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Intrapreneurship activity and access to finance in natural science: Evidence from the UK academic spinoffs

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A R T I C L E I N F O

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A B S T R A C T

Recent research on the intrapreneurial activity at universities has demonstrated that access to finance and firm profits highly depend on the adoption of digital technologies and the stage of growth. This paper aims to contribute to the ongoing debate on the factors that affect access to finance and profitability of academic spinoffs across different stages of spinoff growth. We distinguish and define an intrapreneurial academic spinoff to argue that the intrapreneur's own development of digital technology, stage of growth, and the field of science represent three boundary conditions to access external finance and gain profitability. Using the data from 89 intrapreneurial academic spinoffs in natural sciences, such as physical sciences and astrophysics, mathematics, chemical sciences, earth and related environmental sciences as well as 660 spinoffs from other fields of science in the United Kingdom over 2015–2019, this paper examined the role of spinoff growth stage and development of digital technologies in access to finance and profitability of this type of spinoffs. The paper offers implications for policymakers, intrapreneurial spinoffs, and university managers.

1. Introduction

The landscape of universities has recently undergone a notable shift towards intrapreneurial activities, fuelled by the commercialization of latent academic knowledge research. This trend has gained significant attention in the realms of technology entrepreneurship and ecosystems research (Bienkowska and Klofsten, 2012; Bienkowska et al., 2016; Brem and Radziwon, 2017; Klofsten et al., 2021). At the core of this shift is the academic scientist, whether they play the role of a researcher or teacher, driven by the goal to act entrepreneurially (Vohora et al., 2004; Abreu and Grinevich, 2013; Guerrero and Urbano, 2012). Their objective is clear: to harness and bring to market the new knowledge they generate, which, if uncommercilized, remains unexploited (Van Burg et al., 2008).

However, the landscape of entrepreneurship within universities is not homogeneous. While some researchers generate basic knowledge (Audretsch, 2014) and stay within the realm of university, others focus on applied knowledge and combining their research roles with entrepreneurial activity giving birth to academic spinoffs, thus embodying the role of 'intrapreneurs' (Klofsten and Jones-Evans, 2000; Klofsten, 2008; Vanhaverbeke and Peeters, 2005). As defined by Baruah and Ward (2015: 811–812), intrapreneurship activity is "the innovation practice within an organization through which employees undertake new business activities and pursue different opportunities". A similar understanding of intrapreneurship is echoed by Burkholder and Hulsink (2022: 1), stating that "academic intrapreneurship refers to the individual behaviors of scientists who depart from their customary research and education initiatives and become involved in knowledge commercialization without leaving academia". These individuals who leave their professional role at the university to pursue entrepreneurial opportunities are entrepreneurs (Parker, 2011). Their ventures are often rooted in the knowledge spillover theory of entrepreneurship, which posits that uncommercialized knowledge, typically in a foirm of basic knowledge created within a university, can be commercialized by intrapreneurs (Guerrero and Urbano, 2014). These academic entrepreneurs breathe life into basic knowledge, either by initiating new firms or by creating academic spinoffs (Stuart and Ding,

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2006; Visintin and Pittino, 2014; Fukugawa, 2022; Burkholder and Hulsink, 2022). University often remains a key stakeholder in academic spinoffs and retains spin-off shares.

Despite considerable advancements in research on intrapreneurial capabilities within companies and universities (Klofsten et al., 2021; Guerrero et al., 2016, 2021) and the antecedents of university intrapreneurship (Valka et al., 2020), gaps remain in understanding the key mechanisms and boundary conditions that allow academic spinoffs to commercialize their knowledge and achieve high performance, their growth trajectory, and the timeline for fundraising and growth. Existing research has also not adequately explored the factors and conditions that might either bolster or hinder the visibility and hence the ability of spinoffs to use different sources of funding for growth (Åstebro et al., 2013, 2019; Civera et al., 2020; Di Gregorio and Shane, 2003).

Access to finance and profitability are two interrelated challenges that are especially pronounced in the early stages of spinoff growth e.g. pre-trading and early market entry (Clarysse et al., 2007). At these phases, investors typically seek tangible evidence of potential success, like a minimum viable product or a proof of concept, before committing funds to either basic or applied research (Shane and Stuart, 2002; Conti et al., 2013; Bradley et al., 2013; Abreu and Grinevich, 2013). Thus, academic spinoffs often grapple with substantial obstacles in fundraising and profit generation if unable to expedite experimentation and prove their concept at early stages. While academic spinoffs that fail to showcase market-ready products and investment in digital technologies significantly hamper their signaling ability to investors, subsequently affecting their propensity to fundraise and profitability (Guerrero et al., 2015; Cunningham et al., 2020), the boundary conditions that shape propensity of fundraise and firm performance remain unknown. Field of science is an impactful moderator of this relationship.

In the natural science field, the journey from invention to commercialization is lengthy and is fraught with high market and product uncertainties, risks associated with experimentation, and challenges of adopting new and complex digital technologies. Spinoffs in natural sciences, as opposed to other fields of science, embody the fundamental disciplines and academic traditions of the Humboldt University model. Researchers in natural sciences prioritize "knowledge for its own sake," which Audretsch (2014: 317) recognizes as the gold standard of scholarly inquiry under the Humboldt University model, rather than seeking applied solutions to pressing societal problems and challenges. Consequently, the nature of knowledge produced in natural sciences differs substantially from the applied knowledge generated in fields such as biochemistry, informatics, and bioengineering. These fields are tasked with devising solutions and applications for significant societal challenges.

Given the unique characteristics of natural science spinoffs that hinge on basic knowledge, intrapreneurs often encounter immense challenges in procuring finance during the early stages and often invest in digital technologies to accelerate the journey of knowledge transfer. Without the commitment of industry and government to invest significant funds to transform a fundamental research idea into a market-ready product, the transition from basic knowledge creation to experimentation, fundraising, market commercialization, and initial profitability in the natural sciences is notably protracted compared to other scientific domains (Audretsch et al., 2023).

We aim to fill this existing gap in the literature by asking the following research question: "What is the role of boundary conditions such as the stage of growth, digitization, and the field of science in influencing access to external finance and profitability for intrapreneurial academic spinoffs?" To answer this question, we consider both external factors (e.g., field of science) and internal ones (e.g., stage of growth and investment in technology) that might either facilitate or hinder fundraising and profitability (Mustar et al., 2006; Visintin and Pittino, 2014; Li et al., 2016; Connected Commerce Council, 2020, 2021).

We contribute to the academic entrepreneurship literature by demonstrating the extent to which field of science, adoption of digitally-advanced technologies and stage of growth as three boundary conditions can facilitate the propencity to fundraise from various sources and profitability in intrapreneurial academic spinoffs. We do so by employing the firm growth (Churchill and Lewis, 1983; Vohora et al., 2004) and digital capabilities literatures (Giones and Brem, 2017; Secundo et al., 2020; Jovanovic et al., 2021), and by distincting between digitally-advanced and digitally-uncertain intrapreneurial spinoffs (Connected Commerce Council, 2020, 2021).

We contribute to intrapreneurship literature calling for a deeper understanding of the differences between intrapreneurship and entrepreneurship within a university (Urbano et al., 2013; Meoli and Vismara, 2016; Klofsten et al., 2019), by examining how the development of digital technologies and capabilities as well as the timeline of growth changes the propensity to fundraise and grow profits between intrapreneurial spinoffs in natural and non-natural sciences field.

Our findings provide key insights to practitioners, policymakers and university managers on better support and manage natural science intrapreneurial spinoffs at universities. We appeal to policymakers to better support academic intrapreneurship in natural science and learn to recognize important signals from intrapreneurial spinoff in this field (Conti et al., 2013). Drawing on Klofsten et al. (2021) in particular, we argue that the development of digital technology in-house by an intrapreneurial spinoff in the natural sciences provides an additional positive signal to investors attracting more financial equity and debt capital and increasing financial performance (profits). While little attention has been paid to the role of digitalization in intrapreneurial academic spinoffs, we demonstrate that digitally-driven intrapreneurial spinoffs – spinoffs that develop and use new digital technology and find it essential in their business model - are able to access more financial resources and are able to do so earlier than their digitally-uncertain counterparts.

The remainder of the paper is organized as follows. Section 2 discusses the theoretical framework, and Section 3 develops the main hypotheses. Section 4 describes the data and the model specifications used in the empirical analysis, while Section 5 reports the empirical findings. Section 6 discusses the main findings and implications, while Section 7 concludes with theoretical development, limitations, and future research.

