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Information-based Imitation of University Commercialization Strategies: The Role of Technology Transfer Office Autonomy, Age and Membership into an Association

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ABSTRACT

We investigate whether university technology transfer offices (TTOs), i.e. divisions responsible for the commercialization of academic research, imitate their industry peers when designing their commercialization strategy. We borrow from information-based theories of imitation and the literature on academic entrepreneurship to argue that given a TTO's autonomy to strategize independently from its parent university, information from within and outside the TTO affects its propensity to imitate the commercialization strategy of the "most successful peers", i.e. those with the largest live spinoff portfolio and greatest revenues from spinoffs in the industry. We contend that a TTO's experience, that is a function of its age, represents a key internal source of information for the TTO when deciding whether to imitate or not; we also consider the TTO's embeddedness in a network where the most successful peer is also a member as a key external source of information. From data on 86 British university TTOs and their commercialization strategies between 1993–2007 that was drawn from both secondary sources and in-depth interviews with TTO managers, we find that there is a negative relationship between TTOs' autonomy and their level of imitation of the most successful TTO's strategy, and that this relationship is moderated by the TTOs' age and by their membership into an association where the most successful TTO is also a member.

Keywords: commercialization strategy, imitation, autonomy, Technology Transfer Office, spinoff.

INTRODUCTION

With the aim of facilitating innovation and increasing knowledge flows to companies, universities have recently turned to formal technology transfer, i.e. strategies to commercialize intellectual property developed by scientists (Clayton, Feldman, and Lowe, 2018; Geuna and Nesta, 2006; Haeussler and Colyvas, 2011; Hmieleski and Powell, 2018; Mowery and Sampat, 2004). Various researchers have examined the controversial ways in which the academic and industrial worlds have interacted (Mowery et al., 2004; Powell and Owen-Smith, 1998; Stuart and Ding, 2006) and how the transformation of the norms of the academy have evolved with commercialization (Krimsky, 2003; Washburn, 2005). In particular, scholars have examined extensively what makes technology transfer successful (Colyvas, 2007; Fini, Rasmussen, Siegel, and Wiklund, 2018; Shane, 2004), especially the role of Technology Transfer Offices (TTOs), i.e. the structural vehicles that are responsible for universities' commercialization strategies. Yet, regardless of the procedures and reward systems put in place by TTOs to encourage commercialization, the outcome of these strategies remains highly *uncertain*. This is because the value of spinoff firms that TTOs create is difficult to estimate, since most spinoffs fail after few years of operating (Shane, 2004; Zahra, Kaul, and Bolívar-Ramos, 2018).

In this context of uncertainty where the risk of making wrong commercialization decisions is high, TTOs face the following dilemma: *imitate* the most successful TTOs' commercialization strategies or ignore them. In their study on commercialization strategies of TTOs in the USA, Tello, Latham and Kijewski (2010: 1277) highlight this dilemma by noting that "technology transfer office managers should assess to what degree their processes are organizational centric and/or industry best practices." Following the most successful peers can be seen as a way to reduce uncertainty and safeguard the success of a TTO's commercialization strategy by adhering to best practices; ignoring what the leader is doing

can be seen as a TTO's attempt to be more creative than others in its search of successful commercialization. Jo Johnson, Minister for Universities and Science in the UK, recognized this dilemma in a 2017 speech to the Higher Education Funding Council for England when he discussed potential solutions to poor commercialization strategies of UK research (McKernan, 2017):

“Our universities need to find a new gear and accelerate the adoption of the best practice on research commercialization that already exists in some of our universities so that it becomes mainstream.”

Other industry observers have also claimed that “Oxford's example is being replicated around the country by many other universities” (Court, 2001). But managers of some TTOs do not think that imitating the commercialization strategies of industry leaders like Oxford and Cambridge is always a good idea. One TTO manager we interviewed noted:

“Oxford, Cambridge and Imperial, because they are the biggest research powerhouses in the UK, they kind of led the pack in developing ways of commercialization and other universities have found it difficult to emulate them because other universities do not have the volume of deals to be done (the pipeline of innovation) [...] The Royal College of Arts are pushing ahead and are doing things that other people are not necessarily doing... I think it might be so much going their own way as having the imagination and the clout to get things going and to lead on certain developments. Whereas I'm quite happy being a follower and picking and choosing what I think works in our context.”

The purpose of our study is to develop theory on the conditions under which TTOs decide to imitate others or to strategize independently.

Information-based theories of imitation (Lieberman and Asaba, 2006), arising from the fields of economics and sociology (Abrahamson and Rosenkopf, 1993; DiMaggio and Powell 1983; Levitt and March 1988) are the starting point of this paper. These theories argue that when *uncertainty* is high, organizations tend to imitate successful others because they believe that the latter have more information about the likely outcome of strategic actions or because they think that imitation can legitimate their position in the eyes of stakeholders. This central tenet of information-based imitation has been tested in several organizational settings, like

savings and loan associations (Haveman, 1993), aircraft manufacturers (Greve and Seidel, 2015), banks (Greve, 2000), radio stations (Greve, 1996; Greve and Taylor, 2000) and mobile phone vendors (Giachetti and Lampel, 2010; Giachetti and Lanzolla, 2016). If information-based motives for imitation also hold in the academic entrepreneurship field, we should expect TTOs to imitate the best performing TTOs in order to mitigate uncertainty.

However, contrary to most studies in the information-based imitation literature whose empirical settings are stand-alone firms, in the commercialization industry the freedom that TTOs have to strategize depends on the extent to which their parent universities grant them autonomy. Studies have shown that TTOs can take different organizational forms – e.g., a team of scientists within the university, a department within the university, an independent company or even a listed firm – which carry different degrees of autonomy when they commercialize (Bercovitz et al., 2001; Markman et al., 2005). Indeed, calls in the TTO literature to explore the strategic behavior of TTOs (Djokovic and Souitaris, 2008) within different organizational structures (Markman et al., 2005) remain unanswered. In this paper, we ask the following questions: (a) How does the autonomy of a TTO affect its commercialization strategy against the most successful TTO in the industry? (b) Which sources of information does a TTO use to decide whether or not to imitate others in order to mitigate uncertainty in the university commercialization industry? First, we argue that TTO autonomy unleashes creativity and fosters independent strategizing, thereby increasing the likelihood that a TTO will ignore what successful peers do. Second, we argue that TTOs cope with uncertainty by drawing information from their own experience (a function of their age) and from their participation into an industry network where the most successful TTO is also a member. We expect these two variables to moderate the TTO autonomy-imitation relationship.

By investigating how information-based motives for imitation work in the university

commercialization industry, our study complements information-based theories of imitation and the literature on academic entrepreneurship in several ways. First, previous studies have examined imitation by looking at the characteristics of the industry leaders (e.g., their strategy or prestige) (e.g., Baum, Li, and Usher, 2000; Giachetti and Torrissi, 2018; Haveman, 1993) or the characteristics of the industry (e.g., uncertainty, volatility, information asymmetry) (e.g., Semadeni and Anderson, 2010) but there is a shortage of studies that look at the characteristics of the followers themselves (Massini, Lewin, and Greve, 2005). Our study is the first to look at the organizational structure of the follower and specifically at the autonomy of a TTO, that is, the degree to which it has authority to strategize independently (Huyghe et al., 2014). Autonomy has been shown to be important for TTO strategies (Markman et al., 2005) but the literature has yet to explore whether autonomy enables or constrains TTO imitation of its peers.

Second, our study contributes to information-based theories of imitation by looking at how different sources of information affect the way TTOs mitigate uncertainty, and in turn decide whether or not imitate successful others. We argue that in a context characterized by high uncertainty about the likely outcome of strategic decisions, as the university commercialization industry, TTOs use two sources of information before deciding whether to imitate or not successful others: (a) their own stock of information and knowledge about commercialization strategies cumulated over their life cycle, what authors have called “experiential learning” (e.g., Baum et al., 2000), and (b) the stock of information and knowledge absorbed from the observation of successful others, also referred to as “vicarious learning” (e.g., Greve, 1996, 1998; Haunschild, 1993). By integrating research on how different sources of information affect inter-organizational imitation (e.g., Baum and Dahlin, 2007; Simon and Lieberman, 2010) with insights from research on academic entrepreneurships and TTOs, our paper advances the imitation literature by shedding light on

the interplay between TTOs' autonomy and their tendency to rely on internal or external sources of information.

We finally address an enduring gap in the academic spinoffs literature, an area with huge policy implications for both economic and social reasons. Despite some exceptions (e.g., Lockett, Wright and Franklin, 2002), leading scholars in the academic entrepreneurship field have recently lamented that we lack explanations as to how TTOs strategize when commercializing scientific innovations (Yuan, Li, O Vlas, and Peng, 2018), especially in light of (a) the environmental uncertainty that TTOs face (Zahra et al., 2018), and (b) the different organizational structures they may exhibit (Markman et al., 2005). Moreover, while the few studies in the technology transfer field that deal with imitation look at how TTOs patent product innovations and how these “tangible” innovations are imitated by others (e.g., Fosfuri, 2000; Sun et al. 2010), our paper is the first to examine the imitation of “commercialization strategies”, i.e. the set of initiatives put in place by TTOs to launch innovations to the market. We specifically focus on the imitation of commercialization strategies that comprise of TTO joint-ventures and outsourcing agreements. We test our hypotheses with a sample of 86 British university TTOs and their commercialization strategies between 1993–2007 using both secondary data and in-depth interviews with TTO managers.

THEORETICAL BACKGROUND

Information-based theories of imitation

In their review of the imitation literature, Lieberman and Asaba (2006) observe that while rivalry-based theories of imitation, arising from the competitive dynamics literature, focus on how firms imitate industry peers to remain competitive or to limit rivalry (e.g., Giachetti, Lampel, and Li Pira, 2017; Smith, Grimm, Gannon, and Chen, 1991), the basic premise of the information-based theories of imitation is that firms imitate others in an attempt to cope with

the uncertainty they face in their business environment (e.g., Baum, Li, and Usher, 2000; Bikhchandani et al., 1992, 1998; DiMaggio and Powell 1983; Haveman, 1993; Haunschild and Miner, 1997; Levitt and March 1988). According to this stream, when uncertainty is high, firms follow others and particularly those they believe to be possessing superior information, usually market leaders or most successful peers in general (Lieberman and Asaba, 2006).

Moreover, some authors have suggested that imitation of successful peers might be driven by both a “technical rationale” and a “social rationale” (e.g., Haunschild and Miner, 1997). The technical rationale is that, in the absence of clear information, successful peers serve as a valid proxy indicator that a practice has technical value (Abrahamson and Rosenkopf, 1993). For example, Giachetti and Lampel (2010) and Giachetti and Lanzolla (2016) have shown that, in the U.K. mobile phone industry, when uncertainty about consumer preferences and product technologies was high, handset vendors imitated product strategies of the market leader, because the latter was perceived as being more informed about how the product characteristics would evolve. On the other hand, the social rationale is that, when faced with legitimacy challenges emanating from uncertainty in the environment, organizations imitate the most successful organizations that enact and legitimize practices with a taken-for-granted status (Fombrun and Shanley, 1990; Hannan and Carroll, 1992). For example, Haunschild and Miner (1997) showed that US firms doing acquisitions legitimated their status in the eyes of stakeholders by following successful peers when selecting the investment bank that advised them on the deal, especially when there was high uncertainty about the acquisition target. Technical and social information-based motives for imitation have also been observed by Greve and colleagues in various studies in the US aircraft industry (Greve and Seidel, 2015), in the Tokyo banking industry (Greve, 2000), and in the US radio broadcasting industry (Greve, 1996, 1998; Greve and Taylor, 2000).

What is more, authors in the information-based imitation literature have argued that firms can draw mainly on two sources of information before deciding whether to imitate or not: (1) information *internal* to the firm that is a function of the firm's prior experience with a particular strategic behavior, i.e. what authors have called "experiential learning", and (2) information *external* to the firm that is observable in the external environment when firms look at what other industry members do, i.e. what authors have called "vicarious learning" (e.g., Baum et al., 2000; Greve, 1996, 1998; Haunschild, 1993; Strang and Macy, 2001). A large body of research has demonstrated that, when firms learn vicariously, they tend to imitate industry peers, whereas firms that learn from their own past behavior tend to deviate from industry peers. Various authors have also noted that, although firms usually combine vicarious learning with experiential learning (Baum and Dahlin, 2007; Cyert and March, 1963; Simon and Lieberman, 2010), the greater their familiarity with a given strategic domain, the lower the influence of the industry peers' actions will be on the focal firm's decision to imitate (Lieberman and Asaba, 2006).

Surprisingly, no study in the information-based literature has so far examined the interplay between the sources of information a firm draws upon when imitating strategies and its organizational structure, e.g. the extent to which its autonomy is determined by its parent organization. The purpose of this study is to investigate this interplay in the setting of university TTOs.

University TTO autonomy and commercialization strategies

In the past two decades, the literature on university commercialization has grown exponentially. Although university commercial activities were initially met with fierce protests because they were seen as altering the nature of academia away from teaching and research (Bok, 2003), scholars have recently shown that these practices have not only gained legitimacy but have become institutionalized (Clayton et al., 2018; Hmieleski and Powell,

2018). This transformation among higher education institutions has been possible through targeted government legislation (e.g. the Bayh-Dole Act in the USA), scientists' efforts to establish authority and meaning to commercial practices and university structures that standardized commercialization across countries (Colyvas, 2007; Owen-Smith, 2011).

