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RESEARCH ARTICLE

Connectedness of entrepreneurial ecosystems: evidence from the mobility of knowledge-intensive entrepreneurs

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Abstract Entrepreneurial ecosystems (EEs) are regarded as ideal breeding ground for knowledge-intensive entrepreneurs (KIEs). Yet, as EEs are mostly considered isolated from each other and their connectedness is neglected, there is a lack of research on their capacity to attract KIEs rather than to locally nurturing them. Inadequate data has been a major obstacle to this line of work as well. Aiming to address this gap, the present study investigates KIEs' mobility providing empirical evidence at support of EEs' connectedness. The career history of 3,897 biotech KIEs across 32 European countries over a 15-year time was analysed. A stochastic actor-oriented model (SAOM) was employed to identify the key determinants attracting flows of biotech KIEs from one EE to another. Crucially, this analysis included both location-specific variables for every EE, as well as the dynamics of the inter-EE mobility network itself. Though the results are specific to KIEs in the biotech sector and more research is necessary to further confirm them, they provide evidence that KIEs' mobility emerges from multiscalar phenomena extending beyond ecosystem boundaries. Both the academic community and policymakers should take such dynamics seriously to understand and shape EEs connectedness to the larger world. Moreover, as KIEs' mobility cannot be fully understood without accounting for inter-EE connectedness, the multiscalar understanding of EEs can significantly benefit from the use of KIEs' mobility data.

Plain English Summary Entrepreneurial ecosystems (EEs) are regarded as ideal breeding ground for knowledge-intensive entrepreneurs (KIEs). The scope of this research is to understand the capacity of EEs to attract KIEs, investigating KIEs' mobility and EEs' connectedness. By a stochastic actor-oriented model

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(SAOM), the professional history of 3,897 biotech KIEs across 32 European countries over a 15-year time was analysed. KIEs' mobility across European EEs emerges from (1) multiscalar dynamics, (2) which goes beyond ecosystem boundaries, (3) KIEs' mobility is closely linked to inter-EE connectedness and local EE characteristics and (4) that operate as self-reinforcing mechanisms for KIEs' aggregation.

Keywords Entrepreneurial ecosystems · Knowledge-intensive entrepreneurship · Entrepreneur mobility · Network analysis

JEL Classification M13 · M19

1 Introduction

The concept of entrepreneurial ecosystems (EEs) has emerged to describe the economic, social and technological interactions sustaining and driving entrepreneurial productivity, frequently at the city or regional scale. Highlighting the dynamic, cumulative and complex features of these interactions, it aims at explaining why some territories are better than others at attracting and growing businesses, and how such interactions evolve over time (Brown & Mason, 2017; Cantner et al., 2021; Mack & Mayer, 2016). These dynamics concentrate key actors and resources in the same geography. There, in the presence of a positive entrepreneurial culture and regulatory environment, the flow of capital, knowledge and talents is highly facilitated, thus favouring the birth and growth of enterprises (Acs et al., 2014; Stam & van de Ven, 2021).

Given the density of resources and connections, EEs are ideal environments for knowledge-intensive entrepreneurs (KIEs) to emerge and thrive (Bertello et al., 2022; Nicotra et al., 2018). This concept identifies the strategic behaviour of entrepreneurs actively acquiring resources (most notably knowledge) by interacting with other organizations, and recombining them into original innovations to obtain a competitive advantage in the market (Malerba et al., 2015; Moraes et al., 2023). Previous studies have specifically investigated how ecosystem features impact the development of such enterprises (Fischer et al., 2022a, b; Siqueira et al., 2023) and hinted at the role played by KIEs in dynamizing their local ecosystem (Malerba & McKelvey, 2020; Sousa & Silva, 2019) but research on the role of KIEs in connecting different ecosystems is still in its infancy.

Since KIEs actively search for resources beyond ecosystem boundaries, they are generally ready to relocate (Bosetti et al., 2015; Elo & Servais, 2018). Interpreted as a maximization choice of individual entrepreneurs (Stephens et al., 2019), the systemic consequences deriving from the relocation of thousands of KIEs have been rarely taken into account (Schäfer & Henn, 2018), particularly from a network perspective (Leal & Harder, 2021). Though this used to be a problem also for the investigation of innovation ecosystem (Binz & Truffer, 2017), the EE literature has been slower to address it, probably for a lack of adequate data and a tendency to focus on spatial dimension at the expenses of more relational approaches (Audretsch & Belitski, 2017; Ferrary & Granovetter, 2009). Overall, this limited consideration for the connectedness of EEs hinders the multiscalar usage of the concept (Alvedalen & Boschma, 2017; Brown & Mason, 2017; Theodoraki & Messeghem, 2017) and, for the specific topic of interest in this paper, from a full understanding of the factors influencing the mobility of KIEs.

To address this gap, the present study investigates KIEs' mobility providing empirical evidence at support of EEs' connectedness (Fischer et al., 2022a, b). The professional history of 3,897 biotech KIEs across 32 European countries over a 15-year time was analysed. Though EEs are not necessarily thematic (Stam & van de Ven, 2021), KIEs' need for specialized knowledge motivates focusing the biotechnology industry from the perspective of within-sector concentrations and externalities (Depret & Hamdouch, 2010; Marshall, 1890). After an initial descriptive assessment, a Stochastic Actor-oriented Model (SAOM) was employed to identify the key determinants attracting KIEs from one EE to another (Leal & Harder, 2021; Ripley et al., 2020). Crucially, this analysis included both location-specific variables for every EE (Stam & van de Ven, 2021), as well as the dynamics of the inter-EE mobility network itself (Leal & Harder, 2021). The results confirm that not all EEs have equal attractiveness to biotech KIEs and that EEs' hierarchical connectedness is fundamental to understand their mobility. Though specific to KIEs in the biotech sector and more research is necessary to further confirm them, they provide evidence that

KIEs mobility emerges from multiscalar phenomena extending beyond ecosystem boundaries (Motoyama & Knowlton, 2016). Both the academic community and policymakers should take such dynamics seriously to understand and shape EEs connectedness to the larger world (Ter Wal & Boschma, 2009). Moreover, as KIEs' mobility cannot be fully understood without accounting for inter-EE connectedness, the multiscalar understanding of EEs can significantly benefit from the use of KIE mobility data (Gluckler, 2007; Schäfer, 2021).

