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RESEARCH ARTICLE

A procedural perspective on academic spin-off creation: the changing relative importance of the academic and the commercial sphere

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Abstract Academic scientists who commercialize their research findings via spin-off creation have to transition from the academic sphere to the commercial sphere. Along this spin-off creation process, they face challenges adapting to the conflicting logics of these spheres. We hypothesize that throughout the three phases of this process, the importance of the academic sphere decreases while the importance of the commercial sphere increases. We collected a representative sample of 1,149 scientists from the German state of Thuringia. To test our hypotheses, we apply dominance analysis and estimate the relative importance of the two spheres. In line with our hypotheses, the importance of the academic sphere declines and the importance of the commercial sphere increases at the beginning of the process. Towards the end of the process, we observe a further decline in the relative importance of the academic sphere, but, unexpectedly, also a decline for the commercial sphere. Notably, our results show that the commercial sphere is in general more important than the academic sphere throughout the process. Our results challenge existing conceptualizations that emphasize the importance of the academic sphere, especially at the beginning of the spin-off founding process. The results provide intervention points for policy measures to promote academic spin-offs.

Plain English Summary *Venturing scientists need to navigate the changing relevance of the academic and commercial spheres throughout the academic spin-off creation process. Strikingly, the influence of the commercial sphere dominates the process early on.*

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We investigate how scientists' embeddedness in two opposing spheres — the academic sphere and the commercial sphere — affects the process of academic spin-off (ASO) creation. These spheres have contrasting institutional and normative structures that influence scientists' behavior. We conceptually divide the ASO

process into distinct phases, starting with the research phase and concluding with the establishment of the spin-off. Venturing scientists need to transition along these phases. We observe that the level of embeddedness in both spheres influences the success of these transitions. Furthermore, the commercial sphere holds greater importance than the academic sphere, right from the outset of the ASO process. To support the creation of spin-offs, policymakers should focus on facilitating scientists' exposure to the commercial sphere. This can be achieved by implementing entrepreneurship education initiatives and encouraging scientists to gain industry experience. Additionally, academic institutions can play a vital role in supporting scientists by reducing administrative burdens and recognizing their entrepreneurial efforts alongside their academic qualifications. Future research could expand our understanding of the relative importance of both spheres in other contexts, such as social entrepreneurship, where commercial and social-oriented logics converge.

Keywords Academic spin-off · Conflicting logics · Process perspective · Phase model · Dominance analysis

JEL Classification L26 · O31 · O33

1 Introduction

Academic spin-offs (ASOs) are an important mechanism for transferring scientific and technological knowledge from academia to practical application in the economy and society (Meoli & Vismara, 2016, Rasmussen et al., 2006, Shane, 2004). These ASOs can have a substantial economic and societal impact by introducing new business models, creating jobs, contributing to the formation and growth of new industries, and addressing grand societal challenges (Fini et al., 2018, Rasmussen et al., 2020, Vincett, 2010). However, despite the increasing number of ASOs in recent decades (Mathisen & Rasmussen, 2019), the rate of ASO projects that have failed or been abandoned at some point in the venture creation process remains high, leaving a large stock of knowledge and commercial opportunities unexploited (e.g., Braunerhjelm, 2007; Fini et al., 2017).

Extensive research has been conducted to understand the ASO creation process, focusing on its phases and the barriers encountered along the way. It has been shown that in this dynamic and multi-phase process, founders need to accomplish a specific set of activities in each development phase before progressing to the next (Ndonzuau et al., 2002, Rasmussen, 2011, van Geenhuizen & Soetanto, 2009, Vohora et al., 2004, Wood, 2011). Academic entrepreneurs must overcome "critical junctures", defined as complex problems that "occur at a point along a new high-tech venture's expansion path, preventing it from achieving the transition from one development phase to the next" (Vohora et al., 2004, p. 159). These critical junctures arise because different phases of spin-off development require distinct configurations of resources, capabilities, network ties, and support. Qualitative studies document how ASOs develop through the creation process depending on the academic entrepreneurs' access to specific resources and social networks in different process phases (Fernández-Alles et al., 2015, Hayter, 2016a, b). Additionally, first quantitative analyses focus on specific phases of the ASO creation process. For instance, Krabel & Mueller (2009) explored the drivers of individual academic scientists' decision to pursue ASO creation, i.e., becoming nascent entrepreneurs, while Landry et al. (2006) investigated the individual and organizational assets that increase the likelihood of ASO formation. However, a quantitative assessment of the entire ASO creation process, its different phases, and the transitions between these phases is still missing. Such an analysis would provide insights into the relevant determinants in each phase and can have implications, beyond scholarly advancement, for practitioners and policymakers (Fini et al., 2018, Sandström et al., 2018).

Prior studies on the determinants of success in the ASO creation process highlight the importance of scientists' embeddedness in both the academic and commercial spheres (Dasgupta & David, 1994, Rasmussen, 2011, Stephan & Levin, 1996). These two spheres represent distinct sets of competencies, activities, and social behaviors. Individuals embedded in a sphere share and appreciate specific attitudes, norms, and logics. They determine social individual behavior from which deviation is only tolerated to a certain degree (Merton, 1968). Thus, the two spheres encompass the different characteristics that describe the scientists and their contexts, serving as meta constructs to describe the two settings in which scientists must be embedded during the ASO creation process. Embeddedness refers to the relationship between the institutional and social structures of a sphere and an individual's behavior within that sphere (Beckert, 2003, Granovetter, 1992, Le Breton-Miller & Miller, 2009, Zukin & DiMaggio, 1990). Specifically, "embeddedness involves: understanding the nature of the structure [i.e. sphere], enacting or reenacting this structure which forges new ties, and maintaining both the link and the structure" (Jack & Anderson, 2002, p. 468). In the context of the ASO creation process, the central issue is that scientists are initially embedded in the academic sphere, where Mertonian norms prevail and knowledge is considered a public good. However, they must also engage with the commercial sphere, which operates under substantially different attitudes, norms, and logics, such as rent-seeking and secrecy. Throughout the process of new venture creation, scientists face tensions between these two spheres due to their opposing logics (Ambos et al., 2008). To successfully create a new venture, scientists must navigate and overcome these tensions (Rasmussen, 2011). While the importance of the two spheres and the challenge of reconciling their differences between the two spheres have been widely acknowledged, empirical insights into the importance and how this importance changes throughout the process are absent so far.

In this study, we aim to bridge this gap by empirically testing the changing relative importance of the academic and commercial spheres along the ASO creation process. To achieve this objective, we adopt a procedural perspective on ASO creation and investigate how scientists' embeddedness in both spheres influences their transition from one process phase to the next. We begin by conceptualizing the ASO creation as a sequential process divided into subsequent phases, drawing on similar approaches in the existing literature (Ndonzuau et al., 2002, Rasmussen, 2011, van Geenhuizen & Soetanto, 2009, Vohora et al., 2004, Wood, 2011). In order to successfully transition from one phase to the next and eventually establish a new firm, scientists must overcome critical junctures that act as barriers between these process phases. We recognize that venturing scientists are initially embedded in the academic sphere, but need to adapt to the commercial sphere. Building on previous research on institutional logics theory (Fini et al., 2010, Perkmann et al., 2019) and the relevance of both spheres in the ASO creation process (Clarysse & Moray, 2004, Fisher et al., 2016, Rasmussen, 2011), we hypothesize that the relative importance of the academic sphere decreases as the process unfolds, while the relative importance of the commercial sphere increases.

To test our hypotheses, we utilize novel survey data collected from a representative sample of 1,149 scientists employed at universities and public research institutes in the German federal state of Thuringia. The survey elicits information about the scientists' past involvement in various phases of ASO creation and their embeddedness in the different spheres. Our cross-sectional dataset enables us to reconstruct each scientist's involvement in the respective phases of the ASO creation process. We estimate the likelihood of individual scientists advancing to the subsequent phase for each phase transition. By applying dominance analysis, we can determine the changing relative importance of scientists' embeddedness in the two spheres throughout the ASO creation process. This method decomposes the overall goodness-of-fit measure of a regression model into the contributions of each predictor variable, allowing us to assess their relative importance. Additionally, we employ different approaches to examine how the relative importance of each sphere changes between phases.

Our results provide support for our hypotheses, showing that the relative importance of the academic sphere decreases throughout the ASO creation process, while the commercial sphere becomes increasingly important. However, we find an exception during the transition into the final phase of venture creation, where the commercial sphere turns out to be less important. These findings partially support the conceptual suggestions by Rasmussen (2011). Furthermore, when comparing the relative importance of the two spheres, our results reveal that the commercial sphere consistently has a higher importance than the academic sphere for transitioning from one phase to the next, even from the early stages of the process, challenging existing perceptions. These results remain stable when subjected to several robustness checks, including alternative estimation approaches, control variables, and operationalizations of the spin-off creation process. Overall, our findings highlight the differential influences of the academic and commercial spheres in different phases of the ASO creation process. Scientists, who are initially embedded in the academic sphere, must adapt to the logics prevalent in the commercial sphere to successfully accomplish spin-off creation.

Our study contributes to the academic entrepreneurship literature in several ways. Firstly, we adopt a micro-level perspective by analyzing the ASO creation process from the viewpoint of individual scientists, focusing on their engagement in spin-off creation. Previous research has remained predominantly at the spin-off project level, neglecting the individual characteristics and tensions. We start from the premise that academic entrepreneurship is an individual endeavor where the scientist as the main actor has to bring his idea to the market (Guerrero & Urbano, 2014, Kleinhempel et al., 2022). Secondly, by starting with a population of scientists working in research organizations, we are able to trace the selection process of ASO throughout the entire ASO creation process, from recognizing a business opportunity based on scientific research to venture creation (Aldrich & Martinez, 2001, Ndonzuau et al., 2002). Thus, we provide quantitative assessment of scientists' discontinuation of their entrepreneurial pursuit along the ASO creation process. Thirdly, we integrate the academic entrepreneurship process theory (Rasmussen, 2011, Vohora et al., 2004, Wood & McKinley, 2010) with the multiple institutional logics theory (Fini et al., 2010, Perkmann et al., 2019). This integration allows for a better understanding of the importance of scientists' embeddedness in both spheres for development until the firm is established and to understand the tensions between the spheres that arise from differences in attitudes, norms and logics faced by scientists during ASO creation. By exploring the impact of scientists' embeddedness in the academic and commercial spheres on their progression along the ASO creation process, we contribute to a better understanding of the complex relationships in the process. Lastly, by employing dominance analysis to determine the changing relative importance of scientists' embeddedness in the two spheres, we can compare the importance of these spheres throughout the ASO creation process. This analytical method enables us to move beyond assessing the effect sizes of individual variables and instead examine the combined influence of multiple variables on the phenomena under investigation, i.e., the two spheres (Azen & Budescu, 2003, Azen & Traxel, 2009, Budescu, 1993).

In the following Section 2, we discuss the peculiarities and differences between the academic and the commercial spheres, propose a conceptualization of the ASO creation process, and present our hypotheses linking both spheres to the individual process phases. Section 3 provides a description of our data and empirical approach. Our analysis is presented in Section 4. Finally, in Section 5, we discuss the results and provide concluding remarks.

2 Theoretical background

2.1 Academic and commercial sphere

Academic scientists primarily engage in the generation and diffusion of knowledge but some of them recognize an opportunity to commercialize the findings. Such an economic opportunity can be exploited via different transfer channels, such as patenting, licensing, or creating a new venture (Bekkers & Bodas Freitas, 2008, D'Este et al., 2019, Ding & Choi, 2011, Wood, 2009). Commercialization activities require scientists to move from the familiar academic sphere into the less familiar commercial sphere. In particular, academic spin-offs (ASO) — firms founded by scientists based on their research outcomes — directly transfer these outcomes into economic application (Karnani, 2012, Steffensen et al., 2000). The entrepreneurial scientists either leave academia altogether to work solely on their spin-off or stay in both the academic and the commercial spheres, sometimes referred to as an entrepreneurial hybrid (Lam, 2010, Nicolaou & Birley, 2003). The latter case is particularly interesting because these scientists need to simultaneously engage with two spheres where opposing logics prevail (Murray, 2010, Rasmussen, 2011, Samsom & Gurdon, 1993, Shinn & Lamy, 2006). The differences between the two spheres and the way to cope with these differences might create tensions or even failures in the ASO creation process (Gurdon & Samsom, 2010).

