Towards a complex adaptive system: the case of Zhongguancun entrepreneurship ecosystem

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Abstract: Entrepreneurship ecosystems are increasingly important to produce high-impact entrepreneurship, not merely limited to new firms creation. However, we know little about the complexity nature associated with a well-functioned entrepreneurship ecosystem in specific contexts. Insights into this nature have benefits in moderating conceptual ambiguities, empirical problems, and policymaking challenges related to entrepreneurship ecosystem research. Against this backdrop, we identify six interrelated complexity properties, in particular integrating complex adaptive system theory and discussions on entrepreneurship ecosystem complexity. We conclude a new entrepreneurship ecosystem model from complex adaptive system perspective, depending on a proper qualitative case — Zhongguancun Science Park, located in Beijing, China. Based on our findings, this study offers three contributions, which accordingly implicate regional entrepreneurship and innovation polices. First, the nonlinear interactions among components drive entrepreneurship ecosystem development. Successful entrepreneurship ecosystems outperform others due to more waves of amplifying and less dampening nonlinear interactions. Second, a vibrant entrepreneurship ecosystem will adaptively reorient evolution process by reducing rigid connectedness among components, instead of falling into decline in a linear life cycle manner. Third, the entrepreneurship ecosystem governance partially follows a "bottom-up-top-down" approach, and meanwhile contains multidimensional levels. Finally, our research mentions limitations in terms of context-specificity and generalizability and thus informs a number of future research opportunities.

Key words: entrepreneurship ecosystem; complex adaptive system; Zhongguancun Science Park; high-impact entrepreneurship

1 Introduction

Regional entrepreneurship and innovation policies are changing their focus from stressing entrepreneurship quantity (i.e., more new companies and self-employment rate) to entrepreneurship quality (i.e., high-impact entrepreneurships by ambitious entrepreneurs) (Zoltan J. Acs et al., 2017; O'Connor et al., 2017; Brown & Mason, 2017). Focusing on individual entrepreneurs and entrepreneurial contexts they embedded (Z. Acs et al., 2014; Autio et al., 2014), e*ntrepreneurship ecosystem* (EE), defined "as a set of interdependent actors and factors coordinated in such a way that they enable productive entrepreneurship within a particular territory" (E. Stam, 2015: 1765), has seen such policy transitions. Because of the strategic role of EEs in promoting sustainable economic competiveness, a consensus among varied governmental agencies is on creating and sustaining well-functioned EEs in specific regions (Mason & Brown, 2014; World Economic Forum, 2013, 2016).

Although seductive, EE and its *complexity* nature were underexplored by extant research, as a result of which might cause conceptual ambiguities, empirical problems, and thus impaired better policy interventions (Zoltan J. Acs et al., 2017; Brown & Mason, 2017). First, previous studies have documented what necessary entrepreneurial components should be involved in an EE (Autio & Levie, 2017; Feld, 2012; Isenberg, 2014; Mason & Brown, 2014; World Economy Forum, 2013). While such a 'recipe' does not inform a successful EE, as several regions contain the same components might show different EE performance in terms of producing high-impact entrepreneurships. Despite scholars evidence that the synergetic interactions among EE components enable performance variance (Colombelli et al., 2017; Spigel, 2015), EE outcomes (i.e., unicorns) always originate from multi-causalities, instead of in a linear fashion (Alvedalen & Boschma, 2016; E. Stam, 2015). Second, a set of scholars have applied the process perspective to EE development (Goswami et al., 2018; Mack & Mayer, 2016; Spigel & Harrison, 2018), we yet find some EEs will reshape themselves to be resilient, rather than evolve in a life cycle way from birth to decline. Third, most literature argues the territory-

specificity is a defining feature of EE and set their research boundaries on certain areas (e.g., Spigel, 2015; Goswami et al., 2018; Mack & Mayer, 2016). While an emerging research insists that the digital infrastructure and technologies reduce entrepreneurship spatial dependence (e.g., Autio et al., 2018; Sussan & Acs, 2017). EE is therefore partially of a location-bounded phenomenon.

To unfold the complexity features referred above, on the one hand, some EE scholars discussed them separately and cast a fragmented landscape (see discussion in O'Connor et al., 2017; Isenberg, 2016; Carayannis et al., 2018). On the other, though recent work offered a 'complete' box of complexity properties that EEs shared (see P. Roundy et al., 2018), their conceptual endeavor neither illustrated how each property could moderate (solve) EE conceptual ambiguities, empirical problems, and practical challenges in policymaking, nor, to our best knowledge, provided much empirical evidence of EE from complexity lens. Therefore, we take a further step to answer the following research question: *how to empirically contextualize an evolving EE from complexity perspective?* Insights into this issue can contribute current theory on EE conceptualization and provide useful guidance for entrepreneurs realizing entrepreneurial opportunities as well as policymakers benefiting from EE development.

To this end, we first conclude six interrelated complexity properties inherent in a successful EE, in particular combing the complexity adaptive systems (CAS) theory (Anderson, 1999; Gell-Mann, 1994; Lewin, 1999) and three strands of current EE discussions. Based on these, second, we test the six properties with a proper qualitative case — *Zhongguancun Science Park*, an emerging EE located in Beijing, China (cf. Du et al., 2018; Li et al., 2017). Third, following the recommended procedures for qualitative research and grounded theory (Gioia et al., 2013; Strauss & Corbin, 1990) help us arrive at a new CAS-based EE model.

Our study follows increasing calls to deepen our empirical understanding of EE complexity nature (e.g., Autio & Levie, 2017; Brown & Mason, 2017; Malecki, 2018; P. Roundy et al., 2018). Our first contribution relates to a better understanding of synergetic nonlinear interactions among EE components. Successful EEs outperform others due in part to more amplifying and less dampening such interactions. Second, we add to the empirical knowledge regarding EE evolutionary dynamics. A vibrant EE will not fall into decline phase linearly, but gradually behave adaptive to internal struggles to be resilient. As the third contribution, we partially confirm the "bottom-up-top-down" EE governance, and multidimensional EE governance boundaries. Overall, we build on complexity science to offer a coherent CAS-based EE model for the future EE studies.