2. Theoretical framework

2.1. Intrapreneurship and entrepreneurship activity at university

In contrast to entrepreneurship activity at a university aiming to commercialize the outcomes of university research (Abreu and Grinevich, 2013; Audretsch, 2014), intrapreneurship activity takes place within a university and in the form of academic spinoffs (Jones-Evans and Klofsten, 1997; Klofsten et al., 2021). While some intrapreneurial spinoffs may be physically located outside of the university campus, they still belong to and are an integral part of the university if they are owned, co-owned, and managed by the university board and if they are related to university staff in their professional and/or research position. Intrapreneurial academic spinoffs are often small firms (Colombo et al., 2019) operating in high-tech and emerging industries (Bock et al., 2018; Visintin and Pittino, 2014) with high human capital (Unger et al., 2011), usually founded by small entrepreneurial teams (Aspelund et al., 2005). Drawing on prior research by Covin and Slevin (1991), recent research by Klofsten et al. (2021: 2) poses that “Intrapreneurship involves a company extending its competence and increasing its opportunities by creating new organizations, new products/services- or combining new resources”. This is consistent with prior works of Antoncic and Hisrich (2003), Parker (2011), Guerrero et al. (2016) and Perlines et al. (2022), that entrepreneurship is known as the act of developing a new venture outside of an existing organization, while intrapreneurship activity is the process of developing a new venture within an existing organization.

That said, there is still no consensus about the dimensions of intrapreneurship or its definition, determinants and conditions (Farrukh et al., 2017; Neessen et al., 2019). The leading role of university employees at intrapreneurial spinout has been emphasized by Neessen et al.

(2019: 545) who describe a "comprehensive model of intrapreneurship in which we integrate the new definition, dimensions, and determinants applicable to individual employees". Authors find that innovativeness, proactiveness, risk-taking, access to finance, opportunity recognition/exploitation and internal/external networking are important factors explaining the choice of intrapreneurial activity.

To promote both intrapreneurship and entrepreneurship in universities, management focuses on nurturing intrapreneurial abilities (Klofsten et al., 2021) to fortify such behavior amongst university researchers (Neessen et al., 2019; Cunningham et al., 2022). This commitment not only enhances the scientific quality but also elevates the likelihood of university spinoffs securing investments from venture capitalists, business angels, and other financial entities (Fukugawa, 2022). Scholars also define an intrapreneurial academic spinoff as "a process where by employees recognize and exploit opportunities by being innovative, proactive and by taking risks, in order for the organisation to create new products and services, initiative self-renewal or venture new businesses to enhance the competitiveness and performance of the organization" (Neessen et al., 2019: 551). Thus, intrapreneurial academic spinoff is a new venture established within a university with a founder (co-founder) or a CEO or both are employees at the university who apply their research in recognition of entrepreneurial opportunities, taking a pro-active innovative approach and taking calculated risks and for the university and a spinoff to create new products and services and commercialize them on the market.

The condition of university staff to be associated with the academic spinoff in a position of a (co)founder or a CEO, enables us to categorize a spinoffs as intrapreneurial academic spinout, rather than an entrepreneurial firm (Civera et al., 2020). Establishing an intrapreneurial spinoff triggers intrapreneurial behavior and activities among university employees, encouraging knowledge commercialization among university faculty and staff (Shane, 2004; Wright et al., 2006).

A predominant barrier for both intrapreneurship and entrepreneurship is resource availability (Klofsten et al., 2019), especially financial resources during the nascent stages of product development and market introduction. This makes intrapreneurial spinoffs rely substantially on university knowledge, networks, financial and infrastructure support (Soetanto and Van Geenhuizen, 2015), as well as support in accessing external finance such as grants, debt and equity funding (Clarysse et al., 2007; Munari and Toschi, 2011). Oftentimes scientists opt to retain their roles within the university, focusing on intrapreneurial activities instead of starting a new business. Supporting these initiatives can augment the university's value and facilitate access to external funding, catalyzing growth in academic spinoffs (Urbano et al., 2013). In pursuit of an intrapreneurial activity, spinoffs will seek three different sources of funding such as debt finance (e.g. short and long term bank loans) (Brown and Lee, 2019), equity finance (equity-based crowdfunding, venture capital and business angels) (Knockaert et al., 2010; Colombo et al., 2022) as well as innovation competitions and grant funding. Grant funding may be most preferred form of financing at the early stage of an intrapreneurial spinoff as this does not require dilution of equity or financial liabilities such s bank loans and paying interest rates (Gustafsson et al., 2020). The recent study of Alsos and Ljunggren (2017) using the signaling theory has demonstrated that positive signals to investors may include a firm having a prototype or already invested in R&D and digital capabilities could increase the likelihood of equity fundraising or receiving the bank loan, while academic spinoffs who received grants were also more likely to secure venture capital (Belz et al., 2021).

2.2. Access to finance and digitalization in intrapreneurial spinoffs

There is limited knowledge regarding the varied ways in which intrapreneurial academic spinoffs are established, and their strategies for securing financial resources and growth, especially across different stages of the growth continuum and various scientific fields. For instance, Bienkowska et al. (2016) showed that academics in the fields of natural science and technology often see the creation of a spinoff company as the primary outcome of entrepreneurial activity. In contrast, those in the arts and social sciences are more inclined towards the social dimensions of entrepreneurship. For them, organizing activities that address societal challenges is a more significant aspect of entrepreneurship (Bienkowska et al., 2016).

Despite the importance of natural science intrapreneurial spinoffs to universities, regions, and society at large, few studies have delved into explaining how these spinoffs secure funding and achieve greater profitability (e.g., Clarysse et al., 2011; Mathisen and Rasmussen, 2019). Compared to spinoffs in other scientific disciplines, intrapreneurial academic spinoffs in natural sciences may confront higher risks due to the intricate technologies involved and the experimental nature of their product innovations and commercialization processes (Clarysse et al., 2005; Moray and Clarysse, 2005). Given the long-term nature of research outcomes, the technological and market uncertainties inherent in natural science innovations, and especially in the early (pre-market) stages, these spinoffs might face challenges in fundraising and accessing bank capital (Soetanto and Van Geenhuizen, 2015). Often, these spinoffs introduce innovative products that need further validation and testing, pushing back their market entry timelines (Colombo et al., 2010; Sørheim et al., 2011). As a result, there's typically a substantial delay for natural science intrapreneurial spinoffs between academic discovery (Gruber et al., 2013), innovation commercialization, and the mass production phase (Wright et al., 2006; Clarysse et al., 2011; Knockaert et al., 2011). This elongated timeline hampers their ability to demonstrate profitability and secure financing to potential investors (Moray and Clarysse, 2005).Therefore, it is important to understand the factors and boundary conditions that may enhance or impede access to finance and profitability of intrapreneurial spinoffs (Vincett, 2010).

3. Hypothesis development

3.1. Intrapreneurial spin-offs and access to finance

Intrapreneurial activity within universities is diverse (Mustar et al., 2006). Heirman and Clarysse (2004) as well as Klofsten and Jones-Evans (2000) examined various academic spinoffs by considering the unique configurations of financial, technological, and human resources. Specifically, Heirman and Clarysse (2004) investigated how variations in a spinoff, combined with environmental factors like technological domain, organizational origin, and industry, can influence resource configuration and performance outcomes. In terms of technological resources, they took into account the innovativeness of the company's core technology, the development stage of the product/technology at the company's inception, and the scope of the product/technology—distinguishing between companies that were developing a singular product and those creating a platform for multiple products.

To manage the high uncertainty and risks associated with access to infrastructure, financial and human resources, the founder or CEO of a spinoff often maintains a university position. This provides a steady income, access to scientific labs and materials, doctoral students, an experimental base, and other university-wide support mechanisms such as technology transfer offices (TTO), university-industry partnerships, and science parks (Audretsch and Belitski, 2019). This foundational support promotes a higher tolerance for risk-taking in uncertain situations.

Although universities frequently back intrapreneurial spinoffs with resources, investors, lenders, and public resource providers might view these spinoffs as too uncertain or risky to finance (Druilhe and Garnsey, 2004). This perspective is especially prevalent for academic spinoffs in natural sciences, for several reasons.

