Spin-offs' linkages to their parent universities over time: The performance implications of equity, geographical proximity, and technological ties

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Running head: *Parent university linkages in academic spin-offs over time*

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ABSTRACT

This study explores the impact of parent university linkages on the market performance of university spin-off firms (USOs). We argue that spin-offs' performance is not only affected by competencies inherited from their parent universities at start-up but also by linkages maintained over time. We longitudinally study 551 USOs established between 2000 and 2008 in Italy. Using estimations that account for attrition and endogeneity, we find that equity-based university linkages increase spin-offs' market performance and that geographical proximity strengthens this effect. Furthermore, increasing technological ties between USOs' entrepreneurial teams and their parent universities has a detrimental effect on performance, especially for companies that remain geographically proximate to their parent universities. The results have implications for theory and practice related to strategic linkages, alliances, and academic entrepreneurship.

INTRODUCTION

Entrepreneurial spin-offs originating from established firms and universities form the majority of new entrants among many types of firms, including, for instance, biotechnology firms (Bonardo et al., 2011; Stuart and Ding, 2006) and companies operating in the US automobile and laser industries (Klepper, 2007). Spin-offs often outperform other types of new ventures in terms of employment rates and company valuation (Andersson and Klepper, 2013; Chatterji, 2009; Dahl and Reichstein, 2007; Fackler et al., 2016; Franco and Filson, 2006). Hence, understanding the drivers of spin-offs' performance is a key issue for strategic management, innovation management, and entrepreneurship research and practice (Klepper, 2009).

Universities worldwide are the source of a considerable number of spin-offs that are set up to commercialize the results of academic research (Fini and Grimaldi, 2017; Shane, 2004). We study parent-child linkages of university spin-offs (USOs), defined as new ventures based on university-developed knowledge, either founded by academics or with an equity participation of the parent university, or both (Fini et al., 2011). USOs are highly knowledge-intensive ventures, having higher innovation performance than comparable firms (Stephan, 2014). Despite high survival rates and some success stories, though, many USOs struggle with low market performance (Harrison and Leitch, 2010; Wennberg et al., 2011). The creation of high-performing spin-offs is a key strategic priority for many universities and policymakers (Pitsakis, 2015), and has been extensively researched (Grimaldi et al., 2011). However, there is scant evidence on how universities can manage their spin-offs to help them achieve high performance.

In general, a spin-off's performance (e.g., lower hazard rates, higher employment, higher company valuation) is affected by the size, performance, and survival of its parent (Andersson and Klepper, 2013; Dick et al., 2013; Eriksson and Moritz Kuhn, 2006; Fackler et

al., 2016; Klepper, 2009), as well as by the degree of knowledge relatedness between the parent and the spin-off (Sapienza et al., 2004). Spin-offs' founders learn valuable skills and get access to networks when working at their parent organizations (Chatterji, 2009; Shane and Stuart, 2002), and parents' corporate cultures endow these founders with different capabilities and pre-entry experience (Cordes et al., 2014). Hence, scholars have argued that spin-offs' superior performance is due to the knowledge and resources they inherit from their parents at founding (Agarwal et al., 2004; Klepper and Sleeper, 2005). In the case of USOs, they draw on informational advantages related to the academic research and knowledge of their parent universities (Agarwal and Shah, 2014), which may be more scientifically oriented and less business oriented compared to those of spin-offs originating from corporations (Zahra et al., 2007).

While the performance implications of parent institutions' initial imprints are well documented, the role of linkages between parents and their spin-offs over time remain relatively unexplored (Ferretti et al. 2019; Semadeni and Cannella, 2011). Hence, it is not clear whether the performance premium for spin-offs is only related to the competencies they inherit at start-up (Clarysse et al., 2011; Franco and Filson, 2006; Shane and Stuart, 2002) or whether this effect is also related to linkages with their parent organizations over time (Knockaert et al., 2011; Zucker et al., 2002). This research gap warrants further investigation because theory emphasizes that a firm's ability to identify and assimilate external resources and knowledge may be more important for performance and growth than the firm's initial stock of resources and knowledge (Cohen and Levinthal, 1990; Nason and Wiklund, 2015). Moreover, access to competencies and resources is particularly important for new and small ventures, which typically possess limited internal resources but may be able to compensate for such shortcomings by relying on alliances and linkages with external actors (Arikan and McGahan, 2010; Moghaddam et al., 2016; Mohr et al., 2013). USOs, in particular, face

challenges in developing the competencies needed to commercialize novel technologies with uncertain market potential, and the university environment may contribute to these challenges (Rasmussen et al., 2014).

We theorize about the performance implications of linkages between USOs and their parent universities over time. Such linkages appear attractive because for a USO, its parent institution represents a familiar network partner with high potential for knowledge and resource transfer (Bierly et al., 2009; Gulati et al., 2009). Different types of spin-offs vary in how intensely they share resources and transfer knowledge with their parent organizations (Parhankangas and Arenius, 2003). For USOs, their parent universities typically possess strong scientific knowledge but more limited commercial and business knowledge (Colombo and Piva, 2012). Hence, parent universities' potential contributions to spin-offs' performance would mostly relate to the transfer of scientific competencies rather than business and market competencies (Rasmussen et al., 2011). Therefore, we address the following research question: *How do USOs' linkages with their parent universities influence USOs' market performance over time?*

We hypothesize that USOs that maintain linkages with their parent universities—represented by equity shares, geographical proximity, and technological ties—will experience benefits and drawbacks from these linkages that influence their market performance. To test this, we use an unbalanced, compact, and dynamic panel of 551 USOs spun off from the population of Italian universities between 2000 and 2008. To account for potential endogeneity of the main predictor (i.e., a parent university's equity ownership in a USO), we run a hierarchical set of models using system generalized method of moments (GMM) estimators (Arellano and Bond, 1991), including instrumental variables. We corroborate the findings through interviews with USOs' founders.

Our results show that the higher a university's equity ownership in a USO, the better the USO's market performance. This effect gets stronger for higher geographical proximity between the parent university and the USO. These results suggest that the parent's formal involvement in the spin-off, paired with access to physical resources from the university, is conducive to better market performance.

On the contrary, we find a negative effect of technological ties between a USO's entrepreneurial team and its parent university on market performance. Further analysis suggests that this effect gets more pronounced for companies that are geographically proximate to their parent universities. The results seem to suggest that some USOs may resemble "extended scientific labs" that lack the business focus needed to perform as commercial ventures.

Our contribution through this study is threefold. First, we add to the strategic management literature by showing how parent-child linkages improve entrepreneurial spin-offs' performance (Semadeni and Cannella, 2011). Specifically, we complement evolutionary perspectives on spin-offs and industry evolution that emphasize the role of inherited knowledge from parent organizations (Ferriani et al. 2012; Franco and Filson, 2006; Klepper and Sleeper, 2005; Nelson and Winter, 1982; Phillips, 2002) by shedding light on the role of access to resources and knowledge from parents over time. Our study indicates that USOs can increase their performance by strategically managing the composition of their university linkages, gaining access to resources from their parent universities over time.

Second, we extend research on alliances in entrepreneurial firms by examining the performance implications of equity-based partnerships (Gulati et al., 2009; Haeussler et al., 2012; Mohr et al., 2013) and other forms of linkages with universities. Specifically, we show that formal equity ownership facilitates spin-offs' performance, whereas technological ties

inhibit it. Geographical distance does not have a direct effect on performance, but it works as a moderator in the relationship between parent universities' ownership on performance.

Third, this study extends the academic entrepreneurship literature, which has extensively examined how universities can increase the quantity of spin-offs and, to some degree, create beneficiary start-up conditions (Epure et al., 2016; Miozzo and DiVito, 2016). By studying universities' role in the post spin-off performance of USOs, we provide additional implications for how the quality of these spin-offs can be further improved (Fini et al., 2017). Further, by considering multiple linkages over time, we provide a more nuanced account of the parent-child relationship in this context.

THEORETICAL BACKGROUND

USOs' parent linkages

Entrepreneurial spin-offs from universities face many obstacles in their efforts to commercialize new knowledge and technology (Vohora et al., 2004). As with any new venture, USOs' resource base is limited and their future success depends on their ability to accumulate knowledge and resources and deploy these in productive ways (Clough et al., 2018; Rasmussen et al., 2011). Research alliances with partner organizations are important assets for entrepreneurial firms in general (Li, 2013) and USOs in particular (Walter et al., 2006). However, entering collaborations with other organizations is resource demanding, challenging, and risky, especially for entrepreneurial ventures (Alvarez and Barney, 2001).