Significant challenges in founding an ASO refer to reaching out from the known academic sphere to a commercial one and adapting and acting within this commercial sphere (Dasgupta & David, 1994, Rasmussen, 2011, Stephan & Levin, 1996). In this process, difficulties arise because the two spheres have opposing logics which we summarize in Table 1. These logics comprise different norms constituting scientists' roles and functions, different understandings and usages of knowledge. Also, the logics contain different reward systems incentivizing a behavior compliant with the respective norms and different motivational factors to perform their roles and functions (Clarysse et al., 2023, Hayter, 2011, Jain et al., 2009, Lam, 2010). Furthermore, in both spheres, competition exists but for different outcomes: academic and commercial success. Specific competencies are required to fulfill their roles and functions and to withstand the competition within each sphere. Overcoming these differences between the two logics is a prerequisite for establishing the ASO. Along this process, scientists must learn, change and adapt to successfully establish a firm. In the following, we discuss the two spheres in more detail and the process of dealing with their idiosyncrasies.

According to Merton (1973), in the *academic sphere*, the ethos of science can be characterized by four norms: communism, disinterestedness, universalism, and organized skepticism. Ziman (1984) added originality as a fifth norm.[1] These norms guarantee the freedom of research, create an open science mentality and treat knowledge as a public good to ensure the progress of science (Baldini et al., 2007, Nelson, 1959, Rosenberg, 1974). Embedded in these norms, scientists are both intrinsically and extrinsically motivated to conduct research. They are intrinsically motivated by the quest for fundamental understanding, the freedom of research, and the enjoyment of puzzle solving (Lam, 2011, Merton, 1968). Extrinsically, they are motivated by community recognition via publications and citations (Lam, 2011). Another extrinsic motivation is financial rewards, which is the least relevant (Lam, 2011). The academic reward system grants peer recognition and reputation to scientists based on their scientific contributions (Dasgupta & David, 1994), leading to a predominant publication orientation and a "publish-or-perish" culture (Ndonzuau et al., 2002). The reward system introduces competition between scientists in terms of quantity and quality of research outputs and competition for scarce inputs they need for their research (van Rijnsoever et al., 2008). To successfully compete in this sphere, specific competencies, such as analytical thinking, methodological and technical skills, and the ability to communicate research results, are needed (Bartunek & Rynes, 2014, de Grande et al., 2014). Overall, the academic sphere is characterized by the underlying impetus of the production and the advancement of knowledge in aiming for the progress of science (Nelson, 1959, Rosenberg, 1974). An economic rationale plays hardly any role.

The *commercial sphere* stands opposite the academic sphere, where fundamentally different logics and norms apply (see Table 1). The norms of this sphere revolve around market competition and rent-seeking, both of which encourage behavior that leads to knowledge generation and application under cost-benefit considerations. This behavior is embedded in bureaucratic control, secrecy, and restrictions on disclosure (Hayter, 2011, Sauermann & Stephan, 2013). Knowledge is understood as a private good. Its exploitation and attainment aims at creating a competitive advantage (Dasgupta & David, 1994, Levin et al., 1987, Stephan & Levin, 1996). The focus is on application-oriented knowledge to solve problems for practical purposes (Bartunek & Rynes, 2014, Stokes, 1997). Especially entrepreneurs exploit such knowledge when they work on a business opportunity (Schumpeter, 1911). They are intrinsically motivated by, for instance, the passionate identification with their business, often describing it as their "baby", or self-realization (Cardon et al., 2005, Huyghe et al., 2016). Extrinsically, entrepreneurs are motivated by, e.g., financial gains and growth ambitions (Cassar, 2007, Hossinger et al., 2021). The reward system recognizes entrepreneurial success via profits and market shares. In this sphere, entrepreneurship-specific knowledge, skills, and competencies are required to found and run a company (Criaco et al., 2014, Stuetzer et al., 2012, Ucbasaran et al., 2008). Also, the ability to evaluate the commercial potential, acquire and manage resources, lead (larger) teams, and show vision for sustainable returns are required (Baldini et al., 2007, Shane, 2004).

Scientists are socialized in the academic sphere, and commercializing research results contradicts their norms. As a result of this socialization process, they usually acquire a "taste for science" (Roach & Sauermann, 2010), lowering their appeal to working within the commercial sphere (Fritsch, 2012). Entrepreneurial activity contradicts the open science mentality, which considers knowledge a public good (Krabel & Mueller, 2009). However, for a successful application of research results in the commercial sphere, scientists need to

[1] "Communism of science" refers to unbiased research, knowledge generation, and sharing since knowledge is considered a public good. "Disinterestedness of science" describes the independent work of scientists, driven solely by the goal of contributing to the knowledge stock as an end in itself. Thus, they conduct their work with integrity, free from any profit-driven motives. "Universalism of science" characterizes the verifiability of research and the independence of research results from the investigator. "Organized skepticism" describes the scientists' approach of critical reflection when theorizing and conceptualizing. "Originality" entails the ambition to continually explore the unknown in order to discover novel research results.

Table 1 Comparison of the academic and commercial sphere

	Academic sphere	Commercial sphere
Norms	Ethos of science defined by the norms communism, disinterestedness, universalism, organized skepticism, and originality (Merton, 1973, Ziman, 1984)	Market competition and rent-seeking under bureaucratic control, secrecy and restrictions on disclosure (Sauermann & Stephan, 2013)
Relation to knowledge	Knowledge production, diffusion, and scientific progress (Nelson, 1959, Rosenberg, 1974)	Appropriation of knowledge for commercial exploitation (Levin et al., 1987)
Motivation	Intrinsic: quest for fundamental understanding, puzzle solving (Lam, 2011, Stokes, 1997)	Intrinsic: passion for business ideas, self-realization (Cardon et al., 2005)
	Extrinsic: reputation, peer recognition and financial returns (Lam, 2011)	Extrinsic: financial gain and growth intentions (Cassar, 2007, Lam, 2011)
Reward system	Career progress and peer recognition via publications, citations, and rankings (Dasgupta & David, 1994)	Maximization of profit and market share
Competition	For journal publications, funding, and research inputs (van Rijnsoever et al., 2008)	For markets, market share, and knowledge (Dosi & Nelson, 2010)
Competencies	Analytical thinking, methodological skills, technical skills, etc. (de Grande et al., 2014)	Ability to evaluate commercial potential, acquire resources, to lead a team, and show a vision (Baldini et al., 2007, Shane, 2004)

Source: Own elaboration

adapt to the logics of the commercial sphere while fulfilling their academic role (Rasmussen, 2011). The transition from the academic to the commercial sphere can be understood as a process. It is challenging, risky, and the actors are confronted with tensions (Ambos et al., 2008, Neves & Franco, 2018, Samsom & Gurdon, 1993). Along this process, the scientists also transition into their role identity and become academic entrepreneurs (Hayter et al., 2022, Jain et al., 2009).

2.2 The two spheres in the academic spin-off creation process

The process of creating an ASO consists of distinct phases, with specific activities and challenges to overcome in each phase (Clarysse & Moray, 2004, Hossinger et al., 2020, Kleinhempel et al., 2022, Ndonzuau et al., 2002, Neves & Franco, 2018, Vohora et al., 2004). It is important to acknowledge that this process involves a degree of trial and error. Therefore, the development of ASO projects is seen as a quasi-linear process with feedback loops within each phase (van Geenhuizen & Soetanto, 2009, Vohora et al., 2004). Based on this understanding, we conceptualize the ASO creation process as comprising four consecutive phases (see Table S3 in Electronic Supplementary Material for similar conceptualizations in the academic entrepreneurship literature). As shown in the upper half of Fig. 1, venturing scientists must navigate three transitions: from the initial research phase to the opportunity framing phase (Transition 1); from the opportunity framing phase to the pre-spin-off phase (Transition 2); and finally, from the pre-spin-off phase to the spin-off phase (Transition 3). In each phase, scientists need to accomplish specific objectives to progress to the next phase, and at each transition, some scientists may drop out of the ASO process. We argue that these dropouts are driven by the individual scientists' embeddedness in the academic and commercial spheres, as well as the changing relevance of these spheres along the ASO process (as depicted in the lower part of Fig. 1). In the following, we discuss the different phases and the importance of embeddedness in both spheres for successful transitions, drawing on and expanding upon prior research by Fini & Toschi (2016), Fisher et al. (2016), Rasmussen et al. (2011), among others.

The *research phase* is the initial stage of the ASO creation process, where venturing scientists focus on conducting scientific research within their respective fields of expertise. They dedicate their efforts to purely academic activities, such as knowledge generation and publication, driven by the pursuit of academic reputation and in adherence to the norms and rules of the academic sphere (Lam, 2011, Merton, 1973, Vohora et al., 2004). Engaging in research activities serves as

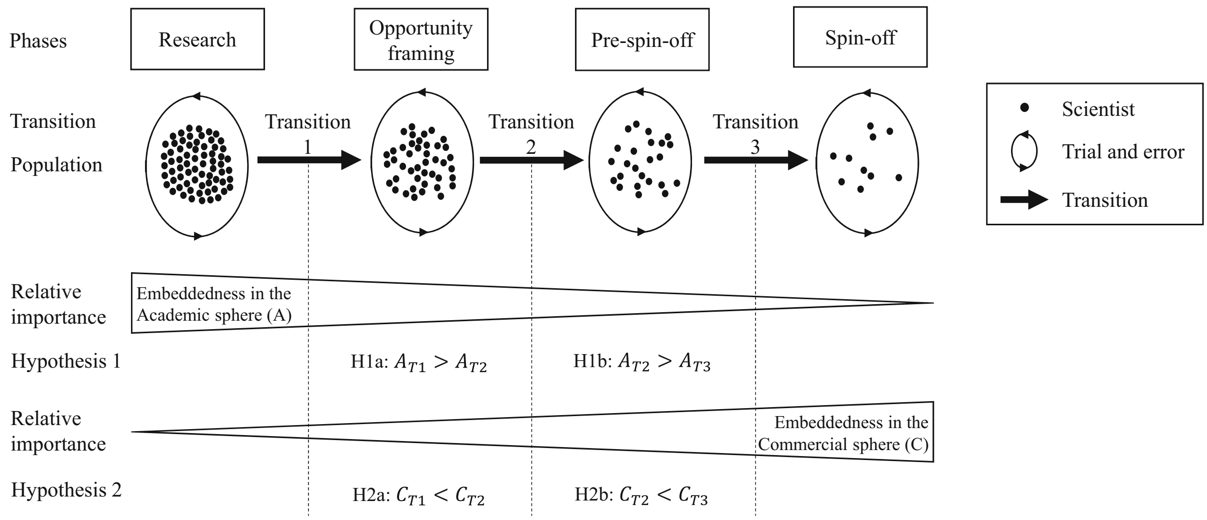

Fig. 1 Conceptualization of the transition process and the changing relative importance of the two spheres

an essential prerequisite for scientists to identify potential business opportunities (Aldawod, 2022, Huegel et al., 2023). Studies have demonstrated that scientists who produce more research output and possess a more diverse knowledge base are better equipped to recognize the commercial potential of their work (see, e.g., Louis et al. 1989).

Following the research phase, scientists enter the *opportunity framing phase* (Transition 1). At this stage, the academic sphere holds greater importance than the commercial sphere, as scientists draw upon their academic embeddedness to validate the commercial potential of their research (Ramos-Rodríguez et al., 2010, Rasmussen et al., 2011). The academic sphere provides a supportive environment where they can leverage their research-oriented norms, access resources, and collaborate with peers to identify entrepreneurial prospects and refine research outcomes into viable business opportunities (Fernández-Alles et al., 2015, Rasmussen et al., 2011). On the other hand, the commercial sphere's relevance is relatively lower in this phase. The commercialization process is in its early stage, and scientists prioritize understanding the potential applications of their research. Interaction with the commercial sphere may involve initial market research or consultation with industry experts, but the emphasis is primarily on nurturing and developing the scientific foundation upon which the spin-off venture will be built (Ndonzuau et al., 2002, Rasmussen et al., 2011). The opportunity framing phase concludes with the commitment to the spin-off project and the initiation of necessary preparatory steps (Vohora et al., 2004). However, not all venturing scientists show their commitment at this stage. Factors such as a lack of entrepreneurial self-efficacy (Huyghe & Knockaert, 2015), insufficient entrepreneurial competencies (González-López et al., 2021), concerns regarding time commitment and risk, or a reluctance to depart from the open science mentality may contribute to scientists' decision not to pursue the spin-off project and abandon the ASO process (Erikson et al., 2015, Krabel & Mueller, 2009, Nelson, 2016).