The most important structural change within universities was the establishment of Technology Transfer Offices, the key vehicle for commercialization. Jensen et al (2003) argue that TTOs are the dual “agents” of a faculty and the overall university that aim to serve the objectives of these principals. TTOs diffused rapidly in the past two decades and assumed the responsibility for disclosing inventions and for evaluating their patentability, their technological validity and their commercialization potential. TTOs also mitigate the uncertainties around the value of the commercialized innovations (Debackere and Veugelers, 2005) and, as intermediaries, they mitigate the asymmetry of information between universities and the industry (Buenstorf and Schacht, 2013; Gallini and Wright, 1990; Huyghe et al, 2014).

To achieve these objectives, TTOs exhibit different structures within university hierarchies. In a historical review, Jong (2006) showed that U.S. universities had no particular commercialization structure in the 1970s and that scientists commercialized their ideas through the “founding laboratories” that were embedded in their departments; these laboratories exhibited different levels of autonomy and collaboration with outside departments of the same university. Since then, several scholars have examined the more sophisticated structures of contemporary TTOs. Bercovitz et al. (2001) showed that TTOs can have a functional or unitary form (U), a multidivisional form (M), a holding company form (H) or a matrix structure (MX) that differ in terms of their autonomy, strategic information-processing capacity, coordination capability and alignment of incentives for commercialization. Further, Markman et al. (2005) identified three TTO archetypes: as a

traditional structure, as a non-profit foundation and as a for-profit venture, each of which has increasing autonomy to devise its own commercialization strategy. More recently, Corsino, Giuri, and Torrisi (2018), Huyghe et al. (2014) and Pitsakis et al. (2015) showed that TTOs are units with more or less centralized roots in a university that enjoy different degrees of autonomy. TTOs that are decentralized enable commercialization to take place autonomously with groups or individual inventors (Debackere and Veugelers, 2005) and TTOs that are centralized work less autonomously with inventors at the research group or departmental levels. There are also “hybrid” TTO structures that exhibit a moderate level of boundary-spanning autonomy for commercialization.

Given their varying degrees of autonomy, TTOs can choose among many commercialization routes, e.g. patenting (Azoulay, Ding, and Stuart, 2005), licensing (Owen-Smith, 2011) or spin-offs (Pitsakis et al, 2015). Our study focuses on commercialization via spinoffs and defines these firms as entities that are spun-off and partly owned by TTOs based on university-owned intellectual property (Shane, 2004). Spinoffs are perhaps the most important and profitable vehicles for commercialization, contributing millions to university budgets (Pitsakis et al, 2015). However, despite the fact that TTOs that endeavor to form spinoffs have grown to incorporate strategic mission statements (Fitzgerald and Cunningham, 2016), we still know little about their full commercialization strategies.

Recent studies by Barletta et al. (2017) and Bekkers and Freitas (2008) looked at TTO strategies via interfirm collaboration. They argue that joint R&D projects among TTOs or between TTOs and external organizations have often led to commercialization via *joint venture* spinoffs. Other authors have examined commercialization strategies when TTOs *outsource* all or parts of their IP portfolio to private firms (Derrick, 2015; Etzkowitz, 2003).

Overall, these commercialization strategies have led academic entrepreneurship scholars to pay increasing attention to TTOs. Hong and Walsh (2009) have argued forcefully that

selecting the appropriate commercialization strategy is a non-trivial process for TTOs, with inevitable consequences for the revenue-generating capabilities of the spinoffs they launch. However, although authors have noted that a TTO's ability to develop "best practices" is paramount to successful commercialization (Shibayama et al, 2012), the literature has considered isolated and individual TTO strategies. Given the underlying uncertainty that persists in the industry, it is worth considering whether TTOs imitate each other's commercialization strategies. To answer this question, we build on information-based theories of imitation but we first discuss the importance of TTO autonomy within the larger university structure.

HYPOTHESES

TTO autonomy and imitation of the most successful TTOs

Scholars have shown that centralizing decision-making in organizations that manage divisions is less likely to be effective than granting autonomy to those divisions. This is because centralization has a negative impact on the variety of learning patterns, reducing a division's ability to understand its complicated business environment and to develop close relationships with counterparts, therefore diminishing its potential (Ambos and Birkinshaw, 2010). Staw, Sandelands, and Dutton (1981) and Shimizu (2007) have shown that strong control by the parent organization causes lack of flexibility to divisions and increased rigidity during times of uncertainty. What is more, whereas open structures with increased autonomy can help mobilize organizational resources and creativity while strategizing (Ambos and Birkinshaw, 2010), centralization limits the degree to which managers can take risk – an important prerequisite to differentiate against rivals. This would suggest that tightly controlled divisions within organizations are less likely to act creatively and more likely to imitate their industry peers.

The link between creativity and a firm's propensity to take risk is at the heart of our argument. Since greater autonomy is likely to unleash creativity with the aim of strategizing differently from others, risk taking might also increase as creativity escalates. As noted by organizational theorists, organizations that enjoy a high level of autonomy tend to have teams that are inclined to explore new business landscapes and assume high risks, thus facing legitimacy challenges in the eyes of stakeholders (Haas 2010). In fact, "a firm which selects strategies outside of the range of acceptability does so at its own peril. It is subject to questions and actions challenging its legitimacy, reliability, and rationality" (Deephouse, 1999: 152). Likewise, imitation theorists have noted that, "pursuing a differentiation strategy [...] is often difficult and risky. A firm cannot be certain that the new position or niche will be superior. Faced with a choice, firms therefore often choose to pursue homogeneous strategies, where they match the behavior of rivals in an effort to [...] reduce risk" (Lieberman and Asaba, 2006: 374).

In line with this perspectives, we should expect that TTOs with greater autonomy are less likely to imitate the commercialization strategies of successful others because they are free to unleash their creativity and to assume risks when designing their commercialization strategies. We elaborate on this as follows.

In the TTO literature, scholars have shown that autonomy has a positive impact on TTO strategizing because it unleashes creativity (Debackere and Veugelers, 2005). For a TTO, being "creative" means exploring alternative commercialization methods that may be dissimilar to what other TTOs are doing. For example, a TTO can commercialize university innovations with a greater or lower focus on joint ventures or by outsourcing its IP to external partners more or less often than industry peers. Tello, Latham and Kijewski (2010) have observed that the autonomous TTO becomes more attractive to inventor scientists, it can select its own production equipment, it can devise its own training methods and it can decide

on how to commercialize innovations independently. As noted by Corsino et al. (2018: 5), “the implications of autonomy for corporate spinoffs are likely different when employees enjoy strategic autonomy [...] Strategic autonomy introduces individuals and teams to higher levels of decision making and allows them to explore business opportunities outside the established chain of command and current corporate strategy”. There is, therefore, a clear link between a TTO’s autonomy and its propensity to design commercialization strategies that deviate from the *status quo* in the industry (Bercovitz et al, 2001; Huyghe et al, 2014). Indeed, Markman *et al.* (2005) have shown that autonomous TTOs exhibit greater creativity in the exploitation of internal resources, most notably management of IP and business development and tend to have a “proactive” approach to innovation, less dependent on what “best practices” would suggest. This means that, despite the high environmental uncertainty in which TTOs operate, a high degree of autonomy is likely to make TTO strategies less dependent on what successful peers do, so that TTOs take more risks when they design their commercialization strategies.

Usually, TTOs rely to varying degrees on commercialization partnerships with external organizations in the form of outsourcing (Derrick, 2015) or joint ventures (Bekkers and Freitas, 2008). We contend that since autonomous TTOs have more freedom to decide the extent to which they rely on outsourcing and joint ventures, they will exhibit greater creativity and more risk-taking in their strategies, thus differentiating themselves from industry peers. For instance, autonomous TTOs may allocate responsibilities or areas of work according to their market needs and they may select suppliers or other business partners freely (Huggins et al, 2008). By contrast, TTOs with lower autonomy would be less free to face legitimacy challenges when they decide to commercialize with external actors and, given environmental uncertainty, they would tend to imitate successful peers. Debackere and Veugelers (2005) have shown that a high degree of TTO financial and managerial

independence facilitates relations between the TTO and third parties such as venture capitalists, investment bankers and patent attorneys. We thus expect autonomy to make TTOs less reliant on others' strategies so that TTOs develop their own commercialization strategies by autonomously deciding how intensely to use joint ventures and outsourcing.

We believe that the rationale for lower information-based imitation by autonomous TTOs is both "technical" and "social" in nature (Haunschild and Miner, 1997). Indeed, autonomous TTOs will prefer to strategize independently than to rely (a) on information from successful peers to design effective commercialization strategies (technical rationale) or (b) on the more legitimated nature of peer's prior decisions in the eyes of stakeholders (social rationale). In sum, information-based theories of imitation (Lieberman and Asaba, 2006) suggest that in environments characterized by high uncertainty about the outcome of strategic decisions, a TTO may look at successful TTOs in the industry as a benchmark for its strategy. This would hold more for TTOs with low autonomy that are unable to form independent commercialization strategies. We hypothesize:

Hypothesis 1. There is a negative relationship between a TTO's autonomy and its imitation of the commercialization strategy of the most successful TTO in the industry.

The moderating effect of TTO age

Organizational learning theorists have long contended that organizations learn both from their own past experience (i.e., experiential learning) and vicariously by observing the behavior of other organizations (Baum *et al.*, 2000; Cyert and March, 1963; Terlaak and Gong, 2008).

While firms with long experience with a practice are less likely to pay attention to the strategic decisions of others because they are confident to have enough information about "what is right or wrong", learning (vicariously) from other organizations can be seen as an "exploratory" process of knowledge acquisition that is more likely to be used when the organization's own experience provides inadequate guidance to navigate risk and uncertainty

in their business environment (Henisz and Delios, 2001). Authors have also noted that firms that learn experientially tend to deviate from the behavior of the other industry members, while firms that learn vicariously tend to imitate the behavior of organizations they observe, with successful peers capturing most of the attention (e.g., Simon and Lieberman, 2010; Srinivasan, Haunschild, and Grewal, 2007).

Some authors have argued that the experience firms perceive to have about the environment is related to their *age*, and that a firm's likelihood of engaging in strategic change depends on its age (Guillén, 2002). Age has been described as a potentially important variable affecting a firm's decision either to follow others or to determine its own course of action. One theoretical viewpoint developed in many studies is that firms become more self-confident in strategic decision-making through the experience they cumulate over time (Baum *et al.*, 2000; Guillén, 2002; Rhee, Kim, and Han, 2006): the older the firm, the more it learns from its past choices and becomes confident on its ability to cope with risks in uncertain environments, and the less likely it is to adapt to what peers do (Sandroni and Squintani, 2013). The rationale for this is both technical and social. "Technical" in the sense that the knowledge of the environment that a firm has accumulated over time reinforces its adopted course of action and its belief that there are no better alternatives to this course of action. With the passage of time, increasing self-confidence decreases a firm's propensity to act upon information received from other organizations, thus lowering the degree of imitation of its peers (Guillén, 2002). The "social" rationale is that with high self-confidence in strategic decision making, an old firm believes its actions are already legitimated in the eyes of stakeholders and there is no perceived need to "follow the leader" (Haveman, 1993) to legitimate its position further.

In light of these arguments proposed by organizational learning scholars, we expect that given the high uncertainty inherent in its business environment, the younger the TTO, the less

self-confident it will be with its commercialization strategy and the higher the need to follow a reference target to mitigate uncertainty. On the other hand, the older the TTO, the more self-confident it would be about the likely output of its commercialization strategy and the lower its need to reduce uncertainty by drawing from successful others. This means that, in the case of an old TTO, because of the relatively high experience it believes it has of the environment, it will not look at successful others as more informed about the environment or as being more legitimated in the eyes of stakeholders. Information-based motives for imitation are, therefore, likely to play a weak role (or no role at all) in driving the TTO's strategy relative to successful peers. Indeed, recent work by Owen-Smith (2003) and Rogers et al. (2000) has shown that older TTOs possess higher "experiential learning" and are able to spin-off ventures more independently than younger TTOs. Based on this discussion, we hypothesize:

Hypothesis 2a. There is a negative relationship between a TTO's age and its imitation of the commercialization strategy of the most successful TTO in the industry.

Moreover, drawing on the above arguments regarding experiential learning and self-confidence in strategic decision making, we expect that a TTO's age will moderate the relationship between the TTO's autonomy and its imitation of the most successful TTO in a way that it becomes more negative. On the one hand, the higher the TTO's autonomy, the higher its propensity to strategize independently, for example when it decides how intensively to rely on outsourcing or joint ventures to commercialize academic research (Hypothesis 1). On the other hand, the autonomous TTO's propensity to distance itself from the most successful peer (and face legitimacy challenges in the eyes of stakeholders) will grow with the experience it has accumulated through the years. This pushes the autonomous TTO to increasingly believe it can assume risks that distance it from best practices, and to decide its strategy without the need for informed or legitimated references. This is because,

although autonomous TTO decision makers cannot initially be certain of the outcomes of their commercialization strategies, with repetition they gain experience and confidence and, over time, their understanding and capabilities improve (Owen-Smith, 2003). This process increases their confidence in facing legitimacy challenges by differentiating themselves from peers, the most successful TTO included. We, therefore, hypothesize as follows:

Hypothesis 2b. The relationship between a TTO's autonomy and its imitation of the commercialization strategy of the most successful TTO in the industry is negatively moderated by the TTO's age.