The remainder of the paper is structured as follows. First, we review three strands of EE literature, followed by a presentation of challenges relating to each strand. We then conclude six integrated complexity properties based on CAS theory and apply them to conceptualize EEs. Next, we present our research design, the context of the selected case, and the results from the qualitative analyses. In conclusion, we propose a CAS-based EE model. Finally, we state theoretical contributions to current EE knowledge, implications for policymakers, possible limitations, and consequently research opportunities for EE scholars.

2 Literature Review

2.1 An overview of EE: main ideas and challenges

The value of EE concept lies in its *systemic* feature (Brown & Mason, 2017; Malecki, 2018; E. Stam, 2015), in help of explaining how entrepreneurial actors such as individuals, organizations, and institutions are combined to produce high-impact entrepreneurship in certain economic and institutional contexts (Z. Acs et al., 2014; Autio et al., 2014; Garud et al., 2014). We observed there are at least three EE *schools* consolidating such systemic feature, and thus discriminates it from other similar phenomena like national/regional innovation systems, industrial clusters, innovation milieu, innovation ecosystems (cf. Autio et al., 2018). Specifically, the *systemic* components indicate what are participatory elements included into a successful EE; the *systemic* processes help understand how EE develops over time; the *systemic* governance structures explicate in what ways an EE creates "*productive*" entrepreneurships by "*ambitious*" entrepreneurs (E. Stam, 2015). To be productive, we follow Brown and Mason (2017) that a hallmark of a successful EE is creating high-impact or high-

performance entrepreneurships (Zoltan J Acs, 2008). While to be ambitious, entrepreneurs devote to create unicorns (Zoltan J. Acs et al., 2017) or blockbuster ventures (Mason & Brown, 2014).[1]

EE as components. An vibrant EE builds on a systemic list of engaged components, which help us understand what an successful EE looks like (Neck et al., 2004; H. Van de Ven, 1993). First, an EE is generally seemed to accommodate six main components: markets, policy, finance, culture, supports, and human capitals (cf. Cohen, 2006; Feld, 2012; Isenberg, 2011; E. Stam, 2015). Every component is made of numerous agents and has a set of sub-components. In a reductionist way, these components can be classified into three interactive coherent dimensions (Spigel, 2015) — material (including policy and governance, universities, support services, physical infrastructure, open markets), social (including worker talent, investment capital, networks, mentors and role models), and cultural (including supportive culture, histories of entrepreneurship. Second, these components are not isolated to work. Instead, the sufficiency of, and optimal interactions among, components cause high-performed EE through entrepreneurial processes (e.g., Ghio, 2017; Radinger-Peer et al., 2018; Spigel, 2015; Theodoraki et al., 2017). Although well-documented, the "component" school has been criticized because the "laundry list" of components show limited knowledge about the their criticality in different EEs and in different time, and therefore, are unlikely to present a clear holistic reasoning of causes and effects (E. Stam, 2015).

EE as processes. To add the temporal understanding, EE is considered to experience different phases (birth, growth, sustainment, and decline) and shows evolutionary dynamics over time (Mack & Mayer, 2016). This is important in that some components matter as EE evolves (Spigel & Harrison, 2018). For example, from birth to growth stage, there is a growing perception among policymakers about the urgency to build EE, financial capital being easier to obtain, networks among entrepreneurs being tight for commercial success, social norms being accepted in favor of innovative entrepreneurship. We observed current literature focused mainly on EE's early evolution stages. For instance, Thompson et al. (2018), following the field theory, evidenced Seattle ecosystem's transition phase enabled by related relational and temporal micro-dynamics. Radinger-Peer et al. (2018) emphasized how finance-funding and political regulations are interacted to influence early ecosystem sustainability. As well as the internal dynamics, external resources, such as a quantity of skilled migrants, facilitate ecosystem emergence with a slow stage-patterned way (Schäfer & Henn, 2018).

However, EE evolution would not always follow a linear and "predesigned" route from nascence to maturity (Brown & Mason, 2017; Radinger-Peer et al., 2018), but seems discontinuous (Brown & Mason, 2017) and even "cyclical and iterative" (Malecki, 2018: 11). Particularly based on cluster life cycle literature (e.g., Martin & Sunley, 2011), Auerswald and Dani (2017) presents a punctuated evolution model to describe how EE grows and becomes adaptive to growing disturbances. Accordingly, an EE would suffer shocks (e.g., economic crisis (Radinger-Peer et al., 2018)) internally and externally, which trigger short periods of restructuring all entrepreneurial resources systemically, followed by longer periods of resources accumulation and conservation for the next wave of high-performance entrepreneurship (Auerswald & Dani, 2017; Holling, 2001; Martin & Sunley, 2011).

EE as structures. Dynamic EEs entail renovating or changing their governance structures constantly (Auerswald & Dani, 2017; Colombelli et al., 2017), in aims of a coherent set of EE components and balanced EE evolution processes. In this study, the 'governance structure', in a micro-foundations manner (Cunningham et al., 2017), denotes how all ecosystem actors are set up or ''designed" (Colombelli et al., 2017) to support high-performance innovative activities. Although the heterogeneity in local contexts, insights into it allows to spot underpinnings why geographically adjoining EEs have diverged growth/performance, and in particular the value for better policy fostering actions (Brown & Mason, 2017).

There are three complementary streams of governance approaches, exhibiting a mixture of public-private EE structures (Zoltan J. Acs et al., 2017; Colombo et al., 2017). Most scholars concentrate on "public" institutions' critical functions in bridging EE micro entrepreneurs and macro-level culture or social aspects. Their argumentations are based on that all EE components can be aggregated into micro-, meso-, and macro-level (Theodoraki & Messeghem, 2017). In line with this thinking, a network of accelerators and incubators (Goswami et al., 2018; P. T. Roundy, 2017),

[1] Unicorns are high-performance start-ups that valued more than $1 billion, which was regarded as a reliable index of EE performance by Zoltan J. Acs et al. (2017).

governmental entrepreneurial support programs (Spigel, 2016) or innovation centers (Jung et al., 2017), and research institutes (Hayter, 2016; Huang-Saad et al., 2017; Miller, 2017), play the mediation role in combing resources, nurturing and spreading shared entrepreneurial cultures, and managing uncoordinated social networks. In contrast, some developed EE governance models by specially highlighting "private" economic actors, such as multinational enterprises (MNEs) (e.g., Bhawe & Zahra, 2017). MNEs' leadership role in enabling knowledge spillovers and new venture diversity causes EE performance variance. Finally, the public-private approach suggests the synergies between finance/venture capitals and public institutions promote the overall effectiveness of EE structures (Audretsch & Link, 2017; Cumming et al., 2017; Radinger-Peer et al., 2018). A key insight therefore is that well-functioned EEs depend largely on a harmonious blend of aforementioned two governance approaches (Colombo et al., 2017).

