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United we stand? Organizational groups and spinoff mortality in the context of academic entrepreneurship

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A B S T R A C T

We study failures between 1993 and 2017 in the complete population of 1731 English and Scottish university spinoffs founded since 1977. We borrow and expand the concept of density dependence from organizational ecology to theorize that a spinoff's propensity to fail is affected by the number of spinoffs active not only in the aggregate population but also within its parent university's portfolio. We contribute to organizational theory, demonstrating the importance of organizational groups that form within larger populations on individual organizations' propensity to fail. We contribute to literature on academic entrepreneurship showing that, for most universities, spinoff portfolio growth can lower associated spinoffs' failure rates, but that such effects need to be juxtaposed to the aggregate population's finite capacity to support an expanding number of spinoffs.

Executive summary

Over the past three decades, spinoffs have emerged as the primary vehicle for universities' technology transfer activities. Extant literature has examined the antecedents to academic entrepreneurship, explored strategies to accelerate spinoff formation at the level of both individual universities and the broader ecosystem, and assessed spinoff performance in terms of growth potential and/or revenues. Relatively less attention has been paid to spinoff failures. We know relatively little about how dynamics in the broader industry intertwine with decisions at the level of the individual university to affect the interrelationships between spinoff entry, survival, and exit. This is problematic because spinoff survival constitutes an important metric of spinoff performance and a stated goal for most parent universities.

Our theory and findings from the complete population of university spinoffs in England and Scotland suggest that a focal spinoff's survival depends crucially on the number of spinoffs in its parent university's portfolio (*group size*) and the number of spinoffs active in the aggregate population (*population density*). Larger group size confers legitimacy to associated spinoffs and eases access to resources, thus lowering mortality rates. This effect olds only up to a threshold, however. Because university resources are finite, competition for resources ensues in groups that grow too large, and spinoff failure rates increase. Such group-level dynamics operate independently from but in parallel with similar dynamics in the aggregate industry, where a U-shaped relationship between population density and spinoff mortality occurs.

Our data show that most universities' spinoff groups are relatively small and could benefit from further growth. By contrast, the

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aggregate population is characterized by crowding. Dynamics at the group level are thus primarily commensalistic, while dynamics at the industry level are competitive, suggesting a sort of a *tragedy of commons*, where individual universities have an incentive to grow their portfolio further at the expense of the aggregate industry's viability.

Our theory and findings reconcile contradictory recommendations by scholars, practitioners and policy makers that have concurrently called for both accelerating and decelerating spinoff formation by demonstrating that such recommendations depend on whether the analysis is conducted from the perspective of an individual university or the entire ecosystem. What is more, in a world characterized by an increasing prevalence of organizational groups of diverse kinds, we show that dynamics occurring within groups might often be at odds with dynamics occurring in the aggregate population. Determining optimal group size, but also deciding on entry to or exit from an industry, requires that group- and industry-level dynamics be examined in conjunction before appropriate organizational and/or group strategies can be devised.

1. Introduction

Over the past three decades, university spinoffs have emerged as a key commercialization vehicle for academic research. Extant literature has examined the antecedents to academic entrepreneurship (Foo et al., 2016; Johnson et al., 2017), explored strategies to accelerate spinoff formation at the level of both individual universities (Di Gregorio and Shane, 2003; Müller, 2010; Wright and Phan, 2018) and the broader ecosystem (Wright et al., 2006; Clayton et al., 2018; Moritz et al., 2021), and assessed spinoff performance in terms of growth potential and/or revenues (Clarysse et al., 2005; Pitsakis and Giachetti, 2020; Wang and Liu, 2021).

Relatively less attention has been paid to spinoff failures and to how these relate to broader dynamics in the industry (Prokop, 2021; Ulrichsen, 2019; Walter et al., 2006). Specifically, our understanding of the interrelationships between spinoff entry, survival, and exit remains rather incomplete (Abootorabi et al., 2021). This is problematic because failures constitute an important metric of spinoff performance (Ulrichsen, 2019: p. 4), and a better understanding of their dynamics holds significant implications for theory and practice.

Existing theoretical models of industry evolution (Carroll and Hannan, 1989; Hannan and Freeman, 1989; Klepper, 1997, 2002) are ill-equipped to fully capture the particularities that characterize the university spinoff industry. Spinoffs operate within a larger spinoff population that can be defined at the level of the broader ecosystem or country, and they compete against each other for attention, talent, and other resources. At the same time, spinoffs are formed and hosted by individual universities, benefiting from symbiotic relationships that develop within a university's spinoff portfolio, but also competing for finite university-specific resources. Theoretical models of industry evolution focus on dynamics that occur at the level of the aggregate population and on their effects on individual organizations, but generally do not account for the effects of interorganizational groupings that form within such populations. Recourse to literature on inter-organizational alliances (Khanna and Rivkin, 2006; Ahuja et al., 2009) or groups that form around a shared locale, a common organizational parent or otherwise shared interests (Lazerson, 1995; Khanna and Rivkin, 2001; Ingram and Yue, 2008) offers some relevant insights. However, this line of literature pays little attention to dynamics that unfold at the level of the aggregate population within which groups form and operate.

Moreover, inferences from research on non-academic startups and their ecosystems are not necessarily directly applicable to spinoffs. Spinoffs are characterized by significant differences in origins, goals, and institutional logics that set them apart as an organizational form clearly distinct from non-academic startups (Fini and Lacetera, 2010; Libaers et al., 2006; see also Rao and Singh, 1999). In comparison to the latter, spinoffs draw on different resource pools (Magomedova et al., 2023; Wright et al., 2006), have significantly lower mortality rates (Croce et al., 2014), and operate in clearly defined, university-specific clusters (Prokop, 2021) that affect their evolution and survival.

Contrasting in-group dynamics to dynamics that occur in the aggregate population is necessary if we are to fully understand the advantages such groups offer to member organizations and the effects they have on the failure rates of organizations in general and spinoffs in particular. In this article, we do so by studying failure rates in the entire population of university spinoffs created in England and Scotland since the inception of the industry. Taking the individual spinoff as our unit of analysis, we aim to understand how a focal spinoff's propensity to fail is affected by the total number of spinoffs active in the aggregate spinoff population and by the number of spinoffs in its parent university's portfolio, respectively.

We borrow from organizational ecology its two principal mechanisms, *legitimacy* and *competition*, that are driven by *population density*, that is, the number of existing organizations of the same organizational form (Carroll and Hannan, 1989; Dobrev and Gotsopoulos, 2010; Hannan et al., 1995). Legitimacy, the degree to which an organizational form is taken for granted, increases at a decreasing rate along with density and lowers organizations' mortality rates. By contrast, competition for resources increases at an increasing rate with density and has a positive effect on mortality rates (Hannan and Freeman, 1977, 1989). When added together, these dynamics create the typical inverse U-shaped pattern of density observed in most industries (Hannan and Freeman, 1989; see also Chang and Park, 2005; Haans et al., 2016).

While drawing on a well-established theory, we contribute to organizational theory by introducing a novel and theoretically and empirically salient level of analysis, that of *organizational groups* that form and operate within a larger population. Ecological studies have focused on dynamics at the level of aggregate populations; we reproduce and confirm such dynamics in our research context but expand our focus to mezzo-level dynamics that occur in discrete organizational groups that operate *within* larger populations (see Baum et al., 2003). As we argue, such groups have legitimizing and competitive effects on their members over and beyond effects that operate at the population level. In populations where such groups are prevalent, density dependence and its effects on organizational mortality in the aggregate population cannot be fully unpacked without taking into account the implications that group membership has for organizations' access to resources. As we demonstrate in the context of university spinoffs, initial increases in a group's size (*i.e.*, the number of organizations that belong to a focal group) lower group members' mortality rates. This effect holds up to a threshold, after which further increases in group size increase members' mortality rates.

Our theory and findings also contribute to literature on university technology transfer. Spinoff survival constitutes an important goal for universities (Magomedova et al., 2023; Wright et al., 2006). In comparison to investors like venture capitalists that focus on their portfolio's aggregate return on investment (Jovanovic and Szentes, 2007), universities adhere to a dual institutional logic in their technology transfer operations, seeking to balance market logic and academic logic (Fini and Lacetera, 2010). Universities thus place greater emphasis on individual spinoffs' promise to commercialize early-stage technology, have a positive social impact, and be economically viable (Wright et al., 2006). However, universities and their technology transfer offices (TTOs) also face constraints in terms of the available capital, talent, and know-how that they can allocate among spinoffs in their portfolio (Rothaermel et al., 2007). A growing spinoff portfolio can bring benefits such as higher legitimacy (*e.g.*, see Sine et al., 2003) or learning-by-doing (Hsu and Kuhn, 2023), yet universities must balance the benefits of a larger portfolio against the needs of individual, resource-hungry spinoffs (Prokop, 2021).

At the same time, the broader spinoff ecosystem also has a finite carrying capacity (Abootorabi et al., 2021) that limits the number of spinoffs it can sustain and affects spinoff failure rates. As we demonstrate, most universities can benefit from growing their spinoff portfolio further as, up to a threshold, doing so allows them to reap size-related benefits that lower their spinoffs' propensity to fail. However, spinoff mortality is also affected by the strategies of other universities which, taken together, might lead to the creation of too many spinoffs and deplete the aggregate industry's carrying capacity.

Relatedly, fully understanding the dynamics and implications of spinoff failure requires that we study such dynamics in a complete and representative spinoff population, over an adequately long time period (Perkman et al., 2013). Prior studies in the field have been criticized for often studying "only the exemplary cases, […] [thus] limiting the understanding of a broader set of outcomes" (Prokop, 2021: p.1), and for choosing "samples [that] are often from one or a limited number of universities" (Mathisen and Rasmussen, 2019: 1900) and therefore lack representativeness. The resulting survivor bias (Mathisen and Rasmussen, 2019) can lead to faulty theoretical claims and strategy recommendations. Some impactful research has sought to remedy such shortcomings (*e.g.*, Abootorabi et al., 2021; Clayman and Holbrook, 2003; Nerkar and Shane, 2003; Prokop et al., 2019; Shane and Stuart, 2002); our article aims to further contribute to this literature, responding to the call of Abootorabi et al. (2021), who note that more work is required in this field to expand our understanding of the dynamics of competition and failure in the spinoff ecosystem, assess its overall "health, and potentially surface useful and actionable policy recommendations" (Abootorabi et al., 2021: p. 19).

2. Academic entrepreneurship & university spinoffs

While universities, especially in the United States (US), have a long history of relations with industry, direct involvement in commercialization efforts is a fairly recent phenomenon (Colyvas and Powell, 2006; Nelson and Rosenberg, 1994). Historically, academic institutions had focused on basic research, whereas technologies with more direct commercial applications were developed by private enterprises (Fini and Lacetera, 2010). Instances of academic entrepreneurship were rare and idiosyncratic, and any attempts by academics to patent their inventions or start their own companies were generally considered "anathema" (Colyvas and Jonsson, 2011: p. 28). Commercialization of university research was actively resisted because it violated long-held norms about the role of universities and the public character of the research they produced (Colyvas and Powell, 2006), suggesting a move away from an *academic* logic toward a *market* logic (Fini and Lacetera, 2010; Sauermann and Stephan, 2013; Llopis et al., 2021).