The moderating effect of a TTO membership into an association where the most successful TTO is also a member

The literature on inter-organizational imitation provides extensive evidence of how firms learn vicariously from successful peers. Imitation of this sort has been found in a broad range of decisions, like market entry (e.g., Greve, 1998, 2000; Haveman, 1993) and new technology adoption (e.g., Giachetti and Lampel, 2010; Greve, 1996, 1998; Greve and Seidel, 2015; Simon and Lieberman, 2010). We contend that a TTO's likelihood of learning vicariously from successful others and of imitating their commercialization practices is contingent upon its embeddedness in a network where successful others are also present.

Studies in the literature on inter-organizational relationships have shown that it is particularly advantageous for firms to be part of some form of network or association (Dacin, Oliver, and Roy, 2007). Industry associations, in particular, are governance bodies that self-regulate the industry to which their members belong (King and Lenox, 2000). They can be found in for-profit but also in non-profit organizational settings, such as public education, and they involve members from a variety of stakeholders such as education, the government, research institutions and private firms (Swan and Newell, 1995). Associations help their members to share knowledge, resources and best practice so that participant firms can

develop their strategies. Through their members' actions, these networks also enhance their members' legitimacy and performance (Oliver, 1990).

Organizations that operate in uncertain environments overcome uncertainty by collecting, sharing and using information through their network. For instance, members lobby collectively against impending threats in the environment (Greenwood, Suddaby and Hinings, 2002). They also combine product and process information via joint publications to promote collective practices such as trade shows (Oliver, 1990). These members also share information about less expensive suppliers, market opportunities or legal assistance (Greenwood *et al.*, 2002) and reduce uncertainty by crafting standards and guidelines that stabilize markets (e.g. certification), through their collective knowledge. Finally, associated organizations shape their image by processing and disseminating information to audiences (Barnett and King, 2008).

Theories of social networks (e.g., Gulati, Nohria, and Zaheer, 2000) suggest that organizations linked to greater network ties are likely to have access to key information about each other, which facilitates imitation. Likewise, authors have found that imitation is more likely among firms that share ties with larger organizations (Greve, 1996; Haunschild, 1993). There is evidence that what we know about the importance of such networks on the decision-making process of firms holds equally well for TTOs. In general, collaborative networks are excellent learning opportunities for universities whose TTOs may not have the necessary knowledge and resources to develop commercialization strategies independently (Huggins et al, 2008). For instance, it has been shown that universities draw knowledge from the external network partnerships they are embedded in and use that knowledge for innovation within their TTOs (Owen-Smith and Powel, 2003). Effectively, boundary-spanning individuals of a TTO monitor the body of knowledge available in the network and transfer that knowledge into their own strategies.

Because the collection and sharing of knowledge and information within the association is the main vehicle through which TTOs combat environmental uncertainty and devise their commercialization strategy, it is expected that TTOs may imitate the most successful TTO in the industry, especially when they are members into an association where the most successful TTO is also a member. The rationale for this imitation process is both technical and social. Since the most successful TTO in a network will be perceived as having more knowledge and information about the industry and what constitutes good commercialization within it (“technical” rationale), and since its commercialization strategies are perceived as more legitimated in the eyes of stakeholders (“social” rationale), a focal TTO may use it as a reference target. This leads us to the following hypothesis:

Hypothesis 3a. TTOs that are members into an association where the most successful TTO is also a member have higher levels of imitation of the commercialization strategy of the most successful TTO than TTOs that are not members of that association.

Moreover, although we expect a negative relationship between a TTO’s degree of autonomy and its level of imitation of the most successful TTO’s strategy (Hypothesis 1), we also expect this relationship to be moderated positively (i.e. to become less negative) by the extent to which the TTO is member of an association of which the most successful TTO is also member. Some authors have showed that TTOs with high autonomy to strategize independently (e.g. independent or listed TTOs) that are also embedded within external relationships like industry associations, tend to conform to norms legitimated within these networks (Bekkers and Freitas, 2008; Colyvas and Jonsson, 2011). The reason is that, although their organizational structure would seem to be appropriate for experimenting with “unconventional” and risky commercialization strategies that do not conform to industry best practices, the fact that they are part of a network exposes their learning process to the

behavior of network members. This implies that TTOs in a network will inevitably tend to draw information about how to strategize from network members, even though they enjoy high autonomy.

We contend that this tendency to learn vicariously is particularly evident when the focal TTO is embedded in a network where the most successful TTO is also a member. That is because, given the high uncertainty inherent in the performance outcomes of commercialization strategies, the strategic behavior of successful network members is likely to not go unnoticed. This means that the fact that an autonomous TTO coexists with the most successful peer in an association is likely to diminish the TTO's independent strategizing and the TTO will increasingly resort to imitation as a response to uncertainty. We hypothesize as follows:

Hypothesis 3b. The relationship between a TTO's autonomy and its imitation of the commercialization strategy of the most successful TTO is positively moderated by the TTO's membership into an association of which the most successful TTO is also a member.

Figure 1 shows our conceptual framework.

<< Insert Figure 1 about here >>

METHODS

Empirical setting: the U.K. spinoff industry

We test our hypotheses in the context of the U.K. spinoff industry. Over the past two decades, U.K. universities have experienced a "revolution" in their traditional mission, moving from teaching and research to embrace commercial activities and economic impact (Etzkowitz, 2003). In 1993, a British government White Paper (HM Treasury, 1993) urged universities to pursue innovation to increase their financial self-reliance and most institutions started founding Technology Transfer Offices, vehicles that would deliver technology commercialization. Since then, British TTOs have commercialized more than 1,400

university innovations via spinoffs.

There are good reasons that make our empirical context well suited to examine information-based theories of imitation, given the uncertain nature of the U.K. spinoffs industry since the 1990s. First, the value of the spinoffs that TTOs create is difficult to estimate as these ventures often fail within the first three years of operations (Shane, 2004). By extension, commercializing knowledge via spinoffs has been a risky strategy that has brought about financial losses and criticism for some universities (Bok, 2003). Second, there has been technological uncertainty as to which inventions and discoveries can best be commercialized and what value spinoffs have in the venture capital market (Bok, 2003; Shane, 2004). As noted by a TTO manager we interviewed:

“We were in a consortium and we put a lot of money at potential academic spinouts and we got 1 out of probably half a dozen that were funded. That was seen as a poor return on investment and there is no activity there now [...] There is a lot of uncertainty and it is about whether we can find the market for an idea. There is also uncertainty about whether an academic can take that idea forward.”

Third, the industry has been largely unregulated and government initiatives to reward commercialization have been vague and unclear. As a result, the spinoffs industry has experienced persistently high environmental asymmetry, making the strategies of leading TTOs a potential imitation target for TTOs with lower resource endowments and knowledge for innovation. In contrast to that, from the in-depth interviews we conducted, it became clear that autonomy fosters creativity among TTOs, and their propensity to take risky, “unconventional” strategic decisions increases even if that leads to negative performance outcomes. As noted by one of our informants:

“I think [our TTO] has more autonomy than they give themselves credit for and they’ve made a lot of crap decisions based on that autonomy. They wasted an enormous amount of money; they made a lot of mistakes over the last few years in the area of commercialization and knowledge transfer etc. They’ve ignored funding and structural opportunities and curiously they have a lot of autonomy to make mistakes.”

Data collection

We gathered data on the full population of spinoff-active English and Scottish universities (86) and their spinoff firms (1,404) from 1993 to 2007. Our unit of analysis is the TTO and each university has exactly one TTO. We collected most data directly from TTOs and supplemented it with information from secondary sources and publications such as those of the Higher Education Statistics Authority (HESA). Our analysis begins in 1993, which is considered to be a significant year for the spinoff industry boom in the U.K. after the publication of a relevant government White Paper, aimed at presenting the government's policy preferences about how to reform the university commercialization industry (HM Treasury, 1993). The White Paper placed TTOs' commercialization practices under greater scrutiny by the national authority and forced TTOs to make information about their strategic conduct publicly available, thereby easing our data collection. Our study observation period ends in 2007 because of the upcoming global financial crisis, which severely hit the U.K. economy, as well as U.K. universities and their TTOs, e.g. their decision to deploy resources to follow or deviate from industry peers' commercialization practices.¹

Spinoffs in our sample can be divided into three categories based on the economic activity they belong to: biotechnology, engineering and services. Figure 1A shows the TTO average spinoff revenue and average spinoff numbers per macro-economic activity in our sample.²

Dependent variable

Level of imitation of the most successful TTO in the industry (i.e., the commercialization leader). We looked at the “most successful TTO” in the industry in terms of the extent to which it is active in commercializing innovations via spinoffs and the extent to which it is able to generate revenues from this commercialization strategy. More specifically, we define

¹ It is worth noting that our panel is unbalanced. This is because some TTOs in our sample began to commercialize academic research via spinoffs after 1993, other TTOs remained inoperative for years, and some entered the industry again after having been inoperative for one or more years.

² To give an example of what is reported in Figure 1A: in 1998, the TTO average spinoff revenues in the biotech sector was nearly 3,000,000 GBP (at 2007 prices), while the TTO average spinoff numbers was nearly 0.4 (i.e., four spinoffs in the biotech sector were created for every ten TTOs).

commercialization leadership as a multidimensional construct, determined by a TTO's commercialization activity in terms of *spinoff numbers*, and *revenues from the commercialization of spinoffs*. We identified two leading TTOs, the TTO of the University of Oxford in the period 1993–2005 and the TTO of the University of Cambridge for the remaining two years, based on an index that combined the contemporaneous size of the TTOs' live spinoff portfolio (i.e. births-deaths³) and the combined revenues that a given portfolio produced each year. To do this, we first normalized the two measures by dividing them by their maximum values in the sample to change them from counts to ratios. Our final measure of commercialization leadership was then computed as follows:

$$\text{Commercialization Leadership}_{i,t} = \frac{\left(\frac{\text{live_spinoffs}_{i,t}}{\text{live_spinoffs_max}}\right) + \left(\frac{\text{spinoff_revenues}_{i,t}}{\text{spinoff_revenues_max}}\right)}{2} \quad (1)$$

The commercialization leader is the TTO with the highest value from equation (1). It is worth noting that our measure of leadership does not consider only the performance (i.e. revenues) of a TTO's portfolio but it also captures a TTO's propensity to commercialize via spinoff initiatives.

Having defined the commercialization leader, the first step in developing the imitation index was to define the object of the imitation, i.e. the set of commercialization strategy variables. We used the following two commercialization strategy variables that emerged both from our literature review and from the interviews we conducted:

A) *Outsourcing intensity*, measured as the number of spinoff deals outsourced to external private firms. In the academic entrepreneurship field, it is common for TTOs to outsource their innovation activities by signing long-term contracts that provide external organizations (e.g., IP Group plc: www.ipgroupplc.com) with full or partial access to their IP portfolio or licensing revenue streams (Derrick, 2015). We expect that the more autonomous a TTO, the

³ We assumed that TTOs would have a better understanding of the leader's commercialization strategy if they observed both its newly established spinoffs and those that had recently ceased operations.

more it would make decisions about how many outsourcing deals to conduct without paying attention to commercialization leaders, resulting in a different (i.e. greater or lower) level of outsourcing intensity.

B) *Joint venture intensity*, measured as the number of joint spinoffs established with other TTOs. This strategy aims to create synergies between the intellectual capitals of two or more teams of academic inventors across TTOs to increase the chances of commercialization (Barletta et al, 2017; Bekkers and Freitas, 2008). As in the case of outsourcing intensity, we expect that the more autonomous a TTO, the more it would make decisions about how many joint ventures to develop without paying attention to the most successful TTOs, resulting in a different (i.e. greater or lower) level of joint venture intensity.

Information on the two strategy variables was collected directly from the universities. All universities were contacted by email and were asked to provide a range of information about their spinoffs and particularly about their outsourcing and joint venture agreements. This information concerning TTOs' strategies was triangulated with public information available on each TTO's website, with public documents and on some occasions with personal interviews with TTO Heads.

Second, for each of the two strategies described above, we computed the absolute deviation (Euclidean distance) between the TTO i strategy at time t and the commercialization leader j strategy at time $t-2$ (i.e.: $|S_{i,t} - S_{j,t-2}|$). We assumed that a smaller absolute deviation between the TTO's strategy and the strategy of the commercialization leader indicates greater imitation of the leader (Baum *et al.*, 2000; Deephouse, 1999; Giachetti and Torrisi, 2018).

One of the TTO managers we interviewed was particularly explicit about the importance of following TTO leaders' way of doing partnerships to commercialize academic research,

and about the reason why a two-year time lag was an appropriate window to account for the time that is needed for a TTO to react to the leading TTO's strategy:

"I spend time looking at other university websites to see what they are doing in whatever area it happens to be in order to see what kinds of deals they've done and, over the years, I've tried to talk to a lot of people who've done those to understand how that better works. And then, once I hear about it (e.g. at Imperial), I got funding in about 10 months [...] But I think they'd been at it for 2 or 3 years already and I didn't know about it."

We then integrated these two measures into a composite measure of imitation of the leader. To do this, we first normalized the two measures by dividing them by their respective maximum values in the sample to change them from counts to ratios.

