014). Thereby, when star scientists are charged with the task of innovating on the basis of radical external technologies, they may suffer from a dismissing and misalignment respect to their role, identity, and work (Gittelman and Kogut, 2003), due to a loss of autonomy weakening their intrinsic motivations to sustain the firms' innovation development (Sauermann and Cohen, 2010). Indeed, investing time and effort in external technologies may reduce a star's opportunities to pursue her own research agenda and sustain her unique position as an innovation leader within the firm (Kehoe and Tzabbar, 2015). This further enhances the impact of the NIH syndrome, as well as the emergence of those cognitive costs making individuals reluctant to use novel external technology (Cassiman and Valentini, 2015). An exemplar case of the damages of the NIH syndrome emerges from the story of Merck & Co., a multinational pharmaceutical company. Indeed, between 70s and 80s, Merck was racing against the pharmaceutical company SmithKline to develop a treatment for peptic ulcers. At that time, Merck's star scientists in charge of new drug development were using traditional techniques falling within their expertize, instead of more recent and effective methodologies developed by others. As stated by Roy Vagelos, former CEO of Merck &

Co., “They were entirely convinced of their future success […]. Looking back, I can see in very precise dollar terms what that cost our company.” (Vagelos and Galambos, 2004, p. 130) This, in fact, was leading Merck & Co. to lose the competition against SmithKline. The turning point was reached when Vagelos forced the resistance of internal star scientists against the use of novel methods and technologies externally developed and acquired the famotidine compound from Yamanouchi Pharmaceutical. Eventually, this strategy promoted the development of Pepcid, which in turn became a blockbuster drug (Vagelos and Galambos, 2004).

Additionally, the NIH syndrome tends to negatively impact on two organizational capabilities that compose the absorptive capacity (Zahra and George, 2002), such as assimilation and transformation (Patterson and Ambrosini, 2015), hence making firms less capable to effectively leverage external technologies to innovate. Indeed, since higher degrees of absorptive capacity are required to manage radical rather than incremental technologies (Nooteboom et al., 2007), the NIH syndrome is a phenomenon that may be particularly detrimental for companies feeding their innovation processes with external radical technologies. Thereby, it is likely that the presence of star scientists may constitute a kind of core rigidity for firms acquiring radical technologies (Leonard-Barton, 1992), since they may lead to follow a path-dependent technological development (Tzabbar and Kehoe, 2014), hence reducing the openness toward the use of external solutions and the extent to which firms innovate upon them. Accordingly, we hypothesize that:

*H2: The presence of star scientists within the acquiring firm negatively moderates the relationship between the radicalness of the acquired technology and the extent to which the firm exploits it for developing proprietary technological innovations; in other words, the threshold level of technology radicalness at which negative returns set in will be lower as firms employ star scientists.*

**Radical acquired technology and upstream strategic alliances**

Upstream strategic alliances are established by firms in order to carry out common activities during the early stage research process in product and technology development (Rothaermel and Deeds, 2004). Thereby, upstream alliances are conducted to expose firms to external stimuli and knowledge opportunities, hence performing explorative research activities and acquiring those competences needed to further enlarge firms' knowledge base (Koza and Lewin, 1998; Lavie and Rosenkopf, 2006; Rothaermel and Deeds, 2004).

However, these explorative inter-firm relationships require the assignment of both managerial and financial resources and specific assets to provide satisfactory outcomes (Das and Teng, 2000), such as the case of dedicated alliance functions (Kale et al., 2002). This is the case of Merck Serono, the biopharmaceutical division of the Merck Group, which employed funds and manpower to create a corporate venture capital arm, MS Ventures, entirely dedicated both to invest and establish collaborations with companies that develop novel technologies relevant for Merck Serono's business. Conversely, also the acquisition of radical technologies may be considered as an explorative activity, since it allows firms to discover new technological domains (Wu et al., 2014), which in turn requires a certain degree of specific investments by firms in terms of resources and co-specialized complementary assets (Teece, 1986). For example, let us consider the case of ad hoc personnel dedicated to the scouting and diffusion of external technologies, as for the T-Labs of Deutsche Telekom, which charges a number of researchers and experts with the task of scouting for novel technological solutions and trends (Rohrbeck et al., 2015). Indeed, dedicated R&D units enhance the capability of firms to acquire and exploit external knowledge (Kale et al., 2002). In fact, dedicated R&D resources are needed to perform a knowledge brokering role, by coordinating tasks such as partner screening, negotiation, and relationship management, and establish routines to effectively find, assess, and acquire external knowledge. Additionally, they may also favor the understanding of firms' actual technological needs, thus increasing the usefulness of the sourced knowledge to support the internal innovation processes. Finally, dedicated R&D resources are required to integrate the external knowledge within the internal innovation processes and leverage complementarities with the extant knowledge basis to generate novel combinations of knowledge that may sustain the innovation development of the firm (Bianchi et al., 2015).