Attitudes toward commercialization of science began to shift slowly in the late 1970s. In the United Kingdom (UK), the 1977 *Patents Act* gave employee inventors the right to share financial benefits from research with their employer. In the US, the Bayh-Dole Act in 1980 allowed universities to retain intellectual property rights to inventions resulting from government-funded research (Colyvas and Powell, 2006). The two acts had similar goals in their respective countries, enticing academic researchers to patent their inventions and claim royalties and commercial benefits from intellectual property owned by universities (Rafferty, 2008).

While endorsement by the state offered political legitimacy (Aldrich and Fiol, 1994; Suchman, 1995) and encouraged technology transfer as the two countries aimed at enhancing competitiveness (Mowery et al., 2004), other stakeholders' perceptions were slow to change. Technology transfer was still conducted in an unsystematic, case-by-case fashion, with just over 20 university TTOs operating in the US in the 1980s (Mowery et al., 2004). Within universities, opposition came from faculty that believed that technology transfer threatened the Mertonian norms of science and could cause the envy of faculty that did not partake in the associated financial benefits (Argyres and Liebeskind, 1998; Bok, 1982; Stuart and Ding, 2006). Outside universities, criticism came from governments, professional societies, the media, social commentators and private investors. For instance, an early attempt by Harvard University to take equity in a spinoff created by one of its faculty members attracted such negative press that the idea had to be abandoned (Argyres and Liebeskind, 1998). The 1984 *Nelkin Report* to the American Association for the Advancement of Science considered technology transfer controversial at best and highlighted issues such as the proprietary secrecy *versus* open communication in science (Nelkin, 1984). For their part, private investors were reluctant to invest in university spinoffs "because the institutional and organizational arrangements were not deemed to be economically promising" (Fini and Lacetera, 2010: p. 6).

The rise of biotechnology and new science-based industries played a key role in the gradual institutionalization of academic technology transfer, as it upset the social order in science. Institutional entrepreneurs within universities reorganized biotechnology departments and used the practical relevance of this scientific field to establish the 'meaning' of commercialization (Colyvas, 2007). Universities then capitalized on emerging opportunities and codified rationales and practices. External stakeholders also acted as institution builders, highlighting the potential of science to increase industrial competitiveness (The Economist, 2002; Jong, 2008). By 1994, technology transfer had become broadly institutionalized in the US (Colyvas, 2007) and an integral part of universities' accepted activities (Argyres and Liebeskind, 1998). TTOs were sprouting up on campuses across the country, and technology transfer activities had become a signal of legitimacy (Powell and Owen-Smith, 1998).

In the UK, the development of technology transfer practices and their legitimation occurred at a relatively slower pace. Material change in attitudes only began after 1993 with the publication of a government White Paper which designated universities as key to the realization of the UK's potential for research impact (HM Treasury, 1993). Universities responded by taking a more structured approach to spinoff creation and the first Technology Transfer Offices were formed. TTOs diffused quickly among English and Scottish universities and, as our data show, by 2005, 88 out of 113 universities had established TTOs. Other European countries followed (Rossi and Geuna, 2011), striving to emulate technology transfer practices from the US and the UK and to diversify their funding sources (Powell et al., 2007). Notable spinoff ecosystems arose in, among others, Norway (Abootorabi et al., 2021), Italy (Fini et al., 2011), Spain (Gonzalez-Pernia et al., 2013), Ireland (O'Kane et al., 2015), and Sweden (Bourelos et al., 2012).

In the UK, as elsewhere in Europe, technology transfer took primarily the form of spinoffs rather than that of licensing which was dominant in the US (Damsgaard and Thursby, 2013; Prokop, 2021). Spinoffs are firms created by universities to commercially exploit the knowledge, technologies or research results that they develop and in which universities maintain an ownership stake (Lockett and Wright, 2005). Compared to licensing, spinoffs constitute a relatively newer form of technology transfer (Wood, 2009), are considered riskier, and are more demanding in terms of university resources (Prokop, 2021).

Spinoffs were initially more controversial than licensing. Universities' direct involvement in profit-making enterprises was seen as a dangerous deflection away from the academic logic and toward big business (Argyres and Liebeskind, 1998; Bok, 2003). Early spinoffs were also considered economically inefficient, as academic entrepreneurs generally lacked ties to the industry (Nicolaou and Birley, 2003), and the ability of universities to effectively manage the commercialization of their scientific output was questionable (O'Kane et al., 2015; Huyghe et al., 2016). However, by 2000, most English and Scottish universities had formed spinoffs and the spinoff population peaked at 1174 operating firms in 2007. Some universities were managing sizeable portfolios, *e.g.*, Cambridge University controlled a maximum of 79 spinoffs in 2004 (see Appendix Table A1).

3. Theory & hypotheses

3.1. Spinoffs as a new organizational form

New organizational forms emerge in response to changes in the social, economic, or technological environment (Hannan and Freeman, 1977; Ruef, 2000). While emergent forms often emulate traits of preexisting forms, what delineates a new organizational form as distinct is that its members share a "common fate with respect to environmental variation" (Hannan and Freeman, 1977: p. 934) and are bounded not only or primarily by product similarity, but also by geography, political boundaries, and a distinct "normative order – the ways of organizing that are defined as right and proper by both members and relevant sectors of the environment" (Hannan and Freeman, 1977: p. 935).

Organizational theorists (*e.g.*, Low and Abrahamson, 1997) explicitly distinguish the concept of the organizational form from economists' definition of an industry as "a group of firms producing products that are close substitutes for each other" (Porter, 1980). Romanelli (1991: p. 81) suggests that the "concept of the organizational form refers to those characteristics of an organization that identify it as a distinct entity and, at the same time, classify it as a member of a group of similar organizations." Rao (1998: p. 912) elaborates that "new organizational forms are new embodiments of goals, authority, technology, and client markets", where the definition of what is sufficiently new and distinct depends on relevant stakeholders' perceptions (Hsu and Hannan, 2005; Negro et al., 2010).

What emerges from organizational theorists' conceptualization of the organizational form is that (1) similarity in end-product is not *ipso facto* necessary nor sufficient a condition for two organizations to be classified under the same form; and (2) the definition and boundaries of an organizational form are elusive, rely on relevant stakeholders' often seemingly arbitrary classificatory schemata, and, in the context of research, necessarily depend on the researcher's objectives (Hannan and Freeman, 1977; Hannan et al., 2007; Rao and Singh, 1999). The emergent organizational form of microbreweries, for instance, differed from the preexisting form of mass brewers primarily in terms of organizational size and the perceived 'authenticity' of its recipes, yet relevant stakeholders considered the two forms as radically different and fundamentally incompatible (Carroll and Swaminathan, 2000).

Organizations of a new form often engage in considerable cultural entrepreneurship as they attempt to craft an oppositional identity that highlights differences from and suppresses similarities to preexisting forms (Lounsbury and Glynn, 2001; Weber et al., 2008). In conjunction with strict adherence to emergent categorical schemata that clearly differentiate member organizations from outsiders, such actions stress the distinctiveness of the new organizational form (Hsu and Hannan, 2005) and lead relevant stakeholders to assign a unique label (*i.e.*, name) to it. In turn, the presence and consistent use of such a linguistic label further reinforces and reifies the perception of an organizational form as distinct from others (Hsu and Hannan, 2005; Zerubavel, 1997; Kennedy, 2008). Such perceptions can become further codified in law, which may define clear prerequisites for an organization's membership to an organizational form and clear boundaries between different forms (Ruef, 2000; Weber et al., 2008).

Two organizations are thus of different form when they feed on distinct – albeit potentially overlapping – resource pools, derive their legitimacy from different institutional logics, are distinguished in law, labeled differently, and/or otherwise perceived as distinct by relevant stakeholders (Hannan and Freeman, 1977; Hannan et al., 2007; Ruef, 2000; Wry et al., 2011). Even seemingly arbitrary differences can warrant the classification of two organizations under different forms, especially when such differences signal closure of distinct social networks and/or institutional processes that erect boundaries between organizational forms. The persistence of such differences can bear real social consequences, as initially nominal differences become substantive over time (Hannan and Freeman, 1989; Rao and Singh, 1999). Prior literature has thus treated as separate organizational forms breweries and microbreweries in the US (Carroll and Swaminathan, 2000); producers of 'regular' meat and grass-fed meat in the US (Weber et al., 2008); banks and financial cooperatives in Singapore (Dobrev et al., 2006); federal hospitals, non-federal general hospitals, non-federal psychiatric hospitals, and non-federal special hospitals in the US (Ruef, 2000); kosher wine producers and non-kosher wine producers in Israel (Simons and Roberts, 2008); internal corporate joint ventures, traditional joint ventures, and internal corporate ventures in the US (Zajac et al., 1991); luxury hotels and budget hotels (Rao and Singh, 1999), *etc*.

In this vein, despite the similarities that university spinoffs bear to non-academic startups, their significantly different goals, sources of authority, and bases of legitimacy delineate them as a clearly distinct organizational form (Fryges and Wright, 2014; Rao et al., 2000). While perhaps not as economically efficient as profit-seeking startups, spinoffs perform functions that are fundamentally different (Fini and Lacetera, 2010). Spinoffs often commercialize particularly disruptive new technologies that are characterized by pronounced uncertainty and long development periods that make them unattractive to non-academic startups and investors (Knockaert et al., 2010; Magomedova et al., 2023). Spinoffs' claims to legitimacy lie in their promise to promote social well-being by speeding up the transfer of primary research to practical applications (Colyvas and Powell, 2006), and by enhancing competitiveness and economic growth (Powell et al., 2007). At the same time, universities seem to engage in technology transfer activities more to signal legitimacy than to profess commercial acumen (Powell and Owen-Smith, 1998); even when such activities produce profits, the latter are used to further support the role of non-profit universities as a socially valuable "resource and catalyst to economic innovation" (Powell et al., 2007: p. 125).

Challenges to spinoff legitimacy also differed from those that other startups might face. Spinoffs were criticized as deflections from the academic logic of universities, and as a threat to the ethos, "the central values [...] and ideals of academic science" (Bok, 1982: p. 142). Their illegitimacy lay not so much with their potential economic inefficiency as with the threat they posed to the dominant normative order (Stuart and Ding, 2006), and the perceived risk that they would spearhead universities' shift away from basic research toward more applied research (Balven et al., 2018; Rothaermel et al., 2007).

Given their different origins, spinoffs demonstrate unique "genetic characteristics" (Colombo and Piva, 2012; Fini and Lacetera, 2010) in terms of the composition of the founding team, growth patterns and adopted strategies. Moreover, the emergence of spinoffs within universities; the legally mandated ownership stake of the parent university (Lockett and Wright, 2005); and spinoffs' access to and competition for university resources suggest that they draw upon different resource pools and follow different evolutionary paths than non-academic startups (Fryges and Wright, 2014; Prokop, 2021).

The presence of a unique linguistic label, as well as legal acts and government initiatives that pertain to university spinoffs (*e.g.*, US Public Law 98–620; 1993 White Paper in the UK) further reinforce the notion of spinoffs as a separate organizational form. As a result, a considerable body of extant academic research focuses specifically on spinoffs, while Libaers et al. (2006) explicitly distinguish spinoffs (*academic spinouts*) from other organizational forms such as corporate spinouts, new technology-based firms, and multinational companies in their study of the UK nanotechnology field.