2 Theory

2.1 Connectedness of entrepreneurial ecosystems

The key elements of EEs were introduced in the Nineties referring to the Silicon Valley (Bahrami & Evans, 1995) and the entrepreneurial productivity deriving from the cumulative interactions between actors within a same region (Spilling, 1996). Different theories on the emergence and persistence of EEs (Thompson et al., 2018) focus on clustering (Delgado et al., 2010), government support (Autio & Thomas, 2018), bonds among actors and institutions (Mack & Mayer, 2016; Spigel, 2017) and value co-creation (Adner, 2017). Nonetheless, they generally agree on recognizing EEs as an evolutionary and spatially bounded phenomena (Brown & Mason, 2017) undergoing different phases in which they rise, grow, decline and regenerate (Alvedalen & Boschma, 2017; Cantner et al., 2021). The concept presents major similarities to innovation ecosystem, innovation systems and industrial clusters (Alvedalen & Boschma, 2017; Brown & Mason, 2017). What ultimately distinguishes them is considering entrepreneurship — rather than innovation or economic productivity at large — the engine behind their lifecycle, and the birth and growth of new enterprises as their primary output (Alvedalen & Boschma, 2017; Brown & Mason, 2017).

Multiple voices in academia have been recognizing that the concept of EE has often received simplistic usage in empirical research. On the one hand, most studies have assumed the scale of EEs to be fixed and corresponding to administrative boundaries of cities, regions and less frequently countries (Cao & Shi, 2021; Fischer et al., 2022a, b), neglecting that different economic processes happen at different levels and in different places (Bailey, 1983; Carayannis et al., 2018). On the other, there has been an excessive focus on the composition of EEs and less on their structure and relations (Brown & Mason, 2017; Carlsson & Stankiewicz, 1991; Ferrary & Granovetter, 2009). In particular, research has neglected the relationships between actors from different locations, furthering the analytical understanding of EEs as disconnected entities (Fuller-Love & Akiode, 2020). Thus, this perspective has often overlooked the actual multiscalarity of many processes in EEs (Carayannis et al., 2018; Fischer et al., 2022a, b).

Though some of these issues have been acknowledged also in the literature on innovation systems and ecosystems (Binz et al., 2014), in the context of EEs they have been particularly difficult to overcome. One reason is the lack of adequate data to proxy entrepreneurship processes, and particularly of relational, spatial and globally available data, as traditional sources such as patents and scientific bibliography are much less relevant to the study of EEs than of similar phenomena (Fischer et al., 2022a, b; Gluckler, 2007; Schäfer, 2021). Hence, research on EEs has been largely declined into one of two flavours: one, as qualitative case studies (Guerrero et al., 2014; Lassalle & Johnston, 2018); two, as quantitative studies leveraging traditional data sources to compare hundreds of or EEs (generally at the regional level) but assuming them to be independent from one another (Audretsch & Belitski, 2017; Audretsch et al., 2021). Accordingly, relational data — particularly on social relations between ecosystem actors — has been used to understand and measure processes within individual EEs, but hardly between them (Fischer et al., 2022a, b; Theodoraki & Catanzaro, 2022), missing on the structural nature of EEs connectedness in many areas. This lack of understanding extends to the mobility of entrepreneurs and KIEs.

2.2 Mobility of knowledge-intensive entrepreneurs

The concept of KIE combines elements from Schumpeterian entrepreneurship, evolutionary economics and innovation systems (Malerba & McKelvey, 2020), characterizing them as risk-taking (Kurz, 2012), knowledge focused (McKelvey & Lassen, 2013) and knowledge-access (Shi & Weber, 2021), and market disruptive (Witt, 2008) actors capable absorbing specialized knowledge and resources from their network and environment (Malerba, 2014; Murmann, 2003; Nan, 2023). For these features, they appear exceptionally relevant to understand the intertwine between innovation and entrepreneurship in high tech sectors such as telecommunications, nanotechnology and biotechnology (Krafft et al., 2014; Sekliuckiene et al., 2016) where the use of open innovation and coopetive strategies is at the highest (Aspelund et al., 2018; Carayannis et al., 2018). For these reasons, EE can be highly attractive to KIEs as ideal environments in which resource diversity can be found and most easily recombined (Bertello et al., 2022; Grande et al., 2022). As knowledge is increasingly specialized and dispersed, however, what is available in the local EE might not suffice, pushing KIEs to seek it in different locations (Mainela et al., 2014; McGaughey et al., 2016).

Lacking a proper literature on KIEs mobility, we reviewed relevant literature on transnational or migrant entrepreneurship. Studies include the identification of local attraction factors such as availability of resources, social capital and amenities (Noonan et al., 2022; Stephens et al., 2019), and the identification of obstructing factors, particularly to minorities and women (Aman et al., 2024; Duan et al., 2022). Most importantly, the role of diaspora entrepreneurs and returnees as catalysers of entrepreneurship and facilitators of internationalization of their home territory has been investigated (Schmutzler et al., 2021). Focusing on this latter aspect, attention has been dedicated to the role of remittances in supporting entrepreneurial activities (Cazachevici et al., 2020; Vaaler, 2011), and brain drain, brain gain and ultimately brain circulation between home and receiving locations (Dustmann et al., 2011; Saxenian, 2002). Indeed, relocating and migrant entrepreneurs have been found to also benefit destination locations with unique sets of cognitive and material resources supporting or even driving the emergence of strong EEs (Harima et al., 2021a; Lassalle & Johnston, 2018).

