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Toward a complex adaptive system: The case of the Zhongguancun entrepreneurship ecosystem

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ABSTRACT

Viable entrepreneurship ecosystems (EEs), which provide sustainable competitive advantages to innovative regions, have become increasingly important for producing high-impact entrepreneurial firms. However, little is known about the complexity nature that viable EEs uncover under specific regional entrepreneurial contexts. By integrating the EE literature and complex adaptive system (CAS) theory, we conducted a case study on the Zhongguancun EE in China. We demonstrate six interrelated complexity properties of a viable EE: a large number of self-organized agents, nonlinear interactions, (in)sensitivity to initial conditions, adaptation to the environment, emergence of successful entrepreneurial firms, and coevolution. Moreover, the integration of these six complexity properties offers an overarching understanding of how the Zhongguancun EE maintained its viability over time. We contribute to the EE literature by developing a more nuanced complexity-based understanding of a viable EE and extend CAS theory at the ecosystem level by highlighting an EE's adaptive process to maintain its viability.

1. Introduction

In recent years, regional entrepreneurship and innovation policies have changed their focus from stressing entrepreneurship quantity (i.e., the number of new firms and self-employment rate) to entrepreneurship quality (i.e., entrepreneurial firms with high growth potential) (Acs, Stam, Audretsch, & O'Connor, 2017; Brown & Mason, 2017; O'Connor, Stam, Sussan, & Audretsch, 2017). Following such policy transitions, Entrepreneurship Ecosystem (EE), which is defined as "a set of interdependent actors and factors coordinated in such a way that they enable productive entrepreneurship within a particular territory" (Stam, 2015, p. 1765), shifted its focus to individual entrepreneurs and the entrepreneurial contexts in which they are embedded (Acs, Autio, & Szerb, 2014; Autio, Kenney, Mustar, Siegel, & Wright, 2014). Given the strategic role of EEs in promoting sustainable economic competitiveness, there is a consensus among various governmental agencies to create and sustain well-functioning EEs in the innovative regions (Mason & Brown, 2014).

Although the concept of EE has attracted increasing research attention, the complexity of its nature is not well understood by the extant research (Brown & Mason, 2017). First, little is known about nonlinear synergies among EE components. Previous studies have documented the necessary entrepreneurial components for a viable EE[1] (Autio & Levie, 2017; Feld, 2012; Isenberg, 2014; Mason & Brown, 2014) and examined how synergetic interactions among these EE components lead to performance variance (Colombelli, Paolucci, & Ughetto, 2017; Spigel, 2015). However, it has been observed that EEs with the same components may demonstrate different performances in terms of producing successful entrepreneurial firms (Spigel, 2015) because EE outcomes (i.e., high impact entrepreneurship) depend on the components' diversity and coherence (Roundy, Brockman, & Bradshaw, 2017), and they often should be explained by nonlinear *multicausalities*

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[1] In this paper, a viable EE refers to an EE that has the system-level ability to give rise to successful entrepreneurial firms (Acs et al., 2017; Brown & Mason, 2017; Mason & Brown, 2014; Stam, 2015).

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(Alvedalen & Boschma, 2016; Stam, 2015).

Second, scholars have applied the process perspective to EE development (Goswami, Mitchell, & Bhagavatula, 2018; Letaifa & Rabeau, 2013; Mack & Mayer, 2016; Spigel & Harrison, 2018). However, the theorization from the process perspective needs further understanding. Although life cycle theory dominates the current discussion, some viable EEs have been found to take a *discontinuous* path to becoming resilient to their environments (Auerswald & Dani, 2017; Roundy et al., 2017) rather than following a predesigned evolutionary route from birth to decline (Malecki, 2018).

Third, EE is partially a location-bounded phenomenon. Most of the literature argues that territory specificity is a defining feature of EE and sets the research boundaries of EEs to either certain nations, subnational regions, or city areas (e.g., Goswami et al., 2018; Mack & Mayer, 2016; Spigel, 2015). However, emerging research suggests that digital infrastructure and technologies reduce entrepreneurship spatial dependence (e.g., Autio, Nambisan, Thomas, & Wright, 2018; Sussan & Acs, 2017). EEs should therefore be considered using *multidimensional* geographic scales.

Taken together, the complexity nature of EEs in terms of multicausality, discontinuity, and multidimensionality remains largely underexplored in the existing literature. Some scholars have separately discussed EE complexity properties, leading to a fragmented view (see discussion in Isenberg, 2016; O'Connor et al., 2017). Recent works building on Complex Adaptive System (CAS) theory have offered a more complete view of the complexity properties shared by EEs and discussed how these properties relate to the birth of EEs (Aeeni & Saeedikiya, 2019; Roundy, Bradshaw, & Brockman, 2018). However, these conceptual endeavors failed to provide any empirical evidence of complexity-based EEs and were rather constrained to the EE birth stage.

To address these research gaps, in the present paper, we aim to offer empirical insights into complexity-based EEs by answering the following research question: how can an EE uncover its complexity properties across different developmental stages to maintain its viability? We conduct a qualitative case study of the Zhongguancun Science Park (hereinafter referred to as the Zhongguancun EE), a viable EE located in Beijing, China (cf. Du, Pan, Zhou, & Ouyang, 2018; Li, Du, & Yin, 2017). The Zhongguancun EE is considered a viable EE because over 70 unicorns (i.e. high impact entrepreneurial firms valued at more than $1 billion)[2] were born there from 2012 to 2018. This EE has become viable through four distinct developmental stages since its genesis in the 1980s; simultaneously, its increasing level of complexity—that is, the multiplicity, diversity, and multilateral interactions of EE agents—supports to our intention to apply CAS theory. Following the recommended procedures for qualitative data analysis (Gioia, Corley, & Hamilton, 2013; Strauss & Corbin, 1990), we identify six interrelated complexity properties that the Zhongguancun EE exhibits: a large number of self-organized agents, nonlinear interactions, (in)sensitivity to initial conditions, adaptation to the environment, emergence of successful entrepreneurial firms, and coevolution. In addition, we integrate these six complexity properties as an overarching framework to offer a complexity-based understanding of a viable EE.

Our study contributes to the current EE literature by providing a more nuanced understanding of the interrelated complexity properties of a viable EE. In line with Roundy et al. (2018), we confirm that a large number of self-organized agents and their nonlinear interactions build the foundation for viable EEs. We complement Roundy et al. (2018) study by showing that although EEs may be sensitive to initial conditions at early developmental stages that could cause evolutionary path dependence, viable EEs can avoid such sensitivity by improving their environmental adaptability. Moreover, our findings indicate that the emergence of successful entrepreneurial firms results from EE agents' collective endeavors, which in turn encourages EE agents to adjust their entrepreneurial activities. Finally, although EEs have open geographic boundaries; boundary openness should operate at multidimensional geographic scales.

Our study also extends CAS theory to the ecosystem level in two ways. First, the development and management of a viable EE depends on (1) nonlinear interactions among EE agents through positive feedback loops, (2) its environmental adaptability, and (3) diverse EE agents exchanging entrepreneurial resources and coevolving in multidimensional geographic boundaries. Second, a viable EE maintains a balanced level of complexity to produce successful entrepreneurial firms through the adaptive development process. Overall, our findings support the idea that CAS theory is a useful lens through which to understand the complexity properties of EEs and provide useful policy implications for entrepreneurship and innovation policies that enable viable EEs.

2. Literature review

2.1. Overview of EEs: Main ideas and the challenges of complexity

The value of the EE concept lies in its systemic features (Brown & Mason, 2017; Malecki, 2018; Stam, 2015), which help to explain how entrepreneurial actors—including individuals, organizations, and institutions—interact to produce various entrepreneurial activities in certain economic and institutional contexts (Acs et al., 2014; Autio et al., 2014; Garud, Gehman, & Giuliani, 2014). We observed that there are at least three schools consolidating EE's systemic features, discriminating them from the perspective of similar phenomena, such as national/regional innovation systems, innovation/industrial clusters, innovation milieu, and innovation ecosystems (cf. Autio et al., 2018). Specifically, *systemic components* indicate what participatory elements are included in a viable EE (Cohen, 2006; Isenberg, 2011; Spigel, 2015). *Systemic processes* help us understand how an EE develops over time (Auerswald & Dani, 2017; Mack & Mayer, 2016; Spigel & Harrison, 2018). And *systemic governance structures* explicate how an EE can be shaped to create successful entrepreneurship (Audretsch & Link, 2019; Colombo, Dagnino, Lehmann, & Salmador, 2019; Cumming, Werth, & Zhang, 2019).

Although fruitful, the current EE research faces several challenges (see Cavallo, Ghezzi, & Balocco, 2018; Stam, 2015). In particular, there is a lack of a theoretical framework to simultaneously examine the systemic components, processes, and governance structures. As EEs are complex, variegated, and temporally discontinuous phenomena, such a framework is therefore warranted. In other words, current research frameworks in the EE literature fail to comprehend the full complexity of these organisms (Brown & Mason, 2017). A holistic guiding framework is important because "construing ecosystems as complex categories can allow for more conceptually robust and relevant applications" (Spigel & Harrison, 2018, p. 158). Specifically, we argue that holistic insights into the complexity nature of EEs will help clarify conceptual ambiguities, solve empirical problems, and, more importantly, facilitate policy.