Spin-offs often find it beneficial to link with their parent organizations because the higher knowledge similarity and capability relatedness with their parent institutions can ease spin-offs' limited access to resources, increase their speed of learning, and decrease their resistance to change (Parhankangas and Arenius, 2003). Moreover, taking advantage of prior experience with the same partner is likely to increase value compared to forming

collaborations with less familiar partners (Gulati et al., 2009; Steinmo and Rasmussen, 2018). Hence, spin-offs' linkages with their parent organizations provide opportunities for resource and knowledge sharing, which in turn help spin-offs overcome some of the liabilities of newness and smallness (Baum et al., 2000; Stinchcombe, 1965).

For USOs, parent linkages are both attractive and attainable. First, USOs draw on unique technological knowledge from their parent universities (Agarwal and Shah, 2014), which typically entails commercializing early-stage technologies that need further development (Jensen and Thursby, 2001). The core knowledge and capabilities of universities are related to research, scientific discovery and exploration, and education (Bercovitz and Feldman, 2007; Bruneel et al., 2010). This type of knowledge is highly complex and often contains a significant tacit element (Zucker et al., 2002), which makes it particularly difficult to transfer across organizations. In this regard, the literature on organizational knowledge transfer suggests that strong ties and trust can be strong drivers for sustaining knowledge transfer (Van Wijk et al., 2008). Hence, parent university linkages may provide access to unique technological knowledge that is not easily available from other sources and serves as an important basis for advancing technological innovations (Bierly et al., 2009; Santoro and Chakrabarti, 2002). For example, young biotechnology firms seem to capitalize on strong "upstream" alliances with academic institutions to provide value to "downstream" partners (Stuart et al., 2007).

Second, universities are generally supportive of their spin-offs. In contrast to the corporate context, where many spin-offs suffer from parent hostility (Walter et al., 2014), USOs are not potential competitors to their parents but are rather seen as desired outcomes that add value to their universities (Pitsakis et al., 2015). Universities often offer significant assistance to USOs at low or no cost, such as technical knowhow, office space, industry networks, and access to finance (Kochenkova et al., 2016; Rasmussen and Borch, 2010).

Because USOs seem to benefit from strong parent linkages (Bonardo et al., 2011; Moray and Clarysse, 2005), it is likely that a combination of linkages would be better than one specific type. Prior research has described a broad variety of types and intensities of linkages between universities and their spin-off firms (Autio, 1997; Fernández-Alles et al., 2015; Rappert et al., 1999). Czarnitzki et al. (2014) found that university linkages, measured as a range of different connections, have a positive effect on USOs' employment growth. However, we know little about the nature of USOs' parent linkages and the combined effect of these linkages on USOs' performance over multiple time periods. Hence, to obtain a comprehensive understanding of the performance effects of USOs' parent linkages, we need to simultaneously consider formal and informal linkages and the interactions among them (Soda and Zaheer, 2012). In line with Sampson (2007), we theorize that the types of linkages between USOs and their parent universities influence the benefits USOs derive from these linkages and hence affect their performance. By looking at equity ownership, geographical proximity, and technological ties, this study aims to uncover the role of different types of linkages as well as the interplay between them over time.

Parent universities' equity ownership in USOs

The most common arrangements to formalize the relationship between a USO and its parent university are a licensing agreement, an equity stake, or a combination of both. Licensing and taking equity appear to be complementary activities (Powers and McDougall, 2005), and a high share of universities' licensing deals with USOs also contain an equity arrangement (Feldman et al., 2002; Jensen and Thursby, 2001; Savva and Taneri, 2015). However, of these options, taking an equity stake has become increasingly widespread. By 2000, 70% of a sample of US research universities had at least one equity deal with a spin-off firm (Feldman

et al., 2002). In Europe, most countries have adopted a university ownership model, making equity in USOs more common (Geuna and Rossi, 2011).

To study the relationship between USOs and their parent universities, we thus focus on equity ownership by parent universities over time. Equity is generally highlighted as a relatively strong linkage between partners that facilitates resource and knowledge transfer by reducing transaction costs and improving organizational relationships (Gulati, 1995; Sampson, 2007). Also, among new ventures more generally, equity-based alliances are associated with higher value creation (Li, 2013). In the context of our study, equity constitutes a strong formal linkage between USOs' and their parent universities, involving an ongoing relationship and some control from the parent institutions. Moreover, universities seem to benefit more from equity stakes than licensing fees in terms of USO formation and income (Bray and Lee, 2000; Di Gregorio and Shane, 2003; Lockett et al., 2003).

A parent university's ownership in a USO signals a very strong linkage for several reasons. Universities can use equity as payment for the use of university-invented intellectual property and as an alternative form of income generation to licensing (Bray and Lee, 2000; Feldman et al., 2002). Holding equity ownership thus generally aligns the interests of both parent universities and their respective firms toward commercializing their technologies and enables universities to lay claim to USOs' future income (Feldman et al., 2002). In addition, equity-based linkages between universities and USOs are more hierarchical than other modes of organizing and are therefore more likely to facilitate resource transfer and knowledge sharing (Grant, 1996). Given the specific and often tacit nature of academic knowledge, ownership linkages between USOs and their parent universities can reduce information asymmetries and increase trust between the two parties. In doing so, ownership linkages improve collaboration conditions between parent universities and USOs and help individuals from both universities and USOs accept knowledge transfer, which in turn creates positive

endowments for USOs in terms of available research and technology. According to previous literature, even if universities tend to limit their investments in equity and follow restrictive policies in this regard (e.g., Muscio et al., 2016; Salvador, 2009), even small equity ties are seen as a significant tie for the development of USOs (e.g., Bray and Lee, 2000; Callan, 2001).

In conclusion, equity ownership legitimizes universities' provision of resources to USOs, such as access to infrastructure (e.g., labs and equipment) (Lubik et al., 2013), research expertise by students and faculty, and networks of industry partners and investors (Rasmussen and Borch, 2010). It also increases USOs' legitimacy within their parent organizations (Fini and Toschi, 2016) and with external resource providers (Fisher et al., 2016). We thus hypothesize the following:

Hypothesis 1: Parent universities' equity ownership in USOs is positively related to USOs' market performance over time

Geographical proximity between parent universities and USOs

USOs' access to resources and knowledge from their parent universities depends on a broad set of linkages and interactions that may not be available through formal linkages, such as equity. For instance, evidence suggests that USOs tend to locate close to their parent universities (Heblich and Slavtchev, 2014). Being physically close facilitates interpersonal interactions whereby knowledge and resources are exchanged (Inkpen and Tsang, 2005). As a result, geographical proximity enables information exchange, impacts knowledge, reduces uncertainty, enhances coordination, and is a major determinant of innovation (Boschma, 2005; Jaffe et al., 1993; Petruzzelli, 2011). Indeed, collaborations between geographically close organizations result in better innovative performance than those between more distant organizations (Jaffe et al., 1993; Phene and Tallman, 2002). In particular, spin-offs tend to

locate close to their parents when they are pursuing more advanced technologies or novel markets (Berchicci et al., 2011), indicating that they benefit from the specialized knowledge of their parents.

Similar findings apply to the geographical proximity between universities and companies. Knowledge flows from public science-based universities to firms decline with geographical distance (Audretsch and Feldman, 1996; Bonaccorsi et al., 2014), so firms can achieve better research and innovation performance by locating near their parent universities (e.g., Arundel and Geuna, 2004; Calderini and Scellato, 2005; Siegel et al., 2003). USOs tend to locate in the vicinity of their parent universities, particularly if they use the infrastructure or have research contracts with these universities (Egeln et al., 2004). Doing so may help USOs maintain both formal and informal relationships with prior colleagues and university actors, which can contribute to USOs' resource acquisition and competency development (Heblich and Slavtchev, 2014; Rasmussen et al., 2014). Therefore, we expect that USOs located in the vicinity of their parent universities benefit from the linkages facilitated by this location.

Hypothesis 2: USOs' geographical proximity to their parent universities is positively related to USOs' market performance over time.

Technological ties between parent universities and USOs

USOs typically develop new technologies and invest significant resources in R&D activity, making their respective parent universities potentially important partners. The contact maintained between a USO's entrepreneur(s) and its parent university may be an important individual-level linkage that facilitates relevant knowledge and resource transfer (Heblich and Slavtchev, 2014; Inkpen and Tsang, 2005). The literature on university-industry collaborations underlines the importance for firms to develop technological relationships with universities by,

for example, engaging university scientists and undertaking co-patenting activities (Jensen and Thursby, 2001; Petruzzelli, 2011; Shane, 2004).