However, only few studies have openly conceptualized the role operated by relocating entrepreneurs in connecting multiple locations (Duan et al., 2022; Fuller-Love & Akiode, 2020). As KIEs move between EEs, in each new location they build new social relations thus indirectly connecting organizations from different EEs (Fuller-Love & Akiode, 2020). Moreover, via their embeddedness in multiple ecosystems (Duan et al., 2022), they also connect EEs to one another leading to the emergence of proper mobility networks which favour further relocations and exchanges between EEs (Elo & Servais, 2018; Nogle, 1994). This is a similar phenomenon to that underlying the emergence of global innovation systems (Binz et al., 2014; Binz & Truffer, 2017) and, as it has been already suggested (Del Giudice et al., 2017; Knight & Liesch, 2016; Mainela et al., 2014), could be a crucial mechanism by which EEs increase their connectedness and acquire multiscalar features (Alvedalen & Boschma, 2017; Binz & Truffer, 2012; Coe & Bunnell, 2003).

2.3 Theoretical framework and hypotheses

The model proposed by Stam and van de Ven (2021) to explain the functioning of — implicitly — isolated EEs was revised (Fig. 1) to account for the connectedness between EEs and explain the mobility of KIEs between them (Alvedalen & Boschma, 2017; Binz & Truffer, 2017; Carayannis et al., 2018).

The starting EEs' framework is organized into three structurally nested components (van de Ven, 1993). Productive entrepreneurship is where resources are effectively recombined into new enterprises, and can be interpreted as the key output of EEs as well as their engine (Blackburn et al., 2018). Next, the resource endowments component includes the assets available within EEs, and most notably a sufficient Demand for a business' products and services (Annoni & Kozovska, 2010), Finance to invest into the business development and growth (Kerr & Nanda, 2009), Intermediaries providing business services and lowering costs (Baaken & Wölfer, 2012), scientific and technical Knowledge that could nurture innovation (Audretsch & Lehmann, 2005), leadership from highly innovative actors (Feldman, 2014), talents with relevant skills and experience (Acs & Armington, 2004) and physical infrastructure connecting the local EE with the rest of the world (Audretsch et al., 2015). Last, the institutional arrangement component constitutes the overarching landscape in which EEs emerge and is fundamentally determined by a combination of reliable and supporting formal institutions (Granovetter,

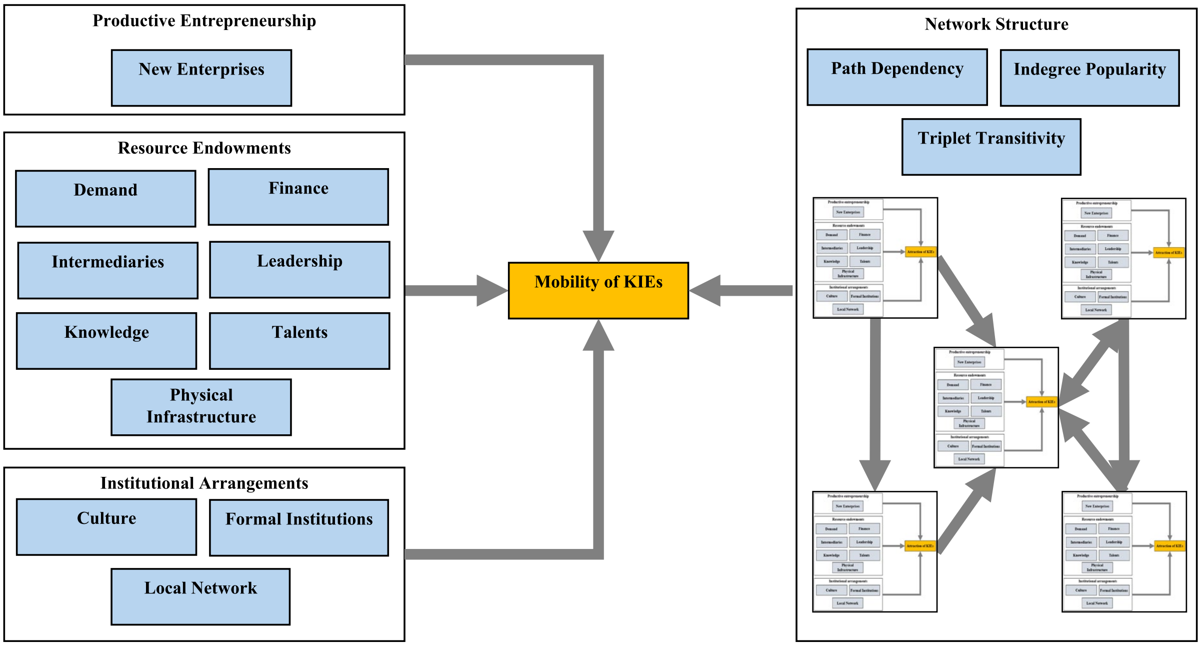

Fig. 1 Theoretical framework. Own work

1992), entrepreneurial culture (Fritsch & Wyrwich, 2014) and a local network of relations embedding actors participating in the ecosystem (Neumeyer et al., 2019). Inviting the reader to the original paper for a thorough discussion of all elements, these factors have been found to play a fundamental role in the creation of new enterprises within existing EEs (Alves et al., 2019; Stam & van de Ven 2021). Accordingly, it would be reasonable to assume that these same factors might — to different degrees — also influence KIEs mobility:

H1.a EEs' productive entrepreneurship positively affects KIEs' mobility
H1.b EEs' availability of resource endowments positively affects KIEs' mobility
H1.c EEs' favourable institutional arrangements positively affects KIEs' mobility