Main challenges. Although fruitful, EE research face challenges (see Cavallo et al., 2018; E. Stam, 2015), especially a lack of a theoretical framework examining the systemic components, processes, and structures simultaneously, considering EE is such a complex, variegated, and temporally discontinuous phenomena. Put another way, current EE frameworks by scholars and policy makers fail to help us "comprehend the full *complexity* of these complex organisms" (Brown & Mason, 2017: 26, emphasis added). Such a guiding framework is important because "[c]onstruing ecosystems as complex categories can allow for more conceptually robust and relevant applications" (Spigel & Harrison, 2018: 8). More specifically, we argue holistic insights into complexity property of EE will bring benefits in clarifying conceptual ambiguities, solving empirical problems, and importantly facilitating policy interventions.[2]

This holds true for all three EE schools concluded before. For the "components" school, it is misleading to interpret indispensable components as a recipe for successful EEs, with a fact they show nonlinear and sometimes chaotic nature (Brown & Mason, 2017). For example, an EE constitutes participants like ambitious entrepreneurs, venture capitalists, business angels, banks, support organizations, political and research agencies. Simply classifying all elements into major parts (e.g., Spigel, 2015) is problematic, considering in some cases entrepreneurs are both disruptive innovations makers and act as capital investors, which implies causes and effects among components is beyond linear tradition. Moreover, martial components such as infrastructure and entrepreneurship policies might create beneficial environments for stand-up entrepreneurs (through open conference and activities), whereas have limited effects on cultural aspects (e.g, entrepreneurs' risk-taking and relevant spirits which is seemed as necessary conditions for high-impact entrepreneurship).

For the "processes" school, despite the increasing findings revel the discontinuity of EE evolution, the argument is challenged in terms of all EE components are able to develop synchronously into optimality that features the resilient stage. For example, the denser finances and strong dedicated entrepreneurial policies do not sufficiently indicate EE vibrancy when their mutual tensions keep a high level (Radinger-Peer et al., 2018). Besides, more failed start-ups do not means EE decline, but instead another wave of productive entrepreneurship because entrepreneurial resources reside (such as experiences and social network) and will be recycled by followers for new innovations, which apparently represents EE resilience (Brown & Mason, 2017; Martin & Sunley, 2011). In summary, a well-functioned EE is far from equilibrium (i.e., not too stable or dynamic).

Last for the "structures" school, a sustainable EE tends to keep a more flat (all EE participants are self-organized) rather than hierarchical governance structure (Colombelli et al., 2017; Isenberg, 2014). For example, EE outputs are always disproportional to the size of the input entrepreneurial resources, which doubts the efficiency of dominant top-down governance approaches. The active role of political agencies might know little what the revolutionary industries need and ways to nurture them. Often, blockbuster innovations appear in an emergent (bottom-up) way. Besides, contemporary digital technologies and infrastructures reduce entrepreneurs' dependence on local feeders or intermediaries obtaining resources in a bounded location (Autio et al., 2018; Sussan & Acs, 2017). In this regard, the governance boundaries are thus hardly to be delineated (Bruns et al., 2017).

[2] In general, complexity refers to the condition of the universe which is integrated and yet too rich and varied for us to understand in simple common mechanistic or linear ways (Sherman & Schultz, 1998). In organization science, organizational complexity results from the number of components, intricacy of interfaces among them, and the number and degree of such intricacy conditions (Ladyman et al., 2013; Lewin, 1999). Here, 'components' or 'agents' have varied organizational forms: individuals, groups, formal and informal organizations, supply chain networks, and even innovation ecosystems.

2.2 EE as complex adaptive systems

To address aforementioned challenges in terms of EE complexity (e.g., non-linearity, far from equilibrium, and emergence property), we apply complex adaptive systems (CAS) theory (Anderson, 1999; Gell-Mann, 1994; Lewin, 1999) into conceptualization of EE phenomena, for two important reasons. First, as the subset of complexity and chaos theory, CAS fits as it shows advantages in explaining how complex causes can produce simple effects, or, simple rules can have unpredictable consequences (Anderson, 1999), which is in accordance with inter-organizational phenomena (also including EE). In other words, CAS is valued because it demonstrates that the dynamic interactions among agents produce more than the sum of the individual ones (Goldstein, 1999; Mckelvey, 1999). Based on these, we see organizational scholars have employed CAS perspective into theorizing, for example, virtual research collaborations (Aydinoglu, 2013), supply networks (Choi et al., 2001), business ecosystems (Peltoniemi, 2006), and even recently innovation systems and clusters (Russell & Smorodinskaya, 2018; Surie, 2017).

Second, as with a general CAS in biology (e.g., a flock of birds and ant colony) includes three main elements: agents, interactions, and the environment (Dooley, 1997; Mitleton-Kelly, 2003), an EE talks about entrepreneurs, the patterns to create entrepreneurship, and multi-level environments they embedded in (Z. Acs et al., 2014). Following this principle, on the one hand, some EE scholars discussed CAS properties separately and cast a fragmented landscape of a CAS-based EE (see discussion in O'Connor et al., 2017; Isenberg, 2016; Carayannis et al., 2018). On the other hand, though recent work offered a 'complete' box of EE properties shared with CAS (see P. Roundy et al., 2018), their conceptual endeavor neither illustrated how each property could moderate (solve) problems, paradox, or ambiguity within three EE schools, nor, to our best knowledge, offered much empirical evidence of EE from CAS perspective.