2.2. EEs as complex adaptive systems

Complex adaptive system (CAS) theory (Anderson, 1999; Lewin, 1999) may be useful for shedding light on the conceptualization of EEs and addressing challenges related to comprehending the complexity nature of an EE (i.e., multicausality, discontinuity, and multidimensionality) for several reasons. First, as a subset of system and chaos theory, CAS theory is advantageous for explaining how complex causes can produce simple effects or how simple rules can have unpredictable consequences (Anderson, 1999), which is relevant to phenomena such as EEs (Ritala & Gustafsson, 2018). Second, EEs share patterns with general CAS in biology (e.g., a flock of birds or an ant

[2] The complete list of unicorn companies. https://www.cbinsights.com/research-unicorn-companies. Accessed 12 September 2018.

colony) that include three fundamental elements: agents, interactions, and the environment (Acs et al., 2014; Dooley, 1997; Mitleton-Kelly, 2003). Third, recent work offers a complete set of complexity properties that a CAS shares with an EE (Aeeni & Saeedikiya, 2019; Roundy et al., 2018). Six properties are proposed to address problems, paradoxes, and ambiguities in EE research: emergence through "self-" organization, open-but-distinct boundaries, complex components, nonlinear dynamics, adaptability through dynamic interactions, and sensitivity to initial conditions (cf. Roundy et al., 2018).

2.2.1. Emergence through "self-" organization

According to CAS theory (e.g., Anderson, 1999), the complexity of CAS is largely attributed to numerous heterogeneous agents who interact with each other with different features and objectives. The agents in an EE are derived from six interdependent components: finance, markets, human capital, supports, culture, and policy (e.g., Isenberg, 2011). The six components can be further integrated into an analysis at the micro-, meso-, and macro levels (Berger & Kuckertz, 2016), that is, finance, markets, and human capital as microfoundations together with supports and policy at the meso level nurture new firm creation. Furthermore, EE components at the micro and meso levels communicate frequently, which in turn form the macro environment (level) including intangible schemata such as entrepreneurial climate, social/cultural norms, conventions, and advocated entrepreneurial spirits. The communication rules and principles influencing each agent are relatively coherent and change incrementally. During this process, EE agents and related entrepreneurial resources may enter or exit while the schemata remain stable, and new schemata may appear based on self-organized agents' interactions without any interventions by central organizer(s) (Feld, 2012; Isenberg, 2016; Spigel & Harrison, 2018).

2.2.2. Open-but-distinct boundaries

A CAS is not a stable and closed system but a dynamic and open system with fluid boundaries (Kauffman & Strohman, 1994). Mitleton-Kelly (2003, p. 32) stated that CASs are "open systems that exchange energy, matter, or information with their environment, and when pushed 'far-from-equilibrium', create new structures and order". Similarly, an EE also has open-but-distinct boundaries. On the one hand, an EE's boundaries are open because the new entrepreneurial resources that flow into the EE can increase agent diversity, which produces more new entrepreneurial activities while driving redundant entrepreneurial resources out of the EE (Spigel & Harrison, 2018). On the other hand, an EE's sociocultural boundaries are clear and relatively stable. As noted earlier, both new and established agents share common intangible schemata (rule sets, logics, and values) that guide their respective entrepreneurial actions (Roundy, 2016). As such, agents who do not demonstrate certain sociocultural elements are treated as EE outsiders.

2.2.3. Complex components

To understand a CAS, we must consider its two opposing features: diversity and unity. Diversity in a CAS not only refers to the multiplicity of agents but also reflects their interactive relationships. For example, agents who randomly change their individual objectives and actions will have new interactive relationships with others. However, when examined at the system level, agents can be integrated into different components with relatively unified principles and attributes (Mitleton-Kelly, 2003).

In a viable EE, ecosystem agents can easily change their roles (for instance, investors become entrepreneurs) and may have multiple roles at one time (an incubator can simultaneously act as an entrepreneurial service provider and an angel investor). However, EE agents at different levels (micro, meso, and macro) (Berger & Kuckertz, 2016; Stam, 2015; Theodoraki & Messeghem, 2017) and as different components (governments, investors, and incubators) (Spigel, 2015) are relatively identifiable.

2.2.4. Nonlinear dynamics

Beyond linear causal models in mathematics, CAS is grounded in the mechanism by which inputs from interacting agents lead to disproportional outcomes (Morel & Ramanujam, 1999). Kauffman (1996) argued that the nonlinearity from inputs to outputs is determined by the degree of agents' diversity and connectedness. Brown and Mason (2017, p. 15) stated that "A key feature of ecosystems is nonlinearity". Considering the nature of nonlinearity, the process of combining all entrepreneurial resources is thus untraceable due to multidirectional causalities (Isenberg, 2016). Nevertheless, we can view EE performance through two different mechanisms: positive and negative feedback loops among (sub)components (McKelvey, 2004). Positive feedback loops suggest that changes in certain components amplify the benefits to others in a recursive fashion. Brown and Mason (2017) describe positive feedback loops as success breeding greater success. Instead of triggering infinite changes, negative feedback loops predict that interacting components move one or all components toward a steady state (Roundy et al., 2018; Stacey, 1995).

2.2.5. Adaptability through dynamic interactions

CASs, such as the human immune system, are stimulated to improve their adaptability, which is defined as a system's capacity to adjust to internal struggles and external threats without endangering its essential function (Chiva, Grandío, & Alegre, 2010). For this purpose, a CAS will remain in a quasi-equilibrium state that helps it produce a better solution (new structures through agent entry, exit, and transformation) to survive (Anderson, 1999; Choi, Dooley, & Rungtusanatham, 2001; Dooley, 1997).

In the EE context, "system-level adaptability emerges from behaviors at lower levels, even as the agents comprising those levels are themselves influenced by system-level changes" (Roundy et al., 2018, p. 4). The internal adaptation process refers to a small event caused by agent interactions that can trigger a cascade of changes and eventually cause system-level behavior. In turn, this process directs EE agents to modify their internal rules and evaluation criteria for fitness—at least temporarily (Kauffman & Strohman, 1994; McCarthy, Tsinopoulos, Allen, & Rose-Anderssen, 2006; Surana, Kumara, Greaves, & Raghavan, 2005). The external adaptation process refers to external disturbances that cause adaptive reactions from EE agents, who accordingly readjust internal diversity and coherence in an accumulated way (e.g., Auerswald & Dani, 2017; Radinger-Peer, Sedlacek, & Goldstein, 2018).

2.2.6. Sensitivity to initial conditions

"The feedback loops and nonlinear relationships create a condition called sensitivity to initial conditions—which results in unpredictability" (Aydinoglu, 2013, p. 6). Sensitivity to initial conditions can help us understand how a CAS achieves its current state via evolutionary path dependence (i.e., new path creation is the result of new combinations based on, and limited by, historical system structures) (Neffke, Henning, & Boschma, 2011).

The extant EE research has confirmed this path-dependence feature (see Radinger-Peer et al., 2018). Early entrepreneurship success (especially well-known entrepreneurs) in EE offers experiences, role models, and entrepreneurial resources for prospective entrepreneurs who will make use of these advantages to promote more successes. In this respect, early entrepreneurial activities pass on *genes* to followers. Combinations of early entrepreneurs' previous ideas are further embedded into the EE and, as a whole, shape future entrepreneurial behaviors. As a result, the diversity of initial EE components can significantly impact its future state (Nylund & Cohen, 2017). By contrast, if past decisions by EE agents focus on a single type of entrepreneurship, these decisions might crowd out other ideas, and the EE might become susceptible to environmental shocks (Brown & Mason, 2017; Roundy et al., 2018). This holds especially true for EEs dominated by a single big firm (Bhawe & Zahra, 2019; Gray, Golob, & Markusen, 1996) or a single industry (Kenney & von Burg, 1999; Spigel, 2015).

3. Methods

We adopted the case study method based on two considerations. First, multiple qualitative data sources and theory-driven data analysis are preferable for studying CAS in different organizational forms (e.g., Brown & Eisenhardt, 1997; McCarthy et al., 2006; Roundy et al., 2018). Second, the case study method has a distinct advantage in situations in which "how" or "why" questions are being asked about events and activities over which the investigators have little to no control (Yin, 2013). Our research question was precisely driven by a retrospective, in-depth analysis of multiagent activities and critical events as well as the development of a viable EE.

We selected the Zhongguancun EE located in Beijing as an appropriate research context for two reasons. First, the Zhongguancun EE has been transformed from an entrepreneurship policy-driven EE into a self-organized ecosystem. During this transformation process, the dispersed Zhongguancun EE agents have become more coherent and are specifically promoted by an inclusive entrepreneurship culture, high-quality human resources, supportive innovation policies, emerging markets, diverse financial agencies, and integrated digital infrastructures (Dong, Hu, Yin, & Kuo, 2019). As a result, the Zhongguancun EE changes from an environment that solely sells electronic products to one that nurtures innovative start-ups (Du et al., 2018). Additionally, such a transformational process features an increasing level of complexity (i.e., agent connectivity, diversity, ambiguity, and dynamicity) in the Zhongguancun EE, which supports our intention to apply CAS theory (de Toni & de Zan, 2016). Second, rich secondary data from various available sources, such as news on websites, newspapers, magazines, videos, books, and academic papers, can provide a holistic view of the Zhongguancun EE and hence be utilized to validate our research findings (van de Ven, 2007; Yin, 2013).

3.1. Description of the Zhongguancun EE

The Zhongguancun EE has been one of the most viable innovation centers in the world and has pioneered many disruptive innovations.[3] Over the last three decades, the Zhongguancun EE has been increasingly expanding its geographic boundary to cover approximately 500 square kilometers and has gathered over 20,000 high- and new-tech enterprises residing in 11 major industry sectors, such as mobile Internet, biomedicine, new energy and environmental protection, new materials, advanced intelligent manufacturing, aerospace engineering, and IT-related services (Dong et al., 2019). Moreover, according to the Zhongguancun Index 2018, the number of patents granted per ten thousand people soared from 1.4 in 2001 to 74.2 in 2017, indicating a trend of active entrepreneurial or innovative activities in the Zhongguancun EE. The EE has achieved the viability to produce high-growth entrepreneurial firms (76 unicorns from 2012 to 2018) through four developmental stages, where the diversity and coherence of Zhongguancun EE agents show periodical features. The four developmental stages and their distinct features are elaborated on in a chronological manner in Fig. 1.