3.2. Spinoff failure dynamics in the aggregate population

Organizational ecology studies dynamics in aggregate populations. As ecologists theorize, legitimacy and competition constitute the two main mechanisms that determine organizational failure rates at the level of an aggregate population (Hannan and Freeman, 1989). Both mechanisms are driven by *population density*, that is, the number of existing organizations of the same organizational form (Carroll and Hannan, 1989; Dobrev and Gotsopoulos, 2010; Hannan et al., 1995). When an organizational form is still new and density is low, lack of legitimacy can hamper access to resources. As density increases, the increasing prevalence of the organizational form attests to its efficiency and reinforces stakeholders' perceptions of it as a useful and appropriate means to an important end (Carroll and Swaminathan, 2000; Dobrev et al., 2006). Increasing density has thus a positive effect on an organizational form's legitimacy, easing access to resources and lowering failure rates in the population (Dobrev and Gotsopoulos, 2010). However, legitimacy increases at a decreasing rate with density and eventually plateaus. As the organizational form becomes taken for granted (Berger and Luckman, 1967), further increases in density have only marginal effects on its legitimacy (Hannan and Freeman, 1989).

Like legitimacy, competition also increases with population density. As more and more organizations lay claims over a relatively fixed pool of resources, competition intensifies. Contrary to legitimacy, however, competition increases at increasing rates with density. Initial increases in density have only small effects on competition, as the resource space remains unsaturated. After a threshold is reached, however, competition intensifies rapidly. As the industry's carrying capacity is exhausted, it becomes increasingly difficult for organizations to secure resources and failure rates accelerate (Carroll and Hannan, 1989; Hannan et al., 1998).

The contrasting dynamics of legitimacy and competition imply a non-monotonic effect of density on organizational survival. Initial increases in density improve survival chances as they increase the organizational form's legitimacy. As density further increases, competition for resources intensifies. Organizations' survival chances deteriorate, and failures accelerate. When added together, these dynamics create the well-documented, inverse U-shaped pattern of density in emerging industries (Carroll and Hannan, 1989; Chang and Park, 2005; Haans et al., 2016; Hannan and Freeman, 1989).

In the context of spinoffs, we analyzed in preceding sections the legitimacy challenges the new organizational form faced. Early spinoffs had to prove their usefulness and appropriateness in a generally hostile environment. Increasing density and good performances gradually changed the views of relevant stakeholders (*e.g.*, academic researchers, regulators, media, *etc.*), conferring legitimacy and leading to the institutionalization of spinoffs as appropriate vehicles for technology transfer (Colyvas, 2007; Jong, 2008).

At the same time, increasing density gradually began exhausting available resources. In the UK, the initial government White Paper of 1993 urged universities to accelerate spinoff formation. Subsequent publications, such as the influential Lambert Report of Business-

University Collaboration (Lambert, 2003), reversed course to suggest that the industry was overcrowded. Similar views were expressed by a House of Commons report in 2013, which raised concerns “that driving an innovation agenda too aggressively through universities may have diminishing returns with regard to commercialization” (House of Commons, 2013: p. 40). Other authors have also noted how a rising number of spinoffs in a country may intensify competition for finite resources in the form of ecosystem support from incubation centers, government grants (Abootorabi et al., 2021), public or public-private collaborative financing schemes (Wright et al., 2006), professional services firms (Clayton et al., 2018), *etc*.

Seeking to better understand failure rates in the field of university spinoffs, we expect the basic premises of ecological theory to apply. We seek to replicate the U-shaped relationship between density and organizational failure in the following baseline hypotheses:

Hypothesis 1a. Initial increases in spinoff population density have a negative effect on spinoff failure rates.

Hypothesis 1b. Increases in spinoff population density beyond a threshold have a positive effect on spinoff failure rates.

3.3. Spinoff failure dynamics within organizational groups

While the effects of density have been thoroughly studied at the population level, less attention has been paid to the dynamics of *organizational groups* that often form within larger populations and to how such groups affect members' survival chances. Organizational groups consist of interlinked organizations that share meaningful and consequential ties to other group members more frequently than to other organizations in the broader population (Borgatti et al., 1990). Such ties might result from being subsidiaries or progeny of the same parent organization (Saxenian, 1994); from shared family ties (Ingram and Lifschitz, 2006); from shared links to a common locale that infuses a sense of community, possibly in juxtaposition to out-of-group competition (Lazerson, 1995; Ingram and Yue, 2008; see also Prokop, 2021); or from an otherwise common identity and/or goals (Das and Teng, 2002). Groups of various kinds are increasingly prevalent in economic life (Gómez et al., 2017), as organizations strive to gain a competitive advantage and reduce risks by capitalizing on complementarities. The resulting horizontal ties among organizations in the same population (Rowley et al., 2004) complicate and blur competitive dynamics. When such groups are present, macro-level studies of industry evolution need to account for the mezzo-level dynamics that unfold at the group level in order to accurately decipher the dynamics of organizational failure.

Two conditions must be fulfilled for a set of organizations to be considered a group within a larger population. First, linkages among group members must be adequately meaningful for external stakeholders to perceive the group as a discrete entity. When a group acquires an identity of its own, membership to the group acts as a signal that allows stakeholders to make inferences about a focal organization's underlying qualities (Davis, 2016; Stuart, 2000). Membership to a sizeable and visible group helps especially young organizations to reduce information asymmetries, as association with a reputable group and already successful and established organizations offers instant credibility and legitimacy (Grandi and Grimaldi, 2003; Kennedy, 2008; Prokop, 2021). For example, belonging to a group whose members are known for superior performance (*e.g.*, Cambridge University spinoffs) creates expectations of excellence for new group members as well (O'Kane et al., 2015; Stuart et al., 2007). Yet, group size can be important for more seasoned members as well. Size is generally associated with success and prestige (Haveman, 1993) and, in the context of spinoffs, group size has been associated with higher legitimacy and media attention (Pitsakis et al., 2015).

Second, group members need to rely on some group-specific common pool of resources that induces commensalism and a sense of common fate (Uzzi, 1997). When the structure of the group and its ability to aid members to compete against outgroup organizations become valuable resources, group members become invested in group membership and performance, and might aid other members in need (Agarwal et al., 2010; Barnett, 2006; Zeng and Chen, 2003). Ingram and Inman (1996), for instance, show how hotels on the Canadian side of Niagara Falls would devise strategies to compete as a group against hotels on the American side. And Ingram and Roberts (2000) describe how Sydney hoteliers would forego a profitable opportunity in order to help rather than antagonize a fellow group-member in need. In the context of academic entrepreneurship, peer networks, group norms, and institutional support that operate primarily at the level of a university and its spinoff group have been found to influence both the formation and the performance of associated spinoffs (Colyvas and Jonsson, 2011; Foo et al., 2016; Johnson et al., 2017; Prokop, 2021; Vedula and Kim, 2019).

It is important to note that the formation of commensalistic organizational groups does not require goal congruence or the voluntary and/or altruistic cooperation of group members (Portes and Sensenbrenner, 1993). Rather, commensalistic dynamics can occur among self-interested actors if group structure facilitates penalties (*e.g.*, ostracism) against non-cooperating members (Gulati et al., 2012) or offers lucrative rewards (*e.g.*, status) for those that make valuable contributions to the group's well-being (Willer, 2009). Equally well, such dynamics can result from the actions of some central actor (*e.g.*, parent organization or university TTO) that controls group resources and determines how they are allocated among members (Khanna and Rivkin, 2006). To the extent that such a central actor aims to enhance the performance of all group members and allocates or withholds group resources accordingly, commensalistic structures can emerge even if individual group members pursue fully self-interested goals.

Sizeable groups confer an array of advantages to their members in addition to legitimacy benefits. Organizations in large groups enjoy group-level economies of scale and better access to resources (Gnyawali and Park, 2011); accumulate and share experience faster (Ahuja et al., 2009); utilize group-level slack resources to better withstand environmental shocks (Ahuja, 2000; Ingram and Roberts, 2000; Uzzi, 1996); and are better able to wage competitive attacks against other groups or organizations, or defend against attacks from outsiders (Gnyawali and Madhavan, 2001; Silverman and Baum, 2002). In the context of academic entrepreneurship, TTOs that manage larger spinoff portfolios are better able to attract expertise in the form of patent agents, lawyers, accountants, and other types of specialized resources, and have better access to external financial resources (Pitsakis et al., 2015). As a group grows in size, such commensalistic effects lower mortality rates among member organizations relative to outgroup organizations. Therefore, at the organizational group level, we hypothesize that:

Hypothesis 2a. Initial increases in a spinoff group's size have a negative effect on group members' failure rates.

At the same time, because group resources are finite, organizational groups need to balance the benefits of group growth against associated costs. An expanding group might impose excessive coordination costs on members (Agarwal et al., 2010; Ahuja, 2000) and/or deplete a group-specific pool of resources (Portes and Sensenbrenner, 1993; Uzzi, 1996). When group members rely more heavily on group-specific resources than on resources in the broader environment, exhausting the group's carrying capacity can render crucial resources scarce and jeopardize organizational survival.

In the context of spinoffs, reliance on group-specific resources is generally high. Because academic entrepreneurs tend to lack skills necessary for launching and growing a company (Goethner et al., 2012), spinoffs rely heavily on their parent university and its TTO for resources such as patenting support (Hsu and Kuhn, 2023); operational, strategic, and legal advice (Gubitta et al., 2016); professional and investor networks (Clarysse et al., 2007; Vedula and Kim, 2019); and direct financing through university-owned or affiliated venture capital (Magomedova et al., 2023) and public-private funds (Wright et al., 2006). Most TTOs, however, face significant constraints in human and managerial resources (Rothaermel et al., 2007), often lack important competencies (Gonzalez-Pernia et al., 2013; Siegel et al., 2003), and have limited capital that they can invest (Magomedova et al., 2023). While such resources are not fixed, they are finite and not easy to expand given the rigidities and conflicting institutional logics that determine resource allocation within universities (Argyres and Liebeskind, 1998; Prokop et al., 2019). As a spinoff portfolio grows larger, the resources and the support that the parent university can allocate for each of the spinoffs that compete for its attention decrease. When the negative effects of intra-group competition overcome the positive effects of commensalism, failure rates among group members increase:

Hypothesis 2b. Increases in spinoff group size beyond a threshold have a positive effect on group members' failure rates.

4. Data and methods

4.1. Data

We test our hypotheses on the complete population of spinoffs founded by English and Scottish universities. We collected data on all 113 universities in England and Scotland and on the 1731 spinoff firms they created since 1977, when the UK Patents Act made spinoffs possible, and until 2017. We collected our data through direct contact with universities and their TTOs or other relevant offices. We defined spinoffs as companies that involve: “(1) the transfer of a core technology from an academic institution into a new company and (2) [where] the founding member(s) may include the inventor academic(s) who may or may not be currently affiliated with the academic institution” (Nicolaou and Birley, 2003: 333). We adopted this strict definition of university spinoffs to ensure that our database only includes established firms with a true and verifiable technology-transfer link with the university.

Each university supplied us with a historical list of all their spinoff firms. Subsequently, we crosschecked our data with a number of spinoff-related reports by Spinouts UK, the Library House, Ernst and Young, the British Venture Capital Association, the Chemical Leadership Council, the Gatsby Charitable Foundation, the Department of Trade and Industry, and the PraxisAuril association. If any of the above sources included a firm missing from our own directly sourced database, we investigated the case. As a principle, we checked each firm's website and secondary sources on the web (*e.g.*, press releases) to confirm its demographic data (*e.g.*, time of founding) and verify the technology transfer link with the university (*i.e.*, its spinoff status). This methodology and the extensive cross-referencing of sources make us confident that no spinoffs were left unidentified, and that our dataset includes all spinoffs ever formed in England and Scotland until 2017. It also alleviates any concerns of left truncation, that is, the possibility that an organization enters the observation set much later than its time of founding (Yang and Aldrich, 2012). Left truncation in conjunction with the possibility that firms that fail early are never recorded in industry datasets are thorny issues that can bias statistical inference and lead to an overestimation of organizations' survival chances (Lambkin, 1988; Yang and Aldrich, 2012). A complete dataset of organizations that have entered and exited an industry since its inception is thus necessary in order to draw meaningful conclusions about the determinants of organizational failure (Hannan and Freeman, 1989).