In doing so, we first integrate EE literature and research on CAS theory to conclude six main interrelated EE properties: large number of interdependent and self-organized agents; non-linear interactions and feedback loops; sensitivity to initial conditions; adaption to environment/far from equilibrium; emergence; co-evolution/multidimensionality. Second, we explain how identifiable properties deal with problems, paradox, or ambiguity existing in three EE schools respectively, which are further tested by a qualitative case study in section 3.

2.2.1 Large number of interdependent and self-organized agents

According to CAS theory (e.g., Anderson, 1999; Gell-Mann, 1994), a primary reason of CAS's complexity is attributed to numerous heterogeneous agents, who interact each other with different features and agendas/objectives. First, they are interdependent since the whole of CAS is survivable than the sum of the parts (e.g., ant colony) (Benbya & McKelvey, 2006). Second, the agents have relatively stable positions, and will get themselves changed constantly. That is, agents with their neighbors share, and thus behave according to, the same "schemata" (a range of communication rules or recognized perceptions), which is possibly replaced with new ones because of recombined agents. To sustain this pattern, agents spontaneously determine to absorb or preclude agents based on needs by shared schemata. This implies a dynamic interacted CAS develops with no central controller, or it is openly self-organized (Anderson, 1999; S. A. Kauffman & Strohman, 1994).

The EEs fit these properties — a large number of interdependent and self-organized actors search for high-impact entrepreneurship. As to the system "diversity", agents in EE are from six interdependent components (e.g., Isenberg, 2011), and each component has no strict limit (political actors can be regulators and also investors or investors might invest new ventures at time *t* and act as entrepreneurs at *t+1*) and is nested (McCarthy et al., 2006). For example, the finance component might have banks, angel and venture capitals, individual investors, political investment agencies, and public welfare funds etc., in which sub-component banks also have many types. As to the system "unity", although components boundaries are loose, the communication rules and principles for each are relatively stable and will change incrementally. For all ambitious entrepreneurs, they communicate frequently and form specialized schemata (e.g., entrepreneurial climate, norms, conventions, and advocated spirits), During this process, entrepreneurs might exit and entry, while the schemata keeps stable and new ones appear based on self-organized entrepreneurs with no interventions by central organizer(s) (Isenberg, 2016; Feld, 2012; Spigel & Harrison, 2018). In this sense, self-organization

matters because EE aims for high-impact innovations, which contain high uncertainties and risks that no individual actors including entrepreneurs themselves can inform how to be productive (Autio & Levie, 2017), and any controls can be counterproductive.

2.2.2 Non-linear interactions and feedback loops

Beyond traditional casual models in mathematics, the CAS is grounded on that interacted agents' inputs result in non-deterministic (i.e., nom-linear) and thus disproportional outcomes (Morel & Ramanujam, 1999). According to Kauffman (1994, 1996), the nonlinearity from inputs to outputs is determined by the degree of agents' diversity and connectedness. For instance, the unevenly distributed agents make impacts dissipated unevenly when energy and information transfer from one to another. Due to this feature, the inputs by some agents might have an amplifying (i.e., positive feedback loops) or dampening (i.e., negative feedback loops) effect on others (Anderson, 1999; Bergmann Lichtenstein, 2000), as it is the case for stock markets (e.g., a large-scale change such as merger activities may lead to little reactions from stockholders, while a small change in finance policy may end up having an overarching outcomes such as dumping behaviors) (Choi et al., 2001).

"A key feature of ecosystems is nonlinearity" (Brown & Mason, 2017: 15). Considering the nature of nonlinearity, the process from combing all entrepreneurial resources, including the numerous actors and non-actors (e.g., information and recourses), changing schemata, and high quality interactions, to produce system behaviors (high-impact entrepreneurship) is untraceable because of multidirectional causalities (Isenberg, 2016). Yet we see EE performance through two different mechanisms: positive and negative feedback loops among EE (sub)components (McKelvey, 2004).

The positive feedback loops mean the changes in certain components amplify the benefits to other related in a recursive fashion. Brown and Mason (2017) describe it as success breeding bigger success. For example, a group of graduates in EE manages to introduce attractive products into markets. Early financial success attracts followers, skilled workers, and possible venture capitals, whose involvement improves the products' quality and popularity and form/shape shared schemata. Gradually, their economic and social contribution capture much attention from more participants such as governments, social media, NGOs, and universities, whose supports largely accelerate the precursors' scale-up. This, in turn, lays foundation to future high-growth innovations by serial entrepreneurs or even new ones from investors and universities (Spigel & Harrison, 2018). Hence, the 'loop' is self-reinforced (Lichtenstein et al., 2007). Instead of triggering infinite changes, a negative feedback loop predicts that interacted components causes one or all of them move towards a steady state (P. Roundy et al., 2018; Stacey, 1995). To continue foregoing example, the growth speed of graduates' innovative products will decelerate due to unavailable required complementary technologies and skilled workers (even if investors are enough). As a result, the tensions between entrepreneurs and investors happen (a lot of investors get impatient). Thus a negative feedback loop plays.

2.2.3 Sensitivity to initial conditions

"The feedback loops and nonlinear relationships create a condition called sensitivity to initial conditions — which results in unpredictability" (Aydinoglu, 2013: 6). This feature helps understand how the CAS achieves the current state in way of evolutionary path dependence — new path creation is a result of new combinations that are based on and limited by the existing regional industry structure (Neffke et al., 2011). Scholars illustrate that path dependence is relevant to CAS on the condition that agents in CAS are locked in waves of complementary positive feedbacks loops (e.g., Blomme, 2012). If positive feedback loops endure, the CAS development in certain direction turns to be irreversible. As such, every CAS's initial events and decisions count since small changes in agents might cause radical divergent evolution processes (Anderson, 1999; Dooley, 1997).