Our final measure of imitation was computed as the difference between 1 and the average of the two ratios as follows:

$$\text{Imitation}_{i,t} = 1 - \frac{\sum_{a=1}^2 (|S_{a,i,t} - S_{a,j,t-2}| / (1 + \max \Delta S_{a,t}))}{2} \quad (2)$$

where $S_{a,i,t}$ is the TTO i strategy a at time t and $S_{a,j,t-2}$ is the leader j strategy a at time $t-2$, and $\max \Delta S_{a,t}$ is the maximum value of $|S_{a,i,t} - S_{a,j,t-2}|$. This measure of imitation takes values ranging from 0 to 1, with 1 representing the highest level of imitation of the commercialization leader in the sample. It is worth noting that we used a composite index of imitation to capture the simultaneous effect of different types of imitative behaviors. For instance, a change in one type of imitation (e.g., JV intensity) may be offset or balanced out by variations in the other type (outsource intensity) and vice versa. Composite indices of imitation have been used by various authors (e.g., Deephouse, 1999; Giachetti and Torrisi, 2018) who do not look at imitative behaviors in isolation but measure a firm's overall propensity to imitate across several dimensions.

Of course, universities are of different sizes and have different specializations (e.g., some have no medical school), therefore, not all TTOs start with the same intellectual capacity to commercialize. To account for this, we ensured that the strategy values for the focal TTO and

the leader were divided by the number of submissions made by their parent to the Research Assessment Exercises (RAE) in 1992, 1996 and 2001 (e.g. www.rae.ac.uk/1992). In RAE exercises (now replaced by the “Research Excellence Framework”), each university specifies the number of academic scientists (i.e. potential innovators) that are active in a list of maximum 72 units of assessment or scientific fields. For example, if a university had made 10 submissions in 5 scientific fields, its TTO would have started from a disadvantaged position compared to a TTO that relied on 50 submissions in 20 scientific fields. The formula we used for the RAE-weighting was as follows:

$$\text{RAE-weighting} = \frac{\text{RAE}_{i1} \cdot \mu_{i1}}{72} + \frac{\text{RAE}_{i2} \cdot \mu_{i2} + \text{RAE}_{i3} \cdot \mu_{i3}}{69} \quad (3)$$

where RAE_{i1} is the RAE of 1992 with 72 units of assessment and RAE_{i2} and RAE_{i3} are the RAEs of 1996 and 2001 with 69 units of assessment and μ_{ij} is the number of scientists who submitted their work in each RAE exercise.

The commercialization leaders we identified by means of equation 1 were corroborated by a set of in-depth interviews with the Heads of seven representative TTOs (Table 1A, Appendix). Quotes reported in Table 2A in the Appendix, confirm that most Heads were aware that the TTOs of Oxford and Cambridge are the leaders in commercialization.

Independent variables and moderators

Consistent with the response time we used to calculate the imitation index (equation 2), all independent variables (moderators and controls included) were lagged by two years.

TTO autonomy. Like other studies in the TTO literature, we defined our main independent variable “TTO autonomy” as a count measurement (Corsino et al., 2018), ranging from 0 to 4, where 0 indicates the lowest level of autonomy and 4 the highest. Specifically: “0”, the TTO comprised of few business development professionals; “1”, the TTO was a team within a university department (Jong, 2006); “2”, the TTO was a department within a university (Jong, 2006); “3”, the TTO was an independent company of the university (Bengtsson, 2017);

“4”, the TTO was a partly stock-exchange listed company (Pitsakis et al, 2015). To capture this data, we directly contacted universities and asked them about their TTO autonomy and structure over the years. For private and public TTOs, we checked their year of incorporation via the FAME database.

Further, from interviews we had with TTO managers (Table 3A, Appendix), it was made clear to the authors that this categorization was a good measure of autonomy. The interviewees unanimously agreed that the mandate of a TTO was explicit and well defined: TTOs had responsibility for the transfer of academic knowledge by acting as intermediaries between the university and the market. This means that they had strategic and operational authority in their decisions. However, while TTOs had a clear mandate to carry out commercialization, their autonomy varied because of administrative controls that were imposed on them by the parent, e.g. in terms of budgeting/financial reporting. For this reason, our variable “TTO autonomy” could change from one category to another during the 15 years of our panel.

TTO age. This variable was measured as the number of years since the founding of the TTO. We directly contacted universities and asked them for the exact founding date of their TTOs and if not available, the year they approximately started their operations. Most of our sampled universities were contacted by email and by phone. For some TTOs information about founding dates was available on their university website.

TTO association membership. PraxisAuril (www.praxisauril.org.uk) is the U.K. association of TTOs (formerly PraxisUnico). This variable was measured as the number of years of membership in PraxisAuril for which the commercialization leader was also a member. From our two commercialization leaders, the University of Oxford’s TTO joined the association in 1995, and the University of Cambridge’s TTO joined in 2000 and both

remained in PraxisAuril thereafter. As there was no leader in the association in the first two years of its life (1993–1994), all TTOs got a value of 0.

Control variables

We controlled for several variables that may explain the decision to imitate the leader's strategy. Specifically, we used controls at four levels of analysis: (a) TTO, (b) university, (c) region, and (d) spinoff industry. The inclusion of such control variables intended to rule out alternative explanations about a TTO's imitation of the commercialization leader.

The controls at the TTO level were as follows:

TTO live spinoffs. Since well-performing TTOs may show a greater propensity to strategize independently (Siegel, Veugelers, and Wright, 2007) and may have less incentive to imitate the commercialization leaders because of their self-confidence, we controlled for TTOs innovation performance by calculating the cumulative number of live spinoffs (adding new births minus new deaths) in their portfolio, each year (Breznitz et al, 2008).

TTO revenues (relative). This variable measures a focal TTO's size relative to the commercialization leader's TTO size. Since the leader will be always greater in size by definition (see equation 1), we expect that the greater the size difference between the leader and the focal TTO, the more the latter will perceive the former to possess more information about how to strategize, and therefore the greater will be the imitation (Giachetti and Torrisi, 2018). We measured this variable as the absolute difference between the log of revenues from spinoffs of the focal TTO and the leader over time.

Media coverage. We used media coverage to assess the legitimacy of the TTO. Research in the sociology of organizations has shown that the media may shape perceptions of what is legitimate and desirable behavior in a social system (Pollock and Rindova, 2003). This variable was measured by counting the number of U.K. press clippings that related to a TTO and all of its spinoffs in a single article using the LexisNexis database. We recorded a total of

8,866 articles linked to 1,404 spinoffs and their TTOs. We assumed that the higher the media coverage of a TTO, the less likely the TTO would imitate others.

The controls at the university level were as follows:

University age and size. Although our unit of analysis is the TTO, we expected the age and size of the parent university to act as proxies for the experience and visibility of the TTO and to therefore influence the TTO's strategy. We measured university age by subtracting the year it was founded from the current year in the panel; this information was easily accessible from their websites. We measured university size by using the total number of full-time students of a university captured from the HESA database. We used the natural logarithm of both size and age to correct for skewness (Guillén, 2002).

University patents. We controlled for the number of university-assigned patents using data from the European Patent Office (EPO: www.epo.org). We assumed that the higher the stock of intellectual property owned by each university, the more likely its TTO would forge an independent commercialization strategy.

University Nobel awards. We captured the cumulative number of Nobel awards held by each university as a measure of academic excellence and we expected that the more awards a university had, the more its TTO would forge an independent commercialization strategy.

University funding. Authors have noted that university funding can affect a TTO's commercialization strategy, depending on whether finance is from private or public sources (Bok, 2003; Krimsky, 2003). We controlled for two different sources as follows: (a) funding from industry/private donors and (b) funding from public Research Councils of the U.K. For council funding, we collected data on money received from the Medical (MRC), the Biotechnology and Biological (BBSRC), the Engineering and Physical Sciences (EPSRC) and the Economic and Social Research (ESRC) councils. All information for this variable was collected from the Higher Education Funding Council of England (HEFCE).

The controls at the regional level (nine regions in England plus Scotland) were as follows:

Regional venture capital. This information was captured from the British Venture Capital Association. Our expectation was that high VC availability would make imitation of the commercialization leader less likely as TTOs would be able to attract direct support for their own commercialization strategies.

Regional science parks. We captured the number of regional science parks active each year from the U.K. Science Park Association and we assumed that the more science parks in the vicinity, the more likely it would be for TTOs to imitate each other.

Finally, at the spinoff industry level, we used a set of *Year dummies*. Dummies for the years 2000–2001 were used to capture the increasing uncertainty around the burst of the dot.com bubble in 2000 and the general economic downturn that may have affected the commercialization of different types of spinoffs. We also wanted to control for the possibility of conflicting mimetic requirements occurring around 2006 (Gaba and Terlaak, 2013; Rhee, Kim, and Han, 2006), when Oxford's TTO lost its commercialization leadership to Cambridge's TTO. We, therefore, added time dummies for 2006 and 2007, the latter to check a focal TTO's propensity to imitate Oxford two years after it lost its leadership (i.e., consistent with our two-year lags), and the former to account for inertia in social monitoring patterns, since the informational value of the older model is not likely to erode so quickly. We expected the coefficient of the 2007 dummy to be more positive and significant than the 2006 dummy, indicating that TTOs were increasingly turning their attention to Cambridge, while the role of Oxford as a catalyst was weakening.

RESULTS

Because our dependent variable was a continuous measure, linear regression for panel data was the appropriate technique of analysis (Cameron and Trivedi, 2009). The Breusch–Pagan test showed that our data suffered from heteroskedasticity, and we thus used the generalized

linear squares (GLS) method. The Hausman test indicated that fixed-effects would be a better choice to analyze our data than random-effects and we opted for that.

Table 1 shows the descriptive statistics of the variables in our sample and bivariate correlations. No serious issue with multicollinearity was observed, since all VIF scores were below the usual warning level of 10 (Gujarati, 2003). The regression results are presented in Table 2, starting from the basic model which includes only controls, and adding our independent variables in various steps until Model 5. The regression results with the interaction effects are presented in Model 6. All variables in the regression models were standardized (mean-centered) to prevent multicollinearity (Aiken and West, 1991).

Hypothesis 1 stated that there is a negative relationship between a TTO's autonomy and its imitation of the commercialization leader's strategy. In Model 5, the coefficient of autonomy is negative and significant ($\beta = -0.186, p < .001$), thus supporting Hypothesis 1.

Hypothesis 2a predicted that there is a negative relationship between a TTO's age and its imitation of the commercialization strategy of the most successful TTO in the industry. In Model 5, the coefficient of TTO age is negative and significant ($\beta = -0.392, p < .001$), thus supporting Hypothesis 2a.

Hypothesis 2b stated that the relationship between a TTO's autonomy and its imitation of the commercialization leader is negatively moderated by the TTO's age. As shown in Model 6, the coefficient of the interaction between TTO autonomy and TTO age is negative and significant ($\beta = -0.411, p < .10$), therefore, Hypothesis 2 is also supported. Figure 2 shows a plot of the significant interaction according to the standard procedure (Aiken and West, 1991).

Hypothesis 3a stated that TTOs that are members into an association where the most successful TTO is also a member have higher levels of imitation of the commercialization strategy of the most successful TTO than TTOs that are not members of that association. In

Model 5, TTO membership is negative and significant ($\beta = -0.135, p < .01$), therefore Hypothesis 3a is not supported.

Hypothesis 3b predicted a positive moderating effect of the TTOs membership into an association of which the commercialization leader is also a member on the relationship between a TTO's autonomy and its imitation of the commercialization leader's strategy. As shown in Model 6, the coefficient of the interaction between TTO autonomy and TTO membership is positive and significant ($\beta = 0.342, p < .001$), thereby supporting Hypothesis 3b. Figure 3 shows a plot of the significant interaction according to the standard procedure (Aiken and West, 1991).

<< Insert Figures 2 and 3, and Tables 1 and 2 about here >>

Robustness tests and additional analyses

We checked the robustness of the findings in several ways. First, since some of our informants suggested that, to redesign a commercialization strategy, a TTO's response time could range from two to three years, we repeated the analysis in Table 2 by calculating the imitation index with a 3-year response lag (also lagging all independent variables by three years). As we can observe in Table 3, Models 7-12, we obtained very similar results to the ones in Table 2.

<< Insert Table 3 about here >>

Second, we wanted to test whether our independent variable "TTO autonomy" was endogenous to our regression equation. To account for this possible self-selection bias, we instrumented for the choice of the TTO's degree of autonomy, using the following three university-level variables: (a) the ranking of the university, (b) the presence of a university hospital in its campus and (c) the number of publications of its faculty. We run robust two-stage least square (2SLS) regression (Cameron and Trivedi, 2009) and the results were confirmed for all hypotheses (except Hypothesis 3a), as shown in Table 4, Models 13 and 14.