One specific way USOs and parent universities can retain linkages is through the academic entrepreneurs themselves. Academic entrepreneurs can be involved in USOs and, at the same time, file patents through universities' technology transfer offices. This arrangement allows USOs to maintain close linkages with their parent universities and have access to these universities' social capital and scientific networks (Murray, 2004). Such personal and technological linkages are important because much of the knowledge available at universities is not codified but remains latent (Agrawal, 2006) and is potentially characterized by high uncertainty, information asymmetries, transaction costs, and appropriability hazards (Veugelers and Cassiman, 2005). The importance of developing personal linkages by engaging inventors for successful knowledge transfer has been shown in the context of commercializing university knowledge (Agrawal, 2006). Hence, USOs are likely to benefit if their academic entrepreneurs maintain involvement in the research activities at their parent universities. Therefore, we hypothesize the following:

Hypothesis 3: USOs' technological ties to their parent universities are positively related to USOs' market performance over time.

The combined effect of equity ownership and other linkages

Given USOs' liabilities and their need for a diverse set of resources and competencies to grow (Vohora et al., 2004), the impact of USOs' linkages with their parent universities over time may depend on the combined effects of these linkages. In line with Zahra et al. (2007), we argue that the impact of parent universities' equity ownership on USOs' performance is likely to be moderated by other linkages USOs maintain with their *almae matres*. Equity ownership constitutes a formal relationship between a USO and its parent university but

provides no guarantee that beneficial resource and knowledge transfer will take place. Formal linkages may need to be reinforced by informal linkages to generate positive performance effects (Soda and Zaheer 2012).

Above, we discussed how the geographical proximity between a university and its USO increases the potential for scientific knowledge appropriation and creation (Heblich and Slavtchev, 2014; Treibich et al., 2013). For instance, co-location makes it easier for USOs to access university equipment and laboratories and to maintain networks with scientists. However, such benefits may be limited unless universities formally approve this resource exchange, such as in the case of equity ownership. Universities may only provide support and infrastructure to spin-offs that are formally approved through equity ownership (Munari et al., 2018). Department heads, faculty members, and technical support personnel may find more legitimate ways to spend university resources on USOs when their universities provide formal approval for doing so (Rasmussen et al., 2014). Moreover, equity ownership provides universities an economic incentive to help their USOs succeed as they can eventually cash in their equity. Thus, we hypothesize that the relationship between parent universities' ownership and USOs' market performance is moderated by geographical proximity, as follows:

Hypothesis 4a: Closer geographical proximity between USOs and their parent universities strengthens the positive effect of parent universities' equity ownership on USOs' market performance over time.

Furthermore, as discussed above, another linkage that may strengthen the effect of equity is the technological ties between parent universities and its USO. Greater partnership knowledge is generally seen as a positive outcome of equity-based linkages (Sampson, 2005). For USOs, parent universities may be particularly important providers of technical expertise

(Colombo and Piva, 2012). Hence, formal equity linkages would be more beneficial if they are combined with other linkages that provide specific technological expertise that can help USOs refine their business opportunities (Rasmussen et al., 2011). USOs often depend on close engagement with their parent universities to remain up to date on research and therefore tend to maintain strong ties with their parent institutions (Johansson et al., 2005). In many cases, USOs interact with their parent universities to develop joint knowledge (Treibich et al., 2013). This is the case when USOs' academic entrepreneurs maintain active involvement in the research activities at their parent universities. We expect such personal technological linkages to strengthen the effect of formal ownership linkages. Thus, we hypothesize that the relationship between parent universities' ownership and USOs' market performance is moderated by academic entrepreneurs' technological ties, as follows:

> *Hypothesis 4b: Stronger technological ties between USOs and their parent universities strengthen the positive effect of parent universities' equity ownership on USOs' market performance over time.*

RESEARCH DESIGN

Sample and data collection

To build our sample, we use the population of Italian USOs established between 2000 and 2008, as reported by the technology transfer offices (TTOs) of the 64 Italian STEM universities (n = 578). We selected this timeframe because the first national-level Italian regulation related to commercializing research results through USOs was released in 1999 (Law n. 297/1999 and Ministerial Decree n. 593/2000), so the spin-offs founded after that date can be considered homogeneous in their origins. We chose 2008 as the final year because the global economic crisis began in 2009. As for secondary data, we rely on a rich multilevel (i.e., individuals, organizations, and regions) longitudinal dataset. Because data

related to the dependent variable (*Market Performance*) were available for 551 of the 578 companies, our final sample comprises 551 USOs.

Measurement

We model spin-offs' performance, using time variant variables measured over the 2000–2012 period. The dependent variable—*market performance*—is measured as the natural logarithm of a USO's annual sales revenues in thousand euros (source: business-level data collected by the AIDA—Bureau Van Dijk database; https://aida.bvdep.com). The independent variable—*parent ownership*—is measured as the amount of equity held by a parent university in thousand euros per year since the establishment of its respective USO (source: business registers held by the Italian Companies' House; https://telemaco.infocamere.it).

To operationalize geographical linkages, we measure *geographical proximity*, calculated as the inverse of the straight-line distance in kilometers between a parent university's and its USO's headquarters (source: manual web search). We carefully checked whether USOs are located on universities' premises that are not university headquarters since Italian university departments are often geographically dispersed (i.e., they are seldom found on a unique campus). In either case (i.e., USOs located at universities' headquarters or other premises), we consider the USO as being located on campus. The measure is time variant and is assessed on a yearly basis.

Technological ties are measured as the count of patents assigned to a parent university that were invented by academics who are members of the respective USO's entrepreneurial team (i.e., owners of the company) since the USO's founding (source: PATIRIS database; http://patiris.uibm.gov.it/home). As previous studies have shown that about a third of patents invented by academic researchers are not assigned to their universities (Lissoni et al., 2008; Thursby et al., 2009), with this measure, we proxy the extent to which academic

entrepreneurs are more or less "technologically embedded" in their universities (i.e., the extent to which they still carry out research with their original university lab).

We also include several control variables related to firm, parent institution, and environmental characteristics that might impact our dependent variable. As per firm-level controls, we include *company age*, measured as the number of years since a firm's inception (source: business registers held by the Italian Companies' House). Because time is a key element in companies' development, company age may influence the strength of the relationship between a company and its parent organization (Vohora et al., 2003; van Geenhuizen and Soetano, 2009; Rasmussen, 2011). Because a spin-off's management board can strongly influence its performance through several mechanisms (e.g., providing guidance, signaling the company's quality to external audiences, controlling decisions, providing intense trajectory coaching), we include the variable *parent board membership*, which accounts for the number of academics from the respective parent university sitting on a USO's management board in any given year (source: manual identification from the business registers held by the Italian Companies' House) (Clarysse and Moray, 2004; Semadeni and Cannella, 2011). Acknowledging the importance of firm size (Acs and Audretsch, 1987), we include the variable *number of shareholders*, counting the number of shareholders for a USO in any given year (source: business registers held by the Italian Companies' House). We also control for the *equity capital* (Wright Robbie, 1998), measured as a USO's total equity (in thousands of euros) in any given year (source: business registers held by the Italian Companies' House). To account for the overall patenting efforts carried out by a USO's entrepreneurial team, we control for *innovation skills*, measured as the cumulated number of European patents invented by the focal entrepreneurial team (source: European Patent Office— PATSTAT database; http://epo.org). Lastly, because research has shown that the composition of founding teams in entrepreneurial academic spin-offs is key to their

subsequent market performance (Ensley and Hmieleski, 2005), we control for *shareholders' commercial experience*, measuring the proportion of shareholders who were employed in at least one commercial position during their careers (Visintin and Pittino, 2014) (source: manual extraction of data from shareholders' curricula vitae and personal webpages, such as LinkedIn).

As for university-level controls, we include the variable *technology transfer office*, which captures the presence of a formal TTO at the parent university (Siegel et al., 2003). The variable is operationalized as a time-variant dummy variable equal to 1 if the parent university had a TTO in the focal year and 0 otherwise (source: Italian Ministry of Education and Research and Netval).