Extant EE research also confirms this feature (see Radinger-Peer et al., 2018). On the one hand, early entrepreneurship success (especially well-known ones) in EE offers experiences, role models, established resources for prospect entrepreneurs, who will make use of these advantages promoting more successes. In this respect, early entrepreneurship activities pass genes to followers, which the combinations of previous ideas by them are further embedded into EE and as a whole shape future entrepreneurial behavior. Therefore, the diversity of initial EE components would significantly impact

EE future state, in contrast to less dense EEs (Nylund & Cohen, 2017). On the other hand, if the past decisions by EE agents focus on single type of entrepreneurship, they might crow out others and are susceptible to external shocks (Brown & Mason, 2017; P. Roundy et al., 2018). This is especially true for single big firms influenced (e.g., Bhawe & Zahra, 2017; Gray et al., 1996) or single industry-based EEs (e.g., Kenney & Von Burg, 1999; Spigel, 2015).

2.2.4 Adaption to environment/far from equilibrium

To avoid negative effects by path-dependence, CASs are stimulated to improve their adaptability, defined as a system's capacity to adjust to internal struggles and external threats without endangering its essential function (Chiva et al., 2010; Martin & Sunley, 2006). For this purpose, CAS will be not too static or chaotic but stay in-between: the quasi-equilibrium state let systems produce a better solution (new structures through agents entry, exit, and transformation) to survive (Anderson, 1999; Choi et al., 2001; Dooley, 1997). Taking the human immune system (a sort of CAS) as the example, it has multiple adaptive mechanisms to respond to different pathogens. We then observe CASs are changeable to be resilient instead of staying in one state for too long (Martin & Sunley, 2011).

In the EEs context, "system-level adaptability emerges from behaviors at lower levels, even as the agents comprising those levels are themselves influenced by system-level changes" (P. Roundy et al., 2018: 4). For the internal adaptation process, a small event by agent interactions can trigger a cascade of changes that eventually cause system-level behavior, which in turn direct agents to modify their internal rules and evaluation criteria for fitness, at least temporarily (S. A. Kauffman & Strohman, 1994; McCarthy et al., 2006; Surana et al., 2005). For example, entrepreneurs might realize there is a paucity of talents that can combine traditional automobiles and ICT, which restrict auto emprises' intention to introduce ICT and Internet firms' desire to make business model innovation. As entrepreneurs undertake to combine these two irrelevant things, they feel a need to create a professional platform to enroll trainees. With the affluence of requisite talents, two industries thus spawn some start-ups that forecast a new growth. Moreover, the hybrids set a good example for other industries (e.g, ICT and house furniture industry). Eventually, governments provide more policies or incubators for such activities and investors are enthusiastic about related investments. The EE possesses the system behavior: "cross-border" innovation, which is shared by and in reverse directs EE agents.

While for the external adaptation process, EE theorists have contextualized that external disturbances cause adaptive reactions from EE components, which accordingly readjust internal coherence and diversity in an accumulated way (e.g., Auerswald & Dani, 2017; Radinger-Peer et al., 2018). Continuing the aforementioned cross-border innovation example, a trade war outside the EE might halt auto enterprises and investors' confidence on "Internet car" because the trade war indeed contracts its main market. Many related start-ups would therefore reorient or fail. Although the diversity and coherence among these components are reduced, the strong governments then play the complementary investment roles and issue beneficial policies. The new accumulated resources, experiences, and infrastructure will be put to other cross-border domains. In this way, the investors' confidence is committed to these new agents. Consequently, the enhanced EE coherence and diversity make it resilient to external shocks.

2.2.5 Emergence

CAS maintaining "internal energy" usually starts in a random state but evolves into order (Anderson, 1999; Holland, 1995; Stacey, 1995), during which agents' non-linear interactions give rise to, and affected by, the system-level behavior emergence. Although observable, the CAS emergent behaviors cannot be intentionally organized by any micro agents. In this respect, it is concluded that there is a non-linear relationship between individual actions and the final patterns at the system level (Goldstein, 1999). Taking the stock market as an example, all agents (individual or organizations) continuously trade their stocks and incur market fluctuation, while nobody can accurately predict these macro behaviors (stock index's upward or downward trends). In turn, every time fluctuation will affect participants' subsequent buying and selling decisions. In certain period of time, this collective behaviors will be noticeable for all participants, even if traders might entry and exit (Blomme, 2012).

This feature is equally applicable to entrepreneurship ecosystem (e.g., Akgün et al., 2014; Lichtenstein et al., 2007), as we often find in EEs that "[u]nder certain set of conditions, entrepreneurship seems to just 'happen'" (Isenberg, 2016: 568) that no one can predict beforehand. Put another way, the high-impact entrepreneurship is embedded in agents, and thus happen in bottom-up sense, because no agents are able to control or know the requisite elements high-impact entrepreneurships need in advance. However, seen as EEs' collective behavior, the emergent high-impact entrepreneurship induces all EE components to readjust them into more optimal positions (Colombo et al., 2017). P. Roundy et al. (2018) proposes three coherent "conditions" to understand EE emergence. The key is entrepreneurs' ambitions and unstopped experiments. Around the center — ambitious entrepreneurs, other EE components (especially finance and policy) link themselves to the "shared entrepreneurship rules" and consequently achieve coherence in their actions. Last, being open to agent exits and entrances lets EE stay away from stagnation.

2.2.6 Co-evolution/Multidimensionality

CASs accommodate many other smaller CASs and are meanwhile embedded into larger CASs, and hence complex systems are multidimensional, and all dimensions interact and influence each other (Mitleton-Kelly, 2003; S. A. Kauffman & Strohman, 1994). In a simple sense, individual or ventures (smaller CASs) could affect supply networks (small CASs), which affect regional clusters (big CASs), which affect global economic systems (bigger CASs), and vice versa. These rippling impacts are explained through fractals — self-similar patterns at different scales (Morel & Ramanujam, 1999).