<< Insert Table 4 about here >>

Third, since our econometric model implicitly assumed that TTOs imitate or deviate from only a specific reference target, i.e. the commercialization leader, we wanted to examine whether other TTOs, different from the commercialization leaders we identified, played a role as catalysts for TTOs' strategies. We, therefore, run two regression models, one for each strategy variable, where the dependent variable was the focal TTO's strategy at time t while independent variables were the (same type of) commercialization strategies undertaken at time $t-2$ by a set of highly successful TTOs throughout the observation period. In addition to the two leaders we identified with our commercialization leadership formula, i.e. Oxford TTO (1993-2005) and Cambridge TTO (2006-2007), we also tested Imperial College TTO, as it was mentioned several times in our in-depth interviews (see Table 2A). Since Oxford was the commercialization leader for almost the entire observation period, we should expect the coefficients of its strategy variables to be more positive and significant than the coefficients of the strategy variables of the other two TTOs. This would mean that an increase (decrease) in the magnitude of a strategy variable by Oxford's TTO corresponds to an increase (decrease) of the same type of strategy by the focal TTO two years later. As we can see in Table 5 (Models 15-16), the results confirmed our expectation for one of the two independent strategy variables. This suggests that other reference targets (e.g. Imperial College), different from the two leaders we identified may affect the strategic behavior of TTOs. Future research could examine this important issue, and its implication for our theory.

<< Insert Table 5 about here >>

Finally, although TTO age is likely to strengthen experiential learning and lead to lower imitation of successful TTOs as we discuss in Hypotheses 2a and 2b, some authors have argued that the strategic behavior of older firms can be affected by inertia, i.e. their tendency to not change their strategic posture over time (e.g., Hannan and Carroll, 1992). Inertia would

result in a situation where the TTO neither attempts to imitate nor tries to deviate from the leader, meaning that the significant negative sign of TTO age we observed in our Models 5 and 6 might not be the result of self-confidence but inertia. To test this possibility, we used the 3-year standard deviation (SD) of each commercialization strategy variable as dependent variable, computed from time t to $t+2$, and we run a separate model per each of the two strategy variable as shown in Table 6 (Models 17-18). A negative relationship between TTO age and the SD of the strategy variable would mean that the older the firm, the less likely it would change its commercialization behavior, indicating an increasingly inertial strategic posture. As we observe in Table 6, we found TTO age to be negatively related to the SD for one of the two strategy variables (JV intensity), meaning that some of the differentiating behaviors of older TTOs could in part be attributed to inertia.

<< Insert Table 6 about here >>

DISCUSSION

Implications for theory

The extant literature has offered various explanations as to why firms decide to imitate the behavior of leading firms; yet, so far, the academic entrepreneurship literature has not dealt with imitation. This is surprising because, given the complexity of the environment in which universities operate, there is an increasing tendency to delegate the management of certain assets and activities to TTOs within them (Shane, 2004; Zahra, Kaul, and Bolívar-Ramos, 2018). These TTOs operate with different degrees of autonomy with respect to their parent universities and they may exhibit different responses to what leaders in the industry do. Even more critically, TTOs are the prime vehicles for university commercialization strategies with significant policy and managerial implications (Pitsakis et al, 2015).

The results of our study contribute to the inter-organizational imitation and academic entrepreneurship literatures in several ways. First, while most studies on imitation take the

firm as the unit of analysis, our study examines the behavior of TTOs that are parts of a larger organization. The structure and autonomy of the TTO has recently gained attention among scholars in the academic entrepreneurship literature (Bercovitz et al., 2001; Markman et al., 2005; Pitsakis et al., 2015). Our results show that the extent to which TTOs imitate or differentiate themselves from the commercialization leader in uncertain environments depends on the TTO's degree of autonomy from its parent university. In particular, autonomy triggers creativity, and therefore a greater willingness to challenge the *status quo* by taking risks when strategizing, one of the main prerequisites for differentiation. We found that more autonomous TTOs show a greater propensity to face legitimacy challenges by deviating from the leader's strategy (i.e., lower levels of imitation). With this result, on the one hand we complement the information-based imitation literature (Lieberman and Asaba, 2006) by highlighting the role of organizational autonomy as a factor that mitigates TTOs' pressure to follow leading peers in uncertain environments. On the other hand, we respond to recent calls in the academic entrepreneurship literature to employ a different theoretical angle to explain TTO strategies (Djokovic and Souitaris, 2008; Markman et al., 2005; Yuan et al., 2018).

Second, drawing on information-based theories of imitation (Lieberman and Asaba, 2006), we find that two sources of information, within and outside the TTO, moderate the relationship between the autonomy and the degree of imitation of the commercialization leader. These sources of information are (a) the TTO's age and (b) the TTO's membership into an association of which the leader is also a member.

With regard to the TTO's age, consistent with our expectations, we found that age has a negative direct effect on imitation, and it negatively moderates the relationship between a TTO's autonomy and its level of imitation of the commercialization leader's strategy. These findings support our argument that the autonomous TTO's propensity to distance itself from the leader will be amplified by the experience it has accumulated through the years (age),

giving the TTO a degree of self-confidence that pushes it to increasingly believe it can decide how to strategize without the need to look for references. With these findings, we contribute to the imitation literature by bringing it into the organizational learning literature (Baum et al., 2000; Cyert and March, 1963; Terlaak and Gong, 2008) and the literature on self-confidence in strategic decision making (Baum et al., 2000; Guillén, 2002; Rhee, Kim, and Han, 2006). Our work sheds more light on how internal sources of information can shape the way TTOs strategize vis-à-vis industry peers.

With regards to association membership, our unexpected results about the negative effect of TTO membership on imitation does not fully support findings in the extant inter-organizational imitation and network literatures, which argue that imitation happens more frequently when inter-organizational relationships are present (Abrahamson and Rosenkopf, 1993; Greve, 1996; Haunschild, 1993; Oliver, 1990). This result would suggest that having close ties with successful peers is not likely to foster vicarious learning through imitation of their practices. A possible explanation could be that other reference targets within the industry association, like the industry mean (i.e., the prevalent behavior among association members) or association members that are part of the TTO's strategic group (Fiegenbaum and Thomas, 1995) act as stronger catalysts in driving the imitation of other TTOs. However, we found that TTO membership fosters greater imitation for TTO with high autonomy: the TTO's membership into an association of which the leader is also member positively moderates the relationship between the TTO's autonomy and its level of imitation of the leader's strategy. This finding suggests that the leader plays an important role in driving TTOs' commercialization decisions not when TTOs have low autonomy, but when their high authority to strategize is subject to stimuli by successful peers within the same network. In fact, as we observe in Figure 3, for low levels of autonomy, TTOs with and without membership into an association choose the opposite strategy vis-à-vis the leader, i.e. the

former deviate while the latter imitate. However, as autonomy increases, TTOs without association membership progressively deviate from the leader while TTOs with membership increasingly imitate the leader. Overall, these results point to the importance of external sources of information TTOs draw from when designing their commercialization strategies, a research issue that had so far received scarce attention.

Finally, the results of this study have important implications for the academic entrepreneurship literature, as well as the field of strategy imitation in highly uncertain markets. The field of academic entrepreneurship lies at the intersection between the traditional roles of the university and its innovation, market-like functions. This dual role forces universities to adopt a hybrid strategy to satisfy their multiple stakeholders via TTOs, much like for-profit firms employ corporate subunits to achieve innovation. Indeed, research on spinoff-related strategies has started to explore how these TTOs spin-off new ventures (Lockett *et al.*, 2002), where those ventures are located (Berchicci *et al.*, 2011), how they gain legitimacy (O’Kane *et al.*, 2015) and how they succeed (Colyvas, 2007). Our paper has discussed TTO strategies in highly uncertain environments. We offer a framework for understanding why TTOs imitate the commercialization leader based on their structural, learning and network characteristics. Our work sheds light on the strategic aspects of public organizations in a changing world.

Limitations and extensions

There are opportunities to extend our research as well as to address some of its limitations. First, our analysis investigates patterns of imitation over a wide time-window, corresponding more or less to the life cycle of the modern U.K. university commercialization industry. This means that the industry has passed through various stages from introduction to growth and maturity, with strong implications for TTO strategies and performance. Since in our analysis we do not focus on how patterns of imitation change over time, future research could develop

hypotheses on the changing role of autonomy in shaping imitative behaviors of the leader over various stages of the industry's evolution by borrowing from the industry life cycle literature.

Second, commercialization via TTOs involves other strategies besides spinoffs, e.g. licensing and Knowledge Transfer Partnerships (KTPs) with local private firms. Although it would be interesting to consider licensing and KTPs for the complete commercialization strategies of TTOs, unfortunately, we could not find data on licensing agreements and KTPs for our full observation period. The Business and Community Interaction Survey of the U.K. run by HEFCE does not collect data for each university and it only reports aggregate numbers for licensing and KTPs across the U.K. Further, that database does not go back to 1993, which is the beginning of our panel. What is more, we know from other papers in the academic entrepreneurship literature (e.g., Pitsakis *et al*, 2015) that, in the U.K. university ecosystem, TTO revenues from licensing agreements and KTPs are too small compared to spinoffs. Assuming that detailed longitudinal data on licensing and KTPs become available, future scholars could explore TTO imitation including these commercialization strategies.

Third, as we noted with the additional analyses we present in Models 17 and 18, other reference targets different from Oxford or Cambridge may affect the way TTOs in the U.K. strategize. We suggest future studies to explore other measures of commercialization leadership, maybe with composite indices of different market leadership dimensions. This could reveal whether other commercialization leaders emerge, and whether they effectively act as catalysts for TTOs' strategies.

Fourth, as in most empirical studies in strategic management, our study captures only observable strategies based on information reported in the U.K. press and the publications we examined. But it is likely that the TTOs in our sample are influenced by the strategic behaviors of actors outside the U.K. (e.g. Stanford in the U.S.A. because of their reputation),

or by TTOs with which they have business relationships. Consequently, future research could examine whether the strategic behavior of TTOs in a country are influenced by the strategic behavior of TTOs in other countries.

Finally, although the U.K. university commercialization industry presents structural characteristics that can also be generalized to many other country environments, the largest market for technology transfers (U.S.A.) has significant differences (Colyvas, 2007; Jong, 2006). For example, authors have noted differences in the motivations of universities in the U.K. and the U.S.A. to transfer technology, in the patterns of university technology transfer policies and in the accessibility of university technologies to business (Dectera, Bennett, and Leseure, 2007). We, thus, hope that future research will replicate our analysis in other countries to investigate whether our hypotheses are supported or not, and why.

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APPENDIX

Table 1A. Characteristics of the TTOs whose Heads were interviewed by the authors.^a

	TTO A	TTO B	TTO C	TTO D	TTO E	TTO F	TTO G
TTO staff	70 (+3 part-time)	10	52	40	9	42	1
Research budget	£68.28m	£3.41m	£119.60m	£33.80m	£48.11m	£94.34m	£1.2m
Specialization	Spinoffs	KTPs	Spinoffs/ Licensing	Spinoffs/ Licensing/KTPs	Spinoffs/ Licensing/KTPs	Spinoffs/ Licensing	Licensing
First spinoff	1967	1999	1963	1977	1981	1984	2007
No. of spinoffs	59	14	68	55	31	76	2
Location	Scotland	London	England	Scotland	England	London	London
Autonomy	1 (1998) to 3 (today)	2	3	2	2	3	1
Length of the interview	68mins	66mins	49mins	67mins	99mins	57mins	49mins

^a TTO names have been removed for anonymity.

Table 2A. Evidence of TTO awareness of the commercialization leader

TTO	Key quotes from interviews
A	“We’ve had quite a lot of experience here in the university of playing around equity stakes. We pinched that strategy from, I think it was Stanford or MIT, where we insisted on a non-dilutable equity stake...”[...] ‘I know it has worked with some, e.g. Oxford... Surrey and Southampton have done it, but we just don’t like it. We don’t like that deal structure...”
B	“...the real model of what should be done in the pathways is King’s College. It’s worth talking to them – they are very good with spinouts.’[...] ‘...if you look at the reports on commercial activities you know... Oxford, Cambridge, Imperial are top of the scale.’ ‘...there is a lot that we can learn from all the universities... I mean there is a whole body of work that you ought to be leading up to with regards to the difficulty of spinouts in universities... And there’s people who are much more experts than me in doing that. Loads of discussion papers, maybe you should look up some like UNICO, they have some discussion papers.”
C	“Well we mostly cooperate and meet up with the other three and we talk about our common problems and issues and it doesn’t matter whether it is Cambridge or Stanford or whoever it is.’ [...] ‘Obviously, each of the tech-transfers particularly the bigger ones are all run on different grounds. I mean Imperial Innovations is an AIM-listed company, so their strategy will have to be slightly different from ours. Cambridge is quite similar to us... we know what their KPIs at Cambridge are and they watch us as well. But this is not in a competitive sense really, it’s benchmarking yourself. Because we have to benchmark ourselves against what has to be Cambridge and Imperial so I think that’s healthy.”
D	“Probably the ones who have the best track records are Edinburgh (it has the biggest research base). In England you hear about Oxford and Cambridge and, obviously, Imperial...’ [...] ‘I think it’s fair to say that other schools have come to us, to learn from us. I mean, there are offices that are run by people who started their careers here.”
E	“The sort of people that we would consider being with would be the Imperials, they are the sort of biotechs. UCL is quite good...’ [...] ‘...we have good schools here, you know Oxford, Cambridge and Imperial. OK, they have a very high profile in technology transfer and they have done very, very well.”
F	“We have a good relationship with Imperial so we often swap ideas with Imperial, discuss with them and do the same with Oxford and Cambridge.”
G	“Imperial, UCL and Oxford are doing great but they are in a kind of different league from us. We’ve used UCL for advice because they have done social enterprises before as they are big in health care. We have also been part of a group and we’ve had some funding for commercialization activities in SW London. So Brunel, Royal Holloway, St. George’s, Roehampton and Westminster were all part of it. So those institutions are pretty cooperative.”