Firstly, the founder or CEO is often only partially committed to the new venture, and the university maintains administrative oversight over the spinoff. Not all investors have experience collaborating with universities, and only a minority of them have worked with academic spinoffs in natural sciences. These spinoffs face an increased information asymmetries, because it is often difficult to gauge technology and product maturity in the realm of natural sciences deadling wwith basic knowledge (Gompers, 1995). Secondly, innovations from intrapreneurial spinoffs in the natural sciences demand more time for market validation, knowledge testing, and the experimental phase. This often results in a prolonged commercialization timeline from invention to market, compared to spinoffs in other fields of science (Colombo et al., 2010; Sørheim et al., 2011). Thirdly, due to their technological complexity, academic spinoffs in natural sciences take longer to transition from the research environment to the marketplace (Heblich and Slavtchev, 2014). These entities require specialized equipment and materials for both experimentation and product development and fundamental research—this might include ordering unique equipment and testing materials such as chemical compounds, magnetic accelerators, microscopes, cyclotrons, telescopes and other. Finally, the university usually retains ownership of the intellectual property and has a say in decision-making processes (Sørheim et al., 2011; Munari and Toschi, 2011).To consider access to finance in the different stages of development of intrapreneurial spinoffs, we draw on the early stages of the firm growth model (Churchill and Lewis, 1983), distinguishing between the seed stage, venture/early growth stage, growth stage, established stage, exit stage, and dead stage. Based on the above argument, we hypothesize.

H1a. Intrapreneurial academic spinoffs in natural sciences fundraise equity and debt capital at later stages of firm growth compared to intrapreneurial academic spinoffs in other fields of science.

Most intrapreneurial spinoffs in natural science take a long period to create and transfer knowledge, as intrapreneurial capabilities take longer than other capabilities to develop, integrate, and coordinate, so investing in natural science start-ups creates uncertainty for investors and affects early sales and profits (Bradley et al., 2013).

Guerrero et al. (2020, 2021) explored the relationships between the ordinary capabilities needed to fulfill a university's core strategies (i.e., teaching quality, research quality, and administration) and intrapreneurial capabilities essential for executing a university's entrepreneurial strategy (like sensing opportunities and transforming routines to foster innovation). Their research also considered university outcomes. The speed of developing, integrating, and coordinating skills/assets/-knowledge transfer hinges on an intrapreneurial spinoff's aptitude for acquiring external knowledge or nurturing it internally, processes that are time-intensive. Intrapreneurial capabilities are essential for commercializing innovation, necessitating the genesis of novel technological or innovative ideas before a spinoff can seize economic value in the market – i.e., earn profits.

Bradley et al. (2013) posited that when technology is in its nascent stages, as is often the case with endeavors initiated by natural scientists, it appears too high-risk to entice investors or secure loans from banks. This perception persists unless the technology has been rigorously tested and validated (Colombo et al., 2010), processes that entail laboratory experiments, fundraising efforts, initial market sales, and the generation of preliminary profits. An intrapreneurial academic spinoff might be the sole avenue for developing and commercializing such technology. The formation of a spinoff can make the technology commercially viable (Shane, 2004). Rival researchers might attempt to contest these technologies both formally and informally, potentially influencing pre-market entry and future profit trajectories. Such challenges make investors and lenders particularly circumspect during the early stages of technology development.

Intrapreneurial academic spinoffs in natural science will need more time to claim intellectual property rights (Teixeira and Ferreira, 2019), collaborate on technology with potential customers, suppliers and competitors (Audretsch and Belitski, 2020, 2023), and facilitate transfer technology (Chiesa and Piccaluga, 2000) to secure its property rights, develop products and enter the market. Investors and banks would wish to observe product development and granting intellectual property rights and first profits before investing in the spinoff or lending financial resources.

Investors and financial institutions typically prefer to monitor product evolution, the awarding of intellectual property rights, and the realization of initial profits before committing resources to the spinoff. This approach stands in contrast to intrapreneurial academic spinoffs in other scientific fields, where research outcomes might be more immediately discernible and market-ready (e.g., in domains like food science research, food manufacturing, construction, architecture, design, and agriculture). Natural science-focused intrapreneurial academic spinoffs are likely to generate profits only after market entry, and this profitability needs validation by financial stakeholders. Such dynamics slow the growth trajectory of intrapreneurial spinoffs, impacting their fiscal performance in the spinoff's nascent stages. As a consequence, profits are deferred from the venture and growth phases to the more mature stages of the spinoff's lifecycle. Based on this we hypothesize.

H1b. Intrapreneurial academic spinoffs in natural sciences increase their profits at later stages of firm growth compared to intrapreneurial academic spinoffs in other fields of science.

3.2. Intrapreneurial spin-offs and digitalization

Entrepreneurship and innovation scholars have recognized the role of digitalization as a means to develop intrapreneurial capabilities (Guerrero et al., 2021; Rippa and Secundo, 2019), with digital technologies becoming enablers of intrapreneurship at universities (Rabl et al., 2022). Digital capabilities are an integral part of intrapreneurial capabilities (Guerrero et al., 2021) and facilitate the development and adoption of digital technologies by intrapreneurial spinoffs. Spinoffs that develop digital technologies, invest in digital capabilities, and consider them as part of their business models are defined as digitally driven spinoffs (Connected Commerce Council, 2020). These digitally driven spinoffs are more resilient than digitally uncertain spinoffs. They create more jobs, attract more capital investment, and achieve higher profits. In contrast, intrapreneurial spinoffs that neither develop nor invest in digital technologies, and do not view digital capabilities as essential to their business model, are classified as digitally uncertain spinoffs. Such spinoffs are less resilient, more likely to experience slower growth rates, create fewer jobs, and access less capital (Connected Commerce Council, 2021). Within universities, intrapreneurial spinoffs leverage digital capabilities and develop digital technologies to explore and exploit market opportunities (Giones and Brem, 2017; Secundo et al., 2020). Digital tools are ubiquitous (Li et al., 2016) and can be employed by intrapreneurial academic spinoffs across different fields to enhance processes and operations and to innovate new products and services (Audretsch and Belitski, 2021a). Such technologies can diminish the costs associated with knowledge transfer and operations, signaling quality to stakeholders like investors, governments, and customers (Radko et al., 2022).

The reasons for the dependence of digitally-driven intrapreneurial spinoffs, particularly in natural sciences, on digital technologies in their business models to generate economic value and secure financing are manifold:

Firstly, Digital technologies enhance visibility on websites, enable targeted advertising for new products, and facilitate profiles on digital platforms such as crowdfunding and venture capital platforms. This increases access to equity and debt resources crucial for technology investment and growth (Bock et al., 2018; Knockaert et al., 2011). Spinoffs showcasing evidence of in-house digital technology development or digital tech incorporation that disrupts the market are more likely to secure external funds and boost sales (Belitski and Boreiko, 2022).

Secondly, incorporating digital tech results in better servitization, which is otherwise limited in natural science products. This transformation refines spinoff business models, aligning business with IT strategies and thus optimizing operations for value creation.

Thirdly, digital technology enhances the speed and security of service and product delivery, boosting a firm's competitive edge, especially in sectors where digital adoption is minimal, such as physical sciences and astrophysics, mathematics, and chemical sciences. Other domains like engineering, medical, and healthcare are already familiar with digital technology, implying that while further tech adoption is necessary, the incremental benefits diminish compared to the potential within natural sciences.

Fourthly, digitally advanced spinoffs enable global data sharing, especially using cloud technology. This interconnectivity is vital for labs focused on physics, astrophysics, and chemistry. Compared to other scientific fields, in natural science, simulating materially intense and expensive lab processes can significantly cut down experiment time and foster open-source innovation (Chesbrough et al., 2014), slashing transaction and managerial costs for data gathering, analysis, and simulation (Lu et al., 2022).

Fifthly, digitally advanced spinoffs in natural sciences are better equipped to oversee and integrate data across entities, using tools like cloud technology and live-tracking for lab experiments in fields such as physical sciences, astrophysics, and chemistry. This capability lowers costs and enhances collaboration between major stakeholders. Digitally advanced spinoffs can streamline operations, hasten product development, and communicate research findings more efficiently if they widely adopt digital technologies. This stakeholder engagement is vital for growth and access to external financing, emphasizing the importance of developing digital technologies for intrapreneurial spinoffs.