Therefore, firms engaged in both acquiring external technologies and establishing upstream strategic alliances tend to assign dedicated resources and assets to the management of both these strategies. Accordingly, it is expected that the consequence of the competition for resources and assets' allocation between these two explorative activities, as well as the different modes underlying their governance, results in a limited specialization, reduced scale and scope economies, which thus increase the costs of effectively leveraging acquired radical technologies to innovate (e.g., Lavie et al., 2010). In fact, resources and assets cannot be easily mobilized across explorative activities (Anand and Singh, 1997), since each task calls for specific management attention and knowledge integration capability (Herstad et al., 2015). Notably, an increasing demand for ad hoc resources may cause a number of coordination problems determined by conflicting organizational routines and goals (Lavie et al., 2011), in such a way that costs related to the leverage of the acquired technologies exceed earlier the benefits of their radicalness, hence limiting the effectiveness of this strategy. For instance, the biotechnology company Regulus Therapeutics appoints experienced employees as alliance manager, having the only responsibility to nurture the relationships with both firms and academic partners, in order to reduce the risk of alliance failures (Menzel and Xanthopoulos, 2012). Of course, these are resources that cannot easily be assigned with the task of generating innovation on the basis of external acquired technologies. Indeed, exploring through alliances may weaken firms' capability to undertake experimentation and risk taking in the use of external radical technologies (Stettner and Lavie, 2014), thus reducing the innovative benefits of technology acquisition.

Furthermore, the conflicting effect between these specific types of exploration strategies is expected to be particularly relevant, since both establishing upstream alliances and acquiring external radical technologies may be well conceived as (inbound) open innovation strategies, thus involving different inflows of knowledge from the external environment (Dahlander and Gann, 2010). The extant empirical research showed that increasing the number of external knowledge sources a firm relies on does not necessarily improve the firms' innovative performance, since it may drive them to perform over-search (Laursen and Salter, 2014). This may increase the cognitive, transaction, and organizational costs of managing multiple knowledge sources. In fact, the various coordination problems and process incongruities we discussed above are exacerbated, as firms have to manage not only internal resources, but also a number of interfaces with external actors with a consequent higher complexity and reduced efficiency (Laursen and Salter, 2014). Thereby, it results that different open innovation strategies may be substitutive rather than complementary, in relation with the innovative performance of the firms (Cassiman and Valentini, 2015). Accordingly, the management of upstream alliances and the acquisition and exploitation of externally developed technologies may incur into conflicting needs and organizational routines (Lavie et al., 2010), that eventually threaten the capability of the firm to effectively sustain its innovation processes. Thereby, we formulate our third hypothesis as follows:

*H3: The acquiring firm's upstream strategic alliances negatively moderate the relationship between the radicalness of the acquired technology and the extent to which the firm exploits it for developing technological innovations; in other words, the threshold level of technology radicalness at which negative returns set in will be lower as firms establish upstream strategic alliances.*

## METHODS

### Setting and Data

In order to test our hypotheses, we used the biotechnology industry as setting. The birth of the biotechnology industry is commonly set in 1974, when Stanley N. Cohen and Herbert W. Boyer filed an application to patent the recombinant DNA technique. Afterwards, in 1976, Boyer co-founded with Robert A. Swanson the Genentech company, which produced the first synthetic human insulin; this was the first genetically engineered human therapeutic approved by the U.S. Food and Drug Administration. Since then, the biotechnology industry sensitively grew, to the point that 19,151 biotechnology firms were active in 2013, with an overall R&D expenditure equals to 41,219 million of U.S. dollars (OECD, 2013).

We deemed the biotechnology industry as a suitable setting for the purposes of this study for several reasons. First, this industry is characterized by a strong appropriability regime that favors patenting (e.g., Zucker et al., 2002). Indeed, patents in biotechnology play a crucial role in protecting the results of the internal R&D activities (Phene et al., 2006; Zucker et al., 2002) and promoting the commercialization of knowledge (Zucker et al., 2002). Second, this industry shows high inclination to trade patent rights (Arora et al., 2001). Third, biotechnology patents generally have a narrower scope and require more time and expertize to be developed, compared to patents in other sectors (Check

Hayden, 2011); furthermore, they also must comply with tight standards and regulation, hence reducing the adoption of opportunistic behaviors, such as patent trolling and patent blocking (Chien, 2009). As a consequence, we are confident that in our setting firms acquire patents to nurture their innovation processes, rather than for other strategic reasons. Finally, the employment of star scientists (e.g., Zucker et al., 1998) and the establishment of upstream strategic alliances (e.g., Hess and Rothaermel, 2011) are two relevant innovation strategies for biotechnology firms, especially when they aim at developing new knowledge and competences.