3.2. Data collection

Our data were drawn mainly from 23 group interviews complemented by six types of secondary data, namely, news/industrial articles, online audio and videos, public reports and yearbooks of the Zhongguancun EE, the corresponding author's participatory observations, extensive discussions with experts and practitioners, and industry meeting reports. These secondary data are helpful because they offer very accurate numbers as well as details that complement or contradict interviewees' narratives, thereby allowing for data triangulation (Jick, 1979). In total, we obtained 36.2 hours of recorded interviews and 1443 pages of secondary data resources (excluding yearbooks and academic books).

Primary data was collected via face-to-face interviews with 23 entrepreneurs or senior managers/administrators at the Zhongguancun EE (see Table 1). These representative interviewees were conducted between May and November 2014 under the guidance of the Zhongguancun Administrative Committee (ZAC), a specialized quasi-political agency responsible for managing annual entrepreneurship and innovation information (Du et al., 2018). The 23 interviewees were distributed across six main EE components as categorized by Isenberg (2011). To anonymize our interviewees, we rename them following Isenberg (2011)'s categorization of EE components. For example, among our interviewees, we have two agents from culture components who are coded as culture 1 and culture 2. In this way, we can offer a complete overview of the Zhongguancun EE by combining complementary perspectives from each component. In addition, such high-level interviewees with decades of entrepreneurial experience who have remained within the Zhongguancun EE ensured that we could capture the most informed qualitative data (especially at the policy level).

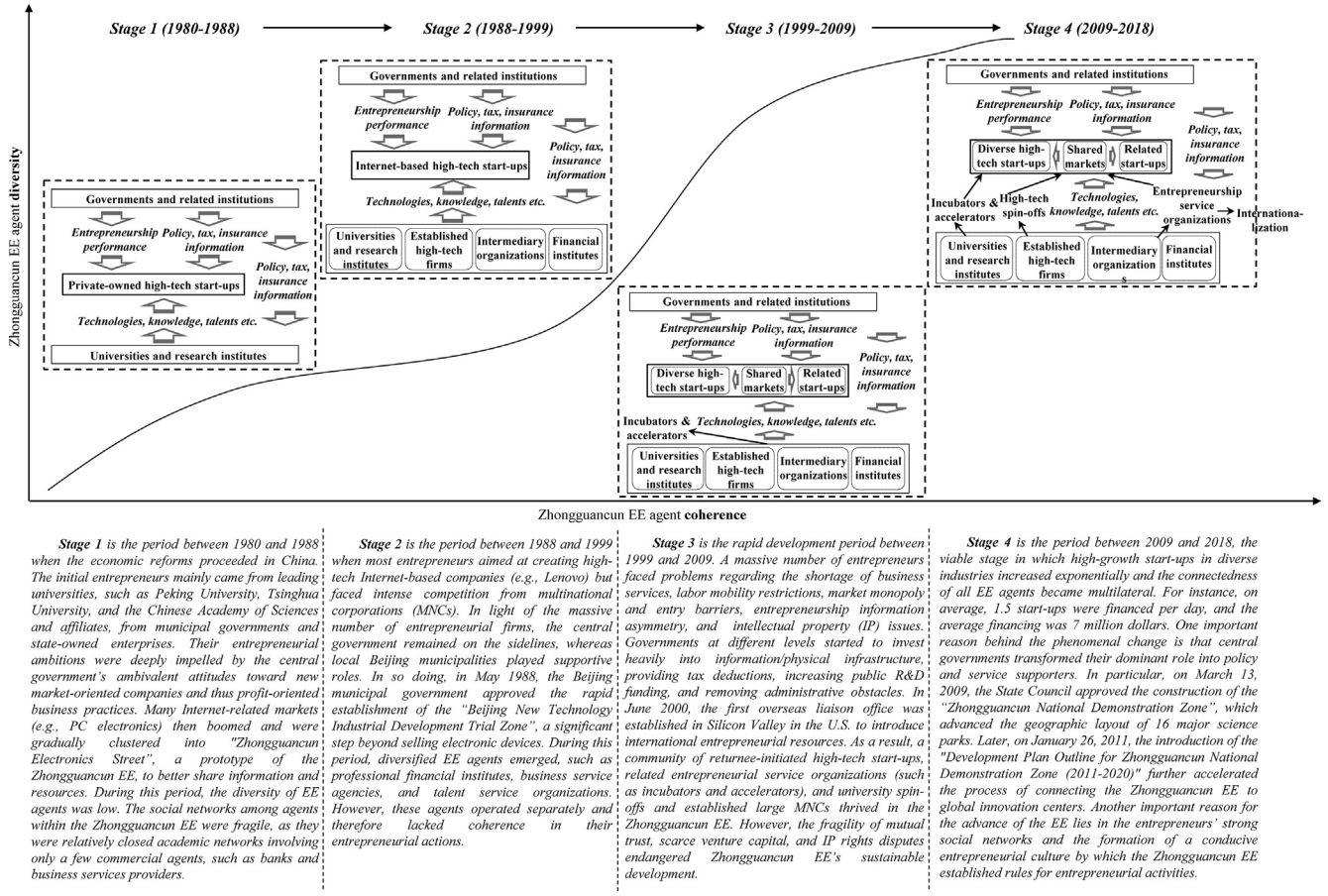
Each anonymously recorded interview involved multiple interviewers and was based on a standardized interview protocol to ensure data reliability (Strauss & Corbin, 1990). Multiple interviewers, including the corresponding author, senior ecosystem experts/scholars, and industrial practitioners, made it possible to collect answers from both academic and practical angles. The interview protocol, which consisted of three main sections, was frequently adjusted according to each interviewee's real-time responses. Specifically, the first section focused on the personal and organizational background of the interviewee. If the interviewee was an entrepreneur, he or she was asked to report on his or her entrepreneurial experience/history and his or her start-up's operating conditions. The second and key section focused on how the interviewees (and the organizations to which they belong) interacted with different EE agents to undertake entrepreneurial activities, on important changes in different industrial contexts in which they have been embedded in recent years, on critical entrepreneurial events or activities that have marked the development of the Zhongguancun EE, and on their evaluations of various agents' (finance, policy, and talent) roles in enabling the success of the Zhongguancun EE. The interview design for the second section allows us to keep a close eye on the three basic elements of a CAS: agents, their interactions, and environments in which multiple interactions occur (Dooley, 1997). The third section asked the interviewees to provide advice on how the Zhongguancun EE could better support future high-impact entrepreneurship.

Diverse secondary data were compiled by the first author to complement and triangulate the primary interview data. This approach further validated our research findings (Jick, 1979; Jonsen & Jehn, 2009). We stopped collecting secondary data when theoretical saturation was achieved (Eisenhardt, 1989; Yin, 2013). Finally, interview data, which were transcribed verbatim in Chinese, together with all secondary data were coded and analyzed using NVivo 11 software.

3.3. Data analysis

All four authors participated in the data analysis via multiple discussions, following the recommended procedures for qualitative research and grounded theory (Gioia et al., 2013; Strauss & Corbin, 1990). In this procedure, researchers are permitted to identify complexity properties to advance the data analysis process (Eisenhardt, 1989). Specifically, we adopted an iterative coding process that involved identifying emerging concepts, examining empirical evidence for supports, consolidating similar concepts to create refined themes,

[3] See more research settings on Zhongguancun EE: http://zgcgw.beijing.gov.cn/ and https://assets.kpmg.com/content/dam/kpmg/tw/pdf/2017/04/changing-landscape-disruptive-tech-2017.



Stage 1 *is the period between 1980 and 1988 when the economic reforms proceeded in China. The initial entrepreneurs mainly came from leading universities, such as Peking University, Tsinghua University, and the Chinese Academy of Sciences and affiliates, from municipal governments and state-owned enterprises. Their entrepreneurial ambitions were deeply impelled by the central government's ambivalent attitudes toward new market-oriented companies and thus profit-oriented business practices. Many Internet-related markets (e.g., PC electronics) then boomed and were gradually clustered into "Zhongguancun Electronics Street", a prototype of the Zhongguancun EE, to better share information and resources. During this period, the diversity of EE agents was low. The social networks among agents within the Zhongguancun EE were fragile, as they were relatively closed academic networks involving only a few commercial agents, such as banks and business services providers.*

Stage 2 *is the period between 1988 and 1999 when most entrepreneurs aimed at creating high-tech Internet-based companies (e.g., Lenovo) but faced intense competition from multinational corporations (MNCs). In light of the massive number of entrepreneurial firms, the central government remained on the sidelines, whereas local Beijing municipalities played supportive roles. In so doing, in May 1988, the Beijing municipal government approved the rapid establishment of the "Beijing New Technology Industrial Development Trial Zone", a significant step beyond selling electronic devices. During this period, diversified EE agents emerged, such as professional financial institutes, business service agencies, and talent service organizations. However, these agents operated separately and therefore lacked coherence in their entrepreneurial actions.*

Stage 3 *is the rapid development period between 1999 and 2009. A massive number of entrepreneurs faced problems regarding the shortage of business services, labor mobility restrictions, market monopoly and entry barriers, entrepreneurship information asymmetry, and intellectual property (IP) issues. Governments at different levels started to invest heavily into information/physical infrastructure, providing tax deductions, increasing public R&D funding, and removing administrative obstacles. In June 2000, the first overseas liaison office was established in Silicon Valley in the U.S. to introduce international entrepreneurial resources. As a result, a community of returnee-initiated high-tech start-ups, related entrepreneurial service organizations (such as incubators and accelerators), and university spin-offs and established large MNCs thrived in the Zhongguancun EE. However, the fragility of mutual trust, scarce venture capital, and IP rights disputes endangered Zhongguancun EE's sustainable development.*

Stage 4 *is the period between 2009 and 2018, the viable stage in which high-growth start-ups in diverse industries increased exponentially and the connectedness of all EE agents became multilateral. For instance, on average, 1.5 start-ups were financed per day, and the average financing was 7 million dollars. One important reason behind the phenomenal change is that central governments transformed their dominant role into policy and service supporters. In particular, on March 13, 2009, the State Council approved the construction of the "Zhongguancun National Demonstration Zone", which advanced the geographic layout of 16 major science parks. Later, on January 26, 2011, the introduction of the "Development Plan Outline for Zhongguancun National Demonstration Zone (2011-2020)" further accelerated the process of connecting the Zhongguancun EE to global innovation centers. Another important reason for the advance of the EE lies in the entrepreneurs' strong social networks and the formation of a conducive entrepreneurial culture by which the Zhongguancun EE established rules for entrepreneurial activities.*

Fig. 1. Developmental stages of the Zhongguancun EE.
Source: authors.