To account for EEs' connectedness, the network structure component was added to the original model (Stam & van de Ven 2021). Previous studies have shown that mobility flows between location pairs can be best understood when the dynamics between other locations are taken into account, thus requiring the adoption of a network perspective (Fawcett, 1989; Nogle, 1994). Within the context of this study, it implies that the mobility of KIEs is at least partially dependent on the structure of existing relocation flows between EEs. Though the topic does not seem to have received much attention from the literature on EEs yet (Alvedalen & Boschma, 2017; Walsh, 2019), in country-level studies, it was found that migration networks see the emergence of multiple and sometimes balancing dynamics resulting from their structure. One such example would be the tendency for KIEs to follow the footsteps of those who relocated before them (path dependency) in order to more easily access resources as well as a consequence of cognitive biases (Lassalle & Johnston, 2018; Noonan et al., 2022). Over time, this path dependency would result in the creation of particularly busy mobility routes and the consolidation of strong connections between EE pairs (Azose & Raftery, 2019). Another example would be the emergence of success-breed-success dynamics between EEs, as ecosystems receiving more flows would acquire a better positioning in the mobility network and thus become even more attractive to future generations of KIEs. This indegree popularity effect would lead to few major hubs in the mobility network where most of the KIEs relocate from their ecosystem of origin (Snijders et al., 2010; van de Rijt et al., 2014). Alternatively, KIEs' mobility might be influenced by the mobility of adjacent EEs, particularly in transitive terms (Davis, 1970). Hence, triplet transitivity would lead to the emergence of hierarchical but more fragmented structures in the inter-EEs' network (Davis, 1970; Kitts et al., 2017). Accordingly, three additional hypotheses were developed:

H2.a Path dependency positively affects KIEs' mobility

H2.b Indegree popularity positively affects KIEs' mobility

H2.c Triplet transitivity positively affects KIEs' mobility

3 Materials and methods

Countries in the European Union (including the United Kingdom as former member) and in the European Free Trade Association have been long integrating their economies and are at the forefront of innovation and entrepreneurship in the biotech sector (Startup Genome, 2022; Windzio et al., 2019), and constituting an ideal ground for this research.

Hence, the terms "founder", "co-founder" and "entrepreneur" and their translations in the official languages of every country were searched for with the help of regex tools in the job titles of a professional career repository. The focus was on profiles within the biotechnology industry, equivalent to NACE M72.1.1 (European Commission, 2010). Reasons to focus exclusively on biotech KIEs are twofold: on the one hand, biotech has received major attention over the years, with many studies investigating network dynamics from the perspective of clusters, innovation ecosystems and KIEs; thus, more easily justifying the approach was followed in this study (Binz et al., 2014; Depret & Hamdouch, 2010; Krafft et al., 2014); second, though EEs are not necessarily thematic, KIEs are generally interested in highly specialized and front-running knowledge within a specific field, thus requiring the use of sector-specific data during the analyses (Malerba, 2014; Malerba & McKelvey, 2020). Last, data to characterize EEs was collected employing the same approach and sources of Stam and van de Ven (2021), aggregating values at the level of Nuts3 regions (Kilroy & Ganau, 2020). Since 32 countries fell within the scope of this research, some adjustments were necessary to guarantee comparability. Detailed information on how each element was measured is available in the Appendix (Table A1).

From the KIE dataset a two-mode network of KIE relocations between EEs (using both KIEs and EEs as nodes) was first constructed. This was later transformed into a one-mode network of EE nodes, in which EEs were connected by the relocations of KIEs, used as edges (Park et al., 2015). The result was a one-mode directed network of EEs' mobility, weighted by the number of KIEs moving between two EEs in every given year. In order to meet the requirements of RSiena, however, this network was further processed dichotomizing its edges at the 90th percentile and discarding EEs with less than 15 KIEs (Leal & Harder, 2021; Ripley et al., 2020). RSiena was then employed to simulate the network evolution over 15 years and identify the EE-specific and network structure factors which best predicted the creation of new connections (mobility flows) between EEs (Leal & Harder, 2021).

4 Results

A total of 3,897 KIEs could be identified and analysed as they moved across 805 Nuts3 regions in 32 countries. Figure 2 portraits key indicators to understand the evolution of the mobility network. First and foremost, it shows that both the number of nodes and the number of ties has undergone a major increase in 15 years, the latter displaying an increase not only in number but also in average weight. Interestingly, while the number of relocations at the international and Nuts0-level increased more than the number of relocations at the Nuts2-level, the average weight of ties increased more at the Nuts2-level than for the Nuts0-level and even more for the international level. Moreover, both the number of nodes and the average weight of ties peaked before the turning of the decade and then decreased again. Nonetheless, as a result of these trends, Fig. 3 shows the 133 Nuts3 regions included in the model, together with the number of diverse mobility flows directed towards each of them in the 15-year time considered. Contrary to previous studies (Leal & Harder, 2021), it was decided to present together the results of both the pooled model (Table 1) and the one-window models (Table A2) in order to immediately present time-heterogeneous results. Time heterogeneities are explicitly indicated whenever statistically significant. Starting from the local EE elements, positive and significant effects for the number of new enterprises, leaders and talent were found in the pooled model, while finance and knowledge only displayed a positive effect in 2008–2013 and in 2011–2016 respectively. On the other hand, negative effects were registered for demand and lack of physical infrastructure in the pooled model, as well as for leaders in 2011–2016 and for knowledge in 2014–2019. In the pooled model, additional positive effects for culture and KIEs' density, and a negative one for formal institutions could also be identified. In the 2008–2013 period, however, this last variable displayed a positive effect. Moving to the network effects, positive ones for path dependency, transitive triplets and a negative effect of indegree popularity were found in the pooled model, with path dependency expressing a negative coefficient in the first period (2008–2013). Significant results were found also for many control variables. In the pooled model, a positive effect was found for indegree activity and language, and a negative one for border crossing and transitive reciprocated triplets. A positive effect of cycle triplets was registered in 2011–2016. Outdegree density and reciprocity confirmed the validity of the model (Ripley et al., 2020).