We focused on the full list of biotechnology firms included in the 2012 BioScan database and, by querying the USPTO patents assignment database, we extracted all the transactions in the period 1980–2012 involving the assignment of a patent interest[1] to a firm included in the list. Additionally, we carefully checked the consistency of the names of the firms acquiring patents, since their identifiers may not be unique in the USPTO database; indeed, these can appear as full names, alternative spelling, or acronyms. We focused on the USPTO since the United States represent the most relevant market for the patenting and trading of biotechnologies (e.g., Arora et al., 2001), as well as to reduce institutional differences that characterize and regulate the transaction of patented solutions across countries (Ginarte and Park, 1997). Therefore, we created a database with 6,208 patents, serving as a basis to test our hypotheses, whose ownership rights were transferred to 350 different biotechnology firms. For each patent, a number of bibliographic information were gathered, such as backward and forward citations, technological classes, and assignor type. Furthermore, we identified star scientists and upstream strategic alliances by relying upon Scopus database and BioScan, respectively. Finally, firm-level data were obtained by employing multiple sources, including BioScan, Securities and Exchange Commission (SEC) filings for publicly traded firms, press releases, and corporate websites.

**Variables**

*Dependent Variable.* The extent to which firms exploit acquired technologies to develop proprietary innovations represents our dependent variable and it was measured by the number of forward citations received by the acquired patents from other acquiring firms' patented inventions (*SelfCit*) up to 2013

(Messeni Petruzzelli et al., 2015). Accordingly, we accounted for the use of the acquired patents as a basis to develop further proprietary technologies, in line with our research question (Cattani, 2005). In fact, the number of a patent's forward citations is a widely accepted indicator of its importance and related impact on the subsequent technological progress (e.g., Rosenkopf and Nerkar, 2001; Trajtenberg, 1990), by unveiling the successful transfer and employment of previous technologies (e.g., Jaffe et al., 1993). Patent citations may be added both by the assignees and examiners (Alcácer and Gittelman, 2006), who carefully check also for the suitability of the previous ones, thus assuring the inclusion of references to only prior useful technologies. Furthermore, it is noteworthy to mention that, in our case, both the citing and the cited patent belong to the same firm, hence increasing our confidence of the consciousness of the firm in including the given citation. Therefore, in this study, we focus on the self-citations of acquired patents to capture their relevance in enhancing and sustaining the acquiring firm's internal innovation process.

*Independent Variable.* The radicalness of the acquired patents (*Radicalness*) was evaluated by considering the lack of prior art, as measured by the number of backward patent citations (Ahuja and Lampert, 2001; Nerkar and Shane, 2007). Prior citations have been largely adopted by previous studies to capture the technological base upon which patents are built (e.g., Jaffe et al., 1993), hence making patents with few or zero backward citations as extremely novel and unique respect to the existing technological solutions. This measure does not suffer from retrospective and success bias and offers a certain consistency for within-industry analyses (Dahlin and Behrens, 2005). By adopting this operationalization, the independent variable results as inversely coded. Indeed, this means that a higher number of backward citations indicates a higher value of the independent variable, which characterizes a less radical technology. On the contrary, a more radical technology is characterized by a low level of backward citations, which corresponds to a lower value of the independent variable. We constructed both linear and quadratic specifications to test the hypotheses.

*Moderating Variables.* Two different moderating effects were tested, regarding the acquiring firms' internal star scientists and upstream strategic alliances. To account for the presence of star scientists (*StarScientists*) we relied on individuals' scholarly publication activity, consistently with previous studies suggesting that scientists that authored an outstanding number of academic publications are deemed as stars (e.g., Furukawa and Goto, 2006; Hess and Rothaermel, 2011; Zucker et al., 2002). Furthermore, publishing activity has been often used to capture the scientific expertise of corporate scientists, providing also evidence of their contribution to the academic realm (Jong and Slavova, 2014). Therefore, we extracted from the Scopus database a list of more than 200,000 scientists that have published at least one article on academic journals while they were affiliated to the biotechnology firms in our list (Hess and Rothaermel, 2011). Then, we define star scientists, in a specific year, as those individuals whose three-year moving average of annual publications was greater than five in that specific year (see also Lacetera et al., 2004; Rothaermel and Hess, 2007). We adopted this dynamic operationalization to establish a reliable correspondence between our variable and the real status of corporate scientists. In fact, with such operationalization, scientists are considered stars in the years characterized by a recent remarkable publication activity; neither earlier, when they still have to reach the star status, nor later, when their productivity, as well as their contribution, may drop. The *StarScientists* variable is highly skewed, thus we used its logarithmic transformation. Since we did not expect the inverted U-shaped relationship between *Radicalness* and *SelfCit* to change shape at any level of *StarScientists* (i.e., to become linear or U-shaped), we tested Hypothesis 2 considering only the interaction between *StarScientists* and the linear term of *Radicalness*, hence not including the interaction between *StarScientists* and the quadratic term of *Radicalness* (Aiken and West, 1991). Concerning the other moderating variable, the establishment of upstream strategic alliances (*Upstream*) was measured by the number of upstream alliances created by the acquiring firms up to the year of the patent assignment agreement (Lavie and Rosenkopf, 2006; Rothaermel and Deeds, 2006), as obtained from BioScan. Specifically, following Koza and Lewin (2000), we used the alliance announcements to recognize upstream relationships as those involving a knowledge generating R&D agreement. Accordingly, we obtained a list of 1,821 upstream alliances. As for the previous moderator, we tested Hypothesis 3 interacting *Upstream* only with the linear term of *Radicalness*.