EEs are characterized by complex 'nested geographies' (i.e. smaller EEs located within larger EEs) which involves multi-scaler interactions with other entrepreneurial actors on a number of different spatial levels, both domestically and internationally (Brown & Mason, 2017). This argument requires scholars conceptualize EEs in a holistic perspective, as EEs on different dimensions (district, city, cluster, regional, national, or global) co-evolve (Autio et al., 2018; Malecki, 2018). Although EEs cannot be completely delineated by spatial locations, they can be set with two reliable indicators (see P. Roundy, 2016; P. Roundy et al., 2018). The first is identifying the representative epicenter(s), a place where high-impact entrepreneurships take place frequently through collection of highly coherent agents. The reason is that as agents become increasingly geographically distant from epicenters, the observable emergent EE behaviors will weaken. With a complement, second, considering the socio-cultural characteristics in terms of high-impact entrepreneurship can distinguish EE components outside of or within social or cultural EE boundaries, though partially and intangibly (Alvedalen & Boschma, 2016).

3 Method

We decided to adopt the case study method to answer our research question, based on several considerations. First, multiple qualitative data sources and theory driven data analysis are preferable to study CASs in different forms (e.g., McCarthy et al., 2006; P. Roundy et al., 2018), and the third author had fully access to very rich data about multi-level elements in EEs. Second, the case study method has a distinct advantage in situations when "how" or "why" questions are being asked about events and activities over which the investigators has little or no control (Yin, 2013). Our research question was driven based on retrospective analysis of activities or critical events in EEs that demonstrated how EE evolved progressively toward a CAS. Third, this project was organized as joint practice research allowing the third author to engage fully in on-site observations of EE while at the same time researching it in collaboration with other three authors (Mathiassen, 2002).

We do so by employing all identified complexity properties into *Zhongguancun Science Park*, an emerging EE located in Beijing (henceforth: Zhongguancun EE; cf. Du et al., 2018; Li et al., 2017). We purposively select Zhongguancun as the appropriate research context for three reasons. First and foremost, Zhongguancun has been transforming from entrepreneurship policy-driven science park to self-organized ecosystem, from selling electronic products to nurturing world-famous unicorns (Du et al., 2018), and based on which, from separated to more coherent EE components (especially the inclusive entrepreneurship culture, high quality human resource, innovation policy, emerging market, diverse finance, and digital infrastructure) (World Economic Forum, 2016). According to CB Insights (2018), since 2012, the unicorns in Beijing boomed. We think this presents a proper research context.

Second, the varied secondary data on websites (e.g., newspapers, related magazines, videos, books, and academic papers) help maintain a holistic view of Zhongguancun EE and validate our research findings (A. H. Van de Ven, 2007; Yin, 2013).

3.1 Description of the empirical setting

Zhongguancun EE (see figure 1) is one of the innovation centers in the world and has pioneered in the forefront of many disruptive innovations (KPMG, 2017).[3] Over the last two decades, Zhongguancun EE has gathered nearly 20,000 high- and new-tech enterprises, ranging from electronic information, biomedicine, energy and environmental protection, new materials, advanced manufacturing, aerospace engineering, to R&D related services. Such rapid development builds on four main stages, during which the diversity and coherence of Zhongguancun EE components show periodical features.

-------Insert Figure 1 around here-------

Stage 1 (1980-1988). At this stage, entrepreneurs mainly come from universities (high density of nationally renowned universities and research institutions including the leading universities in the nation, Peking University, Tsinghua University, and the Chinese Academy of Sciences and its affiliates), governments, and state-owned enterprises, which are deeply facilitated by ambivalent attitudes of central governments toward market-oriented companies. Many Internet-related markets (e.g., PC electronics) then mushroomed in Zhongguancun EE and developed into "Zhongguancun Electronics Street". Yet the social networks among agents were strong, but they are exclusive academic networks involving few commercial agents, such as banks and business services.

Stage 2 (1988-1999). At this stage, entrepreneurs aimed at creating high-tech Internet-based companies, with the intense competition from multinational companies (MNCs) (Zhou, 2005). Central governments sidelined while local Beijing municipalities played supportive roles (e.g., in May 1988, the state council approved the establishment of the Beijing New Technology Industrial Development Trial Zone). During this period, many EE components emerged (e.g, financial institutes and talent service organizations) but were separately operated and therefore lacked consistence in actions.

Stage 3 (1999-2009). At this stage, entrepreneurs and governments felt the limits, in terms of short of business services, labor mobility restriction, state monopoly and entry barriers, IP problems, information asymmetry. Governments in different levels started to enhance information/physical infrastructure, provide tax deductions, increase R&D investments, and solve administrative obstacles. With a result, a community of high-tech start-ups by individuals, related services organizations (incubators and accelerators), and spin-offs (from universities and establishes big companies) thrived, with the maturity of ICT and thus the rise of E-commerce (Zhu & Tann, 2005). However, the fragile mutual trust, unavailability of venture capital, intellectual rights problems exacerbated its development (see Tan, 2006; Zhou, 2005).

Stage 4 (2009-Current). At this stage our research focus on, the start-ups in diverse industries increased exponentially and all EE components' connectedness became complex. Governments changed their role into policy supporters rather than EE managers (Du et al., 2018). Especially, on March 13, 2009, the State Council approved the construction of the Zhongguancun National Demonstration Zone, and made the plan to expand Zhongguancun to a full innovation center with global influence. Later the "Development Plan Outline for Zhongguancun National Demonstration Zone (2011-2020)" was launched by the State Council on January 26, 2011, marking a new starting point for Zhongguancun EE's rapid development. Since then, Zhongguancun EE devotes to mobilizing and energizing disruptive innovation and high-impact entrepreneurship (on average, 1.5 start-ups are financed per day and the average financing is 7 million, cf. Li et al., 2017).

3.2 Data collection

Our research aimed at developing a CAS-based empirical understanding of EE. In so doing, a holistic design and unlimited access to multiple data resources allowed us to reconstruct EE developing history, investigate different actors' activities and opinions, examine the context in which critical activities occurred, and importantly clarify how actions and perceptions of different actor groups

[3] See more research settings on Zhongguancun EE: *http://zgcgw.beijing.gov.cn/*

evolved over time. Our data drew mainly from 23 focus group interviews, which were complemented by six types of secondary data, including news/industrial articles, online audio and videos of Zhongguancun, Zhongguancun public reports and yearbooks, third authors' participatory observations, extensive discussions with experts and practitioners, and industrial meeting reports.