Although our spinoff data go back to 1977, we restrict our empirical analysis to the 1993–2017 period for two reasons. First, even though spinning off was legally possible before 1993, scholars generally identify that year as the actual starting point of the UK spinoff industry (Pitsakis et al., 2015; Pitsakis and Giachetti, 2020). The publication in 1993 of a consequential government White Paper and subsequent government guidance encouraged the creation of TTOs, set out rules for universities' participation in their spinoffs' capital, and established a comprehensive framework that governed the creation of spinoffs. The push to encourage academic entrepreneurship coincided with other similar initiatives in the UK that aimed to promote entrepreneurship and increase the competitiveness of the economy (*e.g.*, the *Enterprise Investment Scheme* of 1994). As no clear-cut rules existed during 1977–1992, spinoffs in that period were relatively rare and idiosyncratic. Most importantly, their entry had not legitimized the spinoff industry, which most stakeholders continued to be skeptical about.

Second, most variables are missing for the pre-1993 period, making the analysis for the earlier years impossible. These reasons force us to treat spinoffs formed before 1993 as lateral (*de alio*) entrants to the spinoff industry. We consider this appropriate given the material differences between spinoffs created before and after 1993; we do, however, recognize potential issues of left-censoring and discuss them in our findings section. Importantly, none of the spinoffs created during the 1977–1992 period failed before the beginning of our observation window. This offers a strong indication of their different nature and suggests that treating them as de alio entrants is appropriate. It also guarantees that our results are not driven by spinoffs that possibly entered and failed before the beginning of our observation period.

Finally, it needs to be noted that our initial intention was to analyze spinoff mortality in all four nations that make up the United Kingdom (*i.e.*, England, Scotland, Wales, and Northern Ireland). Spinoff ecosystems in all four nations emerged in parallel and could be considered part of a larger, country-level ecosystem. At the same time, higher education institutions are supervised by their respective national governments, which might enact somewhat different policies, while national governments are also in charge of collecting regional statistics. In what comes to Wales and Northern Ireland, limitations in data collection did not allow us to be confident that all spinoffs since 1977 could be identified. Moreover, relevant national statistics that we use in our models do not go back further than 1998 for those two nations. Given that complete data on all spinoffs since the inception of the industry are necessary in order to correctly assess the dynamics of spinoff mortality, we chose to restrict our analysis to England and Scotland, that is, the two nations UK for which complete data could be collected and verified.

4.2. Variables

Dependent variable: We use the instantaneous rate of exit from the industry as the dependent variable in our models. Spinoffs fail when they go bankrupt (liquidation) or otherwise stop their operations and enter receivership. Acquisitions by or mergers with other organizations were treated as censored on the right. Spinoffs alive at the end of our observation period were also censored on the right. All relevant events were captured from the Financial Analysis Made Easy (FAME) and Companies House databases.

Independent variables: Our main independent variables are those that measure population density and group size. *Population density* refers to the total number of operating spinoffs in the aggregate population in any focal year (Carroll and Hannan, 1989; Hannan and Freeman, 1989); *group size* measures the number of operating spinoffs in a focal university's portfolio in any focal year. As both variables are measured at the end of each year, we lagged them by one period before entering them in our models. Introducing a higher number of lags produced similar results. Given the hypothesized non-monotonic effect of both population density (H1a & H1b) and group size (H2a & H2b) on spinoff mortality, we also calculate their quadratic terms. In line with established theory, the linear terms capture the effects of increasing legitimacy at the population/group level respectively, while the quadratic terms capture the effects of competition (Carroll and Hannan, 1989; Hannan and Freeman, 1989). As an alternative specification of group size, we also use a number of dummies to define brackets of group density such as *group size* > *45*, *group size* > *65*, and *group size 45–65* (we discuss alternative size specifications in the results section). Categorical dummies have the advantage that they allow for exploring non-linearity without imposing a specific structure on the functional form of the effects on the dependent variable (Haans et al., 2016).

Finally, $\textit{failures}_{t\text{-}1}$ captures the effects of spinoff failures in the aggregate population in period t-1. Failures free up resources in the environment and might improve the survival chances of remaining spinoffs (Abootorabi et al., 2021). At the same time, failures might act as a signal of deteriorating industry conditions and can lead to contagious exits from the industry (Carroll and Delacroix, 1982; Greve, 1995). We also used $\textit{group failures}_{t\text{-}1}$ to explore potential effects of failures at the group level. Failures at the group level not only free up group resources but may also be indicative of a university's strategy. Decisions on spinoff portfolio size, and on how to assess and react to earlier failures are, to some extent, endogenous and perhaps driven by concerns other than simply minimizing spinoff mortality (Degroof and Roberts, 2004; Prokop, 2021). However, $\textit{group failures}_{t\text{-}1}$ were not significant in any of our models and are therefore not included in the models we report.

Control variables: We controlled for various factors that can influence spinoff failure at the individual spinoff, host university, and regional level. At the spinoff level, we control for *spinoff age*, measured as years since founding. Age influences a firm's ability to adapt to environmental change and can affect its propensity to fail (Hannan et al., 1998). We also control for each spinoff's industry, using dummies for *engineering* and *services* spinoffs, while using biotechnology spinoffs as the control group. Finally, *de alio* entry to the industry is captured using a dummy that takes the value of one for spinoffs founded between 1977 and 1992.

At the university level, we measure each university's status using its cumulative number of *Nobel laureates* over the years. As a demonstration of past quality, status creates expectations regarding contemporaneous performance and eases access to resources (Podolny, 1993; Pitsakis et al., 2015). As an alternative, we used university rankings from the Times Higher Education database to measure universities' reputation, but this variable failed to achieve significance in any of our models. We also control for the relative political power of university associations. Almost simultaneously with the emergence of the spinoff industry, four university associations – the Russell Group, the 1994 Group, the Million+, and the University Alliance – were established in 1994. The associations intended to lobby the government, parliament and private bodies for financial and other support, and have been forming common positions on, among others, the exploitation of intellectual property (Brankovic, 2018). We use a dummy to capture a university's membership to the *Russell Group*, which includes the most prestigious universities, and treat all other associations as a control group. Further, we control for *TTO experience*, measuring TTO age in years; for universities that do not have a TTO, we code age as equal to zero (a dummy variable for TTO existence was not significant). We also control for the *cumulative media* attention that a university's spinoff portfolio has attracted. Using the names of each university and each spinoff as keywords, a total of 8886 articles were found on *LexisNexis* and linked to spinoffs and their parent universities.

At the regional level, we measure *regional GDP* and *regional R&D* intensity *per capita*, using their natural logarithms. When economic development or R&D investments are high, entrepreneurial activity and technology transfer likely increase, while resource munificence can lower new ventures' failure rates. Alternatively, when GDP and R&D investments are low in a region, spinoff formation may function as stimulus for the regional economy, with the government supporting investments in research and knowledge transfer (Lockett and Wright, 2005). We collected data from the Office of National Statistics on per-capita GDP and R&D investments in each of the nine regions in England plus Scotland. We also control for regional *venture capital* availability using data from the British Venture Capital Association. Even though early-stage university spinoffs do not constitute the main target for VCs (Croce et al., 2014; Fini et al., 2017; Knockaert et al., 2010; Wright et al., 2006), the availability of VC money may relate to regional attitudes toward entrepreneurship, including universities' spinoff activities. Furthermore, we control for the number of regional *industry science parks* using data from the UK Science Parks Association. Science parks constitute locally available support structures for spinoffs and might lower failure rates among them (but see Prokop, 2021). Finally, to assess any national differences that might affect spinoff mortality differently in England and Scotland, we employed a dummy variable for *Scotland*. The variable was not significant in any of our models and was not included in reported models.

It is worth noting that we do not control directly for the prevalence and performance of non-academic startups, for which complete data for such a long time period cannot be gathered. Moreover, the interrelationship between non-academic startups and university spinoffs is rather unclear. On the one hand, spinoff creation may stimulate (or be stimulated by) non-academic entrepreneurial activity in a region, as a more vibrant entrepreneurial ecosystem emerges. On the other hand, spinoffs might compete against non-academic startups for talent, venture capital funding, spots at local science parks, or access to end-product markets. Because spinoffs generally emerge to commercialize radically innovative technology that is proprietary to their parent university (Fini and Lacetera, 2010); often rely on talent affiliated directly or indirectly with the university (Rothaermel et al., 2007); and often receive funding from university-owned or university-affiliated investment vehicles, and from specialized public-private partnerships like the University Challenge Fund in the UK (Magomedova et al., 2023; Wright et al., 2006), we expect the relationship between the two organizational forms to be primarily symbiotic. While we have no direct measures of non-academic startup activity, the above-mentioned regional-level control variables go a long way in capturing the salient aspects of non-academic startup activity that may bear influence on the survival chances of university spinoffs.

Finally, we include two dummies to capture period effects, *period 2000–2004* and *period 2008–2011*. The year 2000 is widely held to coincide with the maturation of the UK spinoff industry. Most universities had founded spinoffs, and spinoffs had become the dominant form of technology transfer. In that year, the government published a new White Paper that focused on promoting spinoff quality over quantity and established key performance indicators. English and Scottish higher education authorities introduced in 2000 their first special funds for spinoff creation targeted at universities (HEIF funds), focusing on the performance of universities' past spinoffs rather than on their numbers. The year 2000 also corresponds to the burst of the dotcom bubble and a resulting bearish sentiment among technology investors. These factors are suggestive of less favorable conditions for spinoff formation and possibly survival. On the other hand, 2008 represents the beginning of the global financial crisis that might have reduced resource availability and accelerated spinoff failures. The dynamics of population density, spinoff foundings, and spinoff failures since the inception of the industry can be seen in Fig. 1. The two figures that follow, show spinoff density at the group level for all universities (Fig. 2) and for a select group of universities most active in spinoff formation (Fig. 3) respectively, for the period we analyze (1993–2017).

4.3. Methods

Spinoff failure is modeled in an event history model, in which the propensity to fail functions as the dependent variable; each spinoff-year contributes one observation/spell. This approach uses data on the timing of exits to estimate the hazard rate of failure given a set of covariates (Blossfeld et al., 2007). It also requires specifying a functional form of time dependence. Because we are

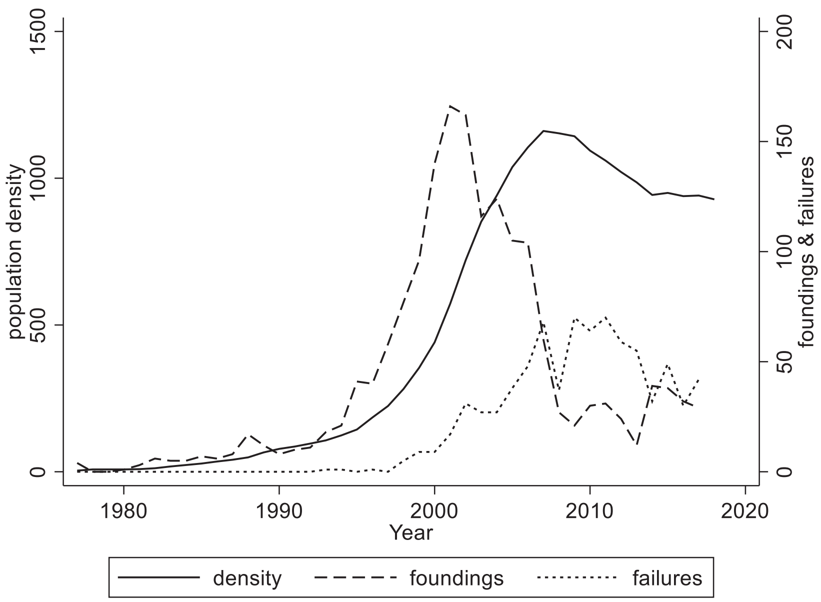

Fig. 1. Spinoff foundings, failures, and population density, 1977–2017.