*Control Variables.* The main effects of the moderating variables were also used as control variables. Additionally, a number of controls accounting for both patents' and firms' characteristics were also included in the model. Specifically, for each acquired patent, we controlled for the number of claims (*Claims*) (Lanjouw and Schankerman, 2004) and for the patent scope (*Scope*), measured as the number of different three-digit U.S. patent classes (e.g., Nerkar and Shane, 2007). In addition, to account for right censoring, namely the risk that older patents can receive more forward citations over a longer time interval (see Hall et al., 2001), we controlled for the age of the patent (*PatentAge*), evaluated as the number of years between the patent's issue year and 2013. Furthermore, following Narin et al. (1997), we measured patents' scientific references (*ScientificCit*) as the number of non-patent references, hence controlling for the linkages between science and technology. Finally, we also added dummy variables to account for the assignment of the patent to the three-digit patent classes pertaining to the biotechnology field (*BioClass*), as defined by USPTO[2] (see Rothaermel and Thursby, 2007), or to other patent classes (*OtherClasses*). To control for acquiring firm's characteristics, we included the effects of its size (*FirmSize*), calculated as the logarithm of the number of employees, and its age (*FirmAge*), measured as the number of years elapsed between the establishment of the acquiring firm and the patent assignment agreement. These variables were calculated by relying on data obtained from BioScan, company websites, and web archives. Additionally, we considered also the number of downstream strategic alliances (*Downstream*) established up to the year of the assignment agreement (Lavie and Rosenkopf, 2006), as measured by the number of collaborations involving joint marketing and service, production or supply agreements, and the presence of non-star scientists (*NonStarScientists*), measured per year by the logarithm of the difference between scientists and star scientists affiliated with the firm (Hess and Rothaermel, 2011). Moreover, we included a variable controlling for the acquiring firm's technological capital (*TechCapital*), evaluated as the number of patents for which the firm applied until the year of the patent assignment agreement (Nooteboom et al., 2007). We also controlled for the type of organization selling the patent (*Assignor*) with a dummy variable taking value one if the assignor is a firm, while zero if it is a university or a public research center. Furthermore, we controlled for the experience of the firm in acquiring patents (*PrevAcqXP*), measured as the number of patents acquired by the focal firm up to the year of the given patent assignment agreement (Leone and Reichstein, 2012). Finally, we included year dummies (*Year*) in the model for capturing temporal trends (*Year* = 2012 represents the omitted category).

**Analysis**

The acquired patent served as the unit of analysis. In our study, the dependent variable is a non-negative integer count variable, which is characterized by overdispersion, since mean is lower than the standard deviation. The negative binomial model allows for differences between mean and standard deviation, contrarily to the Poisson model, which instead assumes an equal value (Hilbe, 2007). Thereby, we applied the negative binomial model to test our hypotheses (Hilbe, 2007). We based the calculation of significance levels on Huber-White robust standard errors in order to account for heteroskedasticity issues. We tested five different models. Specifically, Model 1 is the baseline model, including only the control variables, while Models 2–4 are the partial models, including the linear and quadratic specifications of the independent variable and, separately, each of the moderating variables and the related interaction with the independent variable. Finally, Model 5 is the full model in which all variables are simultaneously considered. In the following, we focus our discussion on the full model, since tests for potential multicollinearity show that the maximum variance inflation factor (VIF) is equal to six, well below the commonly accepted threshold of 10 (Kleinbaum *et al.*, 1998), thus avoiding the risks of bias. Furthermore, the levels of significance of independent and moderating variables remain consistent across models, hence further reducing collinearity concerns.

**RESULTS**

Table I reports descriptive statistics and pairwise correlations with significance levels. All the correlations are below the 0.70 threshold (Cohen et al., 2003), except for the relationships between *Upstream* and *Downstream*, and between *NonStarScientists* and *TechCapital*. However, we ran the models both including and excluding *Downstream* and *TechCapital* and found consistency in our results, thus avoiding concerns about potential bias.

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INSERT TABLE I ABOUT HERE

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In Table II, we present the results of the negative binomial models. Model 1 shows that the number of patent claims ($\beta$ = 0.028, p<0.001) has a positive significant effect on the extent to which firms internally exploit the acquired technology, as well as the number of scientific references ($\beta$ = 0.002, p<0.01), the age of the patent ($\beta$ = 0.046, p<0.001), and having a firm as the assignor ($\beta$ = 0.786, p<0.001). Differently, the age of the firm ($\beta$ = -0.003, p<0.05) exerts a negative significant effect. In Model 2, we included the linear and quadratic terms of *Radicalness*; in Model 3, we added the interaction between *StarScientists* and the linear term of *Radicalness*, while we incorporated the interaction between *Upstream* and the linear term of *Radicalness* in Model 4. Finally, Model 5 is the full model, in which we included all the variables. As discussed in the previous section, we tested our hypotheses on Model 5.