Finally, to account for environmental influences, we acknowledge the role played by venture capitalists (Samila and Sorenson, 2011) and include the variable *regional financial VC support*, measured as the number of investments from venture capitalists in a spin-off's region in any given year (source: AIFI; http://www.aifi.it). In addition, we include year dummies in all specifications to capture time-varying market conditions.

Methodology

Our final dataset consists of an unbalanced, compact, and dynamic panel (n = 551 units; n = 4,263 observations) that covers the period 2000–2012. The panel is characterized by (a) a small T and large N, (b) a predicted linear functional relationship, (c) a dynamic dependent variable correlated to its own past values, (d) independent variables potentially correlated with past and current realization of the error (i.e., non-strictly exogenous), (e) fixed individual effects, and (f) heteroskedasticity and autocorrelation within individuals but not across them (Roodman, 2009). These characteristics make GMM estimators (Arellano and

Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998) particularly suitable for analysis.

Because our dependent variable—*market performance*—has instances that might be highly persistent over time (Lubatkin and Shrieves, 1986), we implemented a System GMM estimator (Arellano and Bover, 1995; Blundell and Bond, 1998) using the xtabond2 Stata module (Roodman, 2009). This method addresses the issue of unobserved heterogeneity by transforming the data through differencing (Wooldridge, 2002). It solves the issue of predetermining the dependent variable by allowing us to include a lagged dependent variable as an independent regressor and to instrument it (as other potentially endogenous variables) with variables that are uncorrelated with the fixed effects. This method also explicitly accounts for firm fixed effects.

Our panel is unbalanced because some companies exited the sample during the observation period (n = 102). We thus consider this attrition by correcting the estimates through a generalization of Heckman's (1979) selection bias (for a similar approach, see Baum and Silverman, 2004; Calvo, 2006). We estimate a first-step probit equation of a USO's probability of exiting in any given year (variable *exit*, equal to 1 if the USO exits and 0 otherwise) (source: Italian Companies' House). In our sample, company exits mainly refer to failures (90% of total exits) rather than to mergers and acquisitions[1].

As predictors, we include company-level demographic information (retrieved from the Italian Companies' House): *company age*, *number of shareholders*, *equity capital*, *parent shareholdership* (a dummy variable equal to 1 if the parent university is a shareholder and 0 otherwise), the presence of a *financial investor at establishment* (a dummy variable equal to 1 if at least one shareholder is a financial institution and 0 otherwise), the presence of a *public*

[1] As a robustness check, we run our selection model and the second-stage estimations excluding companies with a positive exit (i.e., being merged or acquired). The results are comparable to those discussed in the manuscript and are available upon request.

investor at establishment (a dummy variable equal to 1 if at least one shareholder is a public institution and 0 otherwise), the presence of a *portfolio entrepreneur* on the entrepreneurial team, *industry*, *company localization* (according to Nomenclature des Unités Territoriales Statistiques NUTS 1 macro-regions), *company patenting* (number of European patents assigned to the company up to the focal year) (source: European Patent Office), *market performance*$_{(t-1)}$, and *company inactivity* (a dummy variable equal to 1 if the spin-off had no sales revenues for at least three consecutive years and 0 otherwise) (source: AIDA—Bureau Van Dijk). We also include contextual predictors, such as the *research eminence* of the parent university (source: CENSIS—La Repubblica), the presence of a *TTO* at the parent university, *regional entrepreneurship support* (number of incubators in the spin-off's region) (source: web manual search), *regional financial VC support* (source: AIFI), and *year* dummies. In addition, we add the following two exclusionary restrictions (i.e., variables correlated with the probability of exiting and not with *market performance*, which is the dependent variable of our study): (a) whether the company replied to a survey carried out by the project team in 2009 to investigate USOs' financial structures, team composition, market and innovation performance, and growth perspectives (*survey year 2009*) (dummy variable equal to 1 if the company replied and 0 otherwise); and (b) whether the USO changed its legal headquarters since establishment (*change headquarter*) (source: Italian Companies' House). We reason that USOs that did not complete the survey may not have been interested due to perceived difficulties or foreseen exit from the market in the following period[2] and that active companies are more likely to change their operational premises due to positive expected business prospects. We then use the predicted probabilities from this attrition probit to calculate the correction factor (i.e., inverse mills ratio) for the second-step equation.

[2] In our sample, 17 of 102 companies (16.6%) exited before 2009 and were thus unable to answer to the survey launched in 2009. To account for this issue, as a robustness check, we run our selection model and second-stage estimations excluding those companies that exited before 2009. The results are in line with those discussed in the manuscript and are available upon request.

In our second-step equation, we predict USOs' *market performance*. The independent variable—*parent ownership*—is potentially endogenous because universities might invest in USOs based on the firms' market prospects. To deal with this issue, we employ an instrumental variable approach by identifying an exogenous time-variant instrumental variable from university-level USO regulations[3]. The instrumental variable—*university participation to USO losses*—takes the value of 1 if the parent university had an internal policy in place to regulate equity investments in USOs specifically indicating that the university is accountable for USO losses and 0 otherwise. This policy detail may drive parent institutions' decision to invest in USOs' equity capital without being correlated to USOs' revenue sales.

In our models, *year* is treated as exogenous, whereas *market performance*$_{(t-1)}$ is treated as endogenous and is instrumented with its lags at *t-2* and *t-3*. All of the other independent, moderating, and control variables are treated as predetermined (Roodman, 2009) and are instrumented with lags at *t-1* to *t-3*. Because having too many instruments can generate overfitting bias (Baltagi, 2005), we limit the number of instruments in the moment conditions (Roodman, 2009). We carry out the analyses relying on heteroskedasticity-robust standard errors.

To examine the validity of our GMM estimators and of our instruments, we assess the serial correlation tests and the Hansen *J*-statistic for overidentifying restrictions in GMM (Arellano and Bond, 1991).

[3] University-level USO regulations ("*regolamento spinoff*") are publicly available documents produced by universities that set the rules for academics wanting to establish and manage USOs (Muscio et al., 2016).

EMPIRICAL RESULTS

Descriptive analyses

The 551 companies spun off from 52 STEM universities, primarily in northern Italy (56.8%). The companies are mostly limited liability companies (99.4%) operating in the electronics (42.1%), advanced services (28%), biomedical (13.4%), materials (8.9%), and environment (7.6%) industries (Table 1). On average, companies were established in 2004. These companies were generally established through small investments in equity capital (often aimed at meeting the minimum legal requirements) (Balderi et al., 2011; Bax et al., 2014). In addition, our study confirms that universities' investments in USOs' equity tend to be very small, being close to be the minimum required by the USO regulation (Salvador, 2009; Callan, 2001) and aiming at minimizing risks (Muscio et al., 2016). Over the observation period, 30% of the companies changed their geographical location (on average changing 1.8 times), and about 11.7% of the academic entrepreneurs filed new patents assigned to their universities (on average adding 1.7 patents to their patent portfolios). The summary statistics for the time-variant variables are reported in Table 2.

Insert Table 1 and Table 2 about here

Estimation results

The pairwise correlations for our variables are reported in Table 3. The System GMM analyses are shown in Table 4. Model 1 is the baseline model showing the effect of the control variables and including the correction for attrition. Model 2 adds the independent variables. Model 3 shows the two-way moderating effects of *geographical proximity*, and Model 4 shows the two-way moderating effect of *technological ties* of academic entrepreneurs. Model 5 exhibits the fully specified model. The results of the probit selection

model to estimate the correction factor for attrition bias and the related correlation matrix are shown in Tables A1 and A2 in the appendix.

Insert Table 3 and Table 4 about here

Starting with Model 1, as expected, we immediately spot the path-dependent dynamics of sales, with the *lagged market performance* variable having a strongly significant positive effect ($\beta = 0.562$, $p < 0.001$). In addition, *market performance* is positively influenced by the presence of a university member on USOs' boards ($\beta = 0.272$, $p < 0.001$) and the size *of equity capital* ($\beta = 0.001$, $p < 0.05$). At the university level, the presence of a *TTO* is significantly related to an increase in USOs' *market performance* ($\beta = 0.27$, $p < 0.1$). At the regional level, the control for *regional financial VC support* is positive and significant ($\beta = 0.005$, $p < 0.01$).