Table 1
An overview of interviewees.

Item	Date (2014-)	Number of Interviewers	Interviewee Position (Institution)	Belonging to EE Components	Code	Duration (min)
1	05–15	3	Co-founder (Accelerator)	Culture	*co-founder, Culture 1*	110 min
2	05–15	5	Co-founder (Incubator)	Culture	*co-founder, Culture 2*	90 min
3	05–15	3	Co-founder (Incubator)	Supports	*co-founder, Supports 1*	100 min
4	05–27	3	Co-founder (Venture capital)	Finance	*co-founder, Finance 1*	100 min
5	05–29	3	Co-founder (Venture capital)	Finance	*co-founder, Finance 2*	80 min
6	06–19	5	Founder (Incubator)	Supports	*founder, Supports 2*	70 min
7	06–19	2	Director (Incubator & Accelerator)	Supports	*director, Supports 3*	105 min
8	06–19	4	Co-founder (Entrepreneurship service provider and incubator)	Supports	*co-founder, Supports 4*	130 min
9	06–24	5	Chairperson (Venture capital)	Finance	*chairperson, Finance 3*	130 min
10	06–24	4	Co-founder (Mobile Internet social app)	Markets	*co-founder, Markets 1*	90 min
11	06–24	5	Founder (Car-sharing service)	Markets	*founder, Markets 2*	80 min
12	07–04	4	Co-founder (Venture capital)	Finance	*co-founder, Finance 4*	90 min
13	07–18	2	Section Chief (ZAC)	Policy	*section chief, Policy 1*	80 min
14	07–24	4	Senior Consultant (Research institute)	Human Capital	*senior consultant, Human Capital 1*	100 min
15	07–30	4	CEO (Online gaming)	Markets	*CEO, Markets 3*	80 min
16	07–30	4	CEO (Incubator)	Supports	*CEO, Supports 5*	120 min
17	08–01	4	Vice President (Venture capital)	Finance	*vice president, Finance 5*	100 min
18	08–01	4	Secretary General (Chamber of Commerce)	Supports	*secretary general, Supports 6*	85 min
19	08–29	3	President Assistant (Commercial bank)	Finance	*president assistant, Finance 6*	110 min
20	08–29	2	Co-founder (Legal service)	Supports	*co-founder, Supports 7*	76 min
21	09–03	3	CEO (Financing guarantee/service)	Supports	*CEO, Supports 8*	70 min
22	10–28	3	CEO (High-tech electrics)	Markets	*CEO, Markets 4*	90 min
23	11–05	3	Executive Director (University)	Human Capital	*executive director, Human Capital 2*	80 min

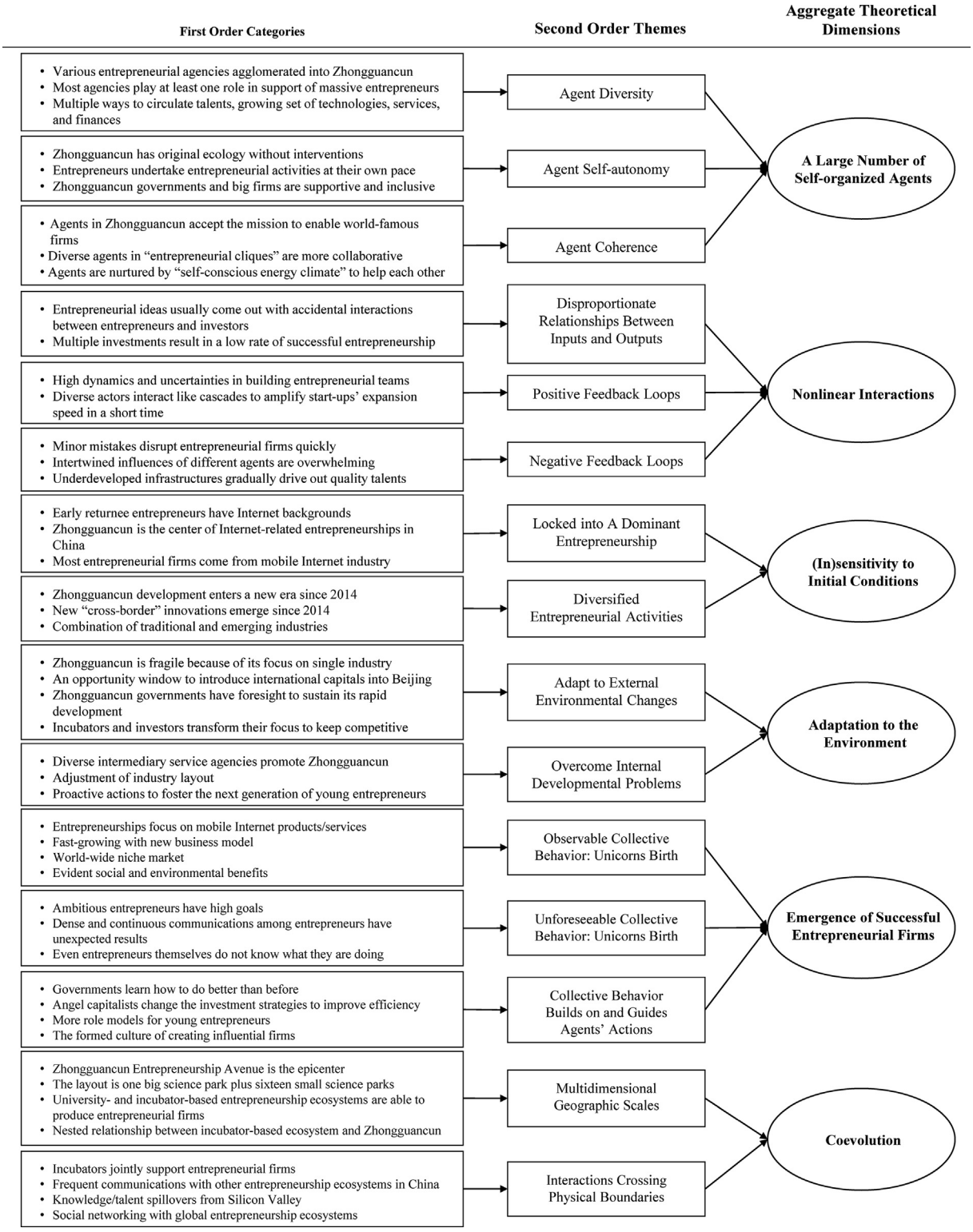


Fig. 2. Data structure: the complexity-based Zhongguancun EE.

and collecting more data until reaching theoretical saturation. An overview of the data structure is illustrated in Fig. 2.

The initial data analysis was based on three stages: open, axial, and selective coding (Strauss & Corbin, 1990). During the open coding stage, using the proposed complexity properties for guidance, the first, second and fourth author independently coded all the data sentence-by-sentence and remained open to what the qualitative materials suggested. This approach ensured that the coders interpreted the data in a similar fashion without missing any emergent information. Although acting independently, we regularly stopped and discussed the coding issues to arrive at a common set of codes. We initially identified 850 codes, each supported by two or more text segments. During the axial coding stage, three authors collated first-order codes that were conceptually similar and relevant to our themes. In addition, the corresponding author played the role of "censor" in group meetings to critically question or challenge the themes determined by the three open

coders to improve data validity. Finally, during the selective coding process, conforming closely to the method suggested by Gioia et al. (2013), we strived to aggregate the identified themes into dimensions, thus formulating a coherent and insightful account of the complexity-based Zhongguancun EE. This stage was again guided by the established CAS literature, as we looked for matched empirical evidence in the data and new insights into the Zhongguancun EE using the six complexity properties (Roundy et al., 2018).

Additional coding and interviewing efforts were made in late 2018 until theoretical saturation was reached. We returned to the dataset in NVivo 11 to improve the consistency of the research results by addressing some information gaps. In cases of confusion or inconsistencies, we triangulated among all the interviewers and authors and, when necessary, checked factual information with key insiders at the Zhongguancun EE by email or phone call. We then began to develop our write-ups; the relevant parts of these were read and commented on by key interviewees and adjusted accordingly. Through this process, our analysis was grounded in qualitative data and internally consistent. Ultimately, we felt confident in the six revealed complexity properties as well as their integral relationships in the case of the Zhongguancun EE.

4. Results

Our analysis revealed six interrelated complexity properties that a viable EE exhibits: a large number of self-organized agents, nonlinear interactions, (in)sensitivity to initial conditions, adaptation to the environment, emergence of successful entrepreneurial firms, and coevolution. In the following section, we elaborate on each complexity property in more detail.