Finally, implementing digital technologies can boost the speed of experiments and data preparation, influencing product development and validation. Collaborative online engagement has proven efficient, as witnessed during the COVID-19 pandemic (Zhang et al., 2021). Outsourcing to locations where experimentation is financially viable and feasible using digital tech is a trend. Digital tools and collaboration help mitigate the risks inherent in the knowledge commercialization process.

Given the distinctions between "digitally-driven" and "digitally uncertain" spinoffs, it's plausible to assert that digitally-driven intrapreneurial spinoffs in natural sciences will utilize the advantages of digital technologies to maximize the applicability of basic knowledge, including via collaboration with external stakeholders and investors. Their digital capabilities enable rapid material experimentation, process simulations, and knowledge exchange, resulting in more significant knowledge spillovers (Knockaert et al., 2011; Audretsch et al., 2021) and, consequently, increased profits and investment (Rodríguez-Gulías et al., 2018). Investors are likely to anticipate considerably higher returns from digitally-driven spinoffs compared to their uncertain counterparts (Connected Commerce Council, 2021). A case in point is the Kromek spinoff in physics. Led by materials scientist Arnab Basu, this radiation-detection technology developer ventured into countering COVID-19 using digital tech, emphasizing digital marketing and management as vital functions.

However, the digital technologies pioneered by intrapreneurial spinoffs in natural sciences are seldom ready for market at inception. These firms will often need more seed and venture capital for growth (Clarysse et al., 2007; Mariani and Belitski, 2022; Cumming et al., 2021). Therefore, we hypothesize that digitally driven spinoffs will achieve greater profitability and access to external finance.Therefore we hypothesize that spinoffs that are digitally driven will achieve greater profitability and access to external finance.

H2. Digitally-driven intrapreneurial academic spinoffs in the natural sciences increase their access to equity and debt capital to a greater extent than digitally-uncertain spinoffs in natural sciences and other fields of science.

H3. Digitally-driven intrapreneurial academic spinoffs in the natural sciences increase their profits to a greater extent than digitally-uncertain spinoffs in natural sciences and other fields of science.

4. Methodology

4.1. Sample

Most datasets represent a static combination of resources at a particular point in time, as conducting longitudinal surveys for potential dynamic analysis is even more costly and time-intensive. Self-reported data from firms is likely to be more biased (Gonzalez et al., 2012) than objective data, especially if managers in growing firms cannot gather enough data on markets, customers, and competitors or underreport data for accounting reasons.

The data agency Beauhurst collects firm-level data for all high-growth firms in the UK (Beauhurst, 2022). This data provides information (daily, monthly, and annually) on all high-growth firms in the UK, including all university spinoffs from 2011 onwards. Beauhurst employs an artificial intelligence algorithm to extract information from websites and annual reports about existing and potential high-growth firms, including university spinoffs. We obtained a comprehensive sample of university (academic) spin-offs identified by Beauhurst as academic spinoffs and officially registered in the UK. This sample comprised 1194 academic spinoffs, including 1047 academic spinoffs in non-natural science fields and 147 in natural science fields. These 1194 academic spinoffs were observed from 2015 to 2019 as a panel. However, not all academic spinoffs are associated with a university or its staff (Klofsten et al., 2021).

To distinguish intrapreneurial academic spinoffs from the broader cohort of academic spinoffs, we drew on previous research on university spinoffs (Mustar et al., 2008; Guerrero et al., 2016, 2021; Klofsten et al., 2021; Valka et al., 2020). We manually examined data from the LinkedIn accounts of a CEO and (co)founder(s) of an academic spinoff (provided within the Beauhurst data). We verified whether a (co) founder(s), a CEO, or both, held full-time research positions (e.g., researcher, assistant, associate, or full professor) at a UK university. University spinoffs with a founder, CEO, or both who had ceased their academic careers and were no longer full-time university employees between 2015 and 2019 (the data collection period) were excluded from our sample. This criterion reduced the number of academic spinoffs in our sample from 147 to 89 in the natural sciences and from 1047 to 660 in non-natural science fields. In cases with conflicting information about employment years or professional roles, we manually checked university websites to determine if a (co)founder or a CEO was listed on the official university/faculty page and whether that information remained current. Consequently, having a full-time professional position at a UK university was a crucial criterion for inclusion in our sample as an intrapreneurial academic spinoff.

Therefore, our final sample consisted of 89 natural science intrapreneurial spinoffs and 660 non-natural science intrapreneurial spinoffs from 2015 to 2019. The number of observations remained consistent across years, allowing us to analyze how independent characteristics influenced the dependent variables consistently. Please refer to Table 1 for sample descriptions of both natural science and non-natural science intrapreneurial spinoffs.

Drawing on OECD (2015) Frascati Manual we describe our sample construction as follows. Intrapreneurial spinoffs in our data which represent natural sciences belong to physical sciences and astrophysics, mathematics, chemical sciences, earth and related environmental sciences. Our sample of natural sciences does not include spinoffs from Computer and information sciences as well as biological sciences.

Intrapreneurial spinoffs in our data which represent non-natural sciences belong to Engineering and Technology (49.35%); Medical and Health Sciences (25.63%); Social Sciences (10.41%); Agricultural Sciences, including agriculture, forestry, fisheries, veterinary medicine, animal and dairy science, veterinary science, agricultural biotechnology (10.12%); and Humanities (4.49%).

Most firms in the sample of natural science academic spinoffs are at the seed stage (start-ups) (40.01% of the sample), the venture stage—early growth (20.02% of the sample), and the growth stage (7.05%).

Table 1
Descriptive summary statistics.

Type of academic spin-off		Natural science = 89 spinoffs				Other fields = 660 spinoffs			
Variables	Description	Mean	St.dev	Min	Max	Mean	St.dev	Min	Max
Grants	Number of grants received	3.84	3.85	0.00	24.00	2.76	3.51	0.00	27.00
Fundraise	Total equity fundraising, in GBP in logarithms	10.63	6.00	0.00	18.48	11.99	6.21	0.00	20.31
Bank loans short term	Total bank short term loans in logarithms	3.42	5.46	0.00	17.42	2.67	5.03	0.00	18.27
Bank loans long term	Total bank long term loans in logarithms	6.68	6.26	0.00	17.42	6.03	6.12	0.00	18.64
Profits	Total profit after tax in logarithms	1.01	3.60	0.00	16.19	0.55	2.74	0.00	18.36
Seed stage	Seed stage = 1, zero otherwise	0.34	0.47	0.00	1.00	0.36	0.48	0.00	1.00
Venture stage	Venture stage = 1, zero otherwise	0.31	0.47	0.00	1.00	0.35	0.48	0.00	1.00
Growth stage	Growth stage = 1, zero otherwise	0.06	0.25	0.00	1.00	0.08	0.27	0.00	1.00
Established stage	Established stage = 1, zero otherwise	0.11	0.32	0.00	1.00	0.05	0.21	0.00	1.00
Pinterest	Spin-off has a Pinterest account = 1, zero otherwise	0.02	0.19	0.00	1.00	0.07	0.25	0.00	1.00
Instagram	Spin-off has Instagram account = 1, zero otherwise	0.20	0.40	0.00	1.00	0.25	0.43	0.00	1.00
Twitter	Spin-off has tweeter account = 1, zero otherwise	0.70	0.33	0.00	1.00	0.76	0.43	0.00	1.00
LinkedIn	Spin-off has LinkedIn account = 1, zero otherwise	0.82	0.33	0.00	1.00	0.88	0.32	0.00	1.00
Women CEO	Women is Chief executive officer = 1, zero otherwise	0.09	0.29	0.00	1.00	0.08	0.28	0.00	1.00
Intangible assets	Intangible assets, GBP in logarithms	4.01	5.72	0.00	15.42	4.33	5.72	0.00	18.35
Working capital	Working capital, GBP in logarithms	9.36	5.36	0.00	1.89	10.46	5.71	0.00	19.05
Fundraising event	Number of fundraising events	3.65	3.23	0.00	12.00	3.36	3.05	0.00	17.00
Digitally-driven	Spinoff uses or develops i) digital technology (platform) aiming to disrupt the existing market is developed by a firm = 1, zero otherwise and ii) firm names digital technology in its business model description on th website = 1, zero otherwise	0.78	0.41	0.00	1.00	0.25	0.43	0.00	1.00
University age	University age (years), where spinoff is established	311.14	169.69	52.00	500.00	291.90	164.66	26.00	500.00
Firm size	Number of full-time employees in logarithms	2.01	0.97	0.60	4.10	2.41	1.06	0.69	6.42

Source: Academic spin-offs Beauhurst (2022).