Table 3A. Evidence of varying degrees of strategic and operational autonomy among TTOs

	Autonomy 0	Autonomy 1	Autonomy 2	Autonomy 3
STRATEGIC				
a) React/adapt to emerging issues (e.g. competitors moves)		<p>“We had a meeting today and we discussed about a new technique for doing it and it is quite a lot more expensive and it takes more time but as time goes on that may come down in price and become quicker. It is a kit that the hospital uses and we have to keep an eye on that to make sure that when we come out with our product that it occupies the place in the market where we are aiming after. That kind of thing I discuss with potentially the research/enterprise director in the faculty and with the academics.” [TTO G]</p>	<p>“In the last 3 years, as far as spinouts are concerned, electrical engineering has become quite dominant – it’s one of the research departments that is closest to the market, and work has been done there in collaboration with firms like Scottish Power, so research there is addressing specific market needs. So it’s a market pool...” [TTO D]</p>	<p>“We don’t have anything like Biofusion but we have two deals, one with IP Group but it’s totally different from all the others.... The other one we have is with Technikos which is in the medical engineering sciences so again anything that is from the engineering... So it doesn’t affect how we commercialise things. But the timing suited us because we got a new chemistry building and same way we could build a medical engineering centre” [TTO C]</p>
b) Take strategic decisions independently (e.g. suppliers)	<p>“I wasn’t here in the early 90’s and I don’t think my boss was either. There were only 1–2 people... Maybe the strategy was there but it takes a while to develop the rules that will ensure that you get the results you wanted otherwise you can stop spending...” [TTO B]</p>	<p>“We have a lot of autonomy but we have to check back with the management team in the Faculty but also up to the Vice-Chancellor. The person I need to keep updated is primarily the Dean of the Faculty and the Pro-Vice-Chancellor of Enterprise”. [TTO G]</p> <p>“We are getting some advice from UCL and in order to do that, we just had to renew the contract we had with them and we asked the Dean to sign off that but I have freedom as to how I use that resource.” [TTO G]</p>	<p>“We have corporate strategy where each department will generate enterprise strategy and that will go into faculty enterprise strategy.” [TTO B]</p> <p>“The other half of my role is to manage the university’s relationship as a shareholder with existing spinout companies and hopefully to help maximize the returns from those companies by adding value to them” [TTO D]</p> <p>“Maybe I’m not talking like a traditional TTO manager – more like a marketing or sales person. I view the university personally as a business: it’s an academic business, a non-profit business, a charity business, but a business nonetheless.” [TTO E]</p>	<p>“It looks as if we are going to move towards a much more active strategy of managing out equity, whereby we look at selling a lot of our equity to secondary funds or we look to, perhaps, sell back our shares to the companies at a reasonable valuation.” [TTO A]</p> <p>“... we have a Board, an external Chairman of the Board and three external Directors and then another three Directors and myself, our Managing Director and our Vice President of Enterprise... But it’s quite nice to have an autonomous Board and be independent and able to do what we want.” [TTO F]</p>
c) Have bargaining power over other actors within the university (e.g. scientists or administrators)	<p>“Most company formation support was provided through what we used to call our Business Development teams. Basically, we had commercial people and they did licensing, they did commercial research contracts... and an academic who wanted to set up a company they did their best.” [TTO A]</p>	<p>“Lots of these things come down to building relationships and trust, so the ones that I work closely with accept the advice and approach to how we do the commercialization. If it gets to a situation where we have different opinions, then we can go up the chain... up to Director of Research.” [TTO G]</p>	<p>“So, we have business development managers based in the faculties, we have this core of people with our Head of Research and Business Development, the Deputy and a couple of Managers sitting here plus, we have some staff which support the academics with research grants.” [TTO B]</p> <p>“We do get proposals from academics saying ‘I’ll just apply for that funding and do some interesting work’ and we would</p>	<p>“So we do involve the academics when we can, we don’t force them because sometimes it can be very good, but at the end of the day we don’t do a deal against an academic’s wishes. But a lot of the times there is a close partnership particularly in a spinout, the project manager and the academic become very close to each other during that period...” [TTO C]</p> <p>“So we do involve the academics when we can, we don’t force them because sometimes it can be very good, but at the end of the day we don’t do a deal against an academic’s wishes. But a lot of the times there is a close partnership particularly in a spinout, the project manager and the academic become very close to each other during that period...” [TTO C]</p>

OPERATIONAL	<p>d) Possess critical strategic resources (e.g. knowledge, networking or even physical resources like space)</p>	<p>“Until 2000 this office was quite small because it was funded by the university. So there would be someone looking after the enterprises, someone looking after KTPs and consultancy – it was maybe half a dozen people.” [TTO B]</p>	<p>“I got control over the budget... for that and when we need academic space... I haven't really needed additional space resources on that but that is a project by project thing. Part of the last spinout deal was working on some space at St George's where they are located and I helped in the negotiations for that.... You wouldn't get an outside company having that deal from them. So I helped to influence the recognition that there was some value in the company being set up internally.” [TTO G]</p> <p>“We decided that it would be more cost-effective to have an external company than do it in-house. That company were experts in taking more volume and they had the technique to create a lot rather than having us trying to do it because we are not good at mass production...” [TTO G]</p>	<p>“No, you won't, you'll get some commercial value to your proposal as well – there's got to be a proper business plan, there's got to be evidence of commercial need rather than just an interesting project that you want to do.” [TTO D]</p> <p>“Some conflicts of interest have to be carefully managed and sometimes they cause friction. Some spinouts had to be set up and occupy space within the university and they needed particularly lab space etc.” [TTO D]</p> <p>“... most of the funds that we have are ultimately derived from grant opportunities from the government to set up certain things – I think it's one million per year or something and if you look at how much the university spends it is insignificant... So we have the legal department – all of what they do is research contracts such as ESRC or EU contracts.” [TTO E]</p>	<p>“ETTC... was established years ago as a joint venture of the university and the city council (the city council is technically still a shareholder but they are not involved anymore)... It has become the vehicle for incubation activities... It owns two buildings and it has a deal to run incubation in two other buildings... it buys staff from Edinburgh Research and Innovation which is the TTO... So, it has to wash its own feet and it has to maintain some funds for emergencies...” [TTO A]</p> <p>“We also have 6 staff dealing with consultancies, and then we have what we call back-office staff dealing with legal, patenting, finance... We'll also provide payroll services for our spinouts and subsidiaries, so that they don't have to – they need such resources – so our HR people will do it for them.” [TTO F]</p> <p>“We also run incubation facilities as well, the UE has four incubation facilities in this campus, and as I said, they run on a commercial basis and they have to break even and maybe make a small profit to contribute to the overall activity. Importantly, they also provide a nurturing place for the companies to grow and develop and therefore have high chances of survival. I am responsible for <i>that</i> as well. To some extent I am responsible for getting something back from the companies, and in particular, I'm responsible for the equity portfolio.” [TTO A]</p> <p>“...are we going to spin-out something that we would see as a totally unethical company? No!” [TTO C]</p> <p>“With regards to whether a technology might be successful for a spinout, there have been cases where we should have licensed</p>
<p>a) New product development</p>	<p>“[They] have a much smaller university but I suspect the lower limit of the university that can profitably or successfully help in company formation activity, so they have a guy who runs the whole thing just pretty much on his own.” [TTO A]</p>	<p>“I work on ideas to become products somehow... I think what will become a product with this RMSA will be something that we license aspects of that product... the chemical processes and possibly the design to a third party who will then sell the product.... We also have another product we work on, that is an [interactive] app in the medical sector for people undergoing cancer treatment and can self-manage their condition and get advice on how to do that and also the mechanism for contacting health care and to reduce the need for the amount of visits that. That's going to be a software product that I think will end up being licensed to someone else who knows how to get to that market.” [TTO G]</p>	<p>“And this university works very much within that in that we have a lot of social projects which don't necessarily bring in a lot of money but they help all the community which is embedded in this region of London.” [TTO B]</p> <p>“I'd say that there are two parts in my role: One is getting new spinouts formed and funded, and that can involve the business planning, the funding, putting commercial management in place, mentoring the academics and making them work through their ideas and what the rules about a potential spinout company would be...” [TTO D]</p>	<p>“Before they [IP Group] came on board we had more people in the TTO and we had to have specialists in the office who were</p>	
<p>b) Modification of existing products</p>	<p>“It has been making small investments between 5–50 grand into university companies. So we have this burgeoning</p>				

	<p>activity – no single strategy, but loosely linked because the individuals decided to talk to one another...” [TTO A]</p>		<p>familiar with/intimately involved with VC markets and knew how they worked or had ended up creating spinouts in the past.... you were a little bit unready and most of them tended to be undercapitalised and with the wrong management team but when IP Group came on board we now have a different character within the TTO.” [TTO E]</p>	<p>instead of spinning out a company. We would have made more money more quickly from licensing. I think where you’ve got a platform technology or a number of products (a pipeline) then I think it’s natural to make it into spinout (and when you think there is the potential to raise investment). When there’s one technology product, it’s natural for it to go down the licensing route. I think also when there’s a huge amount of development that we are not geared up to do then it’s better to license it to a partner who can actually do all that work. So it’s a combination of what the technology actually is and what the founders want and to a certain extent what resources we have at the time.” [TTO F]</p>
<p>c) Modification of production processes</p>	<p>“There must have been somebody around handling IP, but I think it’s probably mid-90’s this sort of idea... Originally the TTO was much more focused on IP than on commercialisation, and then it gradually evolved. We now manage the IP relationship and we constantly use our IP to benefit the university in whichever way we can, which is not necessarily to achieve a commercial return.” [TTO E]</p>		<p>“...we’ve had three investments from the IP Group and it wasn’t a model that we fancied... We felt that they would put pressure to focus on winners and the day to day input and reliance on the funds is something we weren’t comfortable with...” [TTO D]</p> <p>“We are much more interested in the quality of the target, not the quantity of the target. And there are certain parts of the university that keep coming up with good stuff, so we tend to nurture those nuggets within the university. Occasionally we put up applications to merge things along but we’re not sure about the way... there are all sorts of ways.” [TTO E]</p>	<p>“I mean there are examples of joint research but... sometimes we get a call from one of the other universities looking to assist on a company formation project – so my group providing support and we do that as best as we can – but that’s very occasional.” [TTO A/Joint Ventures]</p> <p>“We will also set up spinout companies where we will invest and have external investors to bring in money in return for equity. We do what we call Collaboration Agreements where a company might fund contract research for two years and then have back-to-back licensing... so any of the IP developed over those two years will go to the company... we will get royalties based on that.” [TTO F]</p>
<p>d) Creation or abolition of structural teams/taskforces within the TTO</p>	<p>“...what happened was when I started in 2000 they had a group called [XYZ Ventures] which did licensing and spinouts. Before that they had a small group run my [someone] pretty much on his own that did spinouts and all the licensing was done within the Contracts Research Office (CRO) at [XYZ]. So you had a ventures’ group that just dealt with companies and then you had anything else effectively.” [TTO F]</p>		<p>“Regarding the TTO, it has recently taken on more responsibilities in terms of support from student and alumni activities and providing business support services there... As a result of that we have become more proactive because it tended to be more reactive in the past.” [TTO D]</p> <p>“Within the TTO we have two people who look after IP and manage licenses and we have two people (myself and a colleague) who do the license negotiation and the spinout activity, so that’s four people in</p>	<p>“So UE has one full-time employee working on student company formation from this office and we are looking to expand that, and because of the scale of what is possible, the university really appreciates that. So we have 4 professional full-time employees working solely on company formation from this office essentially, as well as others who are attached to this office but do not work full-time. The school of informatics has some activities of its own but we assist them when we can. It’s a</p>

				<p>total. In another part of the office we have three people doing KTPs, we have somebody who writes large bids to Research Councils, which often involves getting on-board an industrial partner who might be someone who would commercialise stuff at the end. And if you are looking at the enterprise setup, we probably pay for two people to do the incubation.” [TTO E]</p>	<p>modest-size team but it’s growing and the outputs are significant.” [TTO A]</p> <p>“The key people in the tech-transfer or what we call project managers are the ones who negotiate the deals, spin-out the companies and we have fairly comprehensive programmes.” [TTO C]</p>
<p>e) Recruitment and promotion</p>			<p>“Our current director has been here for a long time, the European Funding Manager was the first ever person to be appointed to that position over 20 years ago, so that kind of established a consistency of approach which is helpful.” [TTO D]</p> <p>“So when you’re advertising for people, if you want somebody with a second degree for the biotech sector you get inundated with applications. If you want someone with a second degree in physics and engineering in technology transfer, then you won’t get very many at all. Ideally, you should have both but if you don’t have a choice you pick the business.” [TTO E]</p>	<p>“In the first instance, most company formation support was provided through what we used to call our Business Development teams. Basically, we had commercial people and they did licensing, they did commercial research contracts, and an academic who wanted to set up a company they did their best.... It became apparent that it was inappropriate for these business development people to be working for the university and doing license deals and supporting companies that would then come back looking for those licenses. So this university started looking at ways of separating the company formation support from the licensing activity but because we had the scale, we also recognized that it might be worthwhile pushing company formation a bit more...” [TTO A]</p>	