Looking at the main effects (Model 2), *parent ownership* has a significant positive effect on *market performance* ($\beta = 0.049$, $p < 0.01$), supporting Hypothesis 1. Because the dependent variable is logged, the coefficients should be interpreted as follows: a one-unit change in the independent variable is associated with a $(e^{\beta 1} - 1) * 100$ percent change in the dependent variable. Our results thus show that every 1,000 euros of equity invested by a parent university in a USO (i.e., one unit) increases the USO's market performance by 5%. Next, the coefficient for *geographical proximity* is very small and non-significant. Hence, the analyses in Model 2 do not support Hypothesis 2. The effect of academic entrepreneurs' *technological ties* is marginally significant but negative ($\beta = -0.140$, $p < 0.10$), not supporting Hypothesis 3.

In model 3, the interaction between *parent ownership* and *geographical proximity* is significantly positive ($\beta = 0.001$, $p < .05$), supporting Hypothesis 4a. To make this result

more easily interpretable, in Figure 1 we plotted the two-way interaction across all values of parent ownership. Specifically, we plotted the predicted values of parent ownership on market performance for different levels of geographical proximity (at one standard deviation above and below the mean). Results suggests that as parent ownership increases, its effect on market performance gets stronger for higher level of geographical proximity.

Conversely, the interaction term regarding the moderating effect of academic entrepreneurs' *technological ties* is not significant; thus, Hypothesis 4b is not supported.

Insert Figure 1 about here

Additional empirical analyses

Despite the potential benefits, close university linkages may also pose some disadvantages for USOs. Multiple linkages with the same partner are likely to provide access to overlapping knowledge and may lead to the risk of being locked into a specific exchange relationship (Capaldo and Petruzzelli, 2014). We therefore carried out a set of additional analyses to test the joint effects of *parent ownership*, *geographical proximity*, and *technological ties* on USOs' *market performance*. To this end, we created two sub-groups of USOs. First, we split our sample based on the median of *geographical proximity*, contrasting "high geographical proximity" USOs (if *geographical proximity* > median) with "low geographical proximity" USOs (if *geographical proximity* <= median). Second, we created a split sample based on the median of academic entrepreneurs' *technological ties*, comparing "high technological tie" USOs (if academic entrepreneurs' *technological ties* >= median) with "low technological tie" USOs (if *technological ties* < median). We run the interaction models on these subsamples. While the results should be interpreted cautiously, due to the small number of observations per group and the proliferation of instruments, we find a marginally significant negative

interaction between *parent ownership* and *technological ties* for companies with high *geographical proximity* to their parent universities (i.e., companies "in campus") (β = -0.021, $p < 0.10$), and a positive interaction between *parent ownership* and *technological ties* for companies with low *geographical proximity* to their parent universities (i.e., companies "off campus") ($\beta = 0.028$, $p < 0.05$). These post hoc analyses suggest that increasing *geographical proximity*, together with strong *technological ties* between the academic entrepreneurs at a USO and the parent university, marginally weakens the positive effect of *parent ownership*.

We run additional models to further probe the robustness of our results as follows[4]. We run our analyses by treating the independent, moderating, and control variables as endogenous rather than predetermined (for a similar approach, see Uotila et al., 2009). We obtain qualitatively similar results but with remarkable worsening in the overidentification test in all the models, therefore confirming the better fit of our main models.

We also run two sets of additional models to take into account that the key variables in our study count a significant presence of zeros. First, we run our estimations by using dichotomized variables of *parent ownership*, *geographical proximity*, and academic entrepreneurs' *technological ties* based on their median values[5]. Second, following other scholars (e.g., Robertson et al., 1994; He et al., 2014), we enter both the original variable and the dichotomous variable in the regression. Because using two variables for each independent variable generates instrument proliferation, we cannot use this second method to run our interactions because the models would be overidentified. In general, these models confirm that *parent ownership* has a positive effect on *market performance* and that the absence of *technological ties* has a positive effect on *market performance*.

[4] Due to space limitations, we here describe results which are available in more detail upon request.
[5] Specifically, the dichotomous variables is equal to 1 for values of the independent variable smaller than its median value; 0 otherwise.

To further corroborate our findings, we build an alternative measure to capture the existence and maintenance of technological ties between a university and its USO. We specifically measure co-patenting between the spin-off and the parent university. We searched in the European Patent Office for patents co-assigned to a spin-off and its parent university over the period. Only 10 companies (1.8% of the total sample) have a patent assigned to both the firm and the parent university. We searched for patents in the European Patent Office rather than in the Italian Patent Office because patents filed in the European Patent Office overemphasize the technological linkages between a spin-off and its parent university (because it is generally easier, faster, and cheaper to patent in the national office rather than at the European level). We find a positive and significant correlation between spin-offs that are co-assignees with their parent universities on patents filed with the European Patent Office and spin-offs with entrepreneur inventors of patents assigned to their parent universities (i.e., our main measure of *technological ties*) ($r = 0.23$, $p < 0.01$). We use this operationalization to re-estimate the main models and results are confirmed.

Finally, to account for the extent to which different types of knowledge might be transferred between the USO and the parent university, we measure the co-publishing activity between the spin-off and the parent university. For co-publishing, we searched on Scopus for any existing scientific publication with any of the spin-offs as an author's affiliation. We found only six companies matching this criterion. For each company, we downloaded the details of the publications and identified the number of publications per year, distinguishing those co-authored with the respective parent university. Among these companies, only five (0.9% of the total sample) have a publication together with their parent universities. We also note that three out of these five companies are also co-applicants with their parent universities on patents with the European Patent Office. We find a positive and significant correlation between spin-offs that co-published with their parent universities and spin-offs with

entrepreneur inventors of patents assigned to their parent universities (i.e., our measure of *technological ties*) ($r = 0.10$, $p < 0.05$). We then include this new variable (*knowledge ties*) in the main models, replacing the *technological ties* measure. The results provide evidence that *parent ownership* positively and significantly impacts *market performance* and that academic entrepreneurs' *knowledge ties* (measured by co-publications), positively and significantly impacts *market performance*. In addition, we find a significant negative interaction between *parent ownership* and *knowledge ties*.

These results seem to suggest the existence of different types of ties, which may convey and leverage upon different types of knowledge basis. Yet, because of the small number of companies involved in co-patenting and co-publishing, however, we interpret these results with caution and call for additional evidence in another sample of USOs.

Interpretation of the results via interviews

To further interpret our results, we draw on qualitative data that we collected through interviews with academic entrepreneurs at seven USOs in our sample and two experienced TTO officers. Our informants confirm that linkages with their parent universities are a key issue for USOs.

First, our interviews highlighted that in the analyzed period, Italian universities' decision to invest equity stakes in USOs was in large part aimed at sustaining research activities carried out by academics, as described by one entrepreneur: "Our university had an interest to participate in spin-off equity because there was a belief that spin-offs were a good way to keep all the activities of research groups going" (Company A). As pointed out by our informants, in this context, "the small investment carried out by the university shows that this is not something to cash in revenues" (Company B) but rather a decision carried out by "an internal evaluation panel that analyzed the business plans and approved the participation via

equity if they were in line with the strategic development plans of the university in terms of research" (Company C). As in other national contexts, equity investments are a way for universities to commercialize patented inventions from research. Through participation in equity, universities are able to "support USOs during the growth phase, not much with regard to the injection of capital, but with support in kind— for example, the time of a university representative on the board of directors, which normally takes place if there is a university equity share" (TTO officer 1). Seen from the entrepreneurs' point of view, the right to place a university representative on a USO's board of directors

> is a form of control in companies with many shareholders, where the university does not have a central role. This might be a pure formality when things are going well, but in some instances, the representative of the university could express its negative or contrary opinion with regard to some important decisions—for instance, to avoid certain investments, to avoid payment of debts, or to avoid the entrance of a partner perceived as not desirable or appropriate. (Company C)

All our informants reported that when USOs maintain equity linkages to their parent universities, they have more advantages in terms of accessing resources, such as computers and equipment, laboratories, rooms and co-working spaces, shared administrative support (e.g., secretaries), utilities, information and support to access funding, consulting about intellectual property rights management, human resources (e.g., doctoral students and post-docs), etc. As described by one entrepreneur, there is ample flexibility for USOs formally approved through an equity linkage even when access to resources is regulated through a contractual agreement between the USO and the university: "We pay an insignificant amount of money, around 500 Euro per year, to use infrastructure, labs, instruments within certain limits, but actually there is no control" (Company D). For some entrepreneurs, the benefits of university equity became evident when their universities exited as shareholders: "This detachment from the university is connected to the entry of new managers and will probably lead to different activities in the future. For instance, to use the university equipment, before

we benefited from a 'favor price,' and now, we cannot benefit from it anymore" (Company E).