Table 1 SAOM results for the pooled model

	2008–2022				
	Effect	Coeff	St error	Sig	*T*Stat
Productive entrepreneurship	new_entCC alter	0.361	0.051	***	−0.010
Resource endowments	demandCC alter	−0.073	0.034	*	−0.030
	financeCC alter	0.008	0.009		−0.013
	knowledgeCC alter	−0.008	0.012		−0.025
	leadersCC alter	0.022	0.010	*	−0.067
	phys_infrCC	−0.147	0.037	***	0.050
	talentsCC alter	0.099	0.040	*	−0.040
Institutional arrangements	cultureCC alter	0.027	0.006	***	0.032
	ease_busiCC alter	−0.043	0.011	***	−0.011
	kies_densityCC alter	0.094	0.033	**	−0.008
Network structure	indegree—popularity	−0.009	0.004	*	−0.031
	path_depenCC	0.005	0.002	*	0.020
	transitive triplets	0.207	0.017	***	−0.036
Controls	3-cycles	0.021	0.035		−0.026
	bord_crossCC	−0.578	0.054	***	0.041
	indegree—activity	0.032	0.017		−0.026
	languageCC	0.283	0.051	***	−0.023
	outdegree—activity	−0.005	0.008		−0.034
	outdegree (density)	−2.572	0.046	***	−0.031
	populationCC alter	−0.138	0.147		−0.033
	reciprocity	2.753	0.059	***	0.006
	transitive recipr. triplets	−0.218	0.018	***	−0.028

5 Discussion

This represents the first attempt to employ SOAM to map the mobility of KIEs. As such, the methodology has not been thoroughly tested yet, and multiple choices and assumptions have been necessary when specifying the model in RSIENA which might have influenced the results (Ripley et al., 2020). One such example is the dichotomisation of the inter-EE network, which biases the analysis focusing only on the largest connections and EEs at the expenses of all others (Leal & Harder, 2021). Hence, complementary approaches such as network-intensity SOAM analysis or gravity models would be ideal to complement these results and obtain a more comprehensive picture of KIEs mobility (Broekel et al., 2014; Leal & Harder, 2023). As a further issue, official mobility data at the provincial (Nuts3) level could not be found for the geographical and temporal scope of this study (Darvas et al., 2018). Indeed, data with such granularity is rare and constitutes one of the strongest points of the article (Gluckler, 2007; Schäfer, 2021), but inevitably means that no control variable for general mobility trends could be included in the model. In line with this, though typical for the study of KIE and multiscalar networks (Binz et al., 2014; Krafft et al., 2014), biotechnology is a highly specialized field and actual dynamics may differ in other industries, preventing full generalization (Nicotra et al., 2018). Accordingly, further research should certainly extend this methodology to KIEs in different sectors to confirm these results. Nonetheless, some key findings could be derived from this study.

Biotech KIEs' mobility at the regional, national and international level has massively increased between 2008 and 2022, though with a slowdown since 2020 possibly due to the COVID-19 pandemic. As a result, the inter-EE KIEs' mobility network has become larger (with a participation of more European regions) but also denser, as the ecosystems composing it have become more connected (Fig. 2). While this could be partially influenced by the presence of a larger number of