4.1. A large number of self-organized agents

Our data reveal that the viability of the Zhongguancun EE depends largely on eight dominant EE components (agents) that revolve around a large number of individual entrepreneurs. These agents comprise service-oriented governments, Internet-based industries, universities, dense research institutes, diversified investment agencies, entrepreneurship intermediaries, mass media, and many other entrepreneurial service agencies. Entrepreneurial resources, such as talents, technologies, finances, and services, circulate within and across the Zhongguancun EE and thus connect all EE agents (see Fig. 3).

As shown in Fig. 3, local (universities/research institutes, entrepreneurship intermediaries, and established firms) and overseas (returnees) talents are the two major sources of talent. Most talents choose to establish new firms with help from entrepreneurship intermediaries. To some extent, their entrepreneurial successes enhanced the Zhongguancun EE's attractiveness. Through supportive talent policies in particular, talents are stimulated to flock into the Zhongguancun EE. Regarding entrepreneurial resources of technologies, established ICT (Information and Communication Technology) firms (e.g., Baidu) as well as universities and research institutes are two major providers. These providers license technologies to or codevelop technologies with start-up firms. Additionally, diverse entrepreneurship intermediaries help entrepreneurial firms connect to (international) venture capital. The success of start-up firms and supportive government policies again encourages established ICT firms (e.g., Baidu) as well as universities and research institutes to continuously transfer technologies to start-up firms. Regarding financial resources, various finance agencies, established ICT firms, and governments offer financial support to entrepreneurs. To make the process effective, these financial agents either spend money on building incubators/accelerators given their direct roles in pinpointing high-growth new firms or engage in syndicated investment. As pointed out, *"some entrepreneurial projects have risks…set the pooled funds with governments to improve investment effectiveness…"* (co-founder, Finance 2). The successful entrepreneurs who are benefit from this process turn into new investors providing new streams of financial resources. Finally, the role of various entrepreneurship intermediaries is vital to entrepreneurial activities. Without their service, high transaction costs will result from the distrust among different agents and information asymmetry.

Our data also revealed that EE agents have three defining features. First, EE agents do not have clear role boundaries. In contrast with Silicon Valley, where angel investors and venture capitalists focus only on investment, finance agents in the Zhongguancun EE play additional roles to help entrepreneurs in other aspects, such as with management skills training, resource matchmaking, and even marketing. Similarly, incubators (and accelerators) support massive entrepreneurs with free office space, direct financial resources, and up-to-date entrepreneurial information. As such, these versatile investors and incubators cannot be easily differentiated.

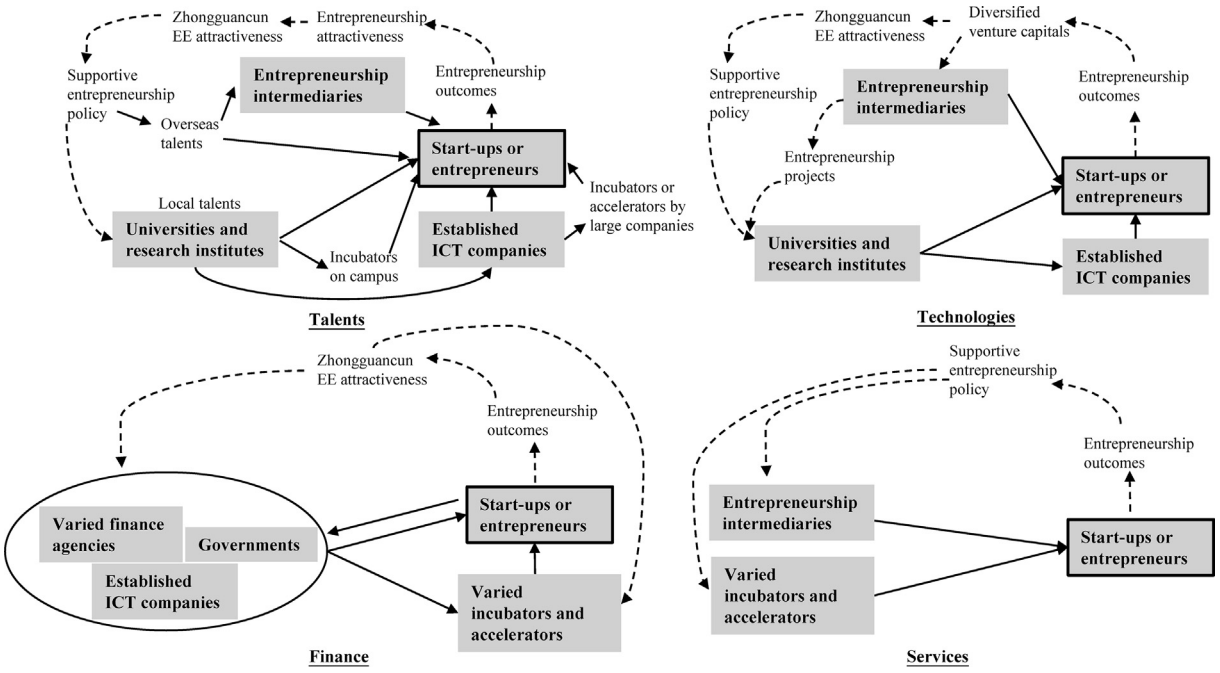
Second, EE agents—especially entrepreneurs—are self-organized without any central controllers. Since 2009, a remarkable transition has occurred within the ZAC. The committee changed its management focus from giving administrative commands ("What you are or are not permitted to do") to providing supportive entrepreneurship policies ("What or how can we help you") because it consciously realized that direct political interventions were disadvantageous to boosting high-quality entrepreneurial activities. Likewise, powerful agents such as investors and established firms also respect entrepreneurs' autonomy/ambition in developing innovations, as confirmed by the following quotes: *"only entrepreneurs themselves know what they really want to offer. We usually do not give them operational support. We do not want to catalyze any start-ups but hope that they can grow at their own pace"* (director, Supports 3). *"If employees of big dotcom companies like Baidu want to try entrepreneurial ideas, they are always allowed to do so in our incubator while keeping their positions in Baidu"* (co-founder, Supports 4).

Third, EE agents are inspired by a unique entrepreneurial culture that motivates and encourages innovation, risk bearing, failure tolerance, community building, and mentoring juniors/newcomers. Everyone who joins this community shares the common mission of building the most innovative EE in China or even the world. Driven by this mission, the agents of the Zhongguancun EE consciously innovate, take risks, help each other, and relay these shared values to the next generation of EE agents. As described, "*Zhongguancun [EE] is a magical place and you cannot find another one elsewhere in China. Many entrepreneurs are attracted by its pleasant local entrepreneurship climate. The local climate formation is to the result of continual efforts by four generations of successful entrepreneurs, acknowledged entrepreneurial core values, and entrepreneurs' inner entrepreneurial passions. Once integrated into such a climate, entrepreneurs are motivated to develop world-famous companies instead of just creating a normal new company…"* (CEO, Markets 4).

4.2. Nonlinear interactions

"As we often see several lucky ones from a thousand start-ups, there is a proverbial rule in terms of the emergence of successful entrepreneurship…It is not about the amount of money you invest but, to a large extent, about the entrepreneurs themselves, luck, and unforeseen factors…" (co-founder, Supports 7). *"I always warn novice angel investors that they can obtain returns by continuously investing 20 times at least in different domains*" (co-founder, Finance 1). These statement correspond to the nonlinear interactions among agents in the Zhongguancun EE, namely, that there is a disproportional relationship between entrepreneurial inputs (diverse entrepreneurial resources) and outputs (successful entrepreneurial firms). Despite the abundant local talent, supportive policies, diversified entrepreneurial services, and accessible financial resources provided by the Zhongguancun EE, only a small percentage of entrepreneurial projects will ultimately succeed.

Moreover, we found that nonlinear interactions exhibited two opposing patterns: positive and negative feedback loops. In positive feedback loops, dynamic interactions among EE agents accelerate new



Note: Four main entrepreneurial resources center around a massive number of entrepreneurs and hence align EE agents and their different entrepreneurial activities. Specifically, frames with thick borders denote the center of certain types of entrepreneurial resources, solid arrows represent direct entrepreneurial resource flows among EE agents, and dotted arrows indicate the recirculation of entrepreneurial resources and the mediation process. This figure is based on qualitative interview data analysis, on-site observations, and relevant secondary data.

Fig. 3. Circulation of entrepreneurial resources in the Zhongguancun EE.
Source: authors.

firm growth in a short time, which further promotes the development of the Zhongguancun EE. To illustrate the point, we draw on 245 news reports on the bike-sharing industry released by *huxiu.com* and *36kr.com*, the two largest entrepreneurship information providers in China. The early success of two bike-sharing start-ups depended on government encouragement that allowed them to distribute sharing bikes on urban streets in Beijing in 2016. Due to the potential benefits to the environment and social welfare, many other closely connected EE agents, including mass media, NGOs, research institutes, and international investors, quickly became involved and offered entrepreneurial resources to the bike-sharing start-ups, which in turn accelerated their development. Eventually, 10 months later, these two start-ups became globally recognized unicorns in the bike-sharing industry. As such, these start-ups attracted many international entrepreneurial resources, which were injected into the Zhongguancun EE.