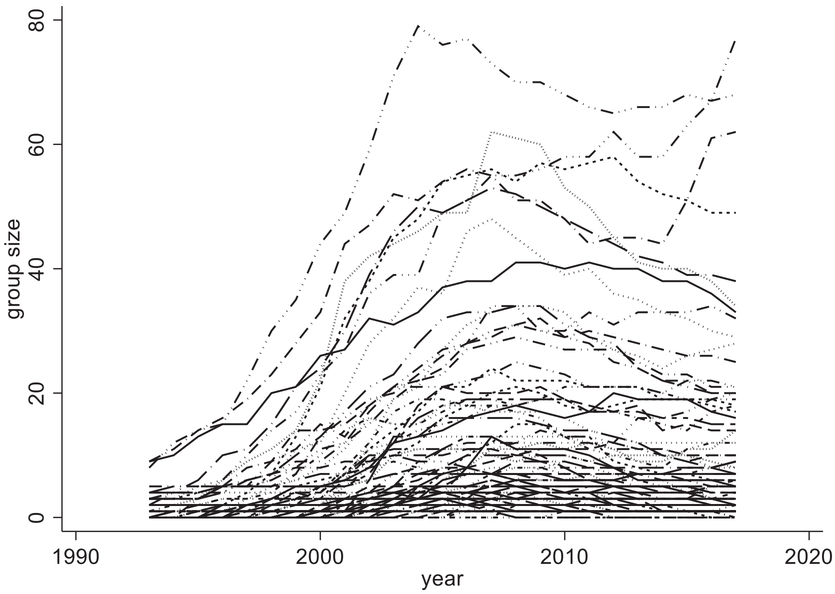

Fig. 2. Spinoff group size by university.

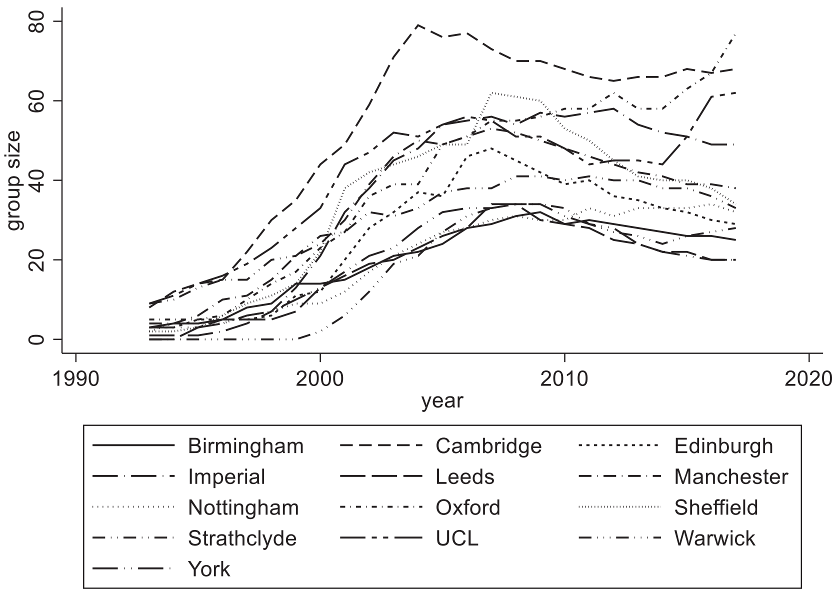

Fig. 3. Spinoff group size by university – select universities.

interested in how dynamics in the broader spinoff industry rather than firm age affect mortality, we use time since the beginning of our observation window in 1993. Since not all spinoffs enter the industry at the same time, we employ the option *enter*() in Stata 18 to specify a spinoff's founding year as the time that it enters the risk set. This specification allows each spinoff to contribute observations (spells) to the data only for the years that it is actually active rather than erroneously recording a spinoff as being at risk even before it is founded. Spinoffs founded before 1993 enter the risk set at the beginning of our observation window (*i.e.*, 1993). For such spinoffs, we have taken a number of steps to ensure that our data are complete, that we have not missed any failures occurring before 1993, and that left-censoring (Yang and Aldrich, 2012) does not bias our results.

Preliminary analyses showed that a parametric Gompertz model maximized model fit over other parametric or non-parametric

Table 1
Descriptive statistics and correlation coefficients for variables in the life-history spell file of university spinoffs in England and Scotland.

Variable		Min.	Max.	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Period 2000–2004	0	1	0.18	0.38																
2.	Period 2008–2011	0	1	0.17	0.38	−0.21															
3.	Regional GDP	9.15	10.81	9.98	0.32	−0.31	0.08														
4.	Regional R&D	4.82	8.49	7.01	0.80	−0.16	−0.02	0.35													
5.	Venture capital $\times 10^{-3}$	0.59	34.30	13.52	10.58	−0.19	−0.11	0.16	0.05												
6.	De alio	0	1	0.10	0.30	0.02	−0.04	−0.14	−0.10	−0.07											
7.	Spinoff age	0	40	7.66	6.26	−0.27	0.01	0.25	0.18	0.00	0.43										
8.	Engineering	0	1	0.50	0.50	−0.01	0.01	−0.09	0.00	0.00	0.04	−0.01									
9.	Services	0	1	0.12	0.32	−0.01	0.00	−0.08	−0.09	−0.01	0.01	0.04	−0.36								
10.	Industrial park	0	13	3.14	3.05	−0.11	−0.02	0.05	0.52	0.03	−0.03	0.15	0.00	−0.07							
11.	Nobel prizes	0	98	13.11	22.94	0.01	−0.02	0.08	0.51	−0.01	−0.02	0.07	0.00	−0.10	0.76						
12.	Russell Group	0	1	0.59	0.49	0.02	−0.03	0.09	0.14	0.00	−0.05	0.04	−0.06	−0.13	0.41	0.47					
13.	*cum.* media	0	2098	315.87	472.95	−0.21	0.05	0.41	0.39	0.07	−0.05	0.18	−0.06	−0.10	0.69	0.53	0.42				
14.	TTO experience	0	45	18.53	10.10	−0.25	0.03	0.17	0.21	0.05	−0.03	0.32	−0.03	−0.05	0.54	0.54	0.47	0.49			
15.	$\text{Failures}_{t\text{-}1}$	0	70	42.00	19.85	−0.59	0.42	0.47	0.20	0.30	−0.18	0.26	0.01	−0.01	0.17	−0.01	0.01	0.27	0.35		
16.	$\text{Pop. density}_{t\text{-}1}$	109	1174	896.13	292.37	−0.19	0.12	0.28	0.32	0.11	−0.05	0.17	−0.01	−0.09	0.67	0.70	0.59	0.68	0.73	0.34	
17.	$\text{Group size}_{t\text{-}1}$	0	79	26.35	20.34	−0.44	0.37	0.33	0.15	0.01	−0.14	0.19	0.01	−0.01	0.12	−0.02	−0.01	0.21	0.26	0.72	0.22
18.	Group size >45	0	1	0.24	0.43	−0.12	0.09	0.35	0.32	0.10	−0.06	0.07	−0.03	−0.10	0.52	0.64	0.46	0.62	0.48	0.22	0.82
19.	Group size 45–65	0	1	0.18	0.38	−0.08	0.10	0.37	0.09	0.08	−0.05	0.01	−0.05	−0.09	0.13	0.21	0.37	0.39	0.24	0.18	0.56
20.	Group size >65	0	1	0.06	0.24	−0.08	−0.01	0.03	0.42	0.05	−0.01	0.10	0.02	−0.04	0.69	0.78	0.22	0.47	0.46	0.10	0.56

Variable		17	18	19
18.	Group size 45–65	0.13		
19.	Group size >65	0.12	0.82	
20.	Group size >65	0.04	0.46	−0.13

Table 2
Maximum Likelihood estimates of failure rates among university spinoffs in England and Scotland, 1993–2017 – orthogonalized independent variables, Gompertz parametric models.

	Model 2.1		Model 2.2		Model 2.3		Model 2.4		Model 2.5		Model 2.6	
Constant	−220.574**	(-7.54)	−239.523**	(-6.79)	−245.291**	(-7.15)	−278.287**	(-7.21)	−284.129**	(-7.86)	−293.424**	(-8.25)
Period 2000–2004	0.801†	(1.89)	1.685**	(3.73)	1.758**	(3.89)	1.784**	(3.95)	1.737**	(3.89)	1.719**	(3.76)
Period 2008–2011	0.052	(0.66)	−0.331*	(-2.25)	−0.395**	(-2.64)	−0.411**	(-2.79)	−0.406**	(-2.74)	−0.360*	(-2.23)
Regional GDP	−0.532*	(-2.34)	−0.496*	(-2.07)	−0.353†	(-1.67)	−0.646*	(-2.28)	−0.724*	(-2.41)	−0.708*	(-2.29)
Regional R&D	−0.089†	(-1.81)	−0.094†	(-1.89)	−0.128**	(-2.59)	−0.134**	(-2.74)	−0.139**	(-2.98)	−0.135**	(-2.66)
Venture capital $\times 10^{-3}$	−0.001	(-0.41)	−0.005	(-1.42)	−0.007†	(-1.94)	−0.007*	(-1.99)	−0.007†	(-1.93)	−0.006	(-1.56)
De alio	−0.099	(-0.31)	−0.105	(-0.34)	−0.120	(-0.38)	−0.099	(-0.32)	−0.089	(-0.28)	0.006	(0.02)
Spinoff age	−0.004	(-0.58)	−0.005	(-0.79)	−0.003	(-0.46)	−0.002	(-0.32)	−0.002	(-0.37)	−0.003	(-0.42)
Engineering	0.012	(0.17)	0.018	(0.24)	0.006	(0.08)	0.002	(0.03)	0.002	(0.03)	0.024	(0.29)
Services	−0.294**	(-2.49)	−0.282**	(-2.04)	−0.328**	(-2.74)	−0.325**	(-2.70)	−0.319**	(-2.66)	−0.312**	(-2.53)
Industrial park	−0.107**	(-2.68)	−0.096**	(-2.40)	−0.091*	(-2.22)	−0.132**	(-3.46)	−0.121**	(-3.06)	−0.119**	(-3.02)
Nobel prizes	−0.051	(-0.94)	−0.039	(-0.56)	−0.026	(-0.74)	−0.028	(-0.91)	0.088	(1.10)	0.030	(0.67)
Russell Group	−0.043	(-0.87)	−0.036	(-0.69)	−0.021	(-0.49)	−0.020	(-0.51)	−0.037	(-0.97)	−0.041	(-1.03)
cum. media	−0.152**	(-3.67)	−0.158**	(-3.08)	−0.184**	(-4.84)	−0.180**	(-4.57)	−0.159**	(-3.91)	−0.076	(-1.80)
TTO experience	−0.205**	(-3.42)	−0.204**	(-3.27)	−0.212**	(-3.75)	−0.247**	(-4.25)	−0.233**	(-3.98)	−0.241**	(-4.27)
$\text{Failures}_{t\text{-}1}$			−0.163**	(-2.72)	−0.279**	(-5.06)	−0.308**	(-5.17)	−0.338**	(-6.16)	−0.347**	(-6.25)
Pop. $\text{density}_{t\text{-}1}$			−0.006**	(-3.80)	−0.006**	(-4.05)	−0.006**	(-4.13)	−0.006**	(-3.73)	−0.006**	(-3.99)
$(\text{Pop. density}_{t\text{-}1})^2 \times 10^{-3}$			0.004**	(4.09)	0.005**	(4.54)	0.005**	(4.68)	0.005**	(4.35)	0.005**	(4.46)
Group $\text{size}_{t\text{-}1}$					−0.196**	(-4.54)	−0.192**	(-4.70)	−0.201**	(-4.61)	−0.101*	(-2.06)
Group size >45							0.129**	(3.09)			0.180**	(4.10)
Group size 45–65									0.136**	(3.21)		
Group size >65									−0.133*	(-2.24)		
Gamma	0.107**	(7.38)	0.118**	(6.64)	0.120**	(7.15)	0.137**	(7.06)	0.140*	(7.69)	0.144**	(8.25)
Log-Likelihood	2758.35		2767.52		2778.11		2782.91		2786.07		2582.08	
LR test *vs.* model (d.f.)			18.34 *vs.* 2.1 (3)		21.08 *vs.* 2.2 (1)		9.60 *vs.* 2.3 (1)		11.92 *vs.* 2.3 (2)			