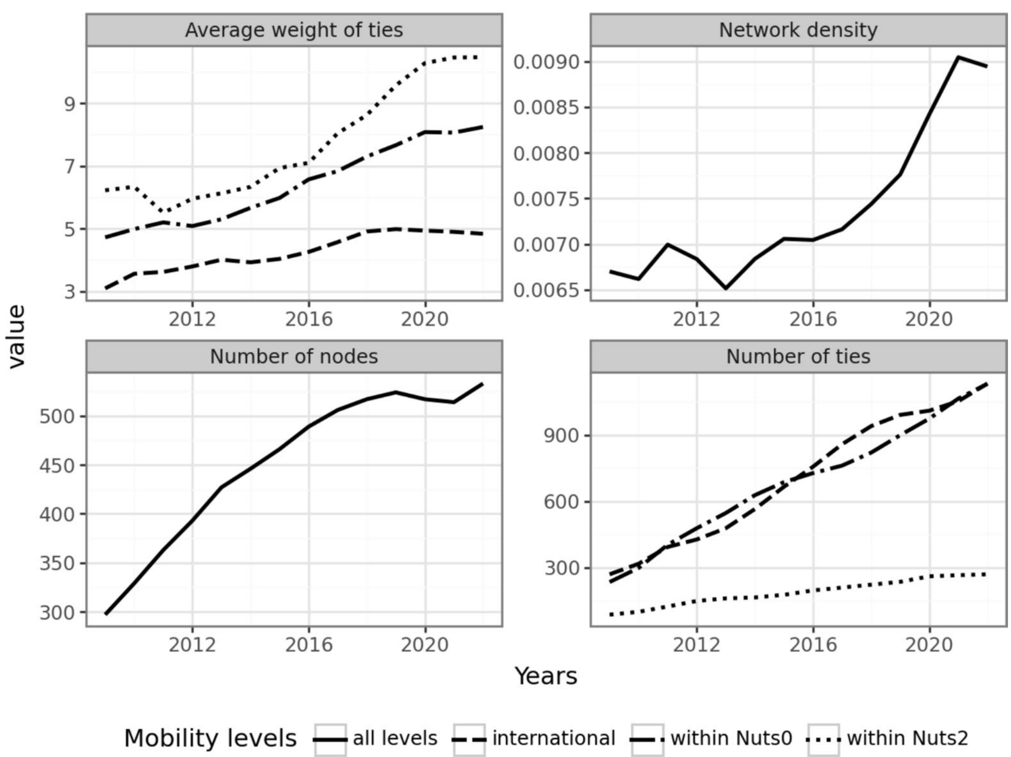

Fig. 2 Key indicators of network evolution. Own work

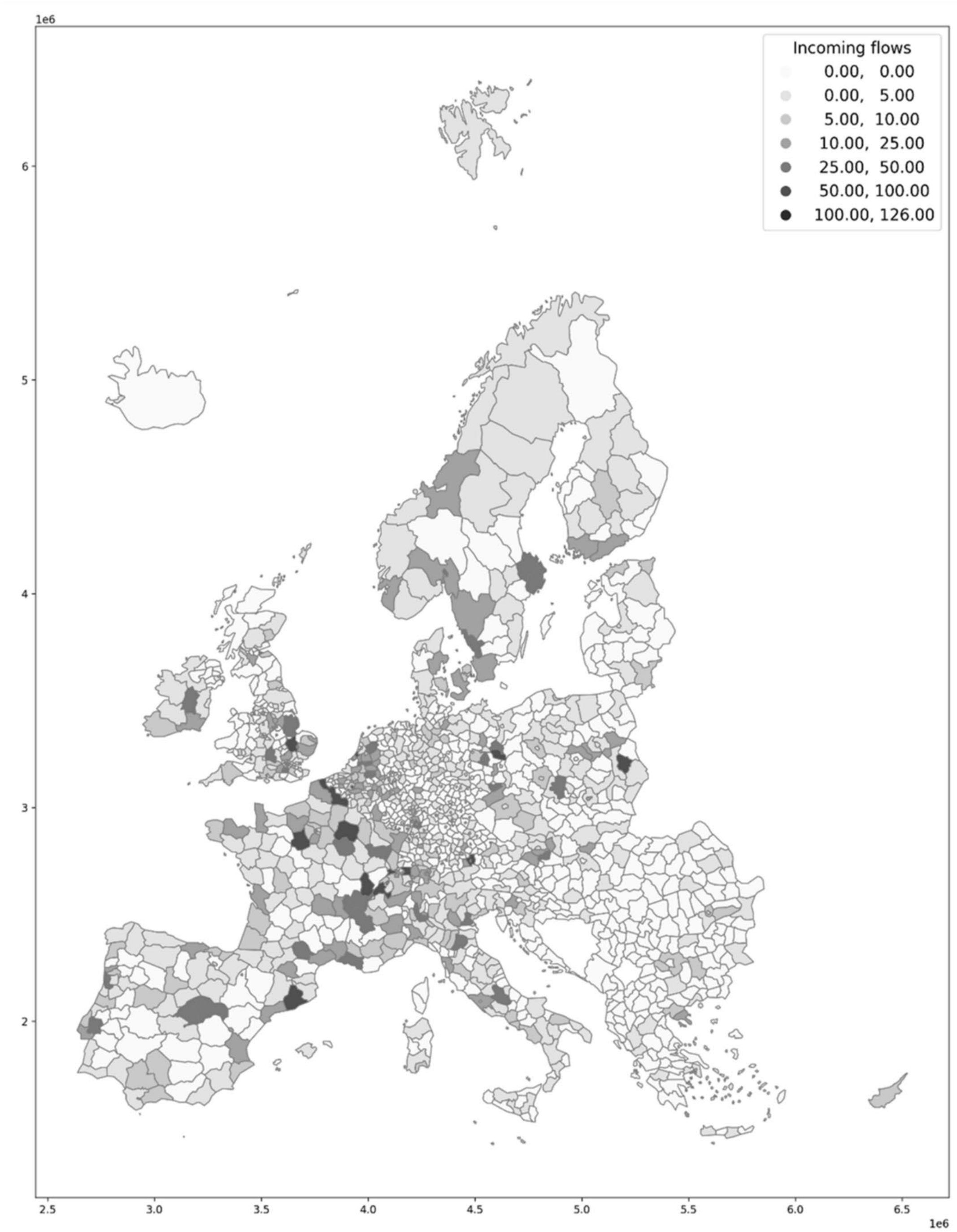

Fig. 3 Number of incoming flows by Nuts3 region. Own work

biotech KIEs and professionals in Europe (Lincoln, 2024; Startup Genome, 2022), it is likely also the result of the growing mobility of skilled professionals, lowering of transportation costs and increased economic integration in the area (Banerjee et al., 2019; Elo & Servais, 2018; Windzio et al., 2019). From trends concerning the number of inter-EE connections and their strength (Fig. 2), distinct dynamics were found to characterize the evolution of the mobility network at different spatial levels: a strengthening of existing connection at the regional level and the creation of weaker but numerous connections at the national and international one (Carayannis et al., 2018; Glick Schiller, 2015; Yamamura, 2023).

Results from the SAOM analysis point in the same direction (Table 1). The number of new enterprises displayed the highest effect on KIEs mobility, thus requiring to accept *H1.a EEs' productive entrepreneurship positively affects KIEs mobility*. This is not surprising, as Productive Entrepreneurship is the distinctive feature of EEs and reasonably also the most fundamental aspect considered by KIEs when seeking to relocate (Sousa & Silva, 2019). Conversely, results concerning Resource Endowments are mixed. Clear evidence of a positive effect was found for leaders, physical infrastructure[1] and talents, but excessive heterogeneity prevented any conclusions on finance and knowledge. Given that KIEs are expected to dedicate much of their energy on the acquisition of these two resources (Malerba & McKelvey, 2020), further research on the matter is necessary. A negative effect was found also for demand: since biotech companies are likely to sell their products globally or at least nationally, there is probably only limited need for a strong demand at the local level (Stam & van de Ven, 2021), hence KIEs may prefer smaller economies which would offer higher density of biotech-specific resources and actors (van de Ven, 1993). Accordingly, *H1.b EEs' availability of resource endowments positively affects KIEs' mobility* was partially accepted. Moving to the Institutional Arrangements component, results support that culture plays a role in attracting KIEs, while higher levels of formal institutions might deter it. This is surprising, as rule of law, low taxes and easy bureaucracy (World Bank n.d.) would be expected to attract KIEs. A potential explanation lies in the use of indicators at the national level as a large part of modelled mobility is intranational (Leal & Harder, 2021; Liñán et al., 2013). Last, local network also displayed a positive effect confirming the importance of actors' density (Meagher & Rogers, 2004; Ter Wal & Boschma, 2009). Accordingly, *H1.c EE's institutional arrangements positively affects KIEs' mobility* was partially supported. Overall, the factors driving entrepreneurship at the local level (Brown & Mason, 2014; Stam & van de Ven, 2021) were confirmed having differentiated effects on KIEs mobility.