Negative feedback loops can be illustrated by two bankrupt bike-sharing ventures in the Zhongguancun EE. One new bike-sharing venture, founded by a returnee entrepreneur from the Silicon Valley in the U.S., occupied nearly 10 percent of its market share within 4 months of its foundation in late 2016. However, a badly managed marketing promotion by local operations managers induced a cascade of negative reactions from other EE agents. At the beginning, the mass media propagated the marketing promotion's illegal elements, which aroused questions from the Beijing local security bureau. These questions again aroused mass media coverage, and then, several potential investors withdrew and upstream suppliers and end users started to lose confidence in the rapid development of the venture. The venture ceased business in October 2017. Another bike-sharing company experienced a similar incident when it began operating in late 2016. The venture claimed bankruptcy in late 2017 as it underestimated the importance of user deposits. The venture misused these deposits, which brought about sudden and widespread resistance from other EE agents (mass social media and end users).

Moreover, we also found that EE agent interactions through negative feedback loops blocked Zhongguancun EE development in a less obvious manner. For example, skilled talents are negatively impacted by the local infrastructure (i.e., high housing prices, traffic problems, and air pollution) surrounding the Zhongguancun EE. *"…you can imagine that entrepreneurs have to pay for house rent with half of their salary. They are definitely demotivated to be innovative. And, they further spend hours on commuting, so I am sure they have no passion for creating big businesses"* (vice president, Finance 5). This problem became intractable in approximately 2015 and 2016 when tens of thousands of entrepreneurs flooded into the Zhongguancun EE. However, *"…the more entrepreneurs that live in Zhongguancun or nearby, the higher the housing prices are. Whereas fewer entrepreneurs will reduce Zhongguancun's viability. Zhongguancun is unable to solve this problem due to the limited living space. If solved improperly and not in timely manner, entrepreneurs will gradually move to Shanghai, Wuxi, or Shenzhen if their living environment worsens too much… this is disadvantageous to Zhongguancun [EE]"* (vice president, Finance 5).

4.3. (In)sensitivity to initial conditions

The boom of Internet-related entrepreneurial activities has driven the rapid development of the Zhongguancun EE in the last two decades. Until 2014, we observed that most successful entrepreneurial start-ups came from the mobile Internet industry, such as Internet services, e-commerce, and online finance/education. The Zhongguancun EE followed such a path-dependent route for two historical reasons. First, the earliest entrepreneurs focused on electronics- or Internet-based industries. Their entrepreneurial successes resulted in rigid investment preferences, accumulated talents, a strong mobile Internet culture, and established social networks. In turn, this contributed to entrepreneurial activities in the mobile Internet industries. Second, early policymakers viewed Internet-related industries as a promising economic growth engine. As such, they released favorable entrepreneurship policies and invested heavily to build digital infrastructures (especially 2G, 3G, and 4G networks). To some extent, these efforts built a solid foundation for entrepreneurs to easily create niche markets in mobile Internet-related

businesses. As stated, *"Zhongguancun has become the epicenter of diverse mobile Internet industries. This means that entrepreneurs have to get close to Zhongguancun if their entrepreneurial projects relate closely to mobile Internet domains"* (vice president, Finance 5). Despite the benefits, the downside of such industry concentration is also stated, *"Zhongguancun [EE] was rich in 'soft' things but short in 'hard' things… For cloud computing, semiconductors, integrated electronics systems, and electronic design, Shanghai and Shenzhen might be more competitive than Beijing Zhongguancun. For this reason, Zhongguancun began to make efforts to distribute new emerging industries. The old industrial layout will change a lot…"* (co-founder, Finance 4).

The development of the Zhongguancun EE has been less sensitive to initial entrepreneurial conditions, particularly considering the recent developmental stages (2009–2018). Since 2014, a striking trend has been that many emerging industries, including biomedicine, smart robots, and aerospace, have sprung up in the Zhongguancun EE (Dong et al., 2019). As a result, synergies between newly introduced industries and the existing mobile Internet industry have produced many cross-border entrepreneurial firms. As analyzed by Greatwall Strategy Consultants in 2017, the success of cross-border innovations benefited much from emerging technologies, such as big data platforms and artificial intelligence technologies. This benefit was verified by one of our interviewees, *"…2014 can be viewed as a new beginning for Zhongguancun. Many emerging entrepreneurial activities are focused on the integration between the mobile Internet industry and other emerging high-tech industries. A good example is the integration of the mobile Internet industry, automobile industry, and smart robot industry…"* (online audio, academic entrepreneur).

4.4. Adaptation to the environment

Along with its insensitivity to initial conditions in the recent developmental stage, the Zhongguancun EE has increasingly improved its adaptability to environmental shocks. In general, the Zhongguancun EE, as a coherent entity, reacts quickly to economic, societal, and institutional environments. For instance, analyzed by Greatwall Strategy Consultants in 2011, the Zhongguancun EE treated U.S. subprime crisis in 2008 as a good opportunity to introduce diverse international venture capitalists to help new firms expand. As a consequence, 23 firms in 2009 and 39 entrepreneurial firms in 2010 successfully went public on the U.S. Nasdaq, though the number of IPO firms in 2007 and 2008 was just 2 and 8, respectively.

Moreover, at one time, a lack of diverse and robust entrepreneurial services, such as market information providers, legal consultants, IP rights protection, fund-raising guarantees, and specialized media propagation, curbed the development of the Zhongguancun EE. As was reported, *"…before the maturity of various entrepreneurial services, around 2009, Zhongguancun did not seem to be a healthy entrepreneurial region"* (chairperson, Finance 3). However, this situation has completely changed due to an ongoing trend in global innovative regions (cities), where diversified and coherent entrepreneurial services are expected to create successful entrepreneurial firms in an efficient way. The Zhongguancun EE's timely response to this trend transformed it into a much more friendly and healthy EE. By 2017, over 190 incubators and accelerators in the Zhongguancun EE collaborated closely to support entrepreneurs and make use of complementary entrepreneurial resources. As described, *"…we introduced a nice entrepreneurial project to an accelerator because it is more suitable to providing specialized entrepreneurial services. In this way, they also collaborate with the others to provide entrepreneurial training to entrepreneurs within their incubators…"* (co-founder, Culture 1).

Finally, the Chinese central government released a policy called "Mass Entrepreneurship and Innovation" in 2014 that required local governments to lower the entry barriers for entrepreneurship and to stimulate innovation. As a result, Zhongguancun local governments and bureaus reformed the lengthy administrative procedures for starting a new firm and set up special funds, such as the "Golden Seeds Fund", for grassroots entrepreneurs. Accordingly, investors proactively changed their investment focus, universities intentionally adjusted their educational orientations, and more entrepreneurs devoted themselves to technology-intensive domains. As underlined by one respondent, *"unlike incubators or accelerators, we start exploring to build an 'aggregator' to nurture such [cross-border] firms. The 'aggregator' integrates the respective strengths of large firms, small films, service agencies, and relevant actors. Such resource integration can accelerate the breeding process of revolutionary products…"* (CEO, Supports 5). These agile actions by EE agents guaranteed sustainable development of the Zhongguancun EE.

4.5. Emergence of successful entrepreneurial firms

Agents in the Zhongguancun EE demonstrate collective behavior, thereby creating influential companies. This collective behavior is *unforeseeable* as no one can predict what influential unicorns look like and thus intentionally create them. However, the emergence of such influential companies is observable due to shared general characteristics, such as mobile being Internet-related, having customer-driven products/services, being fast-growing, having new business models, having worldwide niche markets, and providing substantial social/environmental benefits. The emergence of such collective behavior in the Zhongguancun EE is the result of numerous ambitious entrepreneurs, coherent entrepreneurial actions among various EE agents, and the injection (elimination) of new (redundant) entrepreneurial resources.

First, entrepreneurs in the Zhongguancun EE are ambitious. Regardless of their educational background, gender, age, or social status, entrepreneurs are urged to commercialize innovative ideas that have social, economic, and environmental impacts. As stated, *"Most of them [entrepreneurs] are pursuing self-actualization or showing a pure desire to change society…"* (co-founder, Supports 1).

Second, nonlinear interactions between newly introduced entrepreneurial resources and established mobile Internet elements can produce cross-border entrepreneurs. The emergence of these entrepreneurs has had overarching guiding effects on EE agents. As demonstrated earlier, these effects include investors calibrating their investment strategies, governments reassessing previously introduced entrepreneurial policies and constructing infrastructure, and universities modifying their educational systems for qualified talents.

Third, the development of Zhongguancun EE has benefited from the Silicon Valley EE. According to two representative reports by Greatwall Strategy Consultants, since 1999, there has been a trend of overseas returnees moving from Silicon Valley to the Zhongguancun EE to explore entrepreneurial opportunities. These returnees were attracted by the availability of young talent, technology infrastructure, complete entrepreneurial services, supportive government agents, the closeness to mass markets, and energetic entrepreneurship networks in and surrounding the Zhongguancun EE. This injection of overseas returnees diversified EE components and accelerated EE evolution through heterogeneous technologies, concepts, and knowledge. Therefore, a senior official of ZAC confessed that "*the growing emergence of "Haigui" [overseas returnee] entrepreneurship manifests the success of our talent policies*". This trend has greatly helped the Zhongguancun EE avoid evolutionary path dependence connected to mobile Internet-related businesses.

4.6. Coevolution

Diverse EE agents interact and coevolve in different geographic areas. Zhongguancun Entrepreneurship Avenue, a geographic area with a complete set of EE components, including over 50 established dot-com firms, 45 entrepreneurship service agencies, 50 research institutes and universities, and nearly 2,000 investment agencies, is the Zhongguancun EE epicenter that breeds influential start-ups. Within this geographically bounded region, there are also many smaller EEs. These smaller EEs exchange advantageous entrepreneurial resources to

nurture entrepreneurship. For example, 29 university-based EEs not only receive entrepreneurial services from incubator-based EEs but also supply qualified young entrepreneurs to them. Such ecosystem-level interactions contribute to the overall development of the Zhongguancun EE.