Also, there is a strong interplay between equity linkages and geographical proximity to enable USOs to access many resources. As summarized by one academic entrepreneur, "Having the university as a shareholder implies that we could stay on campus; we have a form of 'authorization'" (Company F). Some entrepreneurs elaborated on the strategic importance of being formally connected with and located at their parent universities: "In 2006, we were incubated by the university, and this gave us greater logistic convenience and other advantages like the meeting room, where we could meet clients and organize meetings. This was really important for our image" (Company G). It is interesting to note that our qualitative data show that the combination of university equity linkages and geographical proximity not only seems valuable for accessing physical resources below market price but also serves as a source of more intangible support and "protection." For instance, several entrepreneurs expressed fears related to the rationalization of public investments in light of a new regulation passed in 2016–2017[6], which states that Italian universities must decide which USO equity investments to maintain. As described by one entrepreneur,

> At our university, there is now a debate about whether spin-offs can stay on campus if the university divests its equity share or does not invest in new spin-offs. I am quite worried about this perspective. . . . To "exit" from the university campus, we would need courage that I feel rather distant in our situation. . . . The university "protects" not only in an economic or financial sense; I would rather say that it offers a "psychological" protection: our perception of entrepreneurial risk is indeed different if we stay here. (Company F)

Through our interviews, we thus highlight the importance of both the tangible and intangible forms of support and protection that parent universities provide when USOs maintain equity linkages and geographical proximity to the parent university.

[6] For an overview and a discussion of implications for USOs, see, for example, Corrieri and Bax (2017).

Finally, our qualitative data shed some light on the mechanisms explaining why USOs' strong technological ties to their parent universities might be detrimental to USOs' market performance. As highlighted by a TTO officer (TTO officer 2), in the period analyzed, the management of intellectual property rights with respect to universities and USOs depended significantly on academic inventors' choices and behavior. According to several of the interviewed entrepreneurs, USOs are embedded in a scientific environment managed by professors and researchers who "are not full-time entrepreneurs" (Company D). USOs do not necessarily apply a strong commercial or entrepreneurial emphasis in their daily operations. For instance, one entrepreneur clearly pointed out the different logics driving his engagement with his USO with respect to a commercial partner: "At establishment, a private company was a shareholder of the spin-off. Having this partner was very useful to understand the commercial aspects of business. However, in our opinion, this partner did not valorize the scientific competences of our human resources, who ended up losing enthusiasm" (Company F). In another instance, a USO helped obtain European grants supporting the research activities of the parent research group. The human resources hired by the USOs served this scientific logic rather than a market logic: "We hire post-docs to work in the company. However, at the end of the day, since they are post-docs, they do not really work for the company—they are requested to do other things from professors, especially if they also want to build their academic career" (Company C). This was echoed by another USO founder, who stated, "If we hire people from 'inside', they might still feel under the 'professor-student' hierarchy" (Company F).

Maintaining such science-based relationships with their universities means that the USOs may be seen as "extended labs" rather than independent commercially successful companies. As explained by a spin-off closely linked to its parent university, "Our customers could not believe that we were a solid and sustainable entity. They asked us, 'If I need

assistance and maintenance, will I find you, or will you be busy grading exams?'" (Company C). Such a view can hence have negative implications in terms of USOs' market performance, as highlighted by our quantitative results.

DISCUSSION AND CONCLUSION

This study investigated how USOs can benefit from parent linkages over time by analyzing how several types of linkages to parent universities influence USOs' market performance. We suggested that USOs can access resources, knowledge, and support from their parent universities by maintaining linkages over time. Because the transfer of resources and knowledge is challenging and relies heavily on interpersonal interactions, USOs benefit from different types of linkages, and the effects of these linkages may be complementary.

Testing our hypotheses on a longitudinal multilevel dataset comprising 551 spin-offs from Italian universities, after accounting for attrition, we find partial support for our hypotheses. First, we find that having linkages through parent universities' equity ownership over time has a clear positive effect on USOs' market performance.

Second, our findings do not support the notion that geographical proximity has a positive effect on market performance. However, our findings show that geographical proximity moderates the impact of ownership linkages on market performance. Specifically, we find that increasing geographical proximity strengthens the positive effect of equity ownership.

Third, we find that technological ties maintained by academic entrepreneurs engaged in serving parent universities' technological development have a negative impact on USOs' market performance. Further, our post hoc analysis indicates that increasing technological ties, coupled with increasing geographical proximity to the parent university, weakens the effect of equity ownership. In sum, the generally positive effect of parent equity ownership linkages might turn negative when the linkages become too strong. This finding is not

surprising in the context of USOs given that the knowledge base of their university parents is confined to the technological domain rather than the market and commercial domains. In fact, while academic collaborations drive knowledge creation (Bierly et al., 2009; Lavie and Drori, 2012), successful commercialization also requires knowledge application. This has been conceptualized as a tradeoff between exploration and exploitation (Levinthal and March, 1993), which can cause firm performance to suffer if a firm is unable to balance developing new knowledge with exploiting current assets. In the case of many strong university linkages, USOs may lack linkages that provide non-technological knowledge (Chatterji, 2009). Arguably, universities do not possess relevant commercial and industrial knowledge, leading to significant tensions between academic and commercial demands (Ambos et al., 2008). Indeed, universities embody an academic institutional logic that "emphasiz[es] the search for fundamental knowledge, research freedom, rewards in the form of peer recognition, and the open disclosure of research results" rather than a commercial institutional logic emphasizing "applied research in a setting shaped by bureaucratic control, limited disclosure, and the private appropriation of financial returns from research" (Sauermann and Stephan, 2013: 889). Academic entrepreneurs are likely to have internalized their parent universities' logic, so by becoming USO owners, they migrate this logic across firm boundaries (Agarwal et al., 2004). As suggested by our qualitative data, the linkages represented by academic entrepreneurs' technological ties likely provide scientific-related rather than market-related knowledge, norms, and practices, which can negatively influence USOs' market performance (Perez and Sanchez, 2003).

Contributions and implications

Our findings add to the scant literature on the performance implications of linkages between USOs and their parent universities over time and thus offer several contributions. First, we

add to the strategic management literature by shedding light on this particular parent-child relationship and its implications for strategy. Evolutionary perspectives of spin-offs emphasize the role of inherited knowledge from parents (Klepper and Sleeper, 2005; Nelson and Winter, 1982; Phillips, 2002), whereas our study outlines the importance of linkages over time for USOs' performance. By building on and extending previous studies, we consider the individual and combined effects of different types of linkages (i.e., equity ownership, geographical proximity, and technological ties) on USOs' market performance over time. Our findings support the argument that ownership linkages are positive and that other linkages can either reinforce or weaken them, implying both benefits and costs of maintaining these linkages.

Second, we extend research on alliances in entrepreneurial firms by examining the performance implications of various configurations of linkages (Gulati et al., 2009; Haeussler et al., 2012; Mohr et al., 2013). In the context of USOs, our findings provide clear evidence of the positive performance effect of formal equity-based linkages and show that this effect partly depends on the existence of other types of linkages. More specifically, geographical proximity strengthens the effect of equity linkages, while technological ties between USOs and their parent universities produce negative results. In this case, spin-offs may lack linkages that provide non-technological knowledge (Chatterji, 2009). Arguably, universities do not possess relevant commercial and industrial knowledge (Ambos et al., 2008). Hence, the linkages represented by academic entrepreneurs' technological ties likely provide scientific knowledge, norms, and practices, which can negatively influence USOs' market performance (Perez and Sanchez, 2003). These linkages may lead USOs to overemphasize knowledge creation (exploration), which could undermine their knowledge-application efforts (exploitation) (Lavie and Drori, 2012).

Third, this paper contributes to the literature on academic entrepreneurship, extending research about USOs' performance (Mathisen and Rasmussen, 2019; Walter et al., 2006) and the ways universities can influence their spin-offs' development. The benefits of university linkages for USOs are well documented (Colombo et al., 2009; Murray, 2004), but several studies have noted that a lack of commercial orientation may be an impediment for USOs' performance (Zahra et al., 2007). We find that university linkages can be positive for USOs, but different types of linkages lead to different results. For USOs, linkages with their parent universities may also introduce liabilities that limit their market performance. USOs that preserve strong linkages with the parents universities may end up with relationship-specific investments and a lower ability to establish relationships with other companies or institutions (Parhankangas and Arenius, 2003).