Moving to the network structure component, an interesting picture emerges. On the one hand, path dependency explained only a small part of the creation of inter-EE ties. This is unexpected, as it suggests that KIEs dedicate limited attention to following the path of who preceded them and that particularly busy mobility routes and strong connections between EE pairs are unlikely (Azose & Raftery, 2019). Nonetheless, given the presence of at least some effect, *H2.a path dependency positively affects KIEs' mobility* was accepted. Second, even more surprisingly, indegree popularity was found having a negative effect on the creation of connections between EEs. The most likely explanation is in the existence of a crowding-out mechanism: though diversity of resources and connections are generally desirable for KIEs (Malerba, 2014), EEs receiving too many incoming flows from other EEs might result less absorbative and too competitive to newly incoming KIEs (Hao & Feng, 2016; Marques, 2008; Niosi & Bas, 2001). Accordingly, *H2.b Indegree popularity positively affects the KIEs' mobility* was rejected. Last, triplets transitivity displayed the most consistent and sizable effect right next to new enterprises. Combined with negative values for transitive reciprocated triplets and cycle triplets (Leal & Harder, 2021), it confirms that the formation of inter-EE connections is primarily driven by locally hierarchical mechanisms (Davis, 1970). Hence, *H2.c Triplet transitivity positively affects the KIEs' mobility* was accepted.

These factors explain the emergence of distinct dynamics in the mobility network. Given the costs still associated with relocating to physically or institutionally more distant EEs and of crowding-out mechanisms (Depret & Hamdouch, 2010), the

[1] A negative coefficient implies that KIEs' mobility is negatively correlated to the increasing road time between EEs (Table A2) a symptom of poor Physical Infrastructure.

majority KIEs' mobility happens at the local level under a hierarchical logic (Davis, 1970) though with many weaker long-distance connections at the national and international one. The result is a multiscalar structure in which denser regional inter-EE networks are connected to one another by national/international connections (Amin & Cohendet, 2005; Hamdouch, 2008; Motoyama & Knowlton, 2016; Oinas, 2002). The combination of these local EE elements (Stam and van de Ven 2021) and inter-EE structures (Ripley et al., 2017) determines the mobility of KIEs.

6 Conclusion

6.1 Theoretical implications

Leveraging career data and SAOM, this paper found that biotech KIEs' mobility across European EEs is a growing phenomenon characterized by multiscalar dynamics (Depret & Hamdouch, 2010; Motoyama & Knowlton, 2016). Hence, its methodological novelty has been fundamental to investigate KIEs network mobility and — at large — EE's connectedness and real-life spatial features (Fischer et al., 2022a, b; Gluckler, 2007; Schäfer, 2021). While these results suggest that KIEs' mobility is primarily a regional phenomenon, however, the "strength of weak ties" should not be overlooked (Granovetter, 1973). Further research should investigate the evolution of this "network of ecosystems" in different sectors (Hamdouch, 2008; Nicotra et al., 2018) and countries (Binz & Truffer, 2017), as well its implications for individual EEs. On the one hand, network positioning may influence resource recombination and productive entrepreneurship (Cooke, 2005; Depret & Hamdouch, 2010), as some EEs could be characterized by more endogenous entrepreneurial processes while others might be more dependent on exogenous ones (Binz & Truffer, 2017; Stephens et al., 2019). On the other, complementarity between closely connected EEs might emerge (Balland & Boschma, 2021; Rikap, 2019), and the role of EE super-connectors between regional networks would certainly require investigation (Saxenian, 1996; Waxell & Malmberg, 2007).

6.2 Managerial implications

This paper demonstrated that both local EE characteristics and inter-EE network features influence KIEs' mobility, and that — at least at the regional level — they operate as self-reinforcing mechanisms for KIEs aggregation (Depret & Hamdouch, 2010; Malerba, 2014). While policymakers can invest in creating ideal local conditions for the emergence of EEs, previous studies on the biotech sector have shown that network dynamics are harder to instantiate ex-novo (Orsenigo, 2001). Accordingly, while providing the necessary EE conditions, policy makers should also invest in attracting KIEs which — thanks to their multiple embeddedness (Duan et al., 2022) — could be major catalysers of innovation and entrepreneurship (Harima et al., 2021b; Lerner, 2010). This could be particularly relevant for Europe and the European Union, where policies directed at KIEs' mobility would be fundamental to increase innovation and productivity in a non-zero-sum logic (Ejermo et al., 2006; Liagouras, 2010; Lopes et al., 2021). Thought not focused on KIEs, the concept of inter-regional Smart Specialization could be the ideal policy ground to experiment in this direction (Balland & Boschma, 2021; Kruse & Wedemeier, 2022).

Answering to recent calls (Fischer et al., 2022a, b; Theodoraki & Messeghem, 2017), this study supports a more relational understanding of EEs and their processes at large (Brown & Mason, 2017). Thus, it provides an example of how mobility data might sustain this empirical and policy endeavour (Gluckler, 2007; Spinazzola et al., 2023), also favouring a convergence with existing literature on innovation ecosystems and global innovation networks (Alvedalen & Boschma, 2017; Binz et al., 2014; Carayannis et al., 2018).