Once scientists commit to their spin-off project, they transition from the opportunity framing phase to the *pre-spin-off phase* (Transition 2). This transition involves translating the identified business opportunity into a concrete business idea and preparing for the establishment of the spin-off (Vohora et al., 2004). In this context, the commercial sphere becomes more important, while the significance of the academic sphere relatively diminishes. The increasing importance of the commercial sphere arises from the need to align the business idea with market demands and considerations. Scientists must understand customer needs, identify suitable markets, and develop a compelling value proposition (Ndonzuau et al., 2002). The commercial sphere operates under different norms and logics, emphasizing market competition, profitability, and the creation of competitive advantage. Scientists need to adapt to these norms and engage with commercial actors, such as industry professionals, investors, and potential customers, to enhance their business idea and receive market validation (Audretsch et al., 2011, Dohse et al., 2021, Fernández-Alles et al., 2015, Hayter, 2016b, Huynh et al., 2017). Furthermore, transitioning to the pre-spin-off phase requires scientists to develop entrepreneurial competencies and perform activities that are specific to the commercial sphere, such as writing a business plan, conducting market analyses, and assessing financial viability (Ndonzuau et al., 2002, Vohora et al., 2004). By contrast, the embeddedness in the academic sphere at this stage holds less relevance, and in some cases, it can even be detrimental to the progress of the ASO process. For instance, uncertainty surrounding the commercial viability of the spin-off project may hinder scientists from establishing a firm (Mathisen & Rasmussen, 2019, Raposo et al., 2008). Moreover, academic career development goals and responsibilities in teaching and administration may leave insufficient time for pre-spin-off activities (Gilsing et al., 2011, Jacobson et al., 2004, Sá et al., 2011). Consequently, these scientists encounter difficulties in fully adapting to the commercial logics, thereby further exacerbating tensions between the academic and commercial spheres (Gümüsay & Bohné, 2018; Gurdon & Samsom, 2010). However, if scientists successfully navigate these conflicting logics, they can transition to the next phase.

In summary, the academic sphere's greater importance during the transition from the research phase to the opportunity framing phase can be attributed to its role in providing the foundation for recognizing a business opportunity based on research activities. Conversely, during the transition from the opportunity framing phase to the pre-spin-off phase, the focus shifts towards leveraging the commercial sphere to frame the business opportunity into a concrete idea, develop a market entry plan, and secure the necessary resources for establishing the spin-off project. Accordingly, we suggest the following hypotheses:

H1a: Scientists' embeddedness in the academic sphere is more important for recognizing a business opportunity based on research activities (Transition 1) than for engaging in pre-spin-off activities based on a framed business opportunity (Transition 2).

H2a: Scientists' embeddedness in the commercial sphere is less important for recognizing a business opportunity based on research activities (Transition 1) than for engaging in pre-spin-off activities based on a framed business opportunity (Transition 2).

The ASO creation process culminates in the *spin-off phase*, wherein research outcomes are eventually transformed into a commercial venture (Fernández-Alles et al., 2015). During the transition towards the spin-off phase (Transition 3), the importance of the commercial sphere further increases while the academic sphere ceases to be relevant (Rasmussen, 2011, Rasmussen & Wright, 2015). As the spin-off project moves closer to commercialization, the focus fully shifts from scientific research and academic networks to the practicalities of running a business. The commercial sphere becomes more pertinent as scientists-turned-entrepreneurs need to acquire resources, secure funding, develop marketing strategies, build customer relationships, and establish a competitive position in the market (Delmar & Shane, 2006, Neves & Franco, 2018). The success of the spin-off venture hinges on effectively navigating the market landscape (Huynh et al., 2017). This requires business-oriented expertise, market knowledge, and the ability to adapt to market dynamics (Berbegal-Mirabent et al., 2015, Neves & Franco, 2018). As such, scientists' embeddedness in the commercial sphere is vital as it provides the necessary tools and frameworks for entrepreneurial success. Additionally, while valuable in the early stages, the academic sphere's norms and practices may not align optimally with the practical aspects of setting up and running a business (Perkmann et al., 2019, Rasmussen et al., 2011, Sauermann & Stephan, 2013).

To conclude, as the venturing scientists progress towards the spin-off phase and enter the business realm, the commercial sphere assumes substantial importance, as it encompasses the practical aspects of executing the business plan, securing entrepreneurial resources, and competing in the market. Meanwhile, the norms and logics of the academic sphere no longer apply. Thus, we hypothesize:

H1b: Scientists' embeddedness in the academic sphere is more important for engaging in pre-spin-off activities based on a framed business opportunity (Transition 2) than for founding a firm based on a business plan (Transition 3).

H2b: Scientists' embeddedness in the commercial sphere is less important for engaging in pre-spin-off activities based on a framed business opportunity

(Transition 2) than for founding a firm based on a business plan (Transition 3).

3 Data and method

3.1 Data

We conducted a novel online survey of scientists in the German Federal State of Thuringia to understand the academic spin-off creation process. Thuringia resembles the heterogeneity in the German research landscape well. There are four universities in Thuringia, including one technical university and one university with a university hospital. Furthermore, seven universities of applied sciences, including one music college, and 25 research institutes are present. The research institutes cover the whole range from basic science-oriented institutes of the Max Planck Society, the Helmholtz Association and the Leibniz Association to the applied science institutes, including the Fraunhofer Society, as well as other public and private research organizations (see Table S4 in Electronic Supplementary Material). This variety of organizations assures coverage of different disciplines and different modes of research.

We collected publicly available contact information and characteristics of the scientists from their institutional web pages. We identified 7,785 scientists who we invited to participate in our web-based survey in December 2019 and January 2020. We received 1,409 responses (18.1% response rate) of which we had to exclude 260 observations due to incomplete answers and conduct our analysis with 1,149 observations. The difference between the sample of respondents and the initial population is marginal and non-response bias unlikely.[2] A comparison with the overall population of scientists at universities in Germany (Statistisches Bundesamt, 2020) shows that our sample is representative in terms of academic rank and gender (Table S2 in Electronic Supplementary Material).

Our survey consists of a set of novel questions on the academic spin-off creation process. To ensure the reliability of our survey, we discussed the items with other scientists and practitioners from technology transfer offices and conducted a pre-test with a random sample of scientists from a comparable German state, as suggested by Sue & Ritter (2007). In our survey, we elicited scientists' general socio-demographic characteristics as well as their engagement in knowledge and technology transfer. We included a list of questions on their spin-off creation activities in the last five years. Respondents were asked separately about their activities in the four different phases of the spin-off creation process (see Fig. 1). Table 5 provides the exact wording of the survey questions. These questions are derived from process schemes from the literature conceptualizing academic entrepreneurship (see Table S3 in Electronic Supplementary Material). Due to the nature of the survey questions, scientists might have referred to both single or team entrepreneurship.

The retrospective survey of their sequential activities allows us to overcome the cross-sectional nature of the survey and to reconstruct the spin-off creation process with its successive phases. Furthermore, asking about the different phases individually allows us to not only consider successful spin-off creations, as is usually the case in studies tracking scientists along the academic spin-off creation process (e.g., Fernández-Alles et al., 2015; Fini et al., 2009; Hayter, 2016b), but also spin-off attempts, which stopped at different phases along the process. We can therefore for each scientist reconstruct the process until they either established a venture or abandoned the venture creation process for whatever reason. For our empirical analysis, we create subsamples of active scientists per phase, as portrayed in our research design (Fig. 1) and data (Table 2). Our study considers only the scientists who, in addition to their spin-off project, continued in academia, neglecting spin-offs where the entrepreneur left academia. This specific subgroup of scientists who are sometimes called "hybrid entrepreneurs" (Lam, 2010, Nicolaou & Birley, 2003) is of our interest because they need to act in both the academic and the commercial spheres.

In addition to the survey data, we collected data on the respondents' publication record from Web of

[2] We compared the key characteristics position, gender, organizational focus, and academic discipline (Armstrong & Overton, 1977) in Table S1 in Electronic Supplementary Material. There are some statistically significant differences concerning the disciplines. There is especially an under-representation of scientists from medicine in our respondents. We believe that our initial data collection included many medical doctors with an affiliation to the university hospital but who are not involved in research anymore.

Science (WoS) and Scopus.[3] Furthermore, we collected the publications' source normalized impact factor (SNIP) as provided in the journal record of Scopus.

3.2 Variables

3.2.1 Dependent variables

To measure a scientist's successful transition along the four phases of the academic spin-off creation process (Research phase, Opportunity framing, Pre-spin-off phase and Spin-off phase), we construct three dummy variables for each successful phase transition. A transition from one phase to the next is regarded as successful in our data if scientists stated that they undertook activities relevant to the subsequent phase. First, we treat all our respondents as part of the Research phase, since they are all scientists conducting research. If respondents reported any development of an idea to found a firm, they made Transition 1 into the Opportunity framing phase. Second, those who reported any activities to prepare the firm foundation managed Transition 2 and, thus, reached the Pre-spin-off phase. Third, respondents completed Transition 3 into the Spin-off phase if they reported the foundation of an academic spin-off. From this information, we construct three dummy variables which take the value 1 if respondents successfully transitioned into the next process phase and 0 otherwise.

3.2.2 Independent variables

We use two sets of variables to operationalize the scientists' embeddedness in the academic and commercial spheres. These sets of variables capture the specific characteristics of each sphere, as described in Section 2. For a comprehensive overview of the variables, see Table 5 in the Appendix.

Academic sphere We use six variables to proxy scientists' embeddedness in and exposure to the academic sphere. First, we create a dummy variable indicating if the scientist is a *Professor* or not.[4] The academic rank of a professor in Germany, especially, is a clear indicator of the embeddedness in the academic sphere. Previous research shows that the deep embeddedness of professors in the academic sphere has a negative relationship with spin-off creation (e.g., Aldridge et al., 2014; Fritsch & Krabel, 2012). Second, we use *Time devoted to research* as an indicator of the extent to which scientists value research activity and how they respond to the incentives provided by the academic reward system. Survey participants were asked to state the share of weekly working hours spent on research activities. Third, the scientist's overall *Number of publications* reflects the scientists' reputation as well as their embeddedness in the scientific community. Furthermore, scientific publications serve as a knowledge pool from which commercializable ideas can be identified. Prior research suggests a positive relationship between publication output, research reputation, and the propensity to be involved in spin-off activities (e.g., Aschhoff & Grimpe, 2014; D'Este et al., 2019; Ding & Choi; 2011; Zucker et al., 1998). We log-transform the scientists' number of publications to account for its skewed distribution. Fourth, we use the *Average impact factor* to measure the quality of scientists' research output. Similar to quantity, a higher quality increases the embeddedness in the academic sphere due to reputation and potentially increases access to resources. We construct the variable by averaging the SNIP for each scientist's journal publication to account for differences across disciplines. Lastly, we include two variables to measure scientists' research orientation within the last five years. Following Amara et al. (2019), respondents were asked to indicate the extent to which they conduct *Basic research*, characterized by contributions to fundamental understanding and the extent to which *Applied research* is conducted, characterized by the consideration of the use of their research results. Both variables were assessed on a 4-point Likert scale, ranging from "not at all" to "a lot". Higher scores indicate stronger embeddedness in the academic system since they aim to generate research output that concen-

[3] Our primary source for publication data is WoS. If a surveyed scientist does not have a publication record in WoS, we queried Scopus, which has a broader coverage for some disciplines esp. for social sciences and humanities (Martín-Martín et al., 2021). If, again, there are no publications listed in Scopus, we treated such cases as zero, which is plausible especially for PhD students. By doing so, we may be underestimating the influence of publications.

[4] We treat junior professors, directors, and heads of departments in research institutes as equivalent to full professors.