Numbers in parentheses are t-statistics; number of spells: 19,992 (17,429 in Model 2.6); number of events: 790 (723 in Model 2.6).
† Significant at 0.1.
* Significant at 0.05.
** Significant at 0.01, two-tailed tests.

specifications. Unlike an exponential model that assumes a time-constant transition rate, a Gompertz model allows the baseline transition rate to change monotonically with time (Klepper, 2002; Link and Scott, 2003). A transition rate that starts low and then accelerates is theoretically in line with the dynamics of a setting where spinoffs receive considerable support from the parent university, face long development times (Mathisen and Rasmussen, 2019), and have relatively low failure rates at their early stages (Croce et al., 2014). This premise is also supported in our models by a gamma coefficient that is positive and statistically significant.

We also ran extensive robustness checks to validate our model choice. An exponential model that assumes a constant transition rate produced similar results but achieved lower fit. A piece-wise exponential model, where the transition rate can differ across different time periods (*i.e.*, *pieces*), confirmed that the transition rate is increasing over time. However, contrary to a Gompertz model, a piece-wise exponential model requires the researcher to set the time pieces rather arbitrarily, while time pieces also showed high correlation with some of our main independent variables. Finally, lognormal and loglogistic models that assume a non-monotonic transition rate did not fit the data well.

Hence, to estimate disbanding rates, we use a Gompertz model of the general form:

$$r_k(t) = \lambda_k exp(\gamma t) = exp\left(X^k \beta^k\right) * exp(\gamma t)$$

where r_k is the time-dependent transition rate, X^k is a vector of variables, β^k is a vector of coefficients, and γ is an ancillary parameter to be estimated from the data. Estimated coefficients are based on robust standard errors clustered at the individual university level.

Because many of our variables display high correlation, we orthogonalized them before including them in the estimation of our models. As a method, orthogonalization starts with the main variable of interest, and transforms variables so that the computed coefficients express the effects of each variable after removing the effects of preceding variables. The resulting transformed variables are uncorrelated with each other but remain correlated with the independent variables. Orthogonalization is commonly used to resolve issues of multicollinearity and unstable coefficient estimates in both linear and non-linear models (Godart and Galunic, 2019; Greve and Seidel, 2015; Pollock and Rindova, 2003; Sine et al., 2003; Sine et al., 2005). In orthogonalizing the variables in our dataset, we started with *group density*, followed by other group size variables (*e.g.*, *group size* > *45*), *failures*$_{t\text{-}1}$, and control variables. Population density was not orthogonalized in any of the models to facilitate the use of its quadratic specification.

Some authors have questioned orthogonalization's ability to actually resolve issues of multicollinearity and have suggested that it increases the risk of type 1 errors (*i.e.*, false positives) (Kalnins, 2018; Mitchell, 1991). To alleviate such concerns, we conducted a number of robustness checks using the original, unorthogonalized variables. To avoid multicollinearity, we first ran reduced-form models, excluding variables highly correlated with our main variables. As an alternative, we used factor analysis to construct composite variables that replaced the original and correlated ones. Loadings suggested the use of two variables: *region* captures the effects of *regional GDP*, *regional R&D*, *venture capital*, and *industrial parks*, whereas *prestige* captures the effects of *Nobel prizes*, *Russell Group*, *cumulative media*, and *TTO experience*. Results from all models were similar.

5. Results

Descriptive statistics and correlations are presented in Table 1. Tables 2 and 3 show the results from the estimation of our models. Model 2.1 includes only control variables. As it can be seen, the availability of resources at the regional level (*regional GDP*, *regional R&D*, *industrial parks*) has a negative and statistically significant effect on spinoff mortality. At the university level, *TTO experience* and *cumulative media attention* lower spinoff mortality rates, while past *Nobel prizes* and participation in the prestigious *Russell group* have no significant effect. At the individual spinoff level, *services* spinoffs have significantly lower mortality rates than spinoffs in biotechnology (control group) or *engineering*. This perhaps has to do with the lower market risk that services spinoffs face and/or with their ability to start generating revenues faster than spinoffs in *e.g.*, biotechnology. Interestingly, *de alio* entry does not have a significant effect on spinoff mortality. Spinoffs founded before 1993 do not appear to enjoy an advantage nor suffer a disadvantage in comparison to later spinoffs. This result puts further at ease any concerns of left-censoring in our data.

Model 2.2 introduces *failures*$_{t\text{-}1}$ and the *population density* measures to test Hypotheses 1a and 1b. In support of both hypotheses, and in confirmation of received theory (Hannan and Freeman, 1989), the linear term of density is negative and significant, whereas the quadratic term is positive and significant. This suggests that initial increases in population density increase the new organizational form's legitimacy; as spinoffs become better accepted, failure rates decline. After a threshold, however, further increases in density cause spinoff failure rates to increase. Extant literature has attributed such effects to the intensifying competition for resources that results from the gradual exhaustion of the industry's carrying capacity as an increasing number of organizations lay claims over a finite resource pool (Abootorabi et al., 2021; Hannan and Freeman, 1989). *Failures*$_{t\text{-}1}$ also has a negative and significant coefficient, suggesting that failures in the population free up resources, thus making survival easier for the remaining spinoffs (Abootorabi et al., 2021). The addition of the population density measures leads to a considerably improved model fit.

In Model 2.3 we introduce *group size*. In support of Hypothesis 2a, group size has a negative and significant coefficient. As a group's size increases, group members benefit from increased group-specific legitimacy and better access to resources, and their failure rates decline relative to non-group members. It is important to note that these effects operate in parallel and independently of the effects of population density, which remain significant. Model fit also increases significantly in comparison to the baseline Model 2.2, suggesting that group size is indeed a significant moderator of spinoff failure.

Hypothesis 2b suggested that the benefits of group size hold only up to a threshold, beyond which failure rates begin to accelerate as competition for group-specific resources intensifies. Because the group size variable has been orthogonalized, computing its square term is not meaningful. Instead, in Model 2.4 we use a dummy variable for large group size (*group size* > *45*) to test for competitive

Table 3
Maximum Likelihood estimates of failure rates among university spinoffs in England and Scotland, 1993–2017 – unorthogonalized independent variables.

	Model 3.1 Reduced model, Gompertz		Model 3.2 Factor/composite variables, Gompertz		Model 3.3 Factor/composite variables, Gompertz		Model 3.4 Reduced model, exponential		Model 3.5 Factor/composite variables, exponential		Model 3.6 Factor/composite variables, exponential	
Constant	−160.931**	(−5.24)	−181.876**	(−6.10)	−152.214**	(−5.17)	−4.515**	(−7.07)	−4.803**	(−9.33)	−4.703**	(−9.21)
Period 2000–2004	1.777**	(3.99)	1.771**	(3.98)	1.750**	(3.95)	1.415**	(3.20)	1.319**	(3.03)	1.341**	(3.08)
Period 2008–2011	−0.373**	(−2.53)	−0.305*	(−2.20)	−0.286*	(−2.08)	−0.441**	(−3.17)	−0.305**	(−2.45)	−0.297**	(−2.38)
Regional GDP	−0.369†	(−1.85)					−0.166	(−0.95)				
Regional R&D	−0.108†	(−1.73)					−0.037	(−0.65)				
Venture capital × 10^{-3}	−0.007*	(−2.06)					−0.011**	(−2.92)				
Region			−0.137*	(−2.29)	−0.148**	(−2.58)			−0.074	(−1.41)	−0.086	(−1.59)
Prestige			−0.278**	(−3.45)					−0.126*	(−2.27)		
De alio	0.008	(0.05)	0.022	(0.12)	0.003	(0.02)	−0.383*	(−2.27)	−0.444**	(−2.63)	−0.414**	(−2.47)
Spinoff age	−0.005	(−0.55)	−0.005	(−0.68)	−0.004	(−0.48)	0.021**	(2.82)	0.026**	(3.42)	0.024**	(3.24)
Engineering	0.061	(0.77)	0.044	(0.59)	0.066	(0.85)	0.076	(0.97)	0.065	(0.86)	0.075	(0.97)
Services	−0.259*	(−2.18)	−0.291**	(−2.47)	−0.242*	(−2.03)	−0.227†	(−1.92)	−0.247*	(−2.11)	−0.225†	(−1.90)
Failures$_{t-1}$	−0.012**	(−4.15)	−0.010**	(−3.62)	−0.010**	(−3.77)	−0.010**	(−3.52)	−0.006*	(−2.28)	−0.007**	(−2.55)
Pop. density$_{t-1}$	−0.005**	(−3.48)	−0.005**	(−3.59)	−0.005**	(−3.38)	−0.002†	(−1.73)	−0.001	(−1.39)	−0.002	(−1.53)
(Pop. density$_{t-1}$)^2 × 10^{-3}	0.004**	(4.28)	0.004**	(4.14)	0.004**	(4.13)	0.003**	(3.38)	0.002**	(2.79)	0.002**	(3.01)
Group size$_{t-1}$	−0.022**	(−2.68)	−0.018**	(−2.65)	−0.021**	(−2.48)	−0.017*	(−2.06)	−0.016*	(−2.22)	−0.017*	(−2.21)
(Group size$_{t-1}$)^2 × 10^{-3}	0.345**	(2.46)	0.375**	(3.12)	0.304*	(2.11)	0.237*	(1.97)	0.257*	(2.20)	0.238*	(1.99)
Group size >65	−0.867**	(−4.98)	−0.687*	(−2.04)	−1.044**	(−5.63)	−0.734**	(−4.20)	−0.682**	(−2.96)	−0.854**	(−4.27)
Gamma	0.079**	(5.09)	0.089**	(5.93)	0.074**	(5.00)						
Log-likelihood	2764.2		2767.43		2760.11		2745.66		2743.15		2741.51	
LR test *vs.* model (d.f.)					-14.66 *vs.* 3.2 (−1)						−3.26 *vs.* 3.5 (−1)	

Numbers in parentheses are t-statistics; number of spells: 19,992; number of events: 790.
† Significant at 0.1.
* Significant at 0.05.
** Significant at 0.01, two-tailed tests.

effects in large groups. While the main effect of group size remains negative and significant, the effect of large group size on spinoff mortality is positive and significant, and model fit increases significantly. These results offer strong support for Hypothesis 2b. We also experimented with alternative definitions of large group size at 30, 35, and 40 spinoffs. Effects were in the same direction but weaker. This suggests that there exists, indeed, a size threshold beyond which within-group competitive effects kick in, whereas legitimation effects dominate at lower levels. Of the 88 universities in our sample that engaged in spinoff formation, only 8 reached a portfolio size beyond 45 at any time during our observation window. This suggests that universities are aware of the limits that resource availability puts on spinoff formation and survival, and limit the size of their portfolio to levels such that within-group competitive effects are not triggered (*e.g.*, see Haans et al., 2016).