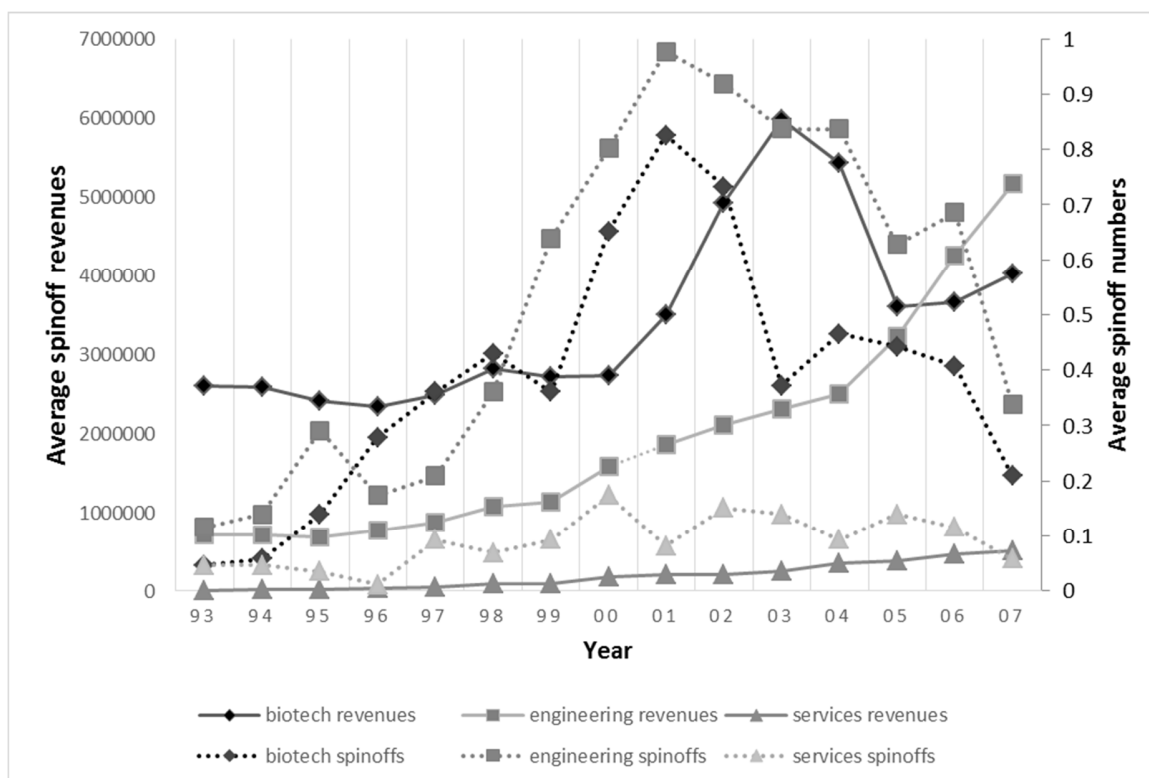


Figure 1A. TTO average spinoff revenues (GBP) and average spinoff numbers by economic activity in England and Scotland, 1993-2007

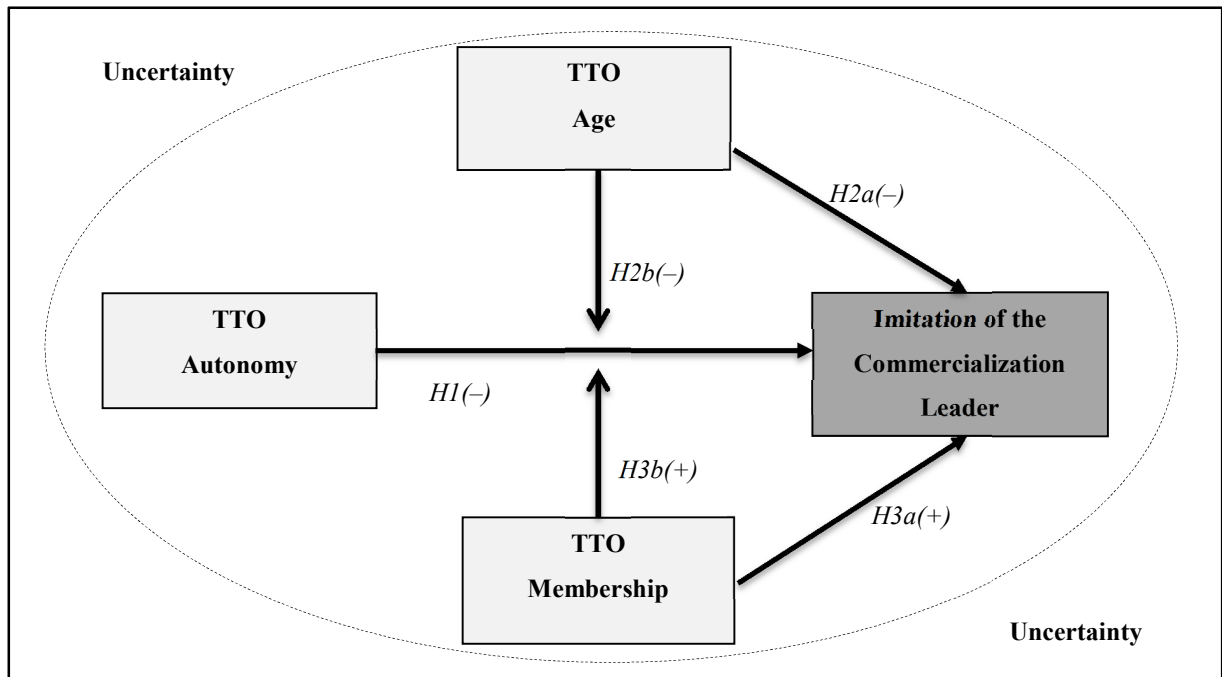


Figure 1. Conceptual Model of the Study

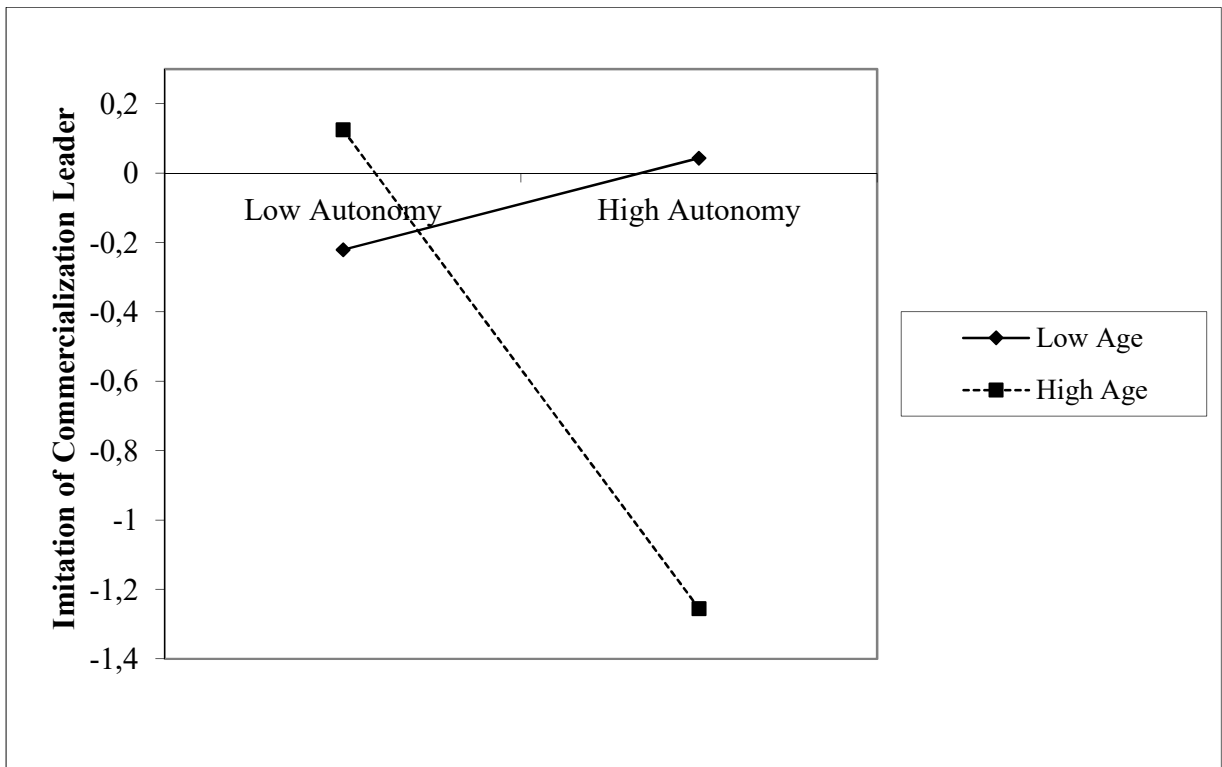


Figure 2. Two-way Interaction between TTO Autonomy and TTO Age

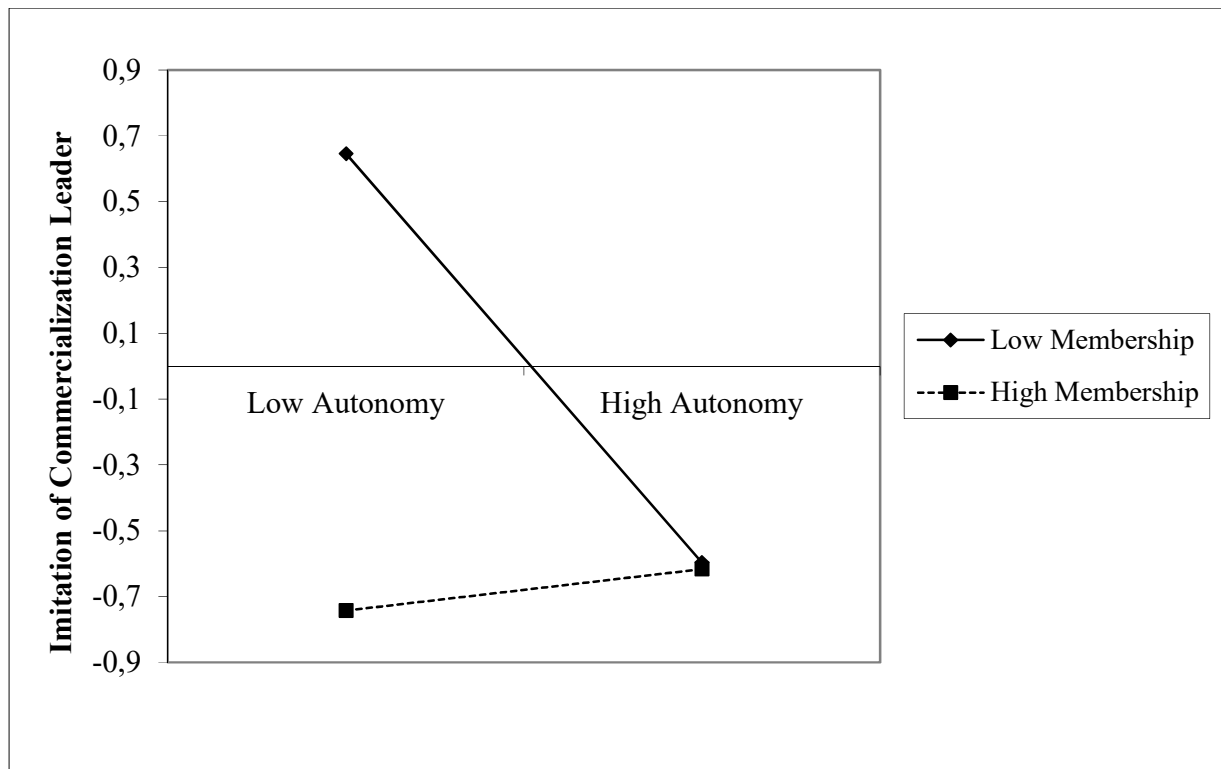


Figure 3. Two-way Interaction between TTO Autonomy and TTO Membership

Table 1. Descriptive Statistics and Correlations

		Mean	SD	Min	Max	1	2	3	4	5	6	7
1	Imitation	0.741	0.139	0.417	1.000	1.000						
2	TTO live spinoffs	7.067	10.647	0.000	74.00	-0.004	1.000					
3	TTO revenues (relative)	8.613	7.323	0.000	25.42	-0.234***	-0.377***	1.000				
4	Media coverage	5.782	16.868	0.000	218	-0.028	0.576***	-0.248***	1.000			
5	University age (ln)	4.566	1.462	1.000	7.810	0.092**	0.448***	-0.343***	0.330***	1.000		
6	University size (ln)	9.470	0.763	4.980	10.86	-0.020	0.281***	-0.144***	0.142***	-0.058†	1.000	
7	University patents	4.971	7.326	0.000	50.00	0.001	0.672***	-0.319***	0.344***	0.435***	0.235***	1.000
8	University Nobel	0.802	3.199	0.000	26.00	0.064†	0.581***	-0.221***	0.304***	0.411***	0.145***	0.477***
9	Industry funding ^a	5412	7036	0.000	61490	0.130***	0.730***	-0.344***	0.481***	0.533***	0.265***	0.690***
10	Bio-council funding ^a	1094	2460	0.000	21131	0.101**	0.667***	-0.289***	0.501***	0.495***	0.203***	0.534***
11	EPSRC funding ^a	4237	6885	0.000	68000	0.027	0.765***	-0.307***	0.477***	0.458***	0.271***	0.688***
12	ESRC funding ^a	566	1258	0.000	22000	0.044	0.395***	-0.140***	0.213***	0.280***	0.168***	0.244***
13	Regional VC	628	796	0.000	4316	-0.086**	0.115***	-0.007	0.204***	0.185***	-0.075*	0.055†
14	Regional Science parks	0.617	0.822	0.000	5.000	-0.012	0.482***	-0.200***	0.313***	0.312***	0.137***	0.396***
15	TTO autonomy	1.282	1.135	0.000	3.000 ^b	0.022	0.444***	-0.192***	0.315***	0.352***	0.264***	0.393***
16	TTO age	5.889	6.884	0.000	33.00	0.067*	0.674***	-0.328***	0.357***	0.413***	0.281***	0.565***
17	TTO membership	2.753	3.428	0.000	11.00	-0.120***	0.327***	0.049	0.221***	0.053	0.364***	0.120***

		8	9	10	11	12	13	14	15	16	17
8	University Nobel	1.000									
9	Industry funding	0.791***	1.000								
10	Bio-council funding	0.616***	0.729***	1.000							
11	EPSRC funding	0.530***	0.765***	0.600***	1.000						
12	ESRC funding	0.268***	0.332***	0.349***	0.345***	1.000					
13	Regional VC	0.059†	0.104**	0.178***	0.146***	0.082*	1.000				
14	Regional Science parks	0.526***	0.542***	0.362***	0.412***	0.153***	-0.109***	1.000			
15	TTO autonomy	0.349***	0.406***	0.437***	0.367***	0.190***	0.120***	0.270***	1.000		
16	TTO age	0.443***	0.550***	0.466***	0.546***	0.222***	-0.074*	0.491***	0.605***	1.000	
17	TTO membership	0.035	0.180***	0.167***	0.270***	0.198***	0.042	0.046	0.223***	0.305***	1.000

All variables are lagged by two years, except Imitation.