Our interviewees emphasized such nested geographic features. Tsinghua University is known as a small, viable research-based EE nested within the Zhongguancun EE because it internally offers necessary entrepreneurial conditions that give birth to new firms: *"…First, as a world-famous technical university, Tsinghua is powerful in R&D. This means that attracting entrepreneurs and investors is relatively easy for them. Second, they have a lot of alumni dispersed around the globe who have connected with other entrepreneurial resources outside of Zhongguancun [EE]. Third, dynamic interactions among CEOs from well-known firms and academia make Tsinghua look like a place producing innovative ideas…"* (chairperson, Finance 3). Another interviewee confirmed this position, stating that *"…Zhongguancun is a big ecosystem, while we are an embedded smaller one. We are able to produce influential entrepreneurships and innovations because we can provide start-ups with required entrepreneurial resources, such as angel funds, technicians, and management consulting services. Like us, I guess many other big incubators or accelerators in Zhongguancun [EE] can do so. We only share the same policies from governments and other entrepreneurial services…"* (secretary general, Supports 6).

Moreover, these smaller EEs do not grow independently but interact frequently in various ways. To best serve Tsinghua graduate entrepreneurs, Tsinghua University launched "TusStar Accelerator" in 2001. In this way the university enhanced frequent collaborations with other incubator- or accelerator-based EEs to acquire complementary resources. *"…we very often call to them. 'Hey, we here are an entrepreneurial team with a promising project that might be better incubated by your institutions', and then, we hand over the team…we do not think this is a loss. Rather, many successful projects will in turn expand our brand influence"* (founder, Supports 2). In addition to spontaneous interactions, many related social activities, such as forums, seminars, and conferences, are regularly coordinated by the ZAC, which also increases the interactions among EEs. *"To sustain a dynamic entrepreneurship climate, we have a tradition of organizing around 150 Zhongguancun Entrepreneurship Forums since 2010, where we gather together various people, including famous entrepreneurs, investors, and experts, to give lectures… to make it continue, I think those incubators, innovation campuses, and various industrial associations play the key roles"* (section chief, Policy 1).

However, the Zhongguancun EE is not a closed region of approximately 500 square kilometers. Paralleling Zhongguancun Entrepreneurship Avenue, there are approximately 16 other entrepreneurship epicenters in Beijing. Although spatially isolated, these regions with specific industries constantly exchange entrepreneurial resources with Zhongguancun Entrepreneurship Avenue. Moreover, such ecosystem-level interactions expand beyond Beijing to other regional EEs in China (e.g., Shenzhen, Shanghai, Hangzhou, and Nanjing). According to the Beijing Business Incubation Association, since 2012, almost 60 percent of the Zhongguancun EE representative incubators and accelerators (e.g., 3 W Café and Legend Star) have set up branches or joint branches in these cities, which permits EE agents (and relevant entrepreneurial resources) to flow among these higher-scale regions.

Finally, there are active ecosystem-level interactions between the Zhongguancun EE and regional ecosystems outside of China. Our data revealed that the ZAC has established 9 liaison offices in entrepreneurial regions and cities, including Silicon Valley, London, Paris, and New York. Returnee entrepreneurs have contributed significantly to the growth of the Zhongguancun EE since 1999. According to annual reports by the Zhongguancun Statistics Center and a talent report by LinkedIn.com in 2017, the number of returnee entrepreneurs in the Zhongguancun EE reached its peak at approximately 13,000 in 2013, compared to a mere 1,100 in 1999. A relevant indicator released online by the ZAC in 2018 suggests that approximately 30 percent of the 76 unicorns were initiated or cofounded by Silicon Valley entrepreneurs. Typically, entrepreneur mobility between Silicon Valley in the U.S. and the Zhongguancun EE is the most evident. Many early successful entrepreneurs are from Silicon Valley, and they function as role models for followers. Due to the comprehensive cooperative relations between the two innovative regions, ranging from education, trade, capital, and business to governments, industrial associations, and chambers of commerce, *"there is an identifiable clique of 'Silicon Valley' entrepreneurs…"* (chairperson, Finance 3).

In a sense, the attracted overseas talents, financial resources, emerging technologies, and leading management experiences has closely linked the Zhongguancun EE in a timely manner with other EEs so that the Zhongguancun EE could coevolve with them in various ways. This perspective is additionally supported by one of our interviewees, *"…Tian [a returnee entrepreneur] considered collaborating with Beijing local governments and created six new companies ranging from cloud software to end cloud-computing marketing based specifically on the constructed cloud-computing platform. After these endeavors, Tian usually returned to Silicon Valley several times every year, attempting to absorb new knowledge, technologies, and concepts from there. Currently, the cloud-computing industry is beginning to take shape…"* (CEO, Supports 5).

4.7. A complexity-based framework for the Zhongguancun EE

Taken together, we also observe that the six complexity properties demonstrated above do not act independently; rather, they work in an integrative manner to ensure the viability of the Zhongguancun EE. Specifically, the properties of a large number of self-organized agents and agents' nonlinear interaction illustrate what the fundamental constituents (and their interactive relationships) are in the Zhongguancun EE; the properties of (in)sensitivity to initial conditions and adaptation to the environment then indicate how the Zhongguancun EE develops/grows as a whole; the properties of emergence of successful entrepreneurial firms and coevolution are regarded as ecosystem governance structures that explain how the Zhongguancun EE can be shaped and, more importantly, the boundaries of the shaping effects.

Furthermore, as visualized by Fig. 4, the six complexity properties are integrated into a coherent framework, which enables an overarching understanding of how the complexity nature of the Zhongguancun EE maintained and improved its viability over time. First, an increasing number of diversified EE agents (y-axis) and their increasingly coherent entrepreneurial actions/activities (x-axis) lay a solid foundation for EE viability that is typically embodied by the continuous emergence of high-impact new firms (e.g., unicorns). This result is caused by the fact that the emergence of successful entrepreneurial firms cannot be foreseen or intentionally planted by any individual agents but was a result of nonlinear interactions among them (see three paralleled dotted arrows). Although unforeseeable, the emergence of successful entrepreneurial firms as collective EE behavior can be observed and in turn motivates EE agents to adjust and even change their individual behaviors to (re)shape the Zhongguancun EE (see the parallel solid arrows). Second, the nonlinear interactions of self-organized agents in the early stage of the EE result in EE path-dependent development. However, by introducing heterogeneous and obsoleting redundant entrepreneurial resources in the EE and further promoting synergetic interactions between new and existing EE components, the EE becomes less sensitive to initial conditions. In addition, the EE develops sustainably as different EE agents coherently adapt themselves to withstand external shocks and solve internal developmental problems. Third, diverse EE agents exchange heterogeneous entrepreneurial resources and therefore coevolve on multidimensional (i.e., university, regional, national, and international) geographic scales (see dotted circles with different sizes in Fig. 4).

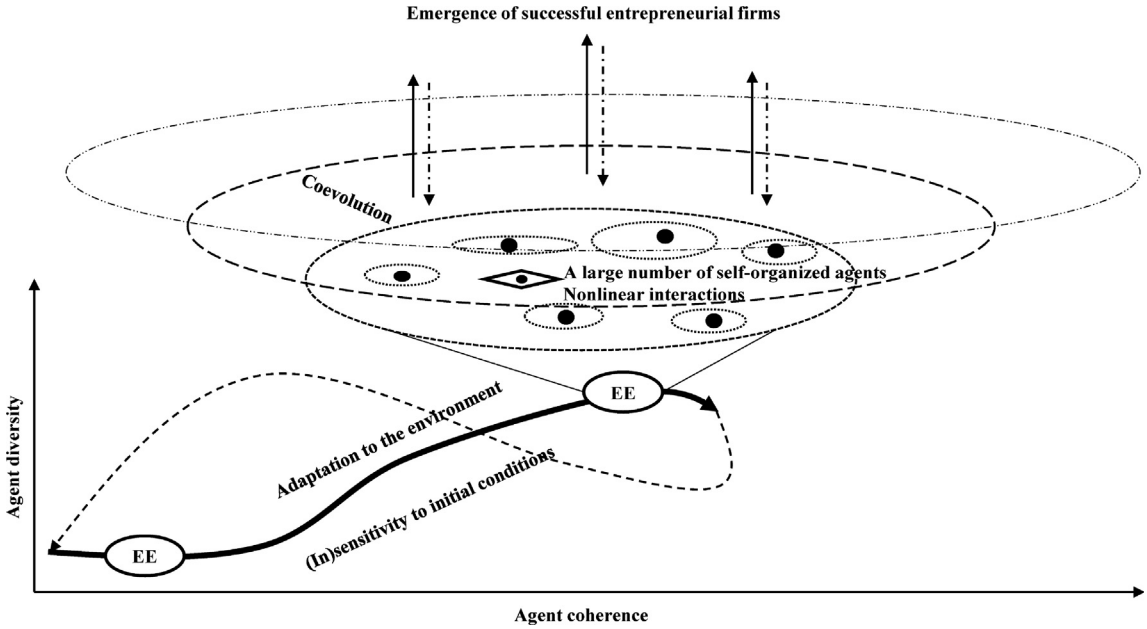


Fig. 4. A complexity-based framework for the Zhongguancun EE.

5. Discussion

Despite the increasing focus on EEs in the literature (e.g., Acs et al., 2017; Autio et al., 2018; Cohen, 2006; Feld, 2012; Isenberg, 2011; Stam, 2015), the complexity nature of EEs has been relatively underinvestigated (Autio & Levie, 2017; Brown & Mason, 2017; Goswami et al., 2018). To address this research gap, we examined a viable EE: the Zhongguancun EE in Beijing, China. Our study revealed six interrelated complexity properties of the Zhongguancun EE that are in line with the main properties that a CAS possesses (Aydinoglu, 2013; Choi et al., 2001; Peltoniemi, 2006; Russell & Smorodinskaya, 2018; Surie, 2017): a large number of self-organized agents, nonlinear interactions, (in) sensitivity to initial conditions, adaptation to the environment, emergence of successful entrepreneurial firms, and coevolution. Moreover, the synthesis of six interrelated complexity properties provides a better understanding of how the Zhongguancun EE maintains its viability through different developmental stages. Our findings make theoretical contributions to both the EE literature and CAS theory and provide useful policy implications.