Model 5 reveals that all the three hypotheses are supported. Specifically, Hypothesis 1 stated that the radicalness of the acquired patent has an inverted U-shaped effect on the extent to which the acquiring firm exploits it for developing further proprietary inventions. We found statistical support for this hypothesis. In fact, Model 5 shows that *Radicalness* is curvilinearly related (inverted-U) with *SelfCit* (*Radicalness*, $\beta$ = 0.024, p<0.001; $Radicalness^2$, $\beta$ = -0.0001, p<0.001). Moreover, in order to provide evidence for the inverted U-shaped relationship, we performed the three-step procedure by Lind and Mehlum (2010), as suggested by the recent literature (Haans et al., 2015). First, we found that the coefficient of $Radicalness^2$ is statistically significant and consistent with the hypothesized sign. Second, we verified that the slope of the relationship is significantly steep both at the lower bound (value equal to 0.236, p<0.001) and at the upper bound (value equal to -0.282, p<0.001) of *Radicalness* data range. Finally, we calculated the turning point of the relationship and its 95 percent confidence interval, based on Fieller's standard errors method, and found that the confidence interval is entirely located within the data range of our independent variable. Thus, we can ensure that the interpretation of the inversed U-shaped relationship is correct, hence confirming Hypothesis 1.

In Hypothesis 2, we predicted a negative moderating effect of star scientists on the relationship between the radicalness of the acquired patent (which is inversely coded) and the subsequent internal technological development, such that a shift in the turning point of the relationship is verified. Model 5 shows a statistically significant impact of the interaction term in the hypothesized direction ($\beta$ =

0.016, p<0.05), thus supporting the second hypothesis. To give further evidence, we performed the test suggested by Haans et al. (2015) to verify that a translation of the turning point indeed occurs, by calculating the derivative of the turning point equation with respect to the moderating variable. We verified that the shift of the turning point is significantly different from zero for meaningful values of *StarScientists* and the effect is in the hypothesized direction, additionally supporting Hypothesis 2. Finally, consistently with Hypothesis 3, also the establishment of upstream alliances has a significant negative moderating effect on the impact of the radicalness of the acquired patent (which is inversely coded) on our dependent variable ($\beta$ = 0.001, p<0.10), resulting in a translation of the turning point of the inverted U-shaped relationship. Additionally, also in this case we applied the test proposed by Haans et al. (2015) to show that the shift in the turning point is significant and in the hypothesized direction for relevant values of *Upstream*. Thereby, Hypothesis 3 is confirmed. Table II shows that the three hypotheses are supported also in partial models (Models 2–4). Furthermore, we found a significant improvement of the fit between Model 1 and Model 5.

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INSERT TABLE II ABOUT HERE
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**DISCUSSION AND CONCLUSIONS**

Acquiring technologies is a relevant and potentially effective strategy for innovating firms, since it may allow them to reduce both time and costs of the innovation development process (Arora and Gambardella, 2010; Ceccagnoli et al., 2014). In this paper, we investigated the impact of the radicalness of the acquired technologies on the extent to which the acquiring firms exploit them for developing technological innovations. Specifically, we found that the radicalness of the acquired patents has an inverted U-shaped relationship with their internal exploitation. In fact, the acquisition of radical technologies provides firms with the advantages of novelty (Dahlin and Behrens, 2005), that may in turn open the door to a wave of related innovations (Ahuja and Lampert, 2001). Nevertheless, firms may find difficulties in exploiting external technologies having a high degree of radicalness, due to the lack of appropriate competences and assets (Wu et al., 2014), adaptation mechanisms (Tushman and Anderson, 1986), and absorptive capacity (Cohen and Levinthal, 1990). Therefore, as acquired technologies become increasingly radical, after a certain threshold, their positive impact on acquiring firms' subsequent internal technological development diminishes.