First, among the primary data are face-to-face interviews with 23 entrepreneurs or senior managers/administrators in Zhongguancun EE (see table 1). Considering such 'high-level' informants ensured that we could capture the best informed (especially macro-level) qualitative data. These representative informants were approached (between May to November 2014) under the guidance by Zhongguancun Administrative Committee, a specialized political agency responsible for managing annual entrepreneurship and innovation information (Du et al., 2018). This accessibility made intended informants fully cover six EE components illustrated by Isenberg (2011).

-------Insert Table 1 around here-------

Every anonymously recorded interview involved multiple interviewers and was based on an interview protocol, in order to ensure data reliability (Strauss & Corbin, 1990). Multiple interviewers, consisting of the third author, relevant experts/scholars, and industrial practitioners, kept the diversity to collect answers from different angles. While the interview protocol, consisting of three main sections, was adjusted frequently according to informants' real-time responses. Specifically, the first section focused on the personal and organizational backgrounds. In case of interviewed entrepreneurs, they also reported their entrepreneurial experience/history and start-ups' operating conditions. The second and key section focused on their interactions with other EE components, the changes of contexts they embedded in recent years, the critical entrepreneurship events or activities, and evaluations on different (finance, policy, and talent) agents' supports. These information laid foundation to subsequent CAS-based EE analyses: agents, interactions, and embedded contexts (Z. Acs et al., 2014; Mitleton-Kelly, 2003). Within the third section, they were required to provide advices on how Zhongguancun EE could better supported future high-impact entrepreneurship.

Second, the captured diverse secondary data (in PDF format) by first author complemented and triangulated interview data and further enhanced our findings' trustworthiness (Jonsen & Jehn, 2009). We stopped data gathering until a point of saturation was achieved where additional data collection could not yield new knowledge to answer research questions (Eisenhardt, 1989; Yin, 2013). Finally, interview data was completely transcribed verbatim in Chinese and, together with all secondary data, coded within Nvivo 11 software for qualitative process analysis.

3.3 Data analysis

All four authors participated into data analysis with multiple discussion sessions, following the recommended procedures for qualitative research and grounded theory (Gioia et al., 2013; Strauss & Corbin, 1990). Doing so permits researchers' exposure to proposed analytic framework to proceed the data analysis process (Eisenhardt, 1989). Specifically, we took an iterative coding process that involved identifying the emerging concepts, examining empirical evidence for supports, consolidating similar concepts to create refined themes, and collecting more data until reaching theoretical saturation. An overview of the data structure was illustrated by figure 2.

-------Insert Figure 2 around here-------

First, initial data analysis was based on three stages: open, axial, and selective coding (Strauss & Corbin, 1990). During the open coding stage, using our proposed CAS-based EE framework for guidance, the first and second author independently coded the whole materials sentence-by-sentence and kept open to what materials suggested. This ensured coders interpreted the data in similar fashion without missing any emergent information. We first identified 113 codes, each supported by two or more text segments. During the axial coding stage, two authors collated first-order codes that were conceptually similar and relevant to our themes building. In addition, the third and fourth authors played the "censor" role in group meetings to critically question or challenge the acquired themes by two open-coders to improve data validity. Finally, during the selective coding process, conforming closely to Gioia method (Gioia et al., 2013), we tentatively strived to aggregate identified themes into

dimensions and thus formulate a coherent and insightful account of CAS-based Zhongguancun EE. This stage was again guided by analytic framework, as we looked for matched empirical evidence and new insights of Zhongguancun EE with six CAS properties (P. Roundy et al., 2018).

Second, additional coding and interviewing efforts were made in late 2018 until theoretical saturation reached. We went back to the dataset in Nvivo for research results consistency, by solving some information gaps. Besides, when confusions or inconsistence happened, we triangulated among all interviewers and authors and, if necessary, checked factual information with key insiders in Zhongguancun EE in via of email or phone call. After foregoing work, we started to present our write-ups, which relevant parts were also read and commented by key informants and adjusted accordingly. As a result, our analysis tightly grounded in qualitative data and internally consistent, reveled not only the six CAS-based EE properties but also their integral relationships in Zhongguancun case.

4 Findings

In this section, we present the results that Zhongguancun EE possesses the proposed six CAS properties, and thus can be concluded into a general coherent CAS-based EE model, depicted by figure 3.

4.1 Large number of interdependent and self-organized agents

It is a consensus that the success of Zhongguancun EE largely depends on diversified entrepreneurial agents or related factors, producing high-impact entrepreneurship by mass entrepreneurs. One informant *(Tsinghua Holdings_chairperson)* summarized eight dominant and interacted Zhongguancun EE agents: service-oriented governments, developed Internet-based industries, universities, dense research institutes, diversified invest agencies, entrepreneurship intermediaries, mass medium, and many other R&D service agencies. Among these agents, entrepreneurial resources, such as talents, technologies, services, and finances, circulated within and across EE boundaries (see figure 4).

-------Insert Figure 4 around here-------

First, the abundant EE agents of each component were interdependent with no clear boundaries. Since 2009, governments in different levels offered many stimulative entrepreneurial policies, which directly inspired numerous entrepreneurs from big well-known ICT companies (e.g., Baidu, Kingsoft, and Lenovo Group). Meanwhile, varied finance and entrepreneurship service agents (e.g., law service companies, incubators and accelerators) mushroomed to support those ambitious entrepreneurs. The quick prosperity also attracted much attention from academic research institutes, who actively provided young talents and transferred their scientific patents. They were indispensable in creating successful entrepreneurship. However, unlike Silicon Valley where angel investors and venture venture capitals focus only on investing, finance agents of Zhongguancun played extra roles, such as skills training, resources matchmaking, and even marketing. Entrepreneurs in incubators and accelerators were also supported with rent-free offices, accessible financial resources, and free entrepreneurship information. These versatile investors and incubators were not easily differentiated, and sometimes they even participated in practical entrepreneurship activities and became entrepreneurs themselves.