Table 2 Descriptive statistics for the three transitions

	Mean			Standard Deviation			Minimum			Maximum		
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Dependent variables												
Transition 1 (=1)	0.22			0.41			0			1		
Transition 2 (=1)		0.58			0.49			0			1	
Transition 3 (=1)			0.44			0.50			0			1
Academic sphere												
Professor (=1)	0.18	0.24	0.30	0.39	0.43	0.46	0	0	0	1	1	1
Time devoted to research	52.37	49.73	46.13	27.11	23.89	24.63	0	0	0	100	100	100
Number of publications	21.86	28.95	25.68	50.89	69.88	70.53	0	0	0	532	532	532
Average impact factor	0.91	0.84	0.74	0.79	0.74	0.66	0	0	0	4.80	4.80	2.40
Basic research	2.54	2.75	2.78	0.71	0.73	0.73	1	1	1	4	4	4
Applied research	2.75	3.11	3.26	0.86	0.74	0.68	1	1	2	4	4	4
Commercial sphere												
Share of publications with industry	0.03	0.05	0.06	0.12	0.15	0.18	0	0	0	1	1	1
Time devoted to KTT	8.22	11.59	14.75	11.95	13.63	15.41	0	0	0	100	100	100
Disclosed IP	0.40	0.90	1.22	1.42	1.82	2.23	0	0	0	16	16	16
Work experience outside academia	1.37	1.72	2.08	1.45	1.52	1.45	0	0	0	4	4	4
Control variables												
Female (=1)	0.37	0.27	0.26	0.48	0.45	0.44	0	0	0	1	1	1
Risk willingness	6.52	7.12	7.39	2.18	2.06	2.01	1	1	3	11	11	11
Organizational focus: between basic and applied	0.64	0.59	0.54	0.48	0.49	0.50	0	0	0	1	1	1
Organizational focus: basic	0.15	0.12	0.10	0.36	0.33	0.30	0	0	0	1	1	1
Organizational focus: applied	0.21	0.29	0.36	0.41	0.45	0.48	0	0	0	1	1	1
Discipline: Computer Science and Mathematics	0.11	0.14	0.15	0.31	0.35	0.36	0	0	0	1	1	1
Discipline: Engineering	0.16	0.21	0.24	0.37	0.41	0.43	0	0	0	1	1	1
Discipline: Humanities	0.10	0.08	0.08	0.30	0.27	0.27	0	0	0	1	1	1
Discipline: Life Sciences	0.15	0.13	0.09	0.36	0.34	0.29	0	0	0	1	1	1
Discipline: Medicine	0.10	0.08	0.07	0.30	0.27	0.25	0	0	0	1	1	1
Discipline: Physics and Chemistry	0.19	0.23	0.22	0.40	0.42	0.42	0	0	0	1	1	1
Discipline: Social Sciences	0.19	0.13	0.15	0.39	0.34	0.36	0	0	0	1	1	1

Note: T: Transition; There are 1,149 observations for T1, 249 observations for T2 and 145 observations for T3 trates on less understood research problems and new academic practices (Amara et al., 2019).

Commercial sphere We use four variables to operationalize the scientists' embeddedness in the commercial sphere. First, the *Share of publications with industry* measures scientists' endowment with both commercialization-specific human capital and network ties with actors from the commercial sphere (D'Este et al., 2012, Fritsch & Krabel, 2012, Krabel & Mueller, 2009). We calculate the variable as the number of publications with at least one co-author with industry affiliation over the total number of publications. Second, scientists can benefit in the same way from previous *Work experience outside academia*. Non-academic work experience can increase awareness of differences between the academic and the commercial sphere, and scientists who previously worked in the industry are more likely to engage in commercial activities and adapt to the commercial sphere (Gulbrandsen & Thune, 2017). Third, the *Time devoted to knowledge and technology transfer (KTT)* indicates how much time scientists spend per week engaging with the commercial sphere. The more time scientists spend on transfer activities, the more likely they are to be familiar with the commercial sphere and to better understand the rules and norms of the commercial sphere. Lastly, we asked the survey participants about their *Disclosed intellectual property (IP)*, the number of ideas or inventions disclosed to the employer that may have commercial potential or be legally protected since 2015. The generation of IP that could potentially be patented indicates scientists' interest in research commercialization and their understanding of the relevance of IP in the commercial environment. Patenting has been found to relate positively to spin-off intentions (Goethner et al., 2012, Prodan & Drnovsek, 2010), nascent academic entrepreneurship (Dohse et al., 2021), and successful firm foundations by academics (Ding & Choi, 2011, Krabel & Mueller, 2009, Landry et al., 2006).

3.2.3 Control variables

In our empirical analysis, we control for several factors that influence the successful creation of academic spin-offs. First, we control for whether the scientist is *Female* or not, since a strong gender gap has been identified in the literature (Guzman & Kacperczyk, 2019). Second, we measure the *Risk willingness* of the survey participants on an 11-point Likert scale according to SOEP-IS Group (2014). Scientists' attitude towards risk is highly influential for the persistence in continuing with the spin-off creation process (Fini & Toschi, 2016, Fritsch & Krabel, 2012, Stephan & El-Ganainy, 2007). Third, we control for organizational heterogeneity in the mode of knowledge generation, which influences the general embeddedness of scientists in a sphere (e.g., Bercovitz & Feldman 2008). We create a categorical variable to account for the *Organizational focus* that distinguishes the research focus of the scientists' organization in three groups: *basic*, *between basic and applied*, and *applied*. We rely on a broad categorization put forward by the German Ministry for Science and Education (Bundesministerium für Bildung und Forschung, 2014).[5] Lastly, we control for differences in spin-off activities across disciplines (see, e.g., Abreu & Grinevich 2013). Therefore, we distinguish seven broader disciplines: *Engineering*, *Humanities*, *Life Sciences*, *Medicine*, *Physics & Chemistry*, *Physics*, *Chemistry*, *Social Sciences*, and *Computer Science and Mathematics*.

3.3 Empirical approach

We apply dominance analysis to test our hypotheses on the relative importance of the two spheres along the academic spin-off creation process. Dominance analysis computes the relative importance of predictors among each other and decomposes the overall goodness-of-fit measure of a regression into the predictors' individual contribution (Azen & Budescu, 2003, Azen & Traxel, 2009, Budescu, 1993). Furthermore, dominance analysis allows to combine different predictors into sets of predictors. Thereby, it is irrelevant how large the sets of predictors are since the predictors are neither weighted nor adjusted. This allows us to assess how

[5] Research institutes of the Leibniz Association, the Max Planck Society and similar are allocated to basic research; universities are located between basic and applied research; and universities of applied sciences as well as institutes such as the ones from the Fraunhofer Society and similar are allocated to applied research (see Table S4 in Electronic Supplementary Material).

much a set of predictors, e.g., related to the academic sphere or the commercial sphere, contributes relatively to the transition to the next phase of the spin-off creation process. Compared to other approaches such as standardized regression coefficients, dominance analysis has the advantage of accounting for correlation among the predictors (Azen & Traxel, 2009).

To conduct dominance analysis, we first run each transition regression to estimate which individual factors of the two spheres influence the progression to the next phase of the ASO creation process. Since each transition is measured by a binary outcome variable Y, we use logistic regression for each of the transitions $T = \{1, 2, 3\}$ and the respective individual scientists i. The estimation results allow us to determine the relative importance of the spheres for each transition in the second step. The logistic estimation takes the following stylized form:

$$\log\left(\frac{Y_{iT}}{1 - Y_{iT}}\right) = \alpha + \beta \mathbf{A}_i + \gamma \mathbf{C}_i + \delta \mathbf{Z}_i + \epsilon_i \qquad (1)$$

where $\mathbf{A_i}$ is the set of variables for the academic sphere and $\mathbf{C_i}$ is the set of variables for the commercial sphere. $\mathbf{Z_i}$ is the set of control variables and ϵ_i is an error term. We estimate the regression for each of the transitions T separately.

We use the McFadden (1974) R^2 as our goodness-of-fit measure for the dominance analysis. The McFadden (1974) R^2 is frequently used in logistic regressions and fulfills the criteria to be used in a dominance analysis (Azen & Traxel, 2009).[6] The calculation of relative dominance is an iterative process. Starting with one predictor, the gain in importance is measured by adding another predictor and so forth. This results in a set of regressions where each predictor is compared against every other predictor, and all combinations of predictors are compared against all other combinations. The general dominance is the average of all the gains the predictor has across the different iterations (see Azen & Traxel 2009 for a detailed example). In our case, we do not conduct the dominance analysis on each predictor but on sets of predictors, the academic and the commercial spheres, as well as the control variables. For each of these three sets, we calculate the general dominance, where the sum of the general dominance is equal to the overall goodness-of-fit measure of the estimation. As suggested in Azen & Traxel (2009), we furthermore apply bootstrapping to generate a distribution of relative dominance values.[7] To empirically test our hypotheses, we conduct two-sided t-tests to compare the mean of the bootstrapped distributions for each sphere across the different transitions.

We conduct three robustness tests concerning our econometric approach, our control variables, and our operationalization of the spin-off creation process. First, we use a different operationalization of the transition process, in which the population of scientists does not change between the phases. Second, we use a linear probability estimation and apply the dominance analysis for the ordinary least squares regressions (Azen & Budescu, 2003, Budescu, 1993). Third, we conduct another set of linear probability regressions, including organizational fixed effects to control for differences between organizations and replace the organizational focus.

4 Results

4.1 Descriptive results

The descriptive statistics in Table 2 and the correlations for each of the three transitions in Tables S5, S6, and S7 in the Electronic Supplementary Material provide a first indication of the transition process and the changes in the relative importance of the two spheres. We report descriptive statistics for the three transitions separately, since they show a distinctive pattern. Concerning the successful transitions along the process, we see a continuously diminished number of scientists in the process. Only 22% (249 out of 1,149) recognized a business opportunity necessary for Transition 1. The next step, developing the opportunity further to reach the pre-spin-off phase (Transition 2), was successful for 58% (145 out of 249). Making it to venture creation (Transition 3), e.g., after acquiring the necessary

[6] Azen & Traxel (2009) propose four criteria that a goodness-of-fit measure should fulfill to be suitable for dominance analysis. Besides the McFadden R^2, the Nagelkerke R^2, and the Estrella R^2 can be used, but Azen & Traxel (2009) show analytically that they result in the same direction of dominance, just with a different level of magnitude. Our results are robust towards the different goodness-of-fit measures.

[7] However, Azen & Traxel (2009) note that bootstrapping generates larger standard errors than sampling from the full population but is still considered reliable.

resources, was achieved only by 44% (64 out of 145), which is 5.6% of the initial sample.[8] Such low success rates are frequently reported in the literature (e.g., Abreu & Grinevich, 2013; D'Este et al., 2019; Haeussler & Colyvas, 2011; Muscio et al., 2022).

For the independent variables constituting the academic sphere, scientists' discontinuation of entrepreneurial pursuit at each phase of the process reveals a selection on specific characteristics in the sample population. For nearly all six variables, we see a clear trend in the means. The share of *Professors* in the sample increases, but the mean *Time devoted to research* decreases along the transitions. Only for the *Number of publications* is there initially an increase but then a decrease in the mean along the process. For publications' *Average impact factor*, we also see a decreasing trend. The two variables describing the extent of the scientists' *Basic research* and *Applied research* show an increase, reflecting an ideal type of scientist in search of both new insights and applications (Amara et al., 2019, Stokes, 1997). When comparing these developments with the scientists who found a firm, these trends are confirmed (see Table 6 in the Appendix).

A similar development can be observed for the variables of the commercial sphere. The means of all four variables *Share of publications with industry*, *Time devoted to KTT*, *Disclosed IP*, and *Work experience outside academia* increase from transition to transition in the remaining samples. When we compare the trends with the scientists who found a firm, the development is continued only for *Time devoted to KTT* and *Work experience outside academia* (see Table 6 in the Appendix).

In addition, the control variables show a similar pattern. We find a decreasing trend in *female* scientists and an increase in *risk willingness*. There is also a selection on organizations that have a focus on applied research along the process. Trends among the disciplines are also observable, e.g., the number of scientists from life science or medicine decline in the population along the process. Overall, the development of the sample characteristics indicates that selection on these criteria takes place, indicating their relative importance for the different spheres.

[8] Descriptive statistics for the 64 successful academic entrepreneurs are provided in Table 6 in the Appendix.

4.2 Regression results and dominance analysis

In the following, we discuss the results of our empirical analysis. To test our hypotheses on the changing relative importance of the academic and commercial spheres along the ASO creation process, we first report logistic regression results for each transition and the respective dominance analysis in Table 3. We estimate one model for each of the three transitions (Models 1–3). For each model, we conduct dominance analysis to decompose the overall McFadden R^2 goodness-of-fit measure into a R^2_A for the academic sphere and a R^2_C for the commercial sphere (and R^2_Z for the control variables). We report the absolute values as well as the relative share of each sphere in the overall McFadden R^2, which is our measure of interest. By using these relative shares, we are able to compare between the different models, i.e., phase transitions, because the constituting variables do not change. Hence, we avoid to assess differences in the spheres' importance due to the overall model fit. In a second step, we bootstrap the dominance analysis and present the distribution of the relative R^2_A and R^2_C values in Fig. 2.[9] Lastly, we conduct two-sided t-tests on the difference in means of the bootstrapped relative R^2_A and R^2_C values for the transitions (see Table 4).

4.2.1 Relative importance of the academic sphere

Central to our analysis is the decomposition of the overall McFadden R^2 goodness-of-fit measure into the Joint R^2_A for the academic sphere and the Joint R^2_C for the commercial sphere for the three models. The overall McFadden R^2 for the three models is 0.131, 0.192, and 0.139 respectively. The values are in line with related literature (e.g., Caliendo et al., 2014, 2020, Davidsson & Honig, 2003) and depict a reasonable model fit according to McFadden (1979). The values are also large enough to allow for a meaningful decomposition. In Model 1 and Model 2 the two spheres account for 77.7% and 80.6% of the overall model fit but in Model 3 only for 31.2%.