In addition to these contributions, this study's findings provide practical implications for how USOs and their university parents can design their relationships. Despite Italian USOs tend to be generally established through small investment in equity capital (Balderi et al., 2011; Bax et al., 2014), they should nevertheless notice that equity investments by their parent universities are significant in sustaining market performance over time. There is therefore room for both academic entrepreneurs and university managers to reflect on the significance of universities' investments in USOs' equity, which can involve rather small amounts (e.g., Salvador, 2009; Callan, 2001) but imply an alignment in reaching strategic objectives and accessing key resources which are conducive to USOs better market performance. Our study thus provides new evidence to supporting the value of equity-based linkages (Li, 2013; Sampson, 2007). In addition, we underline that different formal (i.e., equity) and informal linkages (e.g., geographical proximity and technological ties) can complement each other in situations in which complex technological knowledge is transferred, such as in relationships between companies and universities. Given that

collaboration between firms, including between USOs and their parents, has become a growing and widespread practice for gaining access to resources and knowledge, we hope our study helps institutions devise more effective collaboration strategies.

Our findings also provide policy implications. USOs are seen as engines of economic growth and job creation, and they also act as technology transfer agents that introduce science-based innovations and applications to industry and society (Fini et al., 2018). Our analysis sheds light on a potential reason why these firms play an important role in the entrepreneurial ecosystem (Autio et al., 2018). USOs may be able to maintain strong linkages with their parent universities over time and thereby access unique resources and knowledge. Our study suggests that policies promoting universities' equity positions in spin-offs and generally strengthening university-USO linkages may have a complementary and positive effect on USOs' performance. Legislative changes providing universities ownership to research-based inventions, such as the Bayh-Dole Act in the United States and similar regulations in many other countries, may be a relevant tool to stimulate equity linkages. Despite the obvious benefits of parent linkages, some types of close university linkages can pose disadvantages for USOs and have a detrimental effect on their performance. Our findings suggest that the relationship between equity linkages and USOs' market performance is influenced by more nuanced parent-child relationships, which should be carefully considered when implementing policies to support the establishment and development of USOs.

Limitations and further research

As with any other study, our work comes with limitations. First, following previous studies, we assume that the benefits from parent linkages are caused by access to resources and knowledge, but we do not measure actual resource and knowledge transfer. While we

acknowledge that the performance premium derived from parent linkages may be caused by other benefits, such as economic transactions with a university as a customer or by the signaling or legitimacy effects of being linked to a prominent parent institution, our qualitative interviews indicate that these effects are of relatively less importance for USOs and are not necessarily dependent on the types of linkages included in our study. However, there is still much to learn about the performance implications of different types of parent-child linkages, and more fine-grained studies of the benefits derived from each type of linkage clearly represent promising opportunities for further research. For example, future research could study whether different USO motivations and strategies (e.g., technological innovation vs. market exploitation) (Treibich et al., 2013) influence the usefulness of parent linkages over time. Universities are likely to provide mostly science- and technology-related resources and are thus more valuable partners for USOs with explorative innovation strategies (Soetanto and Jack, 2016).

Second, in studying the effect of parent-child linkages, we only account for the benefits derived by USOs without considering potential benefits or drawbacks for their parent universities. Although we argue that USOs are not hostile spin-offs and that their success is generally in their parent universities' interest (Pitsakis et al., 2015), it is important to know more about the mutual benefits of different types of linkages. Linkages with USOs may also provide universities access to knowledge, and understanding such mutual benefits can shed light on universities' motivations for prioritizing USO creation and maintaining linkages with these firms.

A third limitation of this study relates to the ability to generalize our findings. The USO context makes it likely that the benefits of linkages with parent universities are related to accessing scientific and technological knowledge rather than business-oriented knowledge. Although we believe that these benefits might generalize to corporate spin-offs working with

advanced technological knowledge related to their parents' expertise (e.g., in science-based industries), different patterns of linkages may be beneficial for other types of parent-child relationships or for the transfer of other types of knowledge. Therefore, while our main message—that linkages are beneficial to a certain extent—may hold across different contexts, the role of different linkages and their interplay in different contexts are areas for future research.

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EXHIBITS

Table 1—Industry, legal, and geographical composition of the sample

Industry	No. of firms	%
Advanced services	154	28.0
Biomedical	74	13.3
Electronics	232	42.1
Environment	42	7.6
Materials	49	8.9
Total	**551**	**100.0**
Legal form		
Limited liability	548	99.4
Unlimited liability	3	0.6
Total	**551**	**100.0**
Geographic area (NUTS 2 code)		
Northwestern Italy (ITC)	152	27.6
Northeastern Italy (ITD)	161	29.2
Central Italy (ITE)	115	20.9
Southern (ITF) and Insular (ITG) Italy	123	22.3
Total	**551**	**100.0**

Note: Industry categories are as follows (Fini and Toschi, 2016): Electronics (including aerospace, computers, electronic components, information and telecommunication services, and software), environment (including environment-related services and energy), biomedical (including biochemistry, biotechnology, medical and veterinary, and pharmaceuticals), materials (including mechanical equipment, optical equipment, advanced mechanics, and automation), and advanced services (including architectural, civil engineering, and statistical services).

Table 2—Summary statistics: Dependent, independent, and control variables

Variable	Mean	Std. dev.	Min	Max
Market performance	3.58	2.36	0.00	11.14
Company age	3.74	2.82	0.00	12.00
Geographical proximity	-33.86	92.43	-654.59	0
Technological ties	0.34	0.80	0.00	10.00
Parent board membership	0.89	1.15	0.00	6.00
Number of shareholders	5.73	5.06	0.00	71.00
Equity capital	80.84	379.71	0.00	6035.63
Innovation skills	0.44	1.40	0.00	26.00
Shareholders' commercial experience	0.03	0.10	0.00	1.00
Technology transfer office	0.89	0.31	0.00	1.00
Regional financial VC support	28.82	28.41	1	157
Parent ownership	1.14	3.97	0.00	70.00

N = 4,263 (firm-year observations)

Table 3—Correlation table

		1	2	3	4	5	6	7	8	9	10	11
1	Market performance	1.000										
2	Company age	0.318	1.000									
3	Parent board membership	0.031	-0.120	1.000								
4	Number of shareholders	-0.021	-0.075	0.210	1.000							
5	Equity capital	0.070	0.039	-0.080	0.444	1.000						
6	Innovation skills	0.032	0.190	0.028	0.110	0.088	1.000					
7	Shareholders' commercial experience	0.044	0.024	-0.093	-0.076	-0.022	-0.032	1.000				
8	Technology transfer office	0.107	0.093	0.073	-0.031	-0.088	0.052	0.002	1.000			
9	Regional financial VC support	0.116	0.053	-0.003	-0.034	0.038	0.076	0.005	0.073	1.000		
10	Parent ownership	0.068	-0.049	0.179	0.088	0.032	0.002	-0.042	0.003	0.064	1.000	
11	Geographical distance	0.012	-0.047	0.137	0.097	0.018	0.037	-0.016	0.072	0.037	0.043	1.000
12	Technological ties	-0.028	0.055	0.164	0.141	0.003	0.509	0.003	0.072	0.150	0.060	0.029

N = 4,263
Note: values above 0|.03| are significant at 0.05

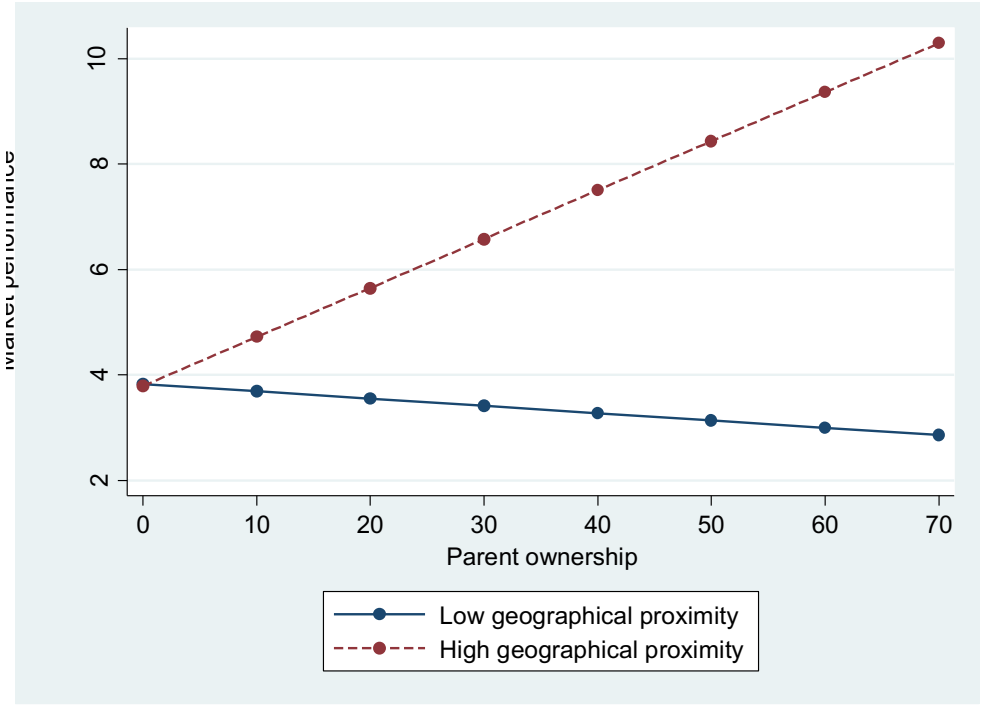
Table 4—Market Performance: System GMM estimation