Furthermore, knowledge is the most relevant resource for firms and favors the establishment and sustainability of competitive advantage (Grant, 1996). This resource may be procured through three prototypical sourcing modes, such as make, buy, and ally (Mudambi and Tallman, 2010), which often are concurrently adopted by firms (Jacobides and Billinger, 2006; Parmigiani and Mitchell, 2009). Therefore, developing innovations built on acquired technologies may be influenced by other interdependent innovation strategies. Indeed, along with the acquisition of patented technologies from other organizations, firms may sustain their internal innovation processes by adopting strategies such as developing technologies in-house by leveraging the capabilities of internal key employees and/or co-creating them by allying with partner organizations (Hess and Rothaermel, 2011; Jacobides and Billinger, 2006; Parmigiani and Mitchell, 2009). Thereby, we focus on the employment of star scientists and the engagement into upstream alliances to capture how the adoption of these different strategies influence the extent to which firms exploit acquired technologies. Specifically, the previous literature highlighted that employing star scientists has a general positive effect on firms' innovativeness (Fleming and Sorenson, 2004; Furukawa and Goto, 2006; Rothaermel and Hess, 2007; Zucker *et al.*, 1998). Nevertheless, our findings indicate that employing star scientists negatively moderates the relationship between the radicalness of acquired technologies and the extent to which the acquiring firm exploits them to innovate. Therefore, this finding suggests that while internal star scientists are paramount for building firms' core competences (Rothaermel and Hess, 2007), they may become a core rigidity (Leonard-Barton, 1992) when they are called to innovate by relying upon the exploitation of external technologies, especially radical ones, due to the so called NIH syndrome. Finally, our results suggest that establishing upstream alliances negatively moderates the impact of radical acquired technologies on the firms' capability to innovate upon them . Actually, both acquiring radical technologies and engaging in upstream alliances are explorative activities that require a significant amount of dedicated resources and complementary assets to be effectively managed (Dahlin and Behrens, 2005; Das and Teng, 2000; Tushman and Anderson, 1986).

Furthermore, firms that establish a greater number of upstream alliances may find particularly difficult to reallocate the required resources to capture the benefits of acquired radical technologies. Thereby, the competition for resources and assets allocation results in increasing the costs of using radical acquired technologies and reducing their exploitation to nurture the internal innovation process.

**Implications for Theory**

This paper provides several theoretical contributions. First, we contributed to the literature on technology strategy and, especially, on markets for technology (see Arora and Gambardella, 2010; Arora et al., 2001) by investigating the impact of the radicalness of acquired technology on its subsequent exploitation by the acquiring firm. Previous studies have in fact mainly discussed the features of the supply and demand side, as well as of the industry in which firms operate (e.g., Arora and Gambardella, 2010; Ceccagnoli and Jiang, 2013; Conti et al., 2013), neglecting however the nature of the acquired technology and how this impacts on its further adoption within the acquiring firm's innovation process. In addition, we investigated also the moderating impact of two different interdependent innovation strategies, such as employing star scientists and engaging in upstream strategic alliances. Second, we advanced the recently growing literature on open innovation (e.g., Cassiman and Valentini, 2015; Chesbrough, 2003), by investigating the joint effect of two distinct open strategies, as acquiring radical technologies and establishing upstream alliances, and revealing their substitutive effect on the subsequent exploitation of the acquired technologies. Third, we added to the current debate on the benefits and costs of employing star scientists within firms (e.g., Gittelman and Kogut, 2003; Zucker et al., 1998), by revealing how they become a constraint when firms are engaged in the acquisition and exploitation of external radical technologies (Tzabbar and Kehoe, 2014). This, in turn, offers new insights into the boundary conditions influencing the relevance of corporate star scientists (see Jong and Slavova, 2014), thus also opening the door to further investigations on the relationship between individual motivations and firm innovation (Sauermann and Cohen, 2010). Fourth, the outcomes of this study also provided further insights adding to the current academic debate on the balance between exploration and exploitation through domain separation (Lavie et al., 2010). Indeed, our results indicate that firms face difficulties in exploring both through markets for technologies, by acquiring radical technologies, and alliances, by establishing upstream agreements, hence confirming the merits of balancing exploration and exploitation across domains (Hess and Rothaermel, 2011; Lavie and Rosenkopf, 2006; Lavie et al., 2011; Stettner and Lavie, 2014). Finally, we analyzed the relationship between the radicalness of the acquired technology and its exploitation by the acquiring firm through the use of three different perspectives of analysis, as firms, individuals, and alliances, hence responding to a recent call for discussing innovation across multiple levels (Gupta et al., 2007).

**Implications for Practice**

This study also outlines three main managerial contributions. First, our findings caution firms' managers and executives in acquiring radical technologies to feed their internal innovation processes. Indeed, despite this strategy may present a number of advantages, relying upon external technological solutions presenting a high degree of radicalness may cause relevant absorption costs, which may in turn limit firms' capability to further exploit these solutions for enhancing their innovativeness. Second, our results show that employing star scientists within firms has a significant role in moderating the relationship between the radicalness of the acquired technology and the extent to which it is exploited to generate further innovations. In particular, this may reduce the firms' opportunities to innovate by relying upon external technologies, especially radical ones. Therefore, given the key role of star scientists for firms' innovativeness (e.g., Kehoe and Tzabbar, 2015), we encourage managers to adopt specific human resource practices, such as training activities and incentive systems, to reduce their NIH attitude and then fully profit from the acquisition of external technologies. For instance, Eli Lilly adopted some approaches to contrast the NIH, as assigning middle and senior managers the ownership of valuable technological solutions, both internally developed and externally sourced (Douglas et al., 2010). Accordingly, the company was trying to reshape the employees' attitude towards the use of external technical solutions. Finally, we noticed the drawbacks of resource scarcity when firms pursue simultaneously different explorative activities, as the case of acquiring radical technologies and establishing upstream strategic alliances. Thereby, if firms face resources limitations, managers should carefully select among the possible explorative activities the one (or those) on which investing their resources.