[9] Azen & Traxel (2009) and Tonidandel & LeBreton (2011) suggest that in the case of relative importance analyses, samples of a dominance analysis should be replicated in sufficient numbers to extend the results by confidence intervals. Therefore, we calculate 5,000 bootstrap samples for each model and provide sample statistics.

Table 3 Logit regression results and dominance analysis for the three transitions

	(1) Transition 1 *Research* to *Opportunity framing*	(2) Transition 2 *Opportunity framing* to *Pre-spin-off*	(3) Transition 3 *Pre-spin-off* to *Spin-off*
Academic sphere			
Professor (=1)	0.045 (0.237)	1.111** (0.475)	0.563 (0.584)
Time devoted to research	-0.003 (0.004)	0.002 (0.008)	0.002 (0.011)
Number of publications	-0.011 (0.078)	-0.238* (0.139)	-0.367* (0.192)
Average impact factor	-0.173 (0.150)	-0.248 (0.242)	0.389 (0.415)
Basic research	0.408*** (0.126)	0.097 (0.225)	-0.017 (0.302)
Applied research	0.376*** (0.099)	0.064 (0.222)	0.015 (0.310)
Joint R_A^2	**0.046 (35.2%)**	**0.057 (29.6%)**	**0.022 (15.8%)**
Commercial sphere			
Share of publications with industry	0.830 (0.878)	1.276 (1.165)	-1.542 (1.589)
Time devoted to KTT	0.005 (0.006)	0.053*** (0.020)	0.028* (0.015)
Disclosed IP	0.942*** (0.193)	0.718** (0.293)	0.168 (0.323)
Work experience outside academia	0.097* (0.058)	0.232** (0.118)	-0.037 (0.148)
Joint R_C^2	**0.056 (42.5%)**	**0.098 (51.0%)**	**0.021 (15.4%)**
Control variables			
Female (=1)	-0.349** (0.178)	0.043 (0.348)	-1.025** (0.501)
Risk willingness	0.101*** (0.038)	0.102 (0.077)	0.145 (0.104)
Organizational focus: basic	-0.260 (0.279)	0.709 (0.477)	0.538 (0.735)
Organizational focus: applied	0.072 (0.223)	0.304 (0.408)	-0.614 (0.499)
Discipline: Engineering	-0.453 (0.306)	-0.154 (0.545)	-0.796 (0.658)
Discipline: Humanities	-0.486 (0.353)	-0.518 (0.665)	0.435 (0.879)
Discipline: Life Sciences	0.007 (0.322)	-0.831 (0.607)	-0.078 (0.823)
Discipline: Medicine	-0.244 (0.341)	-0.026 (0.703)	-0.259 (0.964)
Discipline: Physics & Chemistry	-0.014 (0.297)	-0.106 (0.518)	-0.653 (0.647)
Discipline: Social Sciences	-0.492* (0.293)	0.127 (0.612)	0.721 (0.731)
Joint R_Z^2	**0.029 (22.3%)**	**0.037 (19.4%)**	**0.096 (68.8%)**
Constant	-3.866*** (0.513)	-1.726* (1.037)	-0.928 (1.450)
N	1,149	249	145
Log Likelihood	-522.020	-136.658	-85.699
Akaike Inf. Crit.	1,086.039	315.316	213.399
McFadden R^2	0.131	0.192	0.139

Note: A: Academic sphere, C: Commercial sphere, Z: Controls; Robust standard errors in parentheses; Significance at $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

For Hypothesis 1a, we compare Model 1 with Model 2 and the respective contribution of the academic sphere (Table 3). For Transition 1 in Model 1, the overall McFadden R^2 is 0.131. The dominance analysis decomposes this overall R^2 into the Joint R_A^2 of 0.046 for the academic sphere, which is a relative contribution of 35.2% to the overall model fit. Among the individual variables that constitute scientists' embeddedness in the academic sphere, only the research foci towards *Basic research* and *Applied research* show significant coefficients. Neither the scientists' position nor their publication output matter for Transition 1. With respect

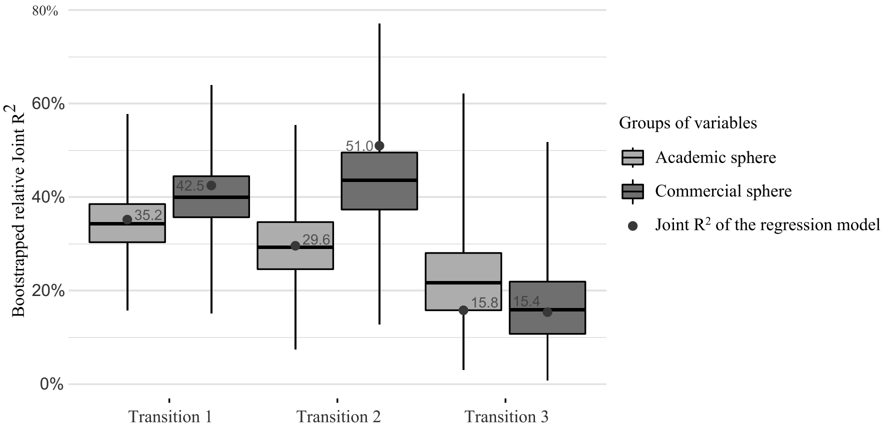

Fig. 2 Dominance analysis on logit estimates for the three transitions based on 5,000 replications

to the bootstrapped sample (Fig. 2 and Table 4), the Joint R_A^2 from the estimation is very close to the bootstrapped median and the average of 34.6%. In Model 2 for Transition 2, the overall McFadden R^2 is higher with 0.192, as is the absolute Joint R_A^2 with 0.057 compared to Model 1. In relative terms, the R_A^2 accounts for only 29.6% in Model 2 and is lower compared to the first model. With respect to the individual variables for the embeddedness in Model 2, being a *Professor* has a significant influence on a successful transition. We also observe a negative but weakly significant coefficient of the *Number of publications*. Since the variable acts as a proxy for the relationship between the embeddedness and the transition success, here higher embeddedness reduces the success.[10] The bootstrapped dominance analysis shows again a similar median as well as a similar average of 29.7% to the Joint R_A^2 of 29.6%. Our Hypothesis 1a postulates lower relative importance of the academic sphere for Transition 2 compared to Transition 1. The negative difference of the Joint R_A^2 for the dominance analyses of the two models supports such a relationship. Also, the bootstrapped distribution supports this relationship, but the distribution for Transition 2 has a higher dispersion than for Transition 1. Furthermore, the t-test on the difference between R_A^2 from Transition 1 and Transition 2 is statistically significant at the 1% level (Table 4). Overall, we find support for Hypothesis 1a, which suggests a higher relative importance of the academic sphere for Transition 1 from the research phase to the opportunity framing phase than for Transition 2 from the opportunity framing phase to the pre-spin-off phase.

For Hypothesis 1b, we compare Model 2 with Model 3 and the respective contribution of the academic sphere (Table 3). In Model 3, for Transition 3, the overall McFadden R^2 is 0.139. The Joint R_A^2 is comparably small, 0.022 in absolute terms and 15.8% in relative terms. Among the individual variables, the *Number of publications* has again a significant but negative coefficient.[11] The other variables show no significant coefficients. The bootstrapped distribution of the relative R_A^2 shows slightly deviating results, with a higher median and an average of 22.5%. Our Hypothesis 1b states that the relative importance of the academic sphere for Transition 3 is lower compared to Transition 2. The negative difference of the Joint R_A^2 for the dominance analyses of Model 2 and Model 3 supports such a relationship, especially if the influence of the *Number of publications* is accounted for. Also, the bootstrapped distribution of the relative R_A^2 supports this relationship and a t-test on the difference between R_A^2 from Transition 2 and Transition 3 is statistically significant at the 1% level (Table 4). Overall, we find support for Hypothesis 1b, which implies a higher relative importance of the academic sphere for Transition 2 from the opportunity framing phase to the pre-spin-off phase than for

[10] Since goodness-of-fit measures do not distinguish between the direction of a coefficient, but we are interested in the influence of higher embeddedness, we estimated an additional Model 2a without the *Number of publications* to remove the negative contribution of the variable to the overall measure of embeddedness. The Joint R_A^2 without this variable is slightly lower with 27.6% of the overall model fit (see Table S8 in Electronic Supplementary Material).

[11] Similar to the previous transition estimation, we estimated an additional Model 3a without the *Number of publications* to remove the negative contribution of the variable to the overall measure of embeddedness. The Joint R_A^2 without this variable accounts now for only 2.4% of the overall model fit (see Table S8 in Electronic Supplementary Material).

Table 4 Differences in bootstrapped relative dominance based on logit estimates for the three transitions

	T1 mean	T2 mean	T3 mean	difference mean T2-T1	difference mean T3-T2
Academic sphere R_A^2	34.6% (0.09)	29.7% (0.10)	22.5% (0.13)	-4.9%***	-7.2%***
Commercial sphere R_C^2	40.1% (0.09)	43.4% (0.12)	17.0% (0.12)	3.3%***	-26.4%***

Note: 5000 bootstrapped replications; Standard errors in parentheses; Differences in means tested by two-sided *t*-tests; T: Transition; Significance at $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Transition 3 from the pre-spin-off phase to the spin-off phase.

4.2.2 Relative importance of the commercial sphere

For Hypothesis 2a, we compare Model 1 with Model 2 and the respective contribution of the commercial sphere (Table 3). In Model 1, the commercial sphere R_C^2 contributes 0.056 to the overall McFadden R^2 of 0.131, which is 42.5% in relative terms. Among the different variables for the embeddedness in the commercial sphere, the *Disclosed IP* and *Work experience outside academia* have positive and significant coefficients. The other two variables are insignificant. Bootstrapping shows a slightly lower median (Fig. 2) and an average of 40.1% for the relative importance of R_C^2 (Table 4). In Model 2 (Table 3), the R_C^2 is 0.098 in absolute terms and 51.0% in relative terms. The significant variables from Model 1 are again significant in Model 2. Additionally, *Time devoted to KTT* has a significant coefficient for Transition 2 to the pre-spin-off phase. Similar to Model 1, the bootstrapped distribution shows in the median (Fig. 2) and on average a smaller R_C^2 (43.4%) (Table 4). The relative R_C^2 51.0% from the initial estimation is above the third quartile of the bootstrapped distribution, showing some considerable deviation. Hypothesis 2a postulates a higher relative importance of the academic sphere for Transition 2 compared to Transition 1. The positive difference of the Joint R_C^2 for the dominance analyses of Model 1 and Model 2 supports such a relationship. The bootstrapped distribution supports this relationship as well but on a slightly lower relative level. The *t*-test on the difference between R_C^2 from Transition 1 and Transition 2 is statistically significant at the 1% level (Table 4). Overall, we find support for Hypothesis 2a, which suggests a lower relative importance of the commercial sphere for Transition 1 from the research phase to the opportunity framing phase than for Transition 2 from the opportunity framing phase to the pre-spin-off phase.

For Hypothesis 2b, we compare Model 2 with Model 3 and the respective contribution of the commercial sphere (Table 3). The commercial sphere in Model 3 has only an absolute R_C^2 of 0.021 and a relative one of 15.4%, indicating a very low contribution to a successful firm foundation. Among the individual variables, only the *Time devoted to KTT* has a significant coefficient. The bootstrapped distribution of the relative R_C^2 is in its median and mean of 17.0% very similar (Fig. 2 and Table 4). Our Hypothesis 2b states that the relative importance of the commercial sphere for Transition 3 is higher compared to Transition 2. The large negative difference of the Joint R_C^2 for the dominance analyses of Model 2 and Model 3 indicates a rejection of such a relationship. The bootstrapped distribution of the relative R_C^2 does not support the hypothesized relationship, either. The *t*-test on the negative difference between R_C^2 from Transition 2 and Transition 3 is statistically significant at the 1% level. Overall, we do not find support for Hypothesis 2b on a lower relative importance of the commercial sphere for Transition 2 from the opportunity framing phase to the pre-spin-off phase than for Transition 3 from the pre-spin-off phase to the spin-off phase.