Most firms in non-natural science academic spinoffs are at the seed stage (start-ups) (44.21% of the sample), venture stage—early growth (19.01% of the sample), and growth stage (3.05% of the sample). A low share of established or exit-stage firms can be explained by the emerging characteristics of the industries and the newness of the technology used in the industry, with many firms still at the experimental stage.

4.2. Variables

4.2.1. Dependent variable

We have five dependent variables. The first variable is the number of grants received from both public and non-public sponsors. Innovation grants are mainly provided by the UK innovation agency, which is part of the UK Research and Innovation. The second variable is a total equity fundraising in GBP in logarithms, which demonstrates access to equity funding including venture capital (VC) and business angels. The third variable is total bank short-term loans in logarithms, and the fourth variable is the total bank long-term loans in logarithms, which is a proxy for access to debt finance. Finally, we estimate firm efficiency in value capture and profitable growth by adding total profits in logarithms in our model.

4.2.2. Explanatory variables

We use the following explanatory variables to test our research hypothesis. Firstly, to test H1a and H1b we used a set of binary variables associated with an intrapreneurial spinoff growth stage, such as seed stage, venture stage, growth stage, established stage, exit stage, dead and dormant stages (H1a-H1b) building on pripor research of firm growth stages (Churchill and Lewis, 1983; Belitski and Desai, 2021). Spinoffs that are at exit, dead and dormant stag is our reference category.

We draw on prior research of Giones and Brem (2017) in identifying the digital technology and we apply the Connected Commerce Council (2021) definition to distinguish between intrapreneurs that are digitally-driven (meaning they have developed new digital technologies and adopted tools they have found essential for their business model) and intrapreneurs that are digitally-uncertain (meaning they have not developed and/or adopted digital technology). As an example, new digital technologies could be developed as part of the Internet of Things, Industry 4.0, artificial intelligence, block chain, automation, remote monitoring, predictive maintenance, smart contracts, big data, and cloud computing (Bock et al., 2018).

In order to test our H2 and H3 related to the relationship between digitally-driven spinoffs and access to finance (H2) and profitability (H3), we used a variable called "digitally driven" which is a binary variable equals one if a firm developed digital technology in-house which is market disruptive, zero otherwise. In addition, we controlled whether a spinoff reported a use of digital technology in the description of their business model or not. In case of no evidence and mentioning using the digital technology in a descriptoin of a business– we considered that digital technology is not essential for their business and hence a firm would be changed for digitally-uncertain. The description of the digital technology on the spinoff website could include development and adoption of new technology, development of technology which is used for product development and testing, transfer and engagement and developed by the company or outsourced to the third parties (Aspelund et al., 2005).

4.2.3. Control variables

We used the number of successful fundraising events as a control for financial investment readiness. We use the binary variable "women-led firm" (1 if a CEO is female, 0 if not) to measure the performance of women-led firms. Female CEOs might have different access to finance in the early stages of business growth compared to male CEOs (Alsos and Ljunggren, 2017). Prior research has shown that women are generally more risk-averse, which could influence the type of financing they choose to access (Audretsch et al., 2022a). The heightened risk aversion of female CEOs, combined with operating in a traditionally "masculine world", might limit their access to equity finance. There is recent evidence supporting this in the context of female leadership in academic spinoffs (Lauto et al., 2022), which could lead to reduced innovation and profits (Audretsch et al., 2022b).

We control for firm size, which is measured as the log of total assets, to account for potential diminishing marginal returns as firm size increases.

Table 2
Results of the fixed effects regression: Dependent variables – access to finance and firm performance.

Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variable	Grants	Grants	Fundraise	Fundraise	Bank loans short term	Bank loans short term	Bank loans long term	Bank loans long term	Profits	Profits
Type of spin-off	Natural sciences	Other fields	Natural sciences	Other fields	Natural sciences	Other fields	Natural sciences	Other fields	Natural sciences	Other fields
Seed stage (H1)	−3.27** (1.60)	−0.02 (0.33)	−0.39 (1.80)	−0.40 (0.58)	−4.66*** (1.65)	−3.02*** (0.70)	−4.99*** (1.76)	−2.58*** (0.78)	−1.73* (0.84)	−1.68*** (0.47)
Venture stage (H1)	−4.72** (1.80)	1.18*** (0.40)	1.37 (1.44)	0.05 (0.14)	−4.10*** (1.52)	2.09** (0.90)	−2.85 (1.80)	1.84** (0.76)	−3.53* (1.87)	1.69*** (0.50)
Growth stage (H1)	4.08 (2.63)	1.87** (0.90)	1.29 (1.04)	1.38** (0.60)	2.25*** (0.72)	1.89** (0.91)	3.71 (2.34)	0.29 (0.96)	4.53** (2.25)	1.97*** (0.60)
Established stage (H1)	2.74 (1.90)	0.43 (1.06)	4.13** (2.03)	2.18*** (0.51)	4.66*** (1.72)	0.45** (0.24)	4.90** (2.25)	0.67 (1.22)	−1.68 (2.36)	−0.63 (0.95)
Pinterest	−4.86*** (1.44)	−0.16 (0.51)	−1.85 (2.68)	−1.46** (0.68)	−3.21 (2.11)	−0.08 (0.78)	−1.93 (3.74)	−0.98 (0.91)	1.72 (3.73)	−0.22 (0.36)
Instagram	−1.69* (0.94)	−0.41 (0.35)	0.65 (1.16)	−0.34 (0.40)	−0.73 (1.40)	0.05 (0.45)	1.78 (1.67)	0.09 (0.57)	−1.20 (0.77)	−0.03 (0.26)
Twitter	1.48* (0.79)	0.54* (0.31)	1.08** (0.50)	0.92* (0.50)	1.77** (0.70)	0.15** (0.06)	1.29** (0.60)	0.47 (0.28)	1.25 (0.70)	0.20 (0.11)
LinkedIn	1.09 (1.00)	0.28 (0.37)	2.86* (1.47)	1.76*** (0.66)	2.03 (1.70)	0.01 (0.58)	−1.13 (2.15)	0.64 (0.69)	1.66* (0.91)	0.09 (0.28)
Women CEO	1.09 (1.52)	0.07 (0.39)	0.82 (1.41)	−0.07 (0.62)	−0.89 (1.16)	1.15 (0.70)	0.19 (2.58)	1.15 (0.81)	−2.12 (1.45)	0.22 (0.35)
Intangible assets	0.05*** (0.01)	−0.01 (0.03)	0.05*** (0.01)	0.100*** (0.03)	0.05*** (0.01)	0.06** (0.03)	0.07** (0.03)	0.07* (0.04)	0.09** (0.03)	0.01** (0.00)
Working capital	0.03 (0.07)	−0.03 (0.03)	0.07*** (0.2)	0.09*** (0.03)	−0.48*** (0.09)	−0.27*** (0.04)	−0.41*** (0.11)	−0.19*** (0.04)	0.02** (0.00)	0.03* (0.02)
Fundraising event	0.22* (0.13)	−0.05 (0.05)	1.30*** (0.21)	1.16*** (0.09)	−0.62*** (0.17)	−0.06 (0.08)	−0.30** (0.15)	−0.10 (0.09)	−0.01 (0.21)	−0.09 (0.07)
Digitally-driven (H2)	0.09 (0.61)	0.88** (0.35)	0.91*** (0.25)	0.34*** (0.12)	1.45*** (0.27)	−0.14 (0.43)	1.96** (0.68)	−0.48 (0.52)	1.19** (0.46)	0.45** (0.18)
University age	0.01*** (0.00)	−0.01*** (0.00)	0.01*** (0.00)	0.01*** (0.00)	0.01*** (0.00)	0.01** (0.00)	0.01 (0.00)	−0.01 (0.00)	−0.01 (0.00)	0.01 (0.00)
Firm size	0.53 (0.56)	0.80*** (0.22)	−0.42 (0.63)	0.22 (0.22)	1.47** (0.70)	1.12*** (0.27)	1.90** (0.84)	1.75*** (0.28)	0.69 (0.49)	0.45** (0.20)
Constant	2.12 (1.83)	0.62 (0.48)	2.49 (2.53)	2.88*** (0.80)	6.03** (2.40)	4.99*** (0.90)	8.32*** (3.01)	6.05*** (1.00)	1.26 (2.37)	0.56 (0.46)
Number of spinoffs	89	660	89	660	89	660	89	660	89	660
Number of obs.	356	2640	356	2640	356	2640	356	2640	356	2640
R2	.411	.330	.692	.523	.546	.304	.407	.386	.287	.317
F-statistics	6.70	5.55	13.63	33.81	11.74	7.49	6.92	11.42	5.68	6.82
Log-likelihood	−197.12	−1717.52	−211.66	−1896.97	−214.45	−1927.35	−235.89	−2063.06	−199.33	−1559.10

Note: Standard errors in parentheses. Significance levels: *** 1%, ** 5%, * 10%; Industry and regional fixed effects are oppressed to save space. Reference region = Northern Ireland; reference industry – finance and financial techonlogies. Standard errors robust for heteroskedasticity are in parenthesis.
Source: Academic spin-offs Beauhurst (2022).