We also tested alternative large group size specifications at 50, 55, 60, and 65 spinoffs. The effects initially weakened and then reversed in sign. We found this puzzling but also suggestive that different dynamics are perhaps at play for very large groups. Therefore, in Model 2.5 we split the original *group size* > *45* dummy into two and introduced separate dummy variables for group size between 45 and 65 spinoffs, and for group size over 65. The main effect of group size remains negative and significant suggesting legitimization, the effect of *group size 45–65* is positive and significant suggesting in-group competition, but the effect of very large group size (>65) on spinoff mortality is negative and significant.

Exploring further, we found that only two universities (Cambridge and Oxford) ever reached group size over 65. These are the most renowned universities in our population, suggesting that the rules of the game are perhaps different for them. Because of exceptional resource availability and long experience in spinoff formation, within-group competition is less of a restrictive factor for spinoffs in their portfolio, while mere association (*e.g.*, Kim and Kim, 2021) with these universities may suffice to guarantee superior access to resources and lower mortality rates. To ensure that our results are not driven by outliers, in Model 2.6 we dropped Cambridge and Oxford spinoffs from our sample. Results from this reduced sample are similar to those from the full sample in Model 2.4: group size has a negative effect on spinoff mortality, but group size over the threshold value of 45 has a positive effect, suggesting that our main findings are robust and support our hypotheses. These effects can be seen in Fig. 4, which plots the hazard rate at different levels of *group size* and *population density*.

5.1. Robustness checks

Orthogonalization of *group size* does not facilitate the inclusion of its square term in our models, while orthogonalization's ability to correct for multicollinearity has also been criticized (Kalnins, 2018; Mitchell, 1991). Therefore, in Table 3, we report additional models using variables in their unorthogonalized form. Model 3.1 is a reduced form model where variables highly correlated with the main independent variables have been dropped. The results confirm all three hypotheses, suggesting that orthogonalization did not lead to Type 1 errors. However, model fit is radically reduced in comparison to the best-fitting Model 2.5. Model 3.4 replicates Model 3.1 but assumes a non-parametric, exponential transition rate rather than a Gompertz model. Fit is reduced further, supporting the choice of a Gompertz model.

In Model 3.2, we use factor analysis to reduce the number of correlated variables. Factor loadings suggested the use of two variables, *region* and *prestige*. Both have negative and significant coefficients, suggesting that regional resource munificence and a

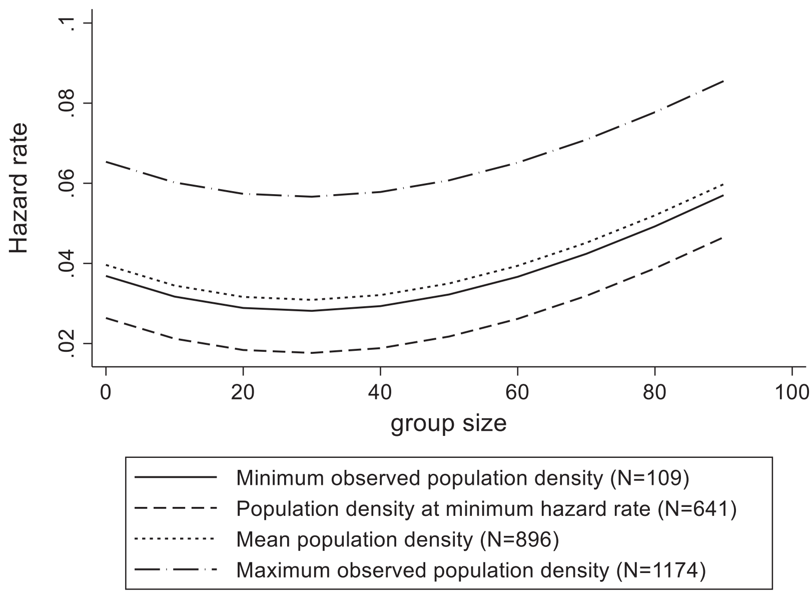

Fig. 4. Mortality hazard by population density (N) and group size.

university's prestige and visibility reduce spinoff failure rates. Other results remain largely unchanged. Model 3.5 replicates these results in an exponential model: the linear term of *population density* is no longer significant, but model fit is also significantly reduced. Finally, in Model 3.3 we drop *prestige* which correlates with *group density* at 0.77. The results from the model offer, again, strong support for our four hypotheses. Model 3.6 replicates in an exponential model and *population density* is, again, not significant. Models 3.5 and 3.6 seem to suggest that the legitimation effects of population density are rather weak, whereas the competitive effects (*i.e.*, the square term) are significant. This might be the result of our analysis starting in 1993 rather than at the very beginning of the industry, when the legitimization effects of population density would presumably have been at their strongest (Chang and Park, 2005; Hannan and Freeman, 1989). This fact together with the low fit of these models and the clearly visible effects in Fig. 4 suggest that the basic premises of ecological theory do hold in the context of university spinoffs, even if the coefficient of population density is not significant in Models 3.5 and 3.6.

We can now use the coefficients from the best fitting Model 3.2 that uses variables in their original form to calculate marginal effects for *population density* and *group size*. A spinoff operating under optimal density conditions (*group size* = 25; *population density* = 641) has a 24.41 % lower propensity to fail than a spinoff operating at the mean values of densities (26; 896); a 38.05 % lower propensity to fail compared to the first spinoff of a university that is a latecomer to the industry (1; 896); and a whole 75.71 % lower propensity to fail than a spinoff operating at *group size* one standard deviation above the mean and at maximum *population density* (48; 1174). As a further robustness check, we tested for the significance of the U-shaped effect (Fernhaber and Patel, 2012; Haans et al., 2016; Lind and Mehlum, 2010) of both *population density* and *group size* on spinoff mortality. Results (available from the authors upon request) confirmed the U-shaped relationships and the statistically significant negative (positive) slopes at the lower (upper) bounds of both *population density* and *group size*.

Even though *group size* varies considerably between universities, its median value (=21) is somewhat lower than the size of 25 that minimizes failure rates at the group level, suggesting that most universities can benefit from growing their spinoff portfolios further. At the same time, the effects of *group size* on spinoff mortality turn positive when the variable reaches 49; during our observation period, only six universities (Cambridge, Imperial, Manchester, Oxford, Sheffield, UCL) reached or surpassed that level at any point in time. This seems to suggest that universities are generally aware of the resource constraints that they face (Baroncelli and Landoni, 2019; Hsu and Kuhn, 2023) and the challenges that too large a spinoff portfolio entails; they thus limit the size of their portfolio so as to reap the benefits of legitimacy and group size for their spinoffs without triggering the effects of within-group competition.

To further explore how dynamics might differ for universities with prolific spinning-off activities, we interacted *group size* with *prestige* while dropping the *group size > 65* variable. The interaction effects failed to achieve significance and we do not report them. Nevertheless, it remains likely that prestigious and resource-rich universities' larger spinoff portfolios reflect a higher capacity to support spinoffs and a larger optimal portfolio size.

In the aggregate population, the negative effects of density on spinoff mortality are maximized when density reaches 641 spinoffs and weaken at higher levels as competitive effects begin to dominate. Population density reaches that level in 2002 before increasing to a peak of 1174 in 2007. Correspondingly, spinoff failures begin to accelerate in the years following 2003 (Fig. 1). These results suggest that, while most universities limit the size of their portfolio relatively close to optimal, crowding characterizes the aggregate population. The spinoff industry thus shows signs of a sort of a *tragedy of the commons* (Ostrom, 1990): the formation of additional spinoffs appears to be beneficial from the perspective of any individual university as, up to a threshold, a growing portfolio lowers' associated spinoffs' propensity to fail, but deleterious for the aggregate industry, where failures accelerate as carrying capacity is exhausted (Abootorabi et al., 2021).

Finally, to further explore the possibility that spinoff failure dynamics may have differed across the different national contexts in UK, we ran our analyses for England alone, dropping from our sample the 293 spinoffs founded by Scottish universities. Results (available from the authors upon request) were similar, confirming all four of our hypotheses. The relatively small number of Scottish spinoffs did not allow us to run similar analyses for the Scottish subsample; a diagrammatic analysis of entry, exit, population density, and group size, however, suggests that dynamics were similar in the context of Scottish spinoffs.

6. Discussion

Research on academic entrepreneurship and university spinoffs has come a long way since Rothaermel et al. (2007) criticized it for being mostly atheoretical (see also Mathisen and Rasmussen, 2019). Building on well-established theoretical paradigms has allowed more recent research to draw inferences that have a stronger theoretical grounding and are more meaningful and generalizable (*e.g.*, see Abootorabi et al., 2021; Fini et al., 2019; Johnson et al., 2017; Foo et al., 2016; Stuart and Ding, 2006). Equally, a stronger theoretical grounding allows research on the unique phenomenon of university spinoffs to contribute back to dominant theoretical paradigms, expanding them in ways that transcend the specific setting of spinoffs. In this article, we have borrowed from organizational ecology (Hannan and Freeman, 1989), as one of the dominant theoretical paradigms of industry evolution, to study the emergence of university spinoffs in England and Scotland and the dynamics of failure among them. Our theorization and findings hold significant implications for both theory and practice.

6.1. Contribution to literature on industry evolution

Voluminous research in organizational ecology (Carroll and Hannan, 1989; Carroll and Swaminathan, 2000), industrial organization (Gort and Klepper, 1982; Klepper, 2002), and technology evolution (Argyres et al., 2015; Suarez and Utterback, 1995) has found evidence of an inverse U-shaped pattern of population density and a U-shaped pattern of organizational mortality that characterizes the evolution of diverse industries. Our analyses confirmed these patterns in the context of university spinoffs in England and Scotland. Our focus on spinoff groups, however, enabled us to go one step further to study the effects of organizational groups that form within larger populations. Networks, alliances, and other groups of interlinked organizations are prevalent in modern economies (Gómez et al., 2017). Members of such groups benefit in terms of legitimacy (Stuart, 2000), learning (Stuart and Ding, 2006), and better access to resources (Ahuja, 2000; Katila et al., 2008), but also compete for the allocation of group-specific resources (Ahuja et al., 2009). As our analysis of organizational groups in the context of spinoffs suggests, sizeable groups confer survival advantages to their members but can also create competitive pressures should they grow too large. Thus, while the survival chances of an organization are never unlinked from dynamics in the aggregate population, they are also heavily influenced by how group-level dynamics unfold. The evolutionary dynamics of an industry in which groups are present cannot be analyzed fully, lest the effects of such groups on organizational mortality are taken into account.