4.2.3 Control variables

The results concerning our control variables show a relative R_Z^2 around 20% for Transition 1 and Transition 2. For Transition 3 in Model 3, it increases to almost 70%. Among the control variables, we observe a significant negative association between female scientists and the recognition of a business opportunity (Transition 1) as well as successful spin-off creation (Transition 3). Furthermore, the risk willingness influences the success of Transition 1 only. The organizational focus does not matter. Also, we hardly find any differences between the disciplines. Only in Transition 1 do scientists from Social sciences have a significantly higher likelihood to make a successful transition than the reference group, scientists from Computer Science and Mathematics.

4.3 Robustness tests

We conduct three robustness tests. First, we use a different operationalization of the spin-off creation process. Second, we apply linear probability models as an alternative estimation approach. Third, we add organizational fixed effects to account for different organizational characteristics and support. Results are presented in the Appendix.

In the first robustness test, we estimate Model 2 and 3 with the overall number of scientists and do not reduce the sample for Transition 2 and Transition 3. This maintains the variation in the independent variables constant across the models (Tables 7 and 8, Fig. 3). The results are qualitatively similar to the initial analysis. We again see a decrease of the academic sphere's relative importance along the spin-off creation process, while at the same time the contribution of the commercial sphere increases in Transition 2 and declines again for Transition 3. However, the decline in Transition 3 is not as pronounced as in the initial analysis, and the relative contribution is nearly as large as in Transition 1 (39.6%). Moreover, a few individual covariates show different effects than in the initial analysis. For instance, for Transition 2, the variable *Professor* is no longer significant, but the research foci towards *Basic research* and *Applied research* show significant coefficients. Overall, the results provide robustness to our results of the main analysis.

In the second test, we estimate Models 1–3 with OLS as linear probability models and conduct the dominance analysis based on the R^2 (Tables 9 and 10 and Fig. 4). The results for the academic sphere show the same tendency as in the main specification, but there is only a slight decrease in the relative importance between Transition 1 and Transition 2 (30.9% vs 30.3%). The t-test on the small negative difference between R_A^2 from Transition 1 and Transition 2 is statistically significant at the 1% level. For the commercial sphere, the results for the first two transitions are also very similar. The relative importance for Transition 1 increases to 48.9% compared to the main specification and is slightly larger than the relative importance of 48.3% for Transition 2. This negative difference is even more pronounced in the bootstrapped sample average and confirmed by the t-test. Overall, we find additional evidence in favor of our Hypotheses 1a and 1b, but no support for Hypothesis 2a because the relative importance in Transition 1 is substantially larger in this estimation. Also, we find again no support for Hypothesis 2b.

The third test accounts for differences between the individual universities and research institutes, such as the general support via technology transfer offices (TTO), or other factors that can influence the success of scientists from a specific organization. We estimate linear probability models including organizational fixed effects and drop the control variables for organizational focus (see Tables 11 and 12 and Fig. 5). The results show the same development as in the previous robustness test in Table 9. Thereby, the absolute R^2 is substantially larger, but nearly entirely attributed to R_Z^2, which includes the organizational fixed effects. This indicates that heterogeneity on the organizational level, such as the TTO support, contributes substantially to the success of the individual spin-off creation process. Again, we find evidence in favor of our Hypotheses 1a and 1b, but no support for Hypotheses 2a and 2b.

Overall, our robustness checks provide additional support for our Hypotheses 1a and 1b and some additional support for Hypothesis 2a.

5 Discussion and conclusions

Entrepreneurial scientists are embedded in the academic sphere but have to engage with the commercial sphere to accomplish venture creation. In this study, we examine how the relative importance of these two spheres changes for different phases in the academic spin-off (ASO) creation process and its impact on scientists' transition along this process. The differences between the academic and the commercial spheres arise from their inherent logics, which reflect fundamentally different views on knowledge production and exploitation. These differences create tensions that academic entrepreneurs have to overcome (Ambos et al., 2008; Murray, 2010; Rasmussen, 2011; Samsom & Gurdon, 1993). Building on previous conceptualizations of the ASO creation process (e.g., Fernández-Alles et al., 2015; Ndonzuau et al., 2002; Rasmussen, 2011, Roberts & Malonet, 1996; Vanaelst et al., 2006, Vohora et al., 2004), we divide the ASO creation process into four consecutive phases: the research phase, the opportunity framing phase, the pre-spin-off phase, and the spin-off phase. In this process, scientists experience phase transitions influenced to varying degrees by the opposing spheres. In particular, we hypothesize a decreasing relative importance of embeddedness in the academic sphere and an increasing relative importance of embeddedness in the commercial sphere as the process unfolds.

To test our hypotheses, we conduct a novel, representative survey of scientists in the German state of Thuringia. Through this survey, we elicit the scientists' entrepreneurial activity and reconstruct the spin-off creation process, including its phase-specific successes or failures. Utilizing this micro-data, we empirically analyze the changing relative importance of the spheres throughout the entire process. This approach overcomes the limitations of previous studies that either analyzed small samples using qualitative methods (e.g., Clarysse & Moray, 2004; Hayter, 2016a, 2016b; Vohora et al., 2004), focused on specific process stages (e.g., Krabel & Mueller 2009), or only considered successful spin-offs (e.g., Landry et al. 2006). Methodologically, we apply dominance analysis (Azen & Budescu, 2003, Azen & Traxel, 2009, Budescu, 1993) to measure the influence of the two spheres on scientists' success in transitioning to the next phase. More technically, dominance analysis decomposes the goodness-of-fit measure of an estimation into the relative contributions of a set of variables that capture a sphere and explain past phase transitions. This approach allows us to overcome the limitations of individual predictors and describe the complex construct of embeddedness in a sphere. Our empirical results provide the first quantitative analysis of scientists' transition across all phases of the ASO creation process, including the associated selection process.

Findings The descriptive results show a strong selection of scientists throughout the ASO creation process, a widespread phenomenon in venturing processes (e.g., Aldrich & Martinez, 2001; Ndonzuau et al., 2002). Especially for Transition 1 between the research phase and the opportunity framing phase, not even a quarter of scientists recognized an opportunity for venture creation in the last five years. In the next phases, there is a considerably diminished number of scientists as well. In the end, 5.6% of the scientists found a firm, which is similar in magnitude to other studies (Abreu & Grinevich, 2013, D'Este et al., 2019). Within the process, we can observe on the descriptive level that the variables constituting the embeddedness in the spheres reflect the selection taking place. For most of the variables of the academic sphere, a decline in their means can be observed. This already implies that, on average, scientists are less embedded in the academic sphere the further they progress in the process. For the variables constituting the commercial sphere, the opposite development is observable. This highlights that the individuals with higher embeddedness, on average, progress further in the venture creation process. Furthermore, certain characteristics of the scientists become prominent. Besides a substantial gender gap in our data regarding recognized business opportunities, there is even a considerably lower share of women who establish a firm in the end, which is observed frequently in entrepreneurship research (Dohse et al., 2021, Guzman & Kacperczyk, 2019). One reason for that could be lower access to venture capital, which seems to be a structural problem for women in Germany (Lins & Lutz, 2016) but also in other countries (Lauto et al., 2022). Another personal characteristic is risk willingness, which is highest among scientists reaching firm foundation. This is in line with the argument that the academic entrepreneur acts against all odds in a Schumpeterian manner (Cantner et al., 2017).

Our estimations and dominance analyses show for the academic sphere a declining relative importance along the ASO creation process, in line with our hypotheses. At the beginning of the process, research activities and the academic environment serve as sources of business ideas. This holds true especially for business ideas derived from basic research despite high uncertainty with respect to their feasibility and economic potential (Aghion et al., 2008, Lacetera, 2009). Scientists with a high research orientation towards both basic and applied research are especially prone to recognize and frame an entrepreneurial opportunity. This result is consistent with the idea of the Pasteur-like scientist who generates new research results and who simultaneously is interested in their practical application (Amara et al., 2019, Stokes, 1997). In the later phases, the relative importance of the academic sphere subsequently declines, in line with the conceptual model by Rasmussen (2011) and others. At the end of the process, the academic sphere plays hardly any role and can even reduce the likelihood to found a firm. Our estimates show that the higher the publication output of a scientist, the lower the likelihood to set up a firm in the last phase. This finding is contrary to previous findings that indicate a strong positive relationship between these two variables. However, most of these cases refer to Pasteur-like star scientists (e.g., Aschhoff & Grimpe, 2014; D'Este et al., 2019; Ding & Choi, 2011, Zucker et al., 1998).

For the commercial sphere, the dominance analysis shows first an increase in relative importance but then a decrease towards the end of the process. This is only partly consistent with our hypotheses, which propose increasing relative importance of the commercial sphere throughout the whole process. In particular, for Transition 1 the relative importance of the commercial sphere is already quite high, and recognizing an opportunity correlates highly with disclosing intellectual property. Such a relationship between patenting and intentions to found a firm is well established (Goethner et al., 2012, Prodan & Drnovsek, 2010). Along with a positive influence of previous work experience (see, for instance, Gulbrandsen & Thune 2017), exposure to the commercial sphere seems to give scientists a positive mindset towards economic activity and lets them pursue such a direction. The relative importance of the commercial sphere increases further along in the process, and the actual time to conduct such activities also becomes relevant for scientists to substantially invest in the founding activity. However, at the end of the process, the relative importance drastically declines. Reasons for this decrease could be related to a higher influence of contextual factors, such as market conditions, available venture capital, technological feasibility, or policy support (Autio et al., 2014, Rizzo, 2015, Wright et al., 2006). We explore the influence of contextual factors in more detail. The scientist's organization accounts for a substantial variation in the transition success, as adding organizational fixed effects in our robustness tests shows. This might be explained via the scope and performance of institutional support, e.g., via activities that are socialized within the organization such as courses and events on entrepreneurial education (Bercovitz & Feldman, 2008, Prodan & Drnovsek, 2010, Stuart & Ding, 2006) or via TTOs (O'Shea et al., 2005, Rasmussen & Borch, 2010). Especially TTOs and incubators are important providers of such dedicated support, consisting of business idea development, provision of infrastructure, and boundary spanning (Clarysse et al., 2005, Huyghe et al., 2014).[12] Nevertheless, we find no support in our data that the commercial sphere has a higher relative importance at the end of the process than in earlier phases.

Besides the provided empirical evidence for the changing relative importance of the two spheres, we also observe interesting differences in their magnitude. At the beginning of the process, when scientists frame a commercial opportunity from their research activity, the commercial sphere already has higher relative importance than the academic sphere. Such an observation contrasts established theories which initially ascribe a lower relative importance to the commercial sphere than to the academic sphere (Rasmussen, 2011). Our finding corresponds to related literature on entrepreneurial opportunity recognition, which already provides evidence for positive associations between business-related competencies as well as commercial experiences and the recognition of entrepreneurial opportunities (Ardichvili & Cardozo, 2000, Ardichvili et al., 2003, George et al., 2016, Shepherd & DeTienne, 2005, Ucbasaran et al., 2009). Integrating the empirical finding on the generally higher relative importance of the commercial sphere in the conceptualization of the spin-off creation process can provide starting points for evidence-based updating of existent conceptualization and further development of the ASO creation theory.

Our results allow us to derive characteristics on the level of the individual scientist as well. The results indicate that due to scientists' engagement with both spheres, especially early on in the process, they have to adapt their role and identity. Jain et al. (2009) show in their qualitative study on scientists' commercialization activity that they develop a hybrid-role identity to successfully handle both logics. To develop such hybridity, scientists need to be ambidextrous to deal with the tension of the opposing spheres. Mom et al. (2009) characterize ambidextrous individuals by their ability to deal with tensions, their adaptability to different roles and

[12] However, in general, there is a controversial debate about the performance of TTOs and evidence regarding their impact on venture creation is ambiguous (see, e.g., Bourelos et al. 2012; Brettel et al., 2013, Chapple et al., 2005, Horner et al., 2019). Hayter (2016a), for instance, points out that TTOs often rather strengthen the academic nature of spin-offs than bridge between the two spheres.

their refinement and renewal of their knowledge, skills and expertise. Even though we do not directly test for the scientists' ambidexterity, selection among the scientists' characteristics along the transfer process hints to such an underlying mechanism. In that sense, our findings are similar to the findings by Ambos et al. (2008) who show that ambidextrous scientists can balance the demands from both spheres and successfully commercialize research results.