Measuring firm size by its total assets and working capital is particularly fitting for firms in emerging industries. This is because many of these firms undergo rapid growth and scaling (Belitski et al., 2023) in the years following their product introductions. We consider the age of the university where the firm was established, as it might correlate with potential access to resources for intrapreneurial spinoffs (Heblich and Slavtchev, 2014; Audretsch and Belitski, 2021b, 2022). We assess the extent of digital presence and the role of social networks, which could be crucial for fundraising, visibility, and sales. To do this, we use a set of binary variables indicating whether businesses are active on platforms like LinkedIn, Pinterest, Twitter, and Instagram. We've incorporated 12 regional fixed effects for the UK as identified by the Office of National Statistics. This encompasses nine regions in England (South-East of England, South-West of England, London, East of England, West Midlands, East Midlands, North-East, North-West, and Yorkshire and Humber) and three countries: Wales, Scotland, and Northern Ireland. The reference category is Northern Ireland. All control variables are considered with a one-year lag.

4.3. Estimation strategy

We employ a random-effects panel data estimation with industry and regional fixed effects. Our dependent variables are continuous, and the data is panel of four years (Wooldridge, 2009). Our dependent variable is y_{it} (firm's ability to raise funding – grant numbers, equity funding, short-term and long-term bank loans) and the profit growth of firm i at time t:

$$y_{it} = \beta_0 + \beta_1 S_{it-1} + \beta_2 D_{it-1} + \beta_3 x_{it-1} + \delta_z + \omega_r + u_{it} \quad (1)$$

Vector S_{it-1} is a set of explanatory variables related to the growth stage of intrapreneurial spinoff i at time t – 1; vector D_{it-1} is a binary variable equals one if an intrapreneurial spinoff i at time t – 1 is digitally-driven, zero otherwise; x_{it-1} is a vector of control variables of the intrapreneurial spinoff i at time t, and u_{it} is an error term (Wooldridge, 2009). Vectors δ_z, ω_r are industry - (z) and region (r) fixed effects. A bootstrapping of errors was also applied, which led to similar results in terms of the sign and significance of all confidants but of a different size.

We started by exploring the multicollinearity of the variables by examining the variance inflation factors for all variables, finding each less than 5. In addition, we analyzed the correlation coefficients, ensuring that no coefficients were greater than 0.70. We analyzed all the variables' histograms and found the errors were identically and independently distributed with constant variance.

5. Results

Table 2 presents the regression results testing our H1 and H2. Our H1a posits that intrapreneurial academic spin-offs in natural sciences raise equity and debt capital at later stages of firm growth compared to intrapreneurial academic spin-offs in other science fields. This hypothesis is supported.

Intrapreneurial spinoffs in natural sciences are less likely to secure grant funding during the seed stage ($\beta = -3.27$, $p < 0.01$) and venture stage ($\beta = -4.72$, $p < 0.01$) compared to the exit stage and compared to spinoffs in other science fields at the seed stage ($\beta = -0.02$, $p > 0.10$) and venture stage ($\beta = 1.18$, $p < 0.01$) (spec. 1, Table 2). Intrapreneurial spinoffs in other science disciplines continue to show higher grant fundraising during the growth stage ($\beta = -0.02$, $p > 0.10$) and venture stage ($\beta = 1.18$, $p < 0.01$), in comparison to the exit stage (spec. 2, Table 2).

Intrapreneurial spinoffs in natural sciences are less likely to raise equity funding during the growth stage than during the exit stage and compared to intrapreneurial spinoffs in other science fields ($\beta = 1.38$, $p < 0.05$) (spec. 4, Table 2). Notably, intrapreneurial spinoffs in natural sciences at the established stage ($\beta = 4.13$, $p < 0.001$) (spec. 3, Table 2) almost double their equity funds when compared to intrapreneurial spinoffs in other fields ($\beta = 2.18$, $p < 0.001$) (spec. 4, Table 2).

Both intrapreneurial spinoffs in natural sciences and other fields secure fewer short-term loans during the seed stage than at the exit stage. Yet, intrapreneurial spinoffs in natural sciences continue to attract lower short-term bank capital during the venture stage ($\beta = -4.10$, $p < 0.05$) (spec. 5, Table 2), while intrapreneurial spinoffs in other fields obtain more debt financing in comparison to the exit stage ($\beta = 2.10$, $p < 0.01$) (spec. 6, Table 2). Both intrapreneurial spinoffs in natural sciences and other disciplines have fewer long-term bank loans at the seed stage ($\beta = -4.99$, $p < 0.01$) and ($\beta = -2.58$, $p < 0.01$) respectively (spec. 7–8, Table 2). While intrapreneurial spinoffs in other fields can access more long-term bank capital during the venture period ($\beta = -1.84$, $p < 0.01$), those in natural sciences do not. However, the increase in bank lending for spinoffs in natural sciences is significant at the established stage ($\beta = 4.90$, $p < 0.01$) compared to the exit stage, and it's considerably higher than intrapreneurial spinoffs in other fields ($\beta = 0.67$, $p > 0.10$) (spec. 7–8, Table 2).

Venture capitalists seem to have a bias related to academic spin-offs at the early stages of firm growth, as these investors struggle to identify and evaluate the technologies used by intrapreneurs (Munari and Toschi, 2010). While we have previously highlighted that radically new technologies can be complicated and difficult to evaluate, increasing the magnitude of information asymmetries and uncertainty, they also have a great potential to generate disruptive technologies.

Our H1b, which posits that intrapreneurial academic spin-offs in natural sciences increase their profits at later stages of firm growth compared to intrapreneurial academic spin-offs in other science fields, is partly supported. The regression coefficient for natural science intrapreneurial spin-offs remains negative and statistically significant at the seed stage ($\beta = -1.73$, $p < 0.05$) and venture stage ($\beta = -3.53$, $p < 0.05$) (spec. 9, Table 2). In contrast, profitability of spin-offs in other sciences increases at the seed stage compared to the exit stage ($\beta = 1.69$, $p < 0.001$) (spec. 10, Table 2). In the growth stage, intrapreneurial spin-offs in natural sciences, compared to the exit stage and spin-offs in non-natural sciences, demonstrate higher profits ($\beta = 4.53$, $p < 0.01$) (spec. 9, Table 2). Interestingly, profit growth at the established stage is consistent with the exit stage for both types of intrapreneurial spin-offs.

Our H2a, which posits that digitally-driven intrapreneurial academic spin-offs in the natural sciences raise more equity and debt capital than digitally-uncertain firms in the natural sciences and spin-offs in other science fields, is supported. Digitally-driven intrapreneurial academic spin-offs in other fields receive, on average, a higher number of grants ($\beta = 0.88$, $p < 0.01$) (spec. 2, Table 2) compared to digitally-driven spin-offs in natural science ($\beta = 0.09$, $p > 0.10$) (spec. 1, Table 2). We find that the adoption of digital technology enables intrapreneurial academic spin-offs in natural sciences to raise more equity funding ($\beta = 0.91$, $p < 0.001$) (spec. 3, Table 2) than other spin-offs ($\beta = 0.34$, $p < 0.001$) (spec. 4, Table 2). Notably, for both short-term and long-term bank finance, we find that digitally-driven intrapreneurial spin-offs in natural science can secure more short-term bank finance ($\beta = 1.45$, $p < 0.01$) (spec. 5, Table 2) and long-term bank finance ($\beta = 1.96$, $p < 0.01$) (spec. 7, Table 2) compared to spin-offs in other fields. This furthers prior research on the role of digitalization for small and medium-sized enterprises (Connected Commerce Council, 2020, 2021) and in university spin-offs (Shane, 2004; Rippa and Secundo, 2019). The coefficient for digitally-driven intrapreneurial startups in other sciences is negative and not statistically significant. This suggests that intrapreneurial spin-offs in natural science are more likely to obtain bank finance if they signal to lenders as digitally-driven intrapreneurial spin-offs. We also find that digitally-driven intrapreneurial spin-offs in natural sciences have a higher level of equity than debt finance, which underscores the role of VCs in supporting university spin-offs (Rodríguez-Gulías et al., 2018; Bock et al., 2018).