**Limitations and Further Research**

Of course this study presents a number of limitations that may however represent venues for further research. First, we considered the effect exerted by upstream strategic alliances, without investigating the nature of the alliance partner or its characteristics, as technological and geographic proximity, that may in turn influence processes and outcomes of the alliance (e.g., Saxton, 1997). Hence, these characteristics may be included in further analyses. Second, we focused on the extent to which radical acquired technologies are exploited by firms to create new value. Nevertheless, future studies may analyze how firms capture the value of radical technologies (Teece, 1986), by marketing them as new products or processes. Third, the influence exerted by industrial features, as market competitiveness, structure, and turbulence, may be accounted, hence providing a deeper investigation into the multi-level nature of the innovation phenomena (Gupta et al., 2007). Finally, our sample is based on biotechnology firms. While this is a relevant field to analyze the effects of patent acquisition (Arora and Gambardella, 2010), it may present specific industry dynamics and features. Therefore, in order to further generalize our findings, scholars may extend the analysis to other industrial sectors.

## NOTES

[1] Namely, the transfer of patent ownership interest (see Section 301 of the USPTO Manual of Patent Examining Procedure).

[2] The USPTO assigns the following patent classes to the biotechnology domain: 424 (drug, bio-affecting and body treating compositions), 435 (chemistry: molecular biology and microbiology), 436 (chemistry: analytical and immunological testing), 514 (drug, bioaffecting and body treating compositions [different sub-classes]), 530 (chemistry: natural resins or derivatives; peptides or proteins; lignins or reaction products thereof), 536 (organic compounds), 800 (multicellular living organisms and unmodified parts thereof and related processes), 930 (peptide or protein sequence), and PLT (plants).

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**TABLE I. Pairwise correlation matrix and descriptive statistics (*n* = 6,208)**

| **Variable** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. SelfCit | | | | | | | | | | | | | | | |
| 2. Radicalness | $0.10^{***}$ | | | | | | | | | | | | | | |
| 3. StarScientists | $0.07^{***}$ | $-0.05^{***}$ | | | | | | | | | | | | | |
| 4. Upstream | 0.01 | $0.04^{***}$ | $0.40^{***}$ | | | | | | | | | | | | |
| 5. NonStarScientists | $0.05^{***}$ | $-0.10^{***}$ | $0.60^{***}$ | $0.40^{***}$ | | | | | | | | | | | |
| 6. PatentAge | $0.05^{***}$ | $-0.26^{***}$ | $0.09^{***}$ | $-0.13^{***}$ | $0.23^{***}$ | | | | | | | | | | |
| 7. Downstream | $0.03^{**}$ | $0.08^{***}$ | $0.36^{***}$ | $0.78^{***}$ | $0.34^{***}$ | $-0.12^{***}$ | | | | | | | | | |
| 8. Claims | $0.11^{***}$ | $0.25^{***}$ | $-0.02^{\dagger}$ | $0.04^{***}$ | $-0.06^{***}$ | $-0.22^{***}$ | $0.04^{**}$ | | | | | | | | |
| 9. ScientificCit | 0.02 | $0.43^{***}$ | $-0.05^{***}$ | $0.08^{***}$ | $-0.18^{***}$ | $-0.29^{***}$ | $0.09^{***}$ | $0.21^{***}$ | | | | | | | |
| 10. Scope | $0.04^{***}$ | 0.00 | 0.00 | $0.04^{**}$ | $0.04^{**}$ | -0.01 | $0.05^{***}$ | $0.12^{***}$ | $0.03^{*}$ | | | | | | |
| 11. Assignor | $0.04^{***}$ | $0.07^{***}$ | $0.06^{***}$ | $0.05^{***}$ | $-0.06^{***}$ | $-0.16^{***}$ | $0.04^{**}$ | $0.03^{*}$ | $0.04^{**}$ | $-0.04^{**}$ | | | | | |
| 12. FirmAge | $-0.06^{***}$ | $-0.07^{***}$ | $0.20^{***}$ | $-0.07^{***}$ | $0.21^{***}$ | $0.13^{***}$ | $-0.07^{***}$ | $-0.19^{***}$ | $-0.19^{***}$ | $-0.12^{***}$ | $0.15^{***}$ | | | | |
| 13. FirmSize | $0.03^{*}$ | $-0.06^{***}$ | $0.51^{***}$ | $0.42^{***}$ | $0.65^{***}$ | $0.31^{***}$ | $0.43^{***}$ | $-0.07^{***}$ | $-0.15^{***}$ | 0.00 | $-0.07^{***}$ | $0.16^{***}$ | | | |
| 14. PrevAcqXP | 0.00 | 0.02 | $0.15^{***}$ | $0.015^{***}$ | $0.22^{***}$ | $0.06^{***}$ | $0.17^{***}$ | 0.01 | $-0.04^{**}$ | -0.01 | $0.05^{***}$ | 0.00 | $0.17^{***}$ | | |
| 15. TechCapital | $0.03^{**}$ | $-0.02^{\dagger}$ | $0.47^{***}$ | $0.33^{***}$ | $0.73^{***}$ | $0.16^{***}$ | $0.32^{***}$ | $-0.05^{***}$ | $-0.11^{***}$ | 0.00 | $0.10^{***}$ | $0.33^{***}$ | $0.52^{***}$ | $0.23^{***}$ | |
| *Mean* | 1.81 | 14.12 | 0.12 | 1.54 | 1.25 | 13.68 | 3.88 | 17.12 | 20.33 | 1.92 | 0.94 | 44.26 | 6.16 | 18.49 | 1.84 |
| *Standard deviation* | 7.11 | 29.80 | 0.28 | 3.18 | 0.95 | 7.63 | 6.92 | 15.60 | 47.98 | 1.01 | 0.24 | 49.02 | 2.75 | 59.45 | 0.85 |
| *Min* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| *Max* | 150 | 410 | 1.67 | 23 | 3.47 | 44 | 39 | 99 | 761 | 8 | 1 | 192 | 11.84 | 638 | 4.35 |