Contributions and implications We make several contributions to the literature on academic entrepreneurship and theory development. Conceptually, we provide a holistic perspective on the ASO creation process, spanning from scientists' research activity to the establishment of a venture. To achieve this, we synthesize existing approaches to understand the ASO process and develop a quasi-linear process with four phases and three transitions, drawing on the concept of "critical junctures" introduced by Vohora et al. (2004). Our focus is on individual scientists, offering a micro-level perspective on their engagement in spin-off creation. Previous research has remained predominantly at the spin-off project level, neglecting individual characteristics and tensions. However, we start from the premise that academic entrepreneurship is an individual endeavor, where scientists, as the main actors, must bring their ideas to the market and navigate the accompanying tensions in the process, whether independently or in a team (Guerrero & Urbano, 2014, Kleinhempel et al., 2022). To understand the tensions and conflicts in the process, we link the academic entrepreneurship process theory (Rasmussen, 2011, Vohora et al., 2004, Wood & McKinley, 2010) with the multiple institutional logics theory (Fini et al., 2010, Perkmann et al., 2019). By connecting these two streams of literature, we enhance our understanding of the influence of scientists' embeddedness in both spheres on successful firm foundations. We derive empirically testable hypotheses to explore the tensions between the spheres arising from differences in attitudes, norms, and logics that scientists encounter during ASO creation. By examining how scientists' embeddedness in the academic and commercial spheres influences their progression throughout the ASO creation process, we contribute to a better understanding of the intricate relationships in the process.

Empirically, by starting with a population of scientists working in research organizations, we are able to trace the ASO selection process from recognizing a business opportunity based on scientific research to venture creation (Aldrich & Martinez, 2001, Ndonzuau et al., 2002). Thus, we provide a quantitative assessment of scientists' discontinuation of their entrepreneurial pursuits throughout the ASO creation process. Our theoretical conceptualization of the process explains this phenomenon, and our results provide the first quantitative evidence of the contrasting influences of the academic and commercial spheres on the complete ASO creation process, substantiating prior research. Our findings affirm the diminishing relative importance of the academic sphere as the process unfolds and demonstrate that researchers have to overcome the norms and logics prevalent in this sphere to progress. Simultaneously, the relevance of the commercial sphere grows, necessitating scientists' embeddedness in this sphere for successful venture creation. Nonetheless, we identify some contradictions at the end of the process, where the relative importance of this sphere declines. This suggests either nonlinearity in the relative importance throughout the process or external forces that lie beyond individual scientists, such as the market environment. Our related finding, that the commercial sphere's relative importance exceeds that of the academic sphere already at the beginning of the process, challenges traditional lines of thought that prioritize the academic sphere in the early stages. However, research on entrepreneurial opportunity recognition points to the relevance of market knowledge in identifying entrepreneurial opportunities (Shane, 2000), which aligns with our findings and underscores the significance of embeddedness in the commercial sphere.

Our central finding of the changing relevance of the academic and commercial spheres along the ASO creation process has important policy implications that can guide interventions aimed at fostering academic entrepreneurship. Our study reveals that the relative importance of the commercial sphere is already higher than the academic sphere at the beginning of the ASO creation process. Policymakers can leverage this finding by facilitating scientists' exposure to the commercial sphere. This can be achieved by implementing entrepreneurship education initiatives and encouraging scientists to gain industry experience (Belitski & Heron, 2017, Bienkowska et al., 2016, Thomas et al., 2020). Additionally, academic institutions can incentivize scientists' engagement with the commercial sector by reducing administrative burdens and recognizing their entrepreneurial activity alongside their academic qualifications (Davey et al., 2016). By bringing scientists and industry actors together, policy initiatives can promote mutual understanding, trust, and collaboration between the two spheres (Hayter, 2016a, Rasmussen et al., 2006), thereby increasing the likelihood of successful ASO creation. Another key policy implication is the provision of tailored support for scientists at different stages of the ASO creation process. Our study identifies distinct phases and highlights the changing relevance of the academic and commercial spheres across these phases. Policymakers can develop targeted support programs that address the specific needs and challenges faced by scientists during each phase. This can include early-stage funding, access to lab facilities, mentorship programs, market validation support, industry partnerships, and regulatory guidance, among others (Sandström et al., 2018). By providing such tailored support, policymakers can effectively assist scientists in navigating the ASO creation process and increase the likelihood of successful outcomes. Finally, our findings indicate that female scientists may encounter specific challenges, particularly at the end of the spin-off creation process. Policymakers should develop targeted support mechanisms to address these disparities and provide equal opportunities for all scientists to participate and succeed in entrepreneurial endeavors (Abreu & Grinevich, 2017).

Limitations and further research Our study has several limitations that merit careful consideration. The cross-sectional nature of our data does not allow for a causal identification of the relative importance of the two spheres. Moreover, we collected retrospective data to reconstruct the spin-off creation process. This requires that participants recall past activities and experiences accurately. For future research, longitudinal study designs to observe entrepreneurial scientists over time would be advisable. Furthermore, our survey specifically targeted scientists who are still affiliated with research organizations, ensuring their embeddedness in the academic sphere. However, this means we did not survey ASO founders who have already left academia, potentially introducing bias in assessing the relative contributions of the two spheres. Another important limitation of this study is the fact that our analysis focuses on individual scientists, overlooking the distinction between single and team entrepreneurship. Team structures are known to play an important factor in the venture creation process (Visintin & Pittino, 2014). Additionally, we lack information on the established ASOs and their characteristics, such as the industry they are operating in or their business idea, which could have an influence on the embedding in the two spheres.

While our study provides the first empirical assessment of the changing relative importance of scientists' embeddedness in two opposing spheres during the ASO creation process, avenues for further research are manifold. Scholars could validate our findings using a broader empirical basis, including longitudinal data or samples from different countries. Furthermore, it could be valuable to consider the interaction between the two spheres, both conceptually and empirically, rather than studying them in isolation. Further research should also explore the ambidexterity of scientists and investigate whether it is endogenous to the process. Moreover, the influence of the two spheres extends beyond ASO creation, impacting other transfer channels, such as science-industry collaboration or licensing of intellectual property. Examining these transfer channels can provide additional insights. Such investigations should also encompass transfer channels that go beyond the professional management of research commercialization, such as open science strategies (Hayter et al., 2020). Finally, applying this research approach to other contexts where the balancing multiple spheres and their logics are crucial for the venturing process, such as social entrepreneurship, holds promise for future entrepreneurship research. In such contexts, reconciling commercial logics with social-oriented logics becomes essential.

Appendix

Table 5 List of variables and their construction

Variable	Survey item and variable construction	Data type
Dependent variables:		
Transition 1 (=1)	Survey item: *Development of an idea to found a firm, e.g. discussion of the idea with others, assessment of the economic potential, or application of creative techniques? (0: No; 1: Yes)*	Binary
Transition 2 (=1)	Survey item: *Foundation preparation, e.g. development of a prototype, preparation of a business plan, or acquisition of resources? (0: No; 1: Yes)*	Binary
Transition 3 (=1)	Survey item: *Completed foundation of a firm, i.e. the launch of business activities? (0: No; 1: Yes)*	Binary
Academic variables		
Professor (=1)	Survey item: *Which of the following options describes your current position best? (0: Other; 1: Professor, Junior Professor, Director, Head of Department)*	Binary
Time devoted to research	Survey item: *How was your scientific working time distributed on average during the last 5 years [regarding research]?* (0% to 100%)	Numerical
Number of publications	Data collected from Web of Science and Scopus (logarithmized)	Numerical
Average impact factor	Average of the scientist's journals' Source Normalized Impact per Paper	Numerical
Basic research	Survey item: *Please assess the extent to which you contribute with your research to scientific progress in your discipline and thus shift the research frontier in your discipline further.* (4-point Likert scale: "Not at all" to "To a large extent")	Numerical
Applied research	Survey item: *Please assess the extent to which your research is targeted towards practical application.* (4-point Likert scale: "Not at all" to "To a large extent")	Numerical
Commercial variables		
Share of publications with industry	Share of scientist's publications in co-authorship with at least one firm (0% to 100%)	Numerical
Time devoted to KTT	Survey item: *How was your scientific working time distributed on average during the last 5 years [knowledge and technology transfer]?* (0% to 100%)	Numerical
Disclosed IP	Survey item: *Disclosure of an idea or invention (that can be attributed to potential commercial exploitation or can be legally protected) to the employer (Number since 2015).* (logarithmized)	Numerical
Work experience outside academia	Survey item: *How many years of work experience outside the public science sector have you gained overall?* (5 categories (in years): 0: =0; 1: <1; 2: 1 <3; 3: 3 <10 ; 4: ≥ 10)	Numerical
Control variables		
Female (=1)	Survey item: *Please indicate your gender.*	Binary
Risk willingness	Survey item: *How do you see yourself: Are you generally a person who is fully prepared to take risks or are you trying to avoid risks?* as used by SOEP-IS Group (2014, p. 36) (11-point Likert scale)	Numerical
Organizational focus	Distinction of organizations between 1: Basic, 2: Between basic and applied, 3: Applied, following Bundesministerium für Bildung und Forschung (2014)	Categorical
Discipline	Data collected from the participants' webpages (7 disciplines: 1: Computer Science & Mathematics; 2: Engineering; 3: Humanities; 4: Life Sciences; 5: Medicine; 6: Physics & Chemistry; 7: Social Sciences)	Categorical

Table 6 Descriptive statistics of the variables for the actual founders (Transition 3=1)

	Founders (Transition 3=1)			
	mean	sd	min	max
Academic sphere				
Professor (=1)	0.33	0.47	0	1
Time devoted to research	45.36	26.05	0	100
Number of publications	14.73	31.09	0	207
Average impact factor	0.73	0.70	0	2.40
Basic research	2.81	0.75	1	4
Applied research	3.28	0.72	2	4
Commercial sphere				
Share of publications with industry	0.04	0.13	0	0.80
Time devoted to KTT	16.83	17.46	0	100
Disclosed IP	1.09	1.63	0	7
Work experience outside academia	2.11	1.39	0	4
Control variables				
Female (=1)	0.20	0.41	0	1
Risk willingness	7.78	1.96	3	11
Organizational focus: between basic and applied	0.60	0.50	0	1
Organizational focus: basic	0.12	0.33	0	1
Organizational focus: applied	0.28	0.45	0	1
Discipline: Computer Science & Mathematics	0.17	0.38	0	1
Discipline: Engineering	0.17	0.38	0	1
Discipline: Humanities	0.09	0.29	0	1
Discipline: Life Sciences	0.11	0.31	0	1
Discipline: Medicine	0.05	0.21	0	1
Discipline: Physics & Chemistry	0.19	0.39	0	1
Discipline: Social Sciences	0.22	0.42	0	1

Note: Transition 3 founders refer to the 64 scientists who founded a firm

Table 7 Logit regression results and dominance analysis for the three transitions with complete sample at each transition

	(1) Transition 1 *Research* to *Opportunity framing*	(2) Transition 2 *Opportunity framing* to *Pre-spin-off*	(3) Transition 3 *Pre-spin-off* to *Spin-off*
Academic sphere			
Professor (=1)	0.045 (0.237)	0.382 (0.291)	0.641 (0.399)
Time devoted to research	-0.003 (0.004)	-0.003 (0.005)	-0.003 (0.007)
Number of publications	-0.011 (0.078)	-0.113 (0.100)	-0.311** (0.140)
Average impact factor	-0.173 (0.150)	-0.261 (0.191)	-0.078 (0.265)
Basic research	0.408*** (0.126)	0.378** (0.155)	0.281 (0.232)
Applied research	0.376*** (0.099)	0.379*** (0.131)	0.369* (0.204)
Joint R_A^2	**0.046 (35.2%)**	**0.061 (30.9%)**	**0.057 (28.1%)**
Commercial sphere			
Share of publications with industry	0.830 (0.878)	1.041 (1.061)	0.032 (1.150)
Time devoted to KTT	0.005 (0.006)	0.019*** (0.007)	0.028*** (0.009)
Disclosed IP	0.942*** (0.193)	1.055*** (0.210)	1.012*** (0.271)
Work experience outside academia	0.097* (0.058)	0.203*** (0.073)	0.127 (0.092)
Joint R_C^2	**0.056 (42.5%)**	**0.096 (48.1%)**	**0.080 (39.6%)**
Control variables			
Female (=1)	-0.349** (0.178)	-0.276 (0.224)	-0.740** (0.349)
Risk willingness	0.101*** (0.038)	0.159*** (0.051)	0.265*** (0.073)
Organizational focus: basic	-0.260 (0.279)	-0.125 (0.375)	0.166 (0.520)
Organizational focus: applied	0.072 (0.223)	0.149 (0.285)	-0.340 (0.428)
Discipline: Engineering	-0.453 (0.306)	-0.633 (0.406)	-1.172* (0.632)
Discipline: Humanities	-0.486 (0.353)	-0.794* (0.444)	-0.574 (0.594)
Discipline: Life Sciences	0.007 (0.322)	-0.357 (0.441)	-0.235 (0.570)
Discipline: Medicine	-0.244 (0.341)	-0.253 (0.446)	-0.600 (0.666)
Discipline: Physics & Chemistry	-0.014 (0.297)	0.019 (0.378)	-0.333 (0.504)
Discipline: Social Sciences	-0.492* (0.293)	-0.356 (0.362)	0.039 (0.452)
Joint R_Z^2	**0.029 (22.3%)**	**0.042 (21.0%)**	**0.066 (32.3%)**
Constant	-3.866*** (0.513)	-5.157*** (0.689)	-6.200*** (1.043)
N	1,149	1,149	1,149
Log Likelihood	-522.020	-348.961	-196.862
Akaike Inf. Crit.	1,086.039	739.923	435.723
McFadden R^2	0.131	0.199	0.203