Our H3, which posits that digitally-driven intrapreneurial academic spin-offs in the natural sciences achieve greater profits than digitally-uncertain firms in the natural sciences and spin-offs in other science fields, is supported. Intrapreneurial spin-offs in natural sciences that adopt digital technology report, on average, a 1.19 percent ($\beta = 1.19$, $p < 0.01$) (spec. 9, Table 2) higher profit than natural science spin-offs that aren't digitally driven. The coefficient is also higher compared to the returns on a digitally-driven approach for academic spin-offs in other sciences ($\beta = 0.45$, $p < 0.01$) (spec. 10, Table 2). This indicates that returns on investment in digital technology and its adoption in business models for profitability are significantly higher for spin-offs in natural sciences compared to spin-offs in other fields. Intrapreneurial academic spin-offs see a greater increase in sales and profits when digital technologies enhance collaboration with external stakeholders and facilitate knowledge exchange using digital tools, thereby accelerating knowledge creation and transfer (Cassiman and Veugelers, 2002; Audretsch and Belitski, 2020).

6. Discussion

Intrapreneurial academic spin-offs serve as crucial conduits in the commercialization of university technologies and knowledge (Pinchot, 1985; Guerrero et al., 2016; Klofsten et al., 2019). University researchers are more inclined to engage in intrapreneurial activities and exhibit intrapreneurial behavior across various fields when their personal expertise and intrapreneurial capabilities receive support from the university in the form of a spin-off (Klofsten et al., 2021).

Like any new venture, intrapreneurial academic spin-offs face financial constraints and aim to source external resources to bridge the funding gap (Mustar et al., 2008; Rasmussen and Sørheim, 2012; Sørheim et al., 2011). This study investigates the differences in access to grants, equity, and debt finance, as well as firm profitability between intrapreneurial academic spin-offs in natural sciences and those in other fields. Using micro-level data from 89 intrapreneurial spin-offs in natural sciences and 660 in other fields from the UK (2015–2019), we analyzed their financial access and profitability across different growth stages. Our findings suggest that early-stage intrapreneurial spin-offs in natural science are perceived as riskier, with more uncertain investments than those in other science fields. Consequently, natural science spin-offs secure fewer public grants and raise less debt finance on average. Despite their innovative nature, the innovations often demand extra investment and validation. This prolonged period from invention to market introduction limits fundraising during the initial stages (Sørheim et al., 2011; Bock et al., 2018).

Our empirical results confirm that intrapreneurial spin-offs in natural sciences secure funding at later growth stages compared to their counterparts. Digitally-driven academic spin-offs in natural science possess a pronounced advantage in fundraising and accessing both short and long-term bank loans over both intrapreneurial spin-offs in other sciences and digitally-uncertain spin-offs in natural sciences. Furthermore, they also achieve higher profits than digitally-driven spin-offs in other fields, reinforcing previous research (Giones and Brem, 2017; Secundo et al., 2020). These findings highlight that intrapreneurial spin-offs from natural sciences benefit more from the adoption and in-house development of digital technologies compared to those from other fields. Emphasizing in-house technology development proves more conducive for profitability than returns on digital tech development in alternative science fields. Investments in internal R&D and human capital to become digitally-driven are crucial. Being digitally-driven can significantly reduce operational, logistics, and transaction costs within spin-offs and enhance collaborations with external stakeholders (Björkdahl, 2020), thereby amplifying information exchange.

Our results demonstrated that the substantial returns on digitally-driven technologies in natural science spin-offs may primarily relate to signaling to stakeholders like investors, governments, lenders, and customers (Giones and Brem, 2017; Cumming et al., 2021). For example, a spin-off may be better equipped to engage with external partners, showcase its innovations, and participate in open innovation strategies (Chesbrough et al., 2014). Investors likely view digitally-driven intrapreneurial spin-offs, especially in natural science, favorably. Many intrapreneurial academic spinoffs struggle to secure high profits and access to grants, equity, and debt financing during their initial growth stages. This can be attributed to challenges like technological risks, market uncertainties (Clarysse et al., 2007), a digital divide (Audretsch and Belitski, 2021a), and a lack of intrapreneurial skills (Guerrero et al., 2015, 2016). We found that digitally advance spinoffs achieve double the equity funding and greater access to bank capital than their digitally uncertain spinoffs.

Our study's results extend previous research on signaling for external finance access by intrapreneurial spin-offs (Conti et al., 2013; Giones and Brem, 2017; Secundo et al., 2020). Consistent with Conti et al. (2013), we found that the amount founders invest positively correlates with business investment.

Drawing upon the existing literature on universities' intrapreneurial capabilities (Meoli and Vismara, 2016; Klofsten et al., 2019, 2021), we argue that it is imperative for universities to integrate intrapreneurship into their business models. Such integration would entail a robust commitment from university managers and researchers (Guerrero and Urbano, 2014; Audretsch and Belitski, 2021b). The objective is to foster a conducive environment for intrapreneurial behavior, supported by clear leadership, defined university policies, systematic incentives, and transparent communication procedures (Klofsten et al., 2019).

Although the current body of research provides valuable insights into academic entrepreneurship in both developed (Klofsten and Jones-Evans, 2000; Guerrero and Peña-Legazkue, 2013) and developing countries (Belitski et al., 2019), there is still a dearth of knowledge about how universities balance research, teaching, and commercialization—their three primary missions (Guerrero et al., 2020, 2021). Moreover, the success of raising funds for intrapreneurial spinouts is not merely contingent on the surrounding institutions, be they formal or informal (Guerrero and Urbano, 2012, 2014), or on the entrepreneurial ecosystems of universities (Belitski and Heron, 2017; Guerrero et al., 2020). Instead, it is intrinsically tied to the intrinsic capabilities of the intrapreneurial spinoffs themselves (Guerrero et al., 2015; Klofsten et al., 2021).

Historical research has expanded our comprehension of entrepreneurial universities as entities (Guerrero et al., 2016; Radko et al., 2022). Yet, there remains a gap in our understanding of the intrapreneurial mechanisms within these institutions, as emphasized by Klofsten et al. (2019).

We address this gap by highlighting the nuanced needs of intrapreneurial academic spinoffs based on their scientific domain. These spinoffs, particularly those in natural sciences, often face longer paths to commercialization, requiring persistent support and investment from the university. Due to the nature of their products and the expertise they necessitate, these spinoffs frequently require extended timelines to develop products, secure funding, and achieve commercialization. We postulate that the utilization of digital technologies can expedite these processes, especially when coupled with simulations for experimentation and open innovation strategies (Li et al., 2016; Lu et al., 2022).

Our study highlights the importance of investment in both digital and intrapreneurial capabilities, enabling spinoffs to adapt swiftly to changes and craft innovation pathways conducive to funding and profitability (Wright et al., 2006; Belitski et al., 2023).

7. Conclusions

Building upon previous research on intrapreneurial activities in universities (Bienkowska and Klofsten, 2012; Audretsch and Belitski, 2013; Bienkowska et al., 2016; Meoli et al., 2019), this study theorizes and empirically tests several boundary conditions for knowldge transfer in intrapreneurial spinoffs in the UK, particularly concerning their access to finance and profitability. This includes factors such as the growth stage of the spinoff (Cunningham et al., 2022), the field of science, and the development and utilization of digital technologies (Clarysse et al., 2005, 2007; Rippa and Secundo, 2019). We specifically spotlight digitally driven intrapreneurial spinoffs, viewing them as catalysts for economic efficiency and tools to signal external stakeholders about a spinoff's quality and readiness for the digital era.