$^{\dagger}p < .10$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

**TABLE II. Negative binomial regression models.**

| Dependent Variable: SelfCit | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| Radicalness | | 0.026*** (0.002) | 0.024*** (0.002) | 0.025*** (0.002) | 0.024*** (0.002) |
| Radicalness$^2$ | | -0.0001*** (0.000) | -0.0001*** (0.000) | -0.0001*** (0.000) | -0.0001*** (0.000) |
| Radicalness x StarScientists | | | 0.020* (0.008) | | 0.016* (0.008) |
| Radicalness x Upstream | | | | 0.001* (0.000) | 0.001† (0.000) |
| StarScientists | 0.203 (0.179) | 0.234 (0.179) | -0.071 (0.234) | 0.222 (0.181) | -0.021 (0.233) |
| Upstream | -0.036† (0.021) | -0.012 (0.021) | -0.007 (0.022) | -0.021 (0.023) | -0.015 (0.023) |
| NonStarScientists | -0.012 (0.080) | 0.059 (0.077) | 0.079 (0.079) | 0.057 (0.078) | 0.072 (0.079) |
| PatentAge | 0.046*** (0.008) | 0.065*** (0.008) | 0.066*** (0.008) | 0.064*** (0.008) | 0.065*** (0.008) |
| Downstream | 0.021† (0.012) | 0.004 (0.011) | 0.003 (0.011) | 0.001 (0.011) | 0.001 (0.011) |
| Claims | 0.028*** (0.002) | 0.023*** (0.002) | 0.023*** (0.002) | 0.023*** (0.002) | 0.023*** (0.002) |
| ScientificCit | 0.002** (0.001) | -0.002* (0.001) | -0.002* (0.001) | -0.002* (0.001) | -0.002* (0.001) |
| Scope | 0.021 (0.045) | 0.040 (0.046) | 0.039 (0.046) | 0.043 (0.046) | 0.041 (0.046) |
| Assignor | 0.786*** (0.199) | 0.626*** (0.194) | 0.642*** (0.197) | 0.629*** (0.195) | 0.642*** (0.197) |
| FirmAge | -0.003* (0.001) | -0.001 (0.001) | -0.001 (0.001) | -0.001 (0.001) | -0.001 (0.001) |
| FirmSize | 0.009 (0.023) | -0.020 (0.022) | -0.023 (0.022) | -0.013 (0.022) | -0.017 (0.022) |
| PrevAcqXP | -0.001 (0.001) | -0.001 (0.001) | -0.002† (0.001) | -0.002† (0.001) | -0.002† (0.001) |
| TechCapital | 0.040 (0.085) | -0.042 (0.085) | -0.057 (0.086) | -0.041 (0.088) | -0.052 (0.088) |
| Patent Class dummies | Included | Included | Included | Included | Included |
| Year dummies | Included | Included | Included | Included | Included |
| Constant term | -2.885*** (0.292) | -2.879*** (0.285) | -2.852*** (0.286) | -2.900*** (0.285) | -2.874*** (0.286) |
| Likelihood ratio test | -7836.00*** | -7770.38*** | -7767.44*** | -7768.12*** | -7766.18*** |
| Improvement in fit over the base model | | 65.62 | 68.56 | 67.88 | 68.82 |
| Number of observations | 6208 | 6208 | 6208 | 6208 | 6208 |

Huber-White robust standard errors in parentheses. †p <.10; *p <.05; **p < .01; ***p <.001.