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Market performance (t-1)	0.562***	0.553***	0.553***	0.561***	0.552***
	(0.033)	(0.033)	(0.034)	(0.033)	(0.034)
Company age	0.031	0.034	0.031	0.030	0.033
	(0.024)	(0.022)	(0.022)	(0.022)	(0.023)
Parent board membership	0.272***	0.250**	0.235**	0.238**	0.250**
	(0.079)	(0.077)	(0.075)	(0.075)	(0.078)
Number of shareholders	-0.036	-0.039*	-0.045*	-0.040*	-0.047*
	(0.028)	(0.020)	(0.020)	(0.019)	(0.020)
Equity capital	0.001*	0.001+	0.001*	0.001+	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Innovation skills	-0.015	0.027	0.029	0.027	0.029
	(0.025)	(0.028)	(0.027)	(0.027)	(0.027)
Shareholders' commercial experience	0.204	0.288	0.240	0.228	0.237
	(0.361)	(0.357)	(0.357)	(0.351)	(0.358)
Technology transfer office	0.270+	0.288*	0.286*	0.268*	0.272+
	(0.138)	(0.136)	(0.138)	(0.134)	(0.139)
Regional financial VC support	0.005**	0.006**	0.006**	0.006**	0.005**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Inverse mills	3.622*	3.774**	3.789*	3.643*	3.608*
	(1.442)	(1.461)	(1.528)	(1.444)	(1.562)
Parent ownership (Par Own)		0.049**	0.093***	0.052**	0.101**
		(0.017)	(0.027)	(0.019)	(0.037)
Geographical proximity (Geo Prox)		0.000	-0.000	0.000	-0.000
		(0.001)	(0.001)	(0.001)	(0.001)
Technological ties (Tech Ties)		-0.140+	-0.139+	-0.129	-0.139
		(0.077)	(0.080)	(0.082)	(0.096)
Par Own x Geo Prox			0.001*		0.001+
			(0.001)		(0.001)
Par Own x Tech Ties				-0.003	0.000
				(0.010)	(0.025)
Year dummies	Included	Included	Included	Included	Included
Constant	-1.225	-0.783	-1.412	-0.090	-0.646
	(0.986)	(1.087)	(1.058)	(0.763)	(1.167)
Number of observations	3,712	3,712	3,712	3,712	3,712
Number of USOs	551	551	551	551	551
Overall model fit—Chi-sq(df)	1155.48(23)***	1246.56(26)***	1382.21(27)***	1349.48(27)***	1203.82(28)***
Serial correlation AR(1) test	0.631	0.624	0.616	0.630	0.607
Hansen test of overidentification restrictions	0.038	0.588	0.735	0.570	0.593

Robust standard errors are in parentheses. All variables are in first differences, which account for firm-level fixed effects. Dependent variable = *market performance (t)*. Independent variables are measured at *t*, with the only exception being *market performance*, which is measured at *t-1*.

*** p < 0.001, ** p < 0.01, * p < 0.05, + p < 0.10

Figure 1 – Interactive effects of parent ownership and geographical proximity on spin-off market performance



Note: Plot of interaction effect at +/- 1 standard deviation from the mean. Predicted values estimated using Model 3. The analysis of confidence intervals indicates the relationship being statistically significant for parent ownership higher than 20.

APPENDIX (TO BE PUBLISHED)

Table A1 – Probit estimation on firm exit

Variables	DV=Exit (0/1)
Company age	0.005
	(0.014)
Number of shareholders	-0.006
	(0.010)
Equity capital	-0.004***
	(0.001)
Parent shareholdership	-0.256***
	(0.063)
Financial investor at establishment	0.431***
	(0.119)
Public investor at establishment	0.637***
	(0.139)
Company patenting	0.091***
	(0.027)
Market performance (t-1)	-0.097***
	(0.014)
Company inactivity	-0.126
	(0.109)
Portfolio entrepreneur	-0.048
	(0.093)
Industry dummies	Yes
Locatization dummies	Yes
Technology transfer office	0.345**
	(0.115)
Research eminence of parent university	-0.003
	(0.005)
Regional entrepreneurship support	0.032+
	(0.018)
Regional financial VC support	0.007***
	(0.001)
Year dummies	Yes
Survey year 2009	-0.402***
	(0.060)
Change headquarter	-0.196**
	(0.061)
Constant	-0.753
	(0.546)
Observations	3,712

Chi-sq(df) = 356.32(35)***
Pseudo R-sq = 0.117
Robust standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05, + p<0.10

Table A2 – Correlation table for probit estimation on firm exit

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Exit	1.000																		
2	Company age	-0.068	1.000																	
3	Number of shareholders	-0.053	-0.075	1.000																
4	Equity capital	-0.062	0.039	0.443	1.000															
5	Parent shareholdership	-0.051	-0.105	0.240	-0.071	1.000														
6	Financial investor at establishment	0.033	0.018	0.143	0.025	0.039	1.000													
7	Public investor at establishment	0.044	0.014	0.052	0.023	0.118	0.063	1.000												
8	Company patenting	-0.014	0.171	0.076	0.105	0.004	0.056	-0.004	1.000											
9	Market performance (t-1)	-0.143	0.366	-0.034	0.064	0.055	-0.063	0.043	0.041	1.000										
10	Company inactivity	0.044	0.055	0.013	0.027	-0.079	0.076	0.002	-0.008	-0.438	1.000									
11	Portfolio entrepreneur	-0.022	0.001	0.147	0.000	0.024	0.055	0.000	0.046	-0.019	0.037	1.000								
12	Industry	-0.106	-0.054	0.093	-0.054	0.122	0.050	-0.007	-0.032	-0.070	0.020	0.008	1.000							
13	Localization	0.023	-0.090	0.031	-0.085	-0.031	-0.096	0.019	-0.010	-0.163	0.008	0.139	0.050	1.000						
14	Research eminence of parent uni	-0.008	-0.083	-0.018	0.018	-0.042	-0.009	0.009	-0.020	0.129	-0.019	-0.013	-0.049	-0.150	1.000					
15	Technology transfer office	0.063	0.093	-0.031	-0.088	0.075	-0.006	0.012	0.027	0.102	-0.053	0.005	0.003	-0.012	-0.002	1.000				
16	Regional entrepreneurship support	0.015	-0.005	-0.051	-0.024	-0.049	0.036	0.165	-0.065	-0.030	-0.006	-0.070	0.073	0.134	-0.010	-0.017	1.000			
17	Regional financial VC support	0.039	0.053	-0.034	0.038	0.075	0.019	-0.022	0.034	0.125	-0.005	-0.052	-0.028	-0.606	0.168	0.073	-0.313	1.000		
18	Year	-0.066	0.639	0.013	-0.030	0.078	-0.024	-0.011	0.148	0.228	-0.023	0.007	0.068	0.100	-0.233	0.222	0.009	-0.028	1.000	
19	Survey year 2009	-0.099	0.085	-0.033	-0.062	-0.037	-0.014	-0.055	0.068	0.155	-0.097	-0.022	-0.155	-0.090	0.028	0.008	0.010	0.080	-0.053	1.000
20	Change headquarter	-0.099	0.046	-0.043	0.039	-0.104	0.033	0.019	0.049	0.137	-0.093	0.038	0.004	-0.126	0.051	-0.026	0.019	0.022	-0.021	0.037

N = 3,712. Note: values above |0.03| are significant at 0.05