Using micro-level data from 2015 to 2019 on 89 natural science intrapreneurial academic spinoffs and 660 from other scientific domains in the UK, we discern significant takeaways for university leaders and policymakers. For instance, spinoffs in natural sciences like physics and chemistry often differ in their financing strategies and timelines compared to those in other academic disciplines. The intricate nature of spinoffs emerging from natural science-focused institutions is often linked to the integration of intrapreneurial and digital capabilities central to their business models, enabling collaboration with spinoffs from diverse scientific backgrounds. Additionally, these spinoff managers must understand the intricacies of their technologies, necessitating a prolonged journey from idea creation to commercialization. For such spinoffs, internally developed digital technologies can be pivotal in fostering relationships with investors, policymakers, and other stakeholders. The in-house progression of such technologies accelerates their transition from tangible labs to virtual simulations.

Furthermore, we advocate for intrapreneurial spinoff managers to invest in digital technologies. This will provide better market oversight and foster global collaborations, promoting open innovation and the Triple-Helix model (Brem and Radziwon, 2017; Jovanovic et al., 2021; Audretsch et al., 2022c) and will significantly increase access to equity and debt finance at the earlier stages of growth.

Our study is not without limitations, which pave the way for future research. Our first limitation concerns the relatively low number of natural science academic spinoffs in the UK. With a count of 147, which further dwindles to 89 after considering specific affiliations, our analysis options regarding financial access and profitability were constrained. Rather than a collective analysis, we separately assessed spinoffs in natural sciences and other disciplines, gauging the impact magnitude for each spinoff type. Subsequent research might employ varied methodologies, such as case studies and interviews, and examine the replicability of our findings beyond UK-centric academic spinoffs. Our second limitation arises from our inability to differentiate between spinoffs where leadership has shifted away from the university, despite the institution retaining control. Although instances of this might be limited, such spinoffs were excluded from our study. Future investigations might delve deeper into the ownership dynamics of these spinoffs.

Prospective studies can also explore other boundary conditions impacting financial access and profitability, such as human and technological resource constraints, geographical influences, and the significance of entrepreneurial university ecosystems researching how we can gauge the financial preparedness of intrapreneurial spinoffs for diverse finance. Moreover, the role of Technology Transfer Offices (TTOs) and commercialization units in assisting academic spinoffs, rather than adhering to conventional knowledge licensing models, warrants further exploration. The crucial role of TTO support for digital intrapreneurs is well-established (Meoli and Vismara, 2016); however, tailoring this assistance based on the scientific domain of the spinoff remains a compelling avenue (Heirman and Clarysse, 2004; Abreu and Grinevich, 2013).

Data availability

The authors do not have permission to share data.

Appendix. A

Table A1
Correlation matrix for spinoffs in natural sciences

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Grants	1																		
2.Fundraise	0.23*	1																	
3.Bank loans short term	0.20	−0.17*	1																
4.Bank loans long term	0.10	0.06	0.60*	1															
5.Profits	0.15	−0.12*	0.14	−0.07*	1														
6.Seed stage	−0.23*	−0.31*	−0.13	−0.26*	−0.11*	1													
7.Venture stage	−0.14	0.40*	−0.22	−0.07*	−0.19*	−0.47*	1												
8. Growth stage	0.07*	0.22*	0.19*	0.32*	0.07*	−0.18	−0.17	1											
9.Established stage	0.05*	−0.34*	0.07*	0.08*	0.05*	−0.2511*	−0.24*	0.09*	1										
10.Pinterest	−0.09	−0.06	−0.01	0.03	0.20	−0.13	−0.13	−0.05	0.13	1									
11.Instagram	−0.20	0.09	−0.02	0.13	−0.14	0.04	0.06	0.12	−0.08	0.06	1								
12.Twitter	0.25*	0.15*	0.21*	0.24*	0.15	0.23*	0.06	0.14	0.05*	0.11	0.28*	1							
13.LinkedIn	0.14	0.36*	0.17*	0.18	0.10	0.21	0.25*	0.09	−0.22*	0.07	0.19	0.32*	1						
14.Women CEO	0.04	0.03*	−0.15	−0.11	−0.08	0.06	−0.11	−0.08	0.16*	0.17	0.06	0.07	0.11	1					
15.Intangible assets	0.17*	0.15*	0.06*	0.09	−0.08	−0.05	0.12	0.05*	−0.06	−0.14	−0.05	0.16	0.01	−0.21*	1				
16.Working capital	0.08	0.21*	−0.42*	−0.24*	0.04*	−0.14	0.2124	0.08*	0.04*	−0.05	−0.04	0.06	0.02	0.01	0.02*	1			
17.Fundraising event	0.27*	0.61*	−0.07*	0.18	0.01	−0.47*	0.26*	0.43*	−0.10	0.06	0.06	0.25*	0.25*	0.06	0.17*	0.16	1		
18. Digitally driven	0.05*	0.11*	0.14*	0.16*	0.05	0.03	−0.10	0.13*	−0.10	0.10*	0.11	0.06	0.17	0.05	0.13*	0.14*	0.03	1	
19. University age	0.09*	0.17	0.13*	0.11*	0.08	0.06	−0.02	−0.09	0.03	−0.07*	−0.03	0.04	0.07	−0.04	−0.02	−0.01	−0.02	0.10	1
20.Firm size	0.37*	0.37*	0.26*	0.36*	0.17*	−0.55*	0.13	0.36*	0.07*	0.12	−0.04	0.34*	0.17	−0.15	0.22*	0.27*	0.51*	0.13	0.18*

Note: Significance level: ** 5% Source: Academic spin-offs Beauhurst (2022).

Table A2
Correlation matrix for spinoffs in other sciences

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Grants	1																		
2.Fundraise	0.09*	1																	
3.Bank loans short term	0.03*	0.05	1																
4.Bank loans long term	0.10*	0.03	0.57*	1															
5.Profits	0.02	0.01	0.21*	0.14*	1														
6.Seed stage	−0.21*	−0.28*	−0.21*	−0.22*	−0.13*	1													
7.Venture stage	0.13*	0.24*	0.04*	0.04*	−0.08	−0.54*	1												
8. Growth stage	0.15*	0.10*	0.07*	0.14*	0.07*	−0.21*	−0.21*	1											
9.Established stage	0.04	0.09*	0.13*	0.13*	0.10*	−0.16*	−0.16*	−0.06	1										
10.Pinterest	0.01	0.01	0.01	−0.01	−0.02	−0.04	−0.01	0.11*	−0.03	1									
11.Instagram	0.01	0.09*	0.02	0.03	−0.01	−0.03	0.04	0.10*	0.01	0.25*	1								
12.Twitter	0.11*	0.19*	0.01	0.03	0.04	−0.07	0.10*	0.08*	−0.01	0.12*	0.29*	1							
13.LinkedIn	0.11*	0.25*	0.01	0.06	0.05	−0.11*	0.13*	0.03	−0.03	0.06	0.14*	0.38*	1						
14.Women CEO	0.05	0.02	0.04	0.02	−0.03	0.02	0.06	−0.02	0.01	0.02	0.05	0.09*	0.06	1					
15.Intangible assets	0.05	0.24*	0.13*	0.16*	0.04	−0.17*	0.04	0.10*	0.04*	0.03	0.04	0.05*	0.06	−0.04	1				
16.Working capital	0.03	0.22*	−0.22*	−0.08*	0.12*	−0.13*	0.09*	0.08*	0.06*	0.01	0.01	0.09*	0.17*	−0.04	0.07*	1			
17.Fundraising event	0.11*	0.60*	0.07	0.10*	−0.06	−0.37*	0.24*	0.20*	−0.01	0.09*	0.16*	0.15*	0.19*	0.04	0.23*	0.12*	1		
18.Digitally driven	0.12*	0.07*	0.02	−0.01	−0.01	−0.11*	0.04*	0.05*	0.09*	−0.03	−0.08*	−0.12*	−0.02	0.01	0.03*	0.02	0.08*	1	
19. University age	−0.07*	0.22*	−0.05	−0.07	0.01	−0.05	0.09*	0.01	−0.01	0.01	0.02	−0.01	0.01	0.07	0.01*	0.13*	0.09*	0.05	1
20.Firm size	0.27*	0.34*	0.22*	0.32*	0.21*	−0.44*	0.06	0.28*	0.20*	0.07	0.14*	0.23*	0.26*	−0.04	0.28*	0.31*	0.40*	0.05	0.0554

Note: Significance level: ** 5% Source: Academic spin-offs Beauhurst (2022).

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