5.1. Theoretical contributions

The first contribution of our study is that we extended the work by Roundy et al. (2018) that conceptualized EEs based on CAS theory. Roundy and colleagues proposed six main complexity properties that both a CAS and an EE share. Furthermore, the authors theorized that the birth of an EE is rooted in ambitious entrepreneurs and their adaptive intentions, EE agents' coherent actions, and new entrepreneurial resource injections. Based on our empirical findings, we offer a more nuanced complexity-based understanding of a viable EE. On the one hand, in line with Roundy et al. (2018), we argue that a large number of self-organized EE agents and their nonlinear interactions build the foundation for a complexity-based EE. On the other hand, our study complements their work in two ways: (1) EEs' sensitivity to initial development conditions is contingent on developmental stages. That is, this property is evident in early EE developmental stages, and then, viable EEs can improve their environmental adaptability to avoid path dependence with new resource injections and EE agents' coherent entrepreneurial actions. (2) EE governance has an "open" fluid boundary, and such boundary openness should be considered at multidimensional geographic scales. Overall, our study lends empirical support that CAS theory is an appropriate lens through which we can better understand EE development and management.

The second contribution of our paper is the integration of the EE literature and CAS theory, which provides three main theoretical implications. First, we showed that viable EEs depend on a large number of self-organized EE agents and their nonlinear interactions. Previous research has shown that diversified EE agents (Cohen, 2006; Isenberg, 2011; Mason & Brown, 2014) and their linear synergetic interactions (Ghio, Guerini, & Rossi-Lamastra, 2019; Radinger-Peer et al., 2018; Spigel, 2015; Theodoraki, Messeghem, & Rice, 2018) support a viable EE but paid less attention to nonlinear interactions. In line with recent conceptual studies on nonlinear relationships among EE agents (Brown & Mason, 2017; Roundy et al., 2018), our findings highlighted that, due to agents' fluid roles, the amplifying synergies (positive feedback loops) among EE agents accelerate the EE development process, whereas dampening synergies (negative feedback loops) restrain the process. Therefore, instead of focusing only on the individual and static functions of EE agents, future studies should adopt a complexity-based, more dynamic view to understand the interactive effects of EE agents on EE development.

Next, we showed that viable EEs are adaptive systems. Our study explained that the historical conditions of entrepreneurial resources in an EE's early development can determine its subsequent development. In other words, entrepreneurial activities and outputs in an EE's early developmental stage can lock the EE into limited industrial domains over time. This finding is consistent with the current literature suggesting that EEs follow a path-dependent evolutionary development process from birth to maturity (Colombelli et al., 2017; Letaifa & Rabeau, 2013; Mack & Mayer, 2016; Spigel & Harrison, 2018). Nonetheless, our study complements this literature by showing that viable EEs can avoid such path-dependent evolution by improving their environmental adaptability and, as a result, escaping the quick declining fate (Auerswald & Dani, 2017). To do so, EEs can intentionally introduce new EE agents, remove old ones, and strengthen their entrepreneurial actions' coherence. We thus suggest that future EE research should pay more attention to the adaptive evolutionary dynamics of the EE development process.

Finally, we showed that a viable EE's governance structure partially follows the "bottom-up-top-down" approach. In contrast to extant scholars who consider the governance structure of an EE to be either "bottom-up" (Isenberg, 2011, 2016) or "top-down" (Bhawe & Zahra,

2019; Spigel, 2015), our findings partly support the "bottom-up-top-down" approach proposed by Colombo et al. (2019) and Stam (2015). Specifically, a viable EE requires fewer direct, "top-down" interventions because the emergence of high-impact entrepreneurship is unmanageable by any single EE agent; rather, high-impact entrepreneurship emerges as a result of self-organized EE agents, the high fluidity of entrepreneurial resources, coherent entrepreneurial actions, and the introduction of new agents from outside. Additionally, such emergence is regarded as a collective behavior and, in turn, guides EE agents to adjust entrepreneurial actions to (re)shape the EE in the future. Although "top-down" tools such as policies can change, for example, infrastructure conditions, financial preferences, and human capital, they have difficulty in changing sociocultural elements, such as the local entrepreneurship climate, that formed in a "bottom-up" way. Therefore, a top-down approach is necessary but insufficient to shape viable EEs. Moreover, a top-down approach faces challenges because viable EEs are geographically nested phenomena with multidimensional scales. In our case, the Zhongguancun EE contains many smaller (university-based) EEs but is embedded within larger (inter)national EEs. These EEs do not develop separately but simultaneously coevolve. We thus argue that future studies should consider the interactive effects of policies at different geographic levels on EE development.

The third contribution is the extension of CAS theory to the ecosystem level. Most prior studies analyzing complexity management concentrated on effects at the individual firm level (Brown & Eisenhardt, 1997; McCarthy et al., 2006), the supply chain network level (Choi et al., 2001), or, recently, the innovation cluster level (Russell & Smorodinskaya, 2018; Surie, 2017). Comparatively less attention has been paid to the relationships between the level of complexity and EE performance. We argue that complexity management in the context of EEs comes down to EE agents' collective endeavors in an adaptive process instead of those of the individual agents. Specifically, as an EE evolves from its genesis, the level of complexity gradually increases until the point when the EE must avoid path dependence by introducing new (and ruling out old) EE agents and strengthening the interconnectedness of (new and existing) EE agents. Therefore, an EE can reduce the diversity and interconnectedness of path-dependent agents (complexity reduction) and simultaneously create new agent diversity and interconnectedness (complexity absorption) to maintain its viability. This adaptive process for sustaining the optimal level of complexity—that is, a manageable level of agent connectivity, diversity, ambiguity, and dynamicity (de Toni & de Zan, 2016)—in an EE does not depend on individual agents; rather, it is the result of various agents' collective endeavors. Our results are thus in line with the complexity management literature (Jacobs, 2013; Vasconcelos & Ramirez, 2011) and highlight that viable EEs can maintain a balanced level of complexity to produce numerous successful entrepreneurial firms.

5.2. Policy implications

This study offers three main policy implications. First, policymakers should recognize the limited effects of "top-down" policy tools on the emergence of high-impact entrepreneurial firms. Because encamped EE agents are self-organized, direct policy interventions might effectively shape hard things in EEs such as funds, infrastructure, and entrepreneurial services but may be relatively weak at shaping soft things such as the entrepreneurship culture that is expected to be formed and changed in a "bottom-up" way. Second, policymakers should update their policies during the different developmental stages of EEs. As indicated by our findings, an EE might fall into a path-dependent development process that will lock all the EE agents and, accordingly, entrepreneurial activities into a single domain. However, policymakers can mitigate such path-dependent evolution processes by introducing new entrepreneurial resources via new policies. As such, the continuity and coordination of various policies might pose a big challenge for policymakers being proactive and sometimes creative. Third, policymakers should shift their policy focus from promoting regional development to national and even international entrepreneurial resource exchanges. Specifically, policymakers should broaden their vision to different geographic levels and consider interconnections when designing entrepreneurship and innovation policies.

5.3. Limitations and future directions

This study has several limitations. First, we did not consider more nuanced complexity features. For example, we revealed nonlinear interactions among EE agents and distinguished two nonlinearity mechanisms, namely positive and negative feedback loops that promote and decelerate EE development. We found only economic outcomes of these two mechanisms. However, in the long run, both mechanisms might have a negative impact on social development (e.g., gender inequality, increased cost of living, and driving out other employment) in emerging economies (Berger & Kuckertz, 2016; Spigel & Harrison, 2018). Future research might consider the different types of outcomes resulting from EE components' nonlinear interactions and their effects on EE development. We also identified the adaptive life cycle from the "exploitation" to "conservation" phase (see Auerswald & Dani, 2017) of Zhongguancun EE when EE agent diversity and entrepreneurial coherence increase with a smooth curve (see Fig. 4). Nevertheless, our results cannot provide robust evidence of how an EE reorients itself from the "release" to "reorganization" phase that is characterized by a sharp decrease in terms of the diversity and coherence of EE agents (Auerswald & Dani, 2017), as we did not observe any critical external shocks triggering the EE's adaptive process. Such EE evolutionary dynamics would be useful for uncovering the complexity nature of an EE's adaptability and discontinuity. A future longitudinal study could help to fill this gap.

Moreover, the use of a specific empirical setting may limit the generalizability of a theory (Yin, 2013). Whether our results can be applied to other productive EEs remains unknown. Future studies could enhance our findings' generalizability with a comparative case analysis involving two or more viable EEs in both emerging (e.g., Bangalore EE) and developed economies (e.g., Berlin EE).

6. Conclusions

How can an EE uncover its complexity properties across different development stages to maintain its viability? To date, scholars have not fully explored the complexity nature of EEs. In view of this gap, through borrowed insights from CAS theory and an in-depth qualitative study of the Zhongguancun EE in China, we identified six integrated complexity properties that were exhibited over time. Our findings provide new empirical insights into EE agents' nonlinear interactions, adaptive evolutionary dynamics, and multiscale governance boundaries. Additionally, our findings highlight an EE's adaptive process to sustain a balanced level of complexity to maintain its viability. By revealing the complexity nature of an EE from an emerging economy, our paper offers useful insights for policymakers to better promote and manage EE development.

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