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Declarations

Appendix

Table A1 Elements for the SOAM analysis

Element	Measurement	Source
New Enterprises	Number of new biotech enterprises	KIEs dataset
Demand	Gross Domestic Product	Eurostat, UKONS
Finance	Investments in biotech startups	Crunchbase
Intermediaries	NA	NA
Knowledge	Investments in Research and Development	Eurostat
Leaders	Number of organizations in European innovation projects	Cordis
Physical Infrastructure	Road time between EE pair	European Commission
Talents	Number of STEM workers	Eurostat
Culture	Belief in entrepreneurial opportunities	Global Entrepreneurship Monitor
Formal Institutions	Ease of Doing Business Index	World Bank
Local Network	Prevalence of KIEs over total population	KIEs network dataset
Indegree Popularity	Effect of incoming flows on additional incoming flows	KIEs network dataset
Path Dependency	Relocating KIEs between EE pair	KIEs network dataset
Transitive Triads	Effect of transitive triplets between EE pair	KIEs network dataset
Cyclic Triads	Effect of cyclical triplets between EE pair	KIEs network dataset
Border Crossing	Presence of a national border between EE pair	European Commission
Indegree Activity	Effect of incoming flows on additional outgoing flows	KIEs network dataset
Language	Shared official language between EE pair	European Commission
Outdegree Activity	Effect of outgoing flows on additional outgoing flows	KIEs network dataset
Outdegree Density	Probability of outgoing flows	KIEs network dataset
Population	Population	Eurostat
Reciprocity	Probability of reciprocity between EE pair	KIEs network dataset
Transitive Reciprocated Triads	Effect of transitive reciprocated triplets between EE pair	KIEs network dataset

Table A2 SAOM results for individual windows

2008–2013					2011–2016				
Effect	Coeff	St Error	Sig	T Stat	Effect	Coeff	St Error	Sig	T Stat
new_entCC alter	0.373	0.154	*	–0.022	new_entCC alter	0.505	0.148	***	0.023
demandCC alter	0.190	0.118		–0.004	demandCC alter	–0.150	0.073	*	0.057
financeCC alter	0.075	0.043	.	0.025	financeCC alter	0.007	0.031		0.017
knowledgeCC alter	–0.029	0.046		0.013	knowledgeCC alter	0.048	0.025	.	0.057
leadersCC alter	–0.036	0.037		0.001	leadersCC alter	–0.036	0.022	.	0.065
phys_infrCC	–0.195	0.141		–0.021	phys_infrCC	–0.227	0.088	**	0.043
talentsCC alter	0.001	0.179		–0.007	talentsCC alter	0.108	0.087		0.055
cultureCC alter	–0.021	0.024		0.063	cultureCC alter	0.028	0.023		0.006
ease_busiCC alter	0.328	0.148	*	–0.001	ease_busiCC alter	0.046	0.031		–0.034
kies_densityCC alter	0.071	0.191		0.004	kies_densityCC alter	0.361	0.077	***	–0.039
indegree - popularity	0.008	0.018		–0.020	indegree - popularity	–0.020	0.011	.	–0.010
path_depenCC	–0.024	0.010	*	0.008	path_depenCC	0.007	0.007		0.004
transitive triplets	0.399	0.068	***	0.032	transitive triplets	0.288	0.038	***	–0.010
3-cycles	0.152	0.141		0.020	3-cycles	0.157	0.073	*	–0.003
bord_crossCC	–1.034	0.174	***	–0.010	bord_crossCC	–0.643	0.115	***	–0.019
indegree - activity	0.205	0.225		–0.006	indegree - activity	0.082	0.037	*	–0.008
languageCC	0.363	0.164	*	0.063	languageCC	0.127	0.108		0.016
outdegree - activity	–0.007	0.083		0.007	outdegree - activity	–0.025	0.018		–0.016
outdegree (density)	–3.475	0.276	***	–0.028	outdegree (density)	–2.695	0.121	***	–0.012
populationCC alter	–0.198	0.508		–0.003	populationCC alter	0.405	0.334		0.055
reciprocity	2.998	0.192	***	0.012	reciprocity	2.814	0.126	***	–0.003
transitive recipr. triplets	–0.506	0.126	***	0.045	transitive recipr. triplets	–0.385	0.051	***	–0.011
2014–2019					2017–2022				
Effect	Coeff	St Error	Sig	T Stat	Effect	Coeff	St Error	Sig	T Stat
new_entCC alter	0.392	0.104	***	0.034	new_entCC alter	0.133	0.089		–0.022
demandCC alter	–0.030	0.061		0.020	demandCC alter	–0.104	0.064		0.026
financeCC alter	0.027	0.028		0.002	financeCC alter	–0.008	0.012		–0.024
knowledgeCC alter	–0.042	0.023	.	–0.014	knowledgeCC alter	–0.018	0.021		0.036
leadersCC alter	0.021	0.019		0.017	leadersCC alter	0.025	0.021		–0.026
phys_infrCC	–0.039	0.071		–0.052	phys_infrCC	–0.090	0.064		–0.035
talentsCC alter	0.115	0.076		0.000	talentsCC alter	0.127	0.071	.	0.020
cultureCC alter	0.034	0.012	**	0.013	cultureCC alter	0.019	0.011	.	–0.024
ease_busiCC alter	–0.002	0.029		–0.007	ease_busiCC alter	–0.029	0.017	.	–0.007
kies_densityCC alter	0.080	0.055		0.034	kies_densityCC alter	0.043	0.049		–0.038
indegree - popularity	–0.011	0.008		0.105	indegree - popularity	0.003	0.007		–0.060
path_depenCC	0.003	0.004		0.043	path_depenCC	0.017	0.005	**	–0.055
transitive triplets	0.204	0.031	***	0.110	transitive triplets	0.202	0.025	***	–0.063
3-cycles	0.057	0.054		0.104	3-cycles	–0.032	0.053		–0.054
bord_crossCC	–0.546	0.107	***	–0.053	bord_crossCC	–0.597	0.098	***	–0.022
indegree - activity	0.121	0.062	*	0.107	indegree - activity	–0.016	0.021		–0.062
languageCC	0.234	0.096	*	0.073	languageCC	0.229	0.091	*	0.018
outdegree - activity	–0.046	0.029		0.109	outdegree - activity	0.012	0.011		–0.067
outdegree (density)	–2.639	0.100	***	0.113	outdegree (density)	–2.658	0.100	***	–0.044
populationCC alter	–0.331	0.295		0.035	populationCC alter	–0.163	0.287		0.008
reciprocity	2.685	0.121	***	0.078	reciprocity	2.755	0.117	***	–0.019
transitive recipr. triplets	–0.225	0.034	***	0.102	transitive recipr. triplets	–0.171	0.030	***	–0.041

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