^a Mean, S.D., Min. and Max. multiplied by 10^3

^b The only TTO with values of autonomy = 4 is Imperial College London's, which was listed in 2006 (i.e. at the end of our observation period). However, observations for the autonomy variable of Imperial College in 2006 and 2007 were dropped since we lagged all independent variables by two years.

$N = 892$

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2. Fixed-effects regression on imitation of the commercialization leader (two-year lags)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
TTO live spinoffs	-0.414*** (0.056)	-0.418*** (0.055)	-0.251*** (0.065)	-0.306*** (0.060)	-0.223*** (0.065)	-0.274*** (0.069)
TTO revenues (relative)	0.117** (0.036)	0.114** (0.036)	0.121*** (0.036)	0.115** (0.036)	0.116*** (0.035)	0.117*** (0.035)
Media coverage	-0.059† (0.031)	-0.059† (0.030)	-0.056† (0.030)	-0.067* (0.030)	-0.061* (0.030)	-0.059* (0.030)
University age (ln)	-1.718*** (0.147)	-1.593*** (0.148)	-1.439*** (0.156)	-1.527*** (0.151)	-1.274*** (0.157)	-1.177*** (0.158)
University size (ln)	-0.871*** (0.106)	-0.808*** (0.106)	-0.789*** (0.106)	-0.768*** (0.107)	-0.690*** (0.106)	-0.596*** (0.109)
University patents	-0.105* (0.046)	-0.091* (0.046)	-0.070 (0.046)	-0.123** (0.046)	-0.076 (0.046)	-0.057 (0.046)
University Nobel	0.786† (0.412)	0.874* (0.407)	0.511 (0.410)	0.499 (0.412)	0.470 (0.408)	0.693† (0.407)
Industry funding	0.401*** (0.093)	0.363*** (0.092)	0.379*** (0.092)	0.405*** (0.092)	0.354*** (0.091)	0.353*** (0.091)
Bio-council funding	0.032 (0.039)	0.028 (0.038)	0.038 (0.038)	0.035 (0.038)	0.035 (0.038)	0.024 (0.038)
EPSRC funding	-0.120** (0.045)	-0.128** (0.044)	-0.106* (0.044)	-0.111* (0.044)	-0.110* (0.044)	-0.108* (0.043)
ESRC funding	-0.054* (0.027)	-0.053* (0.027)	-0.060* (0.027)	-0.042 (0.027)	-0.051† (0.026)	-0.042 (0.026)
Regional VC	-0.104** (0.039)	-0.068† (0.039)	-0.110** (0.038)	-0.107** (0.038)	-0.078* (0.039)	-0.065† (0.038)
Regional Science parks	0.055 (0.084)	0.052 (0.083)	0.060 (0.083)	0.085 (0.083)	0.074 (0.082)	0.071 (0.081)
TTO autonomy		-0.214*** (0.048)			-0.186*** (0.047)	-0.279*** (0.052)
TTO age			-0.502*** (0.105)		-0.392*** (0.109)	-0.238 (0.164)
TTO membership				-0.220*** (0.048)	-0.135** (0.050)	-0.352*** (0.073)
TTO autonomy x TTO age						-0.411† (0.227)
TTO autonomy x TTO membership						0.342*** (0.083)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
(Constant)	-0.303*** (0.027)	-0.308*** (0.027)	-0.319*** (0.027)	-0.307*** (0.027)	-0.323*** (0.026)	-0.327*** (0.026)
<i>N</i>	892	892	892	892	892	892
<i>R</i> ²	0.56	0.57	0.57	0.57	0.59	0.60
F-statistic	59.68***	58.87***	59.17***	58.93***	56.22***	52.97***

Standard errors in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3. Fixed-effects regression on imitation of the commercialization leader (three-year lags)

	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
TTO live spinoffs	-0.355*** (0.056)	-0.363*** (0.055)	-0.235*** (0.062)	-0.250*** (0.058)	-0.202** (0.062)	-0.257*** (0.066)
TTO revenues (relative)	0.067† (0.036)	0.067† (0.036)	0.072* (0.036)	0.066† (0.036)	0.070* (0.035)	0.075* (0.035)
Media coverage	-0.076* (0.033)	-0.074* (0.033)	-0.069* (0.033)	-0.082* (0.033)	-0.073* (0.032)	-0.069* (0.032)
University age (ln)	-1.378*** (0.148)	-1.273*** (0.149)	-1.140*** (0.157)	-1.144*** (0.152)	-0.951*** (0.158)	-0.848*** (0.159)
University size (ln)	-0.624*** (0.104)	-0.584*** (0.103)	-0.578*** (0.103)	-0.513*** (0.104)	-0.477*** (0.103)	-0.382*** (0.105)
University patents	-0.033 (0.047)	-0.021 (0.047)	0.002 (0.047)	-0.052 (0.046)	-0.012 (0.047)	0.002 (0.047)
University Nobel	0.586 (0.434)	0.631 (0.430)	0.299 (0.434)	0.186 (0.432)	0.129 (0.430)	0.360 (0.429)
Industry funding	0.358*** (0.092)	0.326*** (0.092)	0.339*** (0.091)	0.365*** (0.091)	0.323*** (0.090)	0.333*** (0.090)
Bio-council funding	0.050 (0.036)	0.051 (0.036)	0.062† (0.036)	0.059 (0.036)	0.066† (0.035)	0.059† (0.035)
EPSRC funding	-0.028 (0.044)	-0.027 (0.044)	0.002 (0.044)	-0.003 (0.044)	0.012 (0.044)	0.017 (0.043)
ESRC funding	-0.029 (0.026)	-0.029 (0.026)	-0.038 (0.026)	-0.013 (0.026)	-0.024 (0.026)	-0.011 (0.026)
Regional VC	-0.154*** (0.037)	-0.131*** (0.037)	-0.158*** (0.036)	-0.161*** (0.036)	-0.143*** (0.036)	-0.139*** (0.036)
Regional Science parks	-0.033 (0.082)	-0.033 (0.081)	-0.028 (0.081)	-0.003 (0.081)	-0.008 (0.080)	-0.012 (0.079)
TTO autonomy		-0.198*** (0.049)			-0.168*** (0.048)	-0.260*** (0.053)
TTO age			-0.448*** (0.105)		-0.309** (0.108)	-0.170 (0.168)
TTO membership				-0.243*** (0.045)	-0.181*** (0.047)	-0.386*** (0.068)
TTO autonomy x TTO age						-0.389† (0.231)
TTO autonomy x TTO membership						0.318*** (0.076)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
(Constant)	-0.432*** (0.027)	-0.442*** (0.027)	-0.443*** (0.027)	-0.433*** (0.026)	-0.448*** (0.026)	-0.451*** (0.026)
<i>N</i>	844	844	844	844	844	844
<i>R</i> ²	0.53	0.54	0.54	0.55	0.56	0.57
F-statistic	49.28***	48.41***	48.63***	49.92***	47.00***	44.51***

Standard errors in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4. Two-stage least squares regression with instrumental variables

	Model 13	Model 14
TTO live spinoffs	-0.490* (0.230)	-0.876* (0.414)
TTO revenues (relative)	0.078 (0.090)	0.082 (0.089)
Media coverage	-0.044 (0.074)	-0.033 (0.076)
University age (ln)	0.095 (0.925)	0.642 (1.197)
University size (ln)	-0.022 (0.484)	0.622 (0.802)
University patents	0.171 (0.191)	0.280 (0.240)
University Nobel	2.240 (1.496)	3.728† (2.162)
Industry funding	-0.153 (0.396)	-0.131 (0.386)
Bio-council funding	-0.030 (0.101)	-0.106 (0.123)
EPSRC funding	-0.223† (0.131)	-0.198 (0.124)
ESRC funding	-0.070 (0.066)	-0.004 (0.069)
Regional VC	0.427 (0.328)	0.469 (0.348)
Regional Science parks	-0.038 (0.213)	-0.053 (0.215)
TTO autonomy	-3.155† (1.843)	-3.544† (2.045)
TTO age	-0.475† (0.273)	0.508 (0.629)
TTO membership	0.340 (0.317)	-1.281* (0.613)
TTO autonomy x TTO age		-2.674† (1.529)
TTO autonomy x TTO membership		2.464† (1.348)
Year dummies	Yes	Yes
(Constant)	-0.352*** (0.073)	-0.369*** (0.078)
<i>N</i>	883	883
Wald- X^2	193.363	195.257

Standard errors in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5. Fixed-effects regression on the imitation of different (a) leaders and (b) strategies

	Model 15 Outsourcing	Model 16 Joint ventures
TTO live spinoffs	0.037 (0.028)	0.920*** (0.062)
TTO revenues (relative)	0.026† (0.015)	0.032 (0.033)
Media coverage	0.014 (0.013)	0.054† (0.028)
University age (ln)	-0.210** (0.066)	-0.071 (0.146)
University size (ln)	0.068 (0.045)	-0.016 (0.105)
University patents	-0.007 (0.020)	0.135** (0.043)
University Nobel	-0.538** (0.177)	-0.971* (0.387)
Industry funding	0.025 (0.043)	0.217* (0.094)
Bio-council funding	-0.019 (0.017)	0.011 (0.037)
EPSRC funding	0.050** (0.019)	-0.019 (0.042)
ESRC funding	-0.017 (0.011)	-0.009 (0.025)
Regional VC	0.006 (0.017)	0.111** (0.037)
Regional Science parks	0.067† (0.037)	-0.465*** (0.081)
TTO autonomy	-0.025 (0.020)	-0.083† (0.044)
TTO age	0.091† (0.047)	0.223* (0.105)
TTO membership	0.026 (0.021)	0.026 (0.046)
Oxford TTO	0.034† (0.019)	-0.030 (0.055)
Cambridge TTO	Omitted ^a	-0.039 (0.048)
Imperial TTO	0.003 (0.018)	0.142* (0.071)
Year dummies	Yes	Yes
(Constant)	0.041** (0.015)	0.746*** (0.034)
<i>N</i>	879	879
R ²	0.29	0.65
F-statistic	14.28***	63.64***

Standard errors in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ ^a Omitted due to collinearity.

Table 6. Fixed-effects regression on the 3-year standard deviation of commercialization strategies

	Model 17 Outsourcing	Model 18 Joint ventures
TTO live spinoffs	-0.025 (0.030)	0.003 (0.015)
TTO revenues (relative)	0.085*** (0.014)	-0.044*** (0.007)
Media coverage	-0.013 (0.020)	-0.003 (0.010)
University age (ln)	0.108 (0.068)	-0.173*** (0.035)
University size (ln)	0.161*** (0.045)	-0.178*** (0.023)
University patents	-0.008 (0.020)	-0.025* (0.010)
University Nobel	0.287† (0.170)	-0.083 (0.087)
Industry funding	0.023 (0.039)	0.035† (0.020)
Bio-council funding	0.019 (0.016)	-0.022** (0.008)
EPSRC funding	-0.032† (0.018)	-0.032*** (0.009)
ESRC funding	0.010 (0.014)	0.009 (0.007)
Regional VC	0.013 (0.018)	-0.021* (0.009)
Regional Science parks	-0.016 (0.035)	0.024 (0.018)
TTO autonomy	-0.011 (0.021)	0.007 (0.011)
TTO age	0.135** (0.050)	-0.086*** (0.026)
TTO membership	0.009 (0.024)	0.020 (0.012)
Year dummies	Yes	Yes
(Constant)	0.316*** (0.010)	0.140*** (0.005)
<i>N</i>	726	726
R ²	0.19	0.49
F-statistic	7.32***	29.93***

Standard errors in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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