Note: A: Academic sphere, C: Commercial sphere, Z: Controls; Robust standard errors in parentheses; Significance at $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

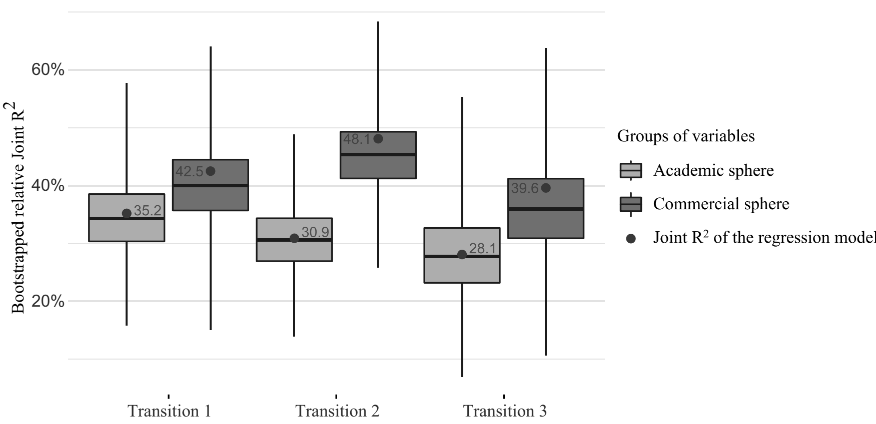

Fig. 3 Dominance analysis on logit estimates for the three transitions with the complete sample based on 5,000 replications

Table 8 Differences in bootstrapped relative dominance based on logit estimates for the three transitions with the complete sample

	T1 mean	T2 mean	T3 mean	difference mean T2-T1	difference mean T3-T2
Academic sphere R_A^2	34.6% (0.09)	30.7% (0.08)	28.1% (0.10)	-3.9***	-2.6***
Commercial sphere R_C^2	40.1% (0.09)	45.3% (0.08)	36.1% (0.11)	5.2***	-9.2***

Note: 5000 bootstrapped replications; Standard errors in parentheses; Differences in means tested by two-sided *t*-tests; T: Transition; Significance at $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 9 OLS regression results and dominance analysis for the three transitions

	(1) Transition 1 *Research* to *Opportunity framing*	(2) Transition 2 *Opportunity framing* to *Pre-spin-off*	(3) Transition 3 *Pre-spin-off* to *Spin-off*
Academic sphere			
Professor (=1)	0.014 (0.037)	0.177** (0.085)	0.124 (0.115)
Time devoted to research	-0.0004 (0.0005)	0.0001 (0.002)	0.001 (0.002)
Number of publications	-0.004 (0.012)	-0.039 (0.024)	-0.077** (0.037)
Average impact factor	-0.023 (0.019)	-0.044 (0.044)	0.087 (0.083)
Basic research	0.060*** (0.019)	0.005 (0.043)	-0.003 (0.063)
Applied research	0.050*** (0.014)	0.029 (0.045)	0.001 (0.064)
Joint R_A^2	**0.044 (30.9%)**	**0.066 (30.3%)**	**0.028 (15.8%)**
Commercial sphere			
Share of publications with industry	0.150 (0.157)	0.231 (0.212)	-0.335 (0.312)
Time devoted to KTT	0.001 (0.001)	0.006** (0.003)	0.006** (0.003)
Disclosed IP	0.199*** (0.037)	0.129*** (0.047)	0.035 (0.063)
Work experience outside academia	0.016* (0.009)	0.049** (0.022)	-0.006 (0.030)
Joint R_C^2	**0.070 (48.9%)**	**0.106 (48.3%)**	**0.027 (15.5%)**
Control variables			
Female (=1)	-0.048** (0.024)	0.004 (0.065)	-0.204** (0.092)
Risk willingness	0.014*** (0.005)	0.023 (0.014)	0.030 (0.021)
Organizational focus: basic	-0.041 (0.038)	0.121 (0.091)	0.113 (0.153)
Organizational focus: applied	0.012 (0.036)	0.053 (0.073)	-0.129 (0.098)
Discipline: Engineering	-0.081 (0.052)	-0.038 (0.103)	-0.171 (0.133)
Discipline: Humanities	-0.077 (0.054)	-0.094 (0.128)	0.091 (0.188)
Discipline: Life Sciences	-0.006 (0.051)	-0.161 (0.117)	-0.008 (0.177)
Discipline: Medicine	-0.047 (0.052)	-0.019 (0.142)	-0.052 (0.187)
Discipline: Physics & Chemistry	-0.008 (0.050)	-0.013 (0.100)	-0.146 (0.132)
Discipline: Social Sciences	-0.081* (0.046)	0.027 (0.111)	0.154 (0.144)
Joint R_Z^2	**0.029 (20.2%)**	**0.047 (21.4%)**	**0.122 (68.7%)**
Constant	-0.127* (0.067)	0.169 (0.205)	0.294 (0.289)
N	1,149	249	145
Residual Std. Error	0.385 (df = 1128)	0.455 (df = 228)	0.487 (df = 124)
R^2	0.143	0.219	0.177

Note: A: Academic sphere, C: Commercial sphere, Z: Controls; Robust standard errors in parentheses; Significance at $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

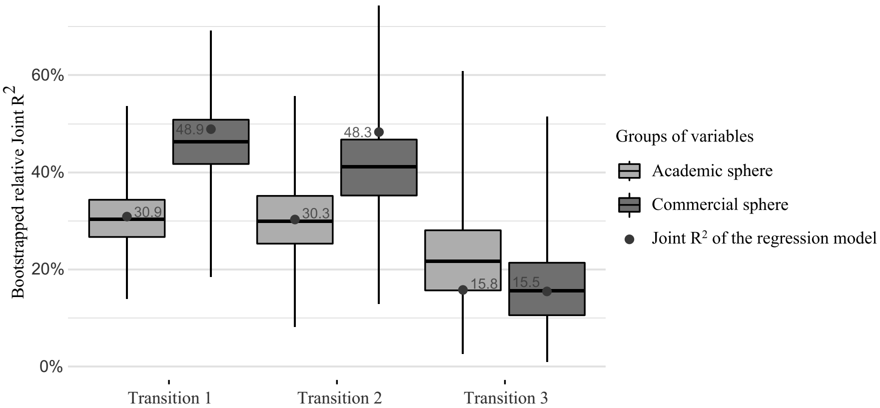

Fig. 4 Dominance analysis on OLS estimates for the three transitions based on 5,000 replications

Table 10 Differences in bootstrapped relative dominance based on OLS estimates for the three transitions

	T1 mean	T2 mean	T3 mean	difference mean T2-T1	difference mean T3-T2
Academic sphere R_A^2	30.7% (0.08)	30.3% (0.10)	22.5% (0.13)	-0.4***	-7.8***
Commercial sphere R_C^2	46.2% (0.10)	41.1% (0.12)	16.6% (0.11)	-5.1***	-24.5***

Note: 5000 bootstrapped replications. Standard errors in parentheses. Differences in means tested by two-sided *t*-tests; T: Transition; Significance at $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

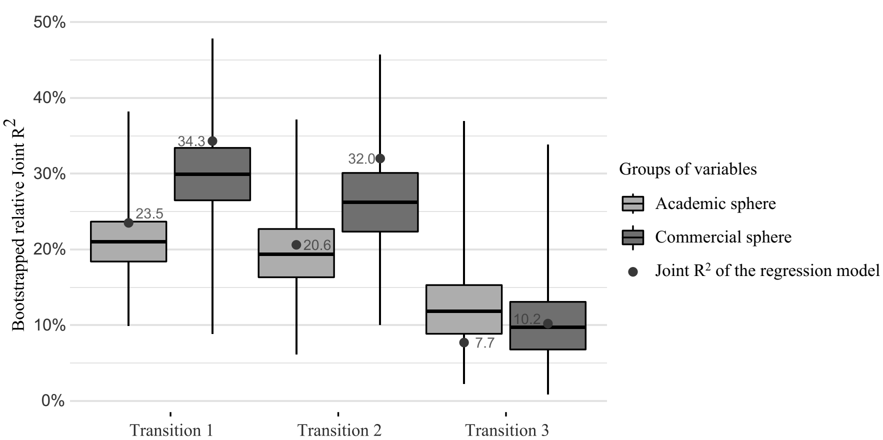

Fig. 5 Dominance analysis on OLS estimates for the three transitions with organizational fixed effects based on 5,000 replications

Table 11 OLS regression results and dominance analysis for the three transitions with organizational fixed effects

	(1) Transition 1 *Research* to *Opportunity framing*	(2) Transition 2 *Opportunity framing* to *Pre-spin-off*	(3) Transition 3 *Pre-spin-off* to *Spin-off*
Academic sphere			
Professor (=1)	0.016 (0.038)	0.222** (0.086)	0.087 (0.134)
Time devoted to research	-0.0005 (0.0005)	0.001 (0.002)	0.001 (0.002)
Number of publications	-0.003 (0.012)	-0.031 (0.025)	-0.072* (0.036)
Average impact factor	-0.033* (0.018)	-0.051 (0.043)	0.103 (0.085)
Basic research	0.064*** (0.019)	-0.012 (0.042)	0.016 (0.066)
Applied research	0.050*** (0.014)	0.041 (0.046)	-0.028 (0.076)
Joint R_A^2	**0.045 (23.5%)**	**0.068 (20.6%)**	**0.026 (7.7%)**
Commercial sphere			
Share of publications with industry	0.188 (0.149)	0.027 (0.190)	-0.457 (0.353)
Time devoted to KTT	0.002* (0.001)	0.008*** (0.003)	0.008*** (0.003)
Disclosed IP	0.188*** (0.039)	0.180*** (0.051)	0.064 (0.073)
Work experience outside academia	0.013 (0.009)	0.040* (0.024)	0.010 (0.034)
Joint R_C^2	**0.065 (34.3%)**	**0.106 (32.0%)**	**0.034 (10.2%)**
Control variables			
Female (=1)	-0.054** (0.024)	0.023 (0.065)	-0.196* (0.102)
Risk willingness	0.015*** (0.005)	0.027** (0.014)	0.031 (0.021)
Discipline: Engineering	-0.093 (0.059)	-0.139 (0.141)	-0.170 (0.184)
Discipline: Humanities	-0.115 (0.071)	-0.225 (0.190)	0.021 (0.330)
Discipline: Life Sciences	0.032 (0.068)	0.018 (0.208)	-0.234 (0.283)
Discipline: Medicine	0.016 (0.069)	-0.141 (0.210)	-0.015 (0.304)
Discipline: Physics & Chemistry	0.078 (0.069)	-0.056 (0.195)	-0.160 (0.271)
Discipline: Social Sciences	-0.057 (0.056)	-0.036 (0.137)	0.014 (0.197)
Organization fixed effects	Yes	Yes	Yes
Joint R_Z^2	**0.080 (42.2%)**	**0.158 (47.4%)**	**0.272 (82.1%)**
Constant	-0.194** (0.078)	0.109 (0.262)	0.220 (0.365)
N	1,149	249	145
Residual Std. Error	0.380 (df = 1095)	0.451 (df = 199)	0.491 (df = 99)
R^2	0.190	0.332	0.332

Note: A: Academic sphere, C: Commercial sphere, Z: Controls; Robust standard errors in parentheses;
Significance at $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table 12 Differences in bootstrapped relative dominance based on OLS estimates with for the three transitions with organizational fixed effects

	T1 mean	T2 mean	T3 mean	difference mean T2-T1	difference mean T3-T2
Academic sphere R_A^2	21.2% (0.06)	19.6% (0.07)	12.3% (0.07)	-1.6***	-7.3***
Commercial sphere R_C^2	30.0% (0.07)	26.3% (0.08)	10.3% (0.07)	-3.7***	-16.0***

Note: 5000 bootstrapped replications; Standard errors in parentheses; Differences in means tested by two-sided *t*-tests; T: Transition; Significance at $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

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