In the context of English and Scottish university spinoffs, we found that most spinoff groups maintained a size that allowed them to enjoy the benefits but not trigger the costs of grouping together. Because universities, as the central actors that control the allocation of group resources, value spinoff survival as an important goal (Magomedova et al., 2023; Wright et al., 2006; see also Powell and Owen-Smith, 1998), they may constrain entry and allocate resources in ways that maximize individual spinoffs' survival chances. In other settings, maintaining optimal size might be more difficult. Large and dominant group members might prefer a group size different from the size that is optimal for smaller members or might attempt to appropriate the lion's share of group resources (Ahuja et al., 2009). If such actions diminish the benefits of group membership for some organizations, groups may fall apart (Baum et al., 2003). Alternatively, incentive misalignment or a central actor's preference for group size over individual organization survival might lead to deleterious levels of in-group competition.

At the same time, dynamics at the group level and the population level might also be at odds. Our results suggest that most universities have an incentive to grow their spinoff groups further, as reaching an optimum (*group size* = 25) can lower failure rates in their portfolio. The aggregate population, however, is characterized by crowding, as an increasing number of spinoffs exhausts the industry's carrying capacity. As these two opposing dynamics imply, individual groups' striving for optimal size might be a further explanation for the overshootings of carrying capacity that are often observed in organizational populations (Burke and van Stel, 2014); the opposing effects of group size and population density have thus to be assessed in conjunction in order to make inferences about organizational mortality.

6.2. Contribution to technology transfer and academic entrepreneurship literature

Our focus on failures in the aggregate population of university spinoffs in England and Scotland since the inception of the industry, and the juxtaposition of population and group level dynamics also fills an important gap in our understanding of the spinoff population's evolution and the crucial interrelationships between spinoff density, survival, and failure (*e.g.*, Abootorabi et al., 2021; Prokop, 2021; Ulrichsen, 2019; Walter et al., 2006). Scholars, practitioners, and policy makers have often lamented the creation of too many spinoffs (Lambert, 2003; House of Commons, 2013; see also Wright et al., 2006), while others have called for the creation of yet more spinoffs (Williams, 2005). As our results suggest, at the heart of such contradictory recommendations might lie a focus on different levels of analysis. While the aggregate industry appears to be rather crowded, for most universities further spinoff portfolio growth could lower associated spinoffs' failure rates.

Some authors have attributed spinoff failures to inadequate resources at the university level, such as dedicated full-time staff, financial support and marketing experience, and suggested that an absence of focus "leads to spreading scarce resources over too many projects" (de Cleyn et al., 2013: 210). However, such resources need time to accumulate and might require a minimum efficient group size (Degroof and Roberts, 2004). Increasing size enhances a group's legitimacy (Grandi and Grimaldi, 2003; O'Kane et al., 2015), helps to build larger networks with external talent and investors (Prokop et al., 2019), helps to attract media attention (Pitsakis et al., 2015), and accumulates experience in creating and managing spinoffs (Fini et al., 2017). As our article thus demonstrates, a better understanding of the dynamics of spinoff failure requires more attention to the effects of group size, and the examination of the potentially significant benefits that accrue from large group size in conjunction with the effects that aggregate population density has on a focal spinoff's propensity to fail.

6.3. Limitations and avenues for future research

In this article, we explored the interplay of population density and group size, and their effects on the mortality of organizations in general, and university spinoffs in England and Scotland in particular. While our theorization and findings make significant contributions, our study also has important limitations. First, while failure constitutes an important metric of organizational performance, in some settings other metrics might be more salient. It is plausible that some universities' technology transfer strategies and decisions on spinoff portfolio size are driven by considerations other than simply minimizing spinoff failure rates (Prokop, 2021). A low selectivity – low support (Degroof and Roberts, 2004) or trial-by-fire (Swaminathan, 1996) strategy could promote the creation of numerous spinoffs that receive relatively little support from their parent university, allowing only the fittest to survive. Similarly, universities could focus on maximizing financial returns from their aggregate spinoff portfolio or on creating a few major hits that bring disproportionate returns and attention. While evidence suggests that universities follow a dual (academic and market) logic in their technology transfer activities (Fini and Lacetera, 2010), seldom prioritize financial returns in associated decisions (Powell and Owen-Smith, 1998), and value spinoff survival as an important goal (Magomedova et al., 2023), potential differences in universities' strategies deserve more attention. This is particularly true under conditions similar to those that characterize the spinoff ecosystem in

England and Scotland, where the university rather than the academic entrepreneur has final say regarding a spinoff's formation.[1]

It is also possible that the quality of spinoffs changes over time, affecting our findings. As spinoffs become the taken-for-granted vehicle for research commercialization, the bar for creating one could become lower. While quality assessments are notoriously difficult for early-stage ventures that attempt to commercialize unproven, early-stage technologies that face lengthy development times, some evidence suggests that spinoff quality actually improves over time (Fini et al., 2017) and that universities become more selective in their technology transfer activities (Hsu and Kuhn, 2023). On the other hand, higher selectivity and related policy changes might suggest that fewer spinoffs are created over time and that universities choose to maintain smaller spinoff portfolios. Fig. 1 corroborates the drop in foundings; by comparison, drops in population density and group size appear to be much more modest, with drops in group size even reversing for some universities (Figs. 1, 2, and 3). Our data do not allow us to infer whether such drops are the effect of earlier overshootings of the industry's carrying capacity or of changes in universities' technology transfer strategies. Future research could collect data on financial returns on universities' spinoff portfolios and relate them to portfolio size and other salient aspects of universities' technology transfer strategies over time.

Finally, even though our findings suggest an optimal group size that is uniform across all universities, individual universities' optima are in fact likely to differ. Prestigious and resource-rich universities or universities with considerable experience in spinning-off activities can presumably support larger portfolios and optimize spinoff mortality rates at higher levels of group density. While we expect the U-shape effect of group size to hold for all universities, further research is required to assess how optimal group size might differ across universities based on individual university characteristics.

7. Conclusion

Introducing group effects to the study of an aggregate population, we have demonstrated how industry evolution constitutes an intricate process that unfolds at multiple and interconnected levels that need to be studied concurrently. Our theorization and findings stress that dynamics at the level of the aggregate industry might be at odds with dynamics at lower levels of analysis, and have opposing effects on organizational mortality. Our findings from the entire population of university spinoffs in England and Scotland suggest that, while competitive crowding perhaps occurs at the aggregate population level, most universities have an incentive to grow their portfolio further, as doing so can lower mortality among associated spinoffs.

This article joins a stream of recent literature (*e.g.*, Abootorabi et al., 2021; Prokop et al., 2019; Ulrichsen, 2019; Walter et al., 2006) to advocate for more attention to be paid to spinoff failures. In the UK, spinoff generation is currently attributed an entire 34.6 % in the university 'impact' rankings (Times Higher Education, 2021). While important as a metric, spinoff generation does not take into account the spinoff ecosystem's finite carrying capacity (Abootorabi et al., 2021), and universities' need to balance foundings with individual spinoffs' survivability (Degroof and Roberts, 2004; Magomedova et al., 2023). As an organizational form and a vehicle of technology transfer spinoffs lie at the intersection of academia and markets. The complexity inherent to the spinoff phenomenon requires that alternative metrics and different theoretical lenses are used to shed light on the multiple salient aspects of universities' research commercialization strategies.

CRediT authorship contribution statement

Aleksios Gotsopoulos: Conceptualization, Methodology, Formal Analysis, Data Analysis, Writing – Original Draft, Writing – Review & Editing, Project Administration, Visualization.

Konstantinos Pitsakis: Data Curation, Methodology, Writing - Original Draft, Writing - Review & Editing.

Data availability

The authors are unable or have chosen not to specify which data has been used.

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[1] We are thankful to an anonymous reviewer for bringing this point to our attention.

Appendix A

Table A1
Spinoff formation descriptives by university.

University	Year of first spinoff	Cumulative foundings	Maximum group size	Group size in 2017
Aberdeen	1996	23	20	16
Abertay Dundee	1995	4	4	1
Aston	1994	17	15	6
Bath	1995	13	9	9
Bath Spa	2004	1	1	1
Birmingham	<1993	47	32	25
Bolton	2004	1	1	1
Bournemouth	2005	2	2	2
Bradford	1994	11	7	3
Bristol	<1993	31	29	21
Brunel	<1993	19	13	7
Cambridge	<1993	107	79	68
City University London	1998	4	3	3
Coventry	2000	13	9	9
Cranfield	1999	6	5	5
DeMontfort	2001	10	7	7
Derby	1999	4	4	2
Dundee	1993	24	20	16
Durham	2000	20	16	9
East Anglia	<1993	8	6	5
East London	2003	2	2	1
Edinburgh	<1993	62	48	29
Essex	1995	6	4	2
Exeter	1993	16	11	8
Glasgow	<1993	40	25	21
Glasgow Caledonian	1999	4	4	4
Goldsmith's College	2001	4	3	2
Greenwich	2003	4	4	1
Heriot-Watt	<1993	34	21	19
Hertfordshire	<1993	11	10	7
Huddersfield	1995	4	4	1
Hull	1999	10	7	6
Imperial College	<1993	79	58	49
Institute of Cancer Research	1998	5	5	4
Keele	1999	8	6	3
Kent	<1993	16	11	5
King's College	<1993	24	18	12
Kingston	2007	3	2	0
Lancaster	1997	20	14	14
Leeds	1994	39	34	20
Leeds Beckett	2001	1	1	1
Leicester	<1993	14	12	10
Lincoln	2002	1	1	1
Liverpool	1996	27	18	12
Liverpool John Moores	1993	4	4	2
London South Bank	1999	13	13	5
Loughborough	1995	29	21	14
Luton (Bedfordshire)	1997	1	1	1
Manchester	<1993	74	53	38
Manchester Metropolitan	1995	4	4	2
Middlesex	2002	4	4	2
Napier	1998	10	9	3
Newcastle	<1993	29	19	18
Northampton	2001	2	2	1
Nottingham	<1993	45	34	32
Nottingham Trent	1999	8	6	5
Oxford	<1993	122	78	78
Oxford Brookes	1995	5	4	2
Plymouth	1998	13	9	6
Portsmouth	2000	4	4	2
Queen Margaret	1998	2	2	1
Queen Mary	<1993	12	12	10
Reading	2000	5	4	1

(*continued on next page*)

Table A1 (*continued*)

University	Year of first spinoff	Cumulative foundings	Maximum group size	Group size in 2017
Robert Gordon	1997	9	8	2
Royal Holloway	1999	8	5	2
Royal Veterinary College	2000	2	2	1
Salford	<1993	14	13	8
School of Pharmacy	1996	5	5	5
Sheffield	<1993	74	62	34
Sheffield Hallam	2002	6	4	3
Southampton	1993	20	19	15
St Andrews	1994	37	20	20
St George's	<1993	7	7	4
Staffordshire	2009	1	1	1
Stirling	2000	3	2	2
Strathclyde	<1993	61	41	33
Sunderland	1996	3	3	1
Surrey	<1993	27	24	18
Sussex	1993	11	10	3
Teesside	<1993	6	6	3
University College London	<1993	101	62	62
Warwick	1999	54	34	28
West of England	2003	2	2	1
West of Scotland (Paisley)	<1993	4	4	1
Westminster	2001	4	3	2
Wolfson Institute	1997	5	5	4
Wolverhampton	2005	4	3	2
York	<1993	43	34	20

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