Second, all entrepreneurial agents and resources were self-organized with no central governors in Zhongguancun EE. A remarkable transition of Zhongguancun was that Zhongguancun Administrative Committee consciously changed their management into services provider role because too many political orders or interventions were disadvantageous to entrepreneurship activities. *"all actors in Zhongguancun are advised to do what they prefer except for the illegal business like drug dealing" (Zhongguancun Administrative Committee_section chief).* Besides, powerful investors also respected entrepreneurs and allowed freedom in innovations, as *"only entrepreneurs themselves know what they really want to make for the markets. So what we can do was giving supports of different kinds" (Zhongguancun Administrative Committee_section chief).*

Third, though "*entrepreneurial branches*" (i.e., start-ups or entrepreneurs from the same companies, universities, incubators, or have same overseas backgrounds) are identifiable, they were not separated but engaged into and hence nurtured by "*self-conscious energy climate*". On the one

hand, entrepreneurs from established companies were more likely to succeed than others because of the close social/emotional ties, inherited norms, and more importantly the available entrepreneurial resources. For example, employees from Baidu would found their new business being complementary to Baidu's products, or based on Baidu's technological platforms. The entrepreneurs in Baidu branch usually supported each other, shared resources and information, behaved according to mutual trust, which guaranteed their survival rate. One the other hand, these entrepreneurial branches formed a stable "self-conscious energy climate", referring to the shared social identity and common cultural self-consciousness of Zhongguancun EE. Specifically, the shared social identity — Zhongguancun members helped them make sense of "who am I"; the cultural self-consciousness meant they strove to pursue blockbusters, and therefore they often showed solidarity, altruisms, and failure tolerance.

4.2 Non-linear interactions and feedback loops

The reason why Zhongguancun EE becomes attractive was that all entrepreneurs were treated with no differentiation. Entrepreneurs could exchange their innovative ideas together, recombine team members, and introduce their products/services to investors in a nonlinear way. For example, 3w café and Cheku café offered the place to enable entrepreneur-investor nonlinear connections:

> *"I think 3w café is not simply regarded as a physical space for dinking, but more a 'melting pot' for entrepreneurships and innovations. We right now hold over 50 entrepreneurship activities every month, drawing people from big companies, universities, traditional industries, investors, grass-roots entrepreneurs, governmental agencies and many you can imagine…What people communicate in 3w café is dominantly related to mobile Internet domain. Yet the communications are hardly limited to it and people will discuss what they feel interested, which definitely produce more new and different innovative ideas." (3w café_founder)*

> *"Entrepreneurial communication events like seminars, industrial conferences, training sessions etc., are interesting and sometimes promote new emerging industry. Taking online travel industry as an example, people will describe a, b, c and so on several business models. Listeners such as investors will present their thinking on them. But very often, you will find they might feel crazy on online dating projects, totally different from previous ideas. Afterwards entrepreneurs will quickly change their business model, or investors turn into new entrepreneurs, and even they collaborate to start a new team to do that…"(3w café_founder)*

The nonlinearity is moreover evidenced by investors' efforts into entrepreneurial outcomes. Except abundant local ICT talents, supportive policies, and diversified entrepreneurial services, financial resources such as angel/venture capitals, private funds, crowding platforms, commercial banks, international investment consortiums, and government-based investments support thousands and hundreds of entrepreneurs and start-ups. However, only a small percentage of them will succeed in markets. As one respondent explained *"…during last decade, there is a big increase of investment agencies in Zhongguancun. Many of them underestimate the start-ups' success rate and invest blindly and irrationally. As we often see several lucky ones from thousand start-ups, this is an unbroken rule in terms of successful entrepreneurship, which is not about money but to a large extent entrepreneurs themselves, luck, and unforeseen factors…"*

We find many unicorns emerged through a mechanism of positive feedback loops among EE components. For example, ofo and Mobike, two leading bike-sharing companies that integrated traditional bicycles and ICT technologies (e.g., Narrow Band IoT, GPS tracking, and mobile payment), initially started their business since 2014. Their early success in Zhongguancun EE depended on central and local governments' encouragement allowing distributing sharing bikes on urban streets, high penetration rates of smartphones and mobile payment by mass customers, and a series of venture capitals. Their bike-sharing services created benefits to environment, social warfare, and local economy, which swiftly attracted many followers providing the same services, policymakers, mass medium, NGOs, research institutes, international investors, and even skilled workers from car-sharing industry. These EE components' active involvement in turn promoted ofo and Mobike's rapid scale-up, as over 100 investing agencies recognized their market potential and thus invested heavily (ofo and Mobike raised $0.7 billion and $0.6 billion respectively). Finally, two

companies were valued up to $3 billion at the end of 2017. Even though there were numerous failed bike-sharing followers, the established social networks, human resources, and operation experiences on managing sharing business were recirculated in Zhongguancun EE, which could help other related mobile Internet businesses.

In contrast, Zhongguancun EE's development was blocked by negative feedback loops, talents (e.g., skilled technicians) were negatively impacted by the high housing price, traffic costs, and air pollution.

AngelCrunch_founder: "…you can imagine that entrepreneurs have to pay for house rent with their half salary. They are definitely demotivated to be innovative. And they further spend hours on commuting that I am sure they have no passion and motives on creating big businesses."

Interviewer: "they can relocate and live nearby."

AngelCrunch_founder: "It is a paradox. The more entrepreneurs living in Zhongguancun or nearby, the higher the housing price the might suffer. Whereas less entrepreneurs will decrease Zhongguancun's viability. Zhongguancun is unable to solve this problem duo to the limited living space. Entrepreneurs will move to Shanghai, Wuxi, or Shenzhen if their living environment worsens much than before...this is disadvantageous to Zhongguancun".

4.3 Sensitivity to initial conditions

The majority of Zhongguancun unicorns since 2012 or start-ups in incubators/accelerators revolved around the mobile Internet industry (i.e., Internet services, e-commerce, online finance/education), for several institutional and economic reasons (CB insights, 2018). First, the rapid growth of digital infrastructure (especially the 3G and 4G networks and high penetration rate of smartphones) and related ICT technologies lays good foundation for unicorns building markets easily. Second, CEOs or founders of unicorns possessed relevant Internet-based working backgrounds, which are highly related to traditional established companies in Zhongguancun EE (e.g., Baidu, Sohu, Lenovo, Kingsoft, Sina, and Netease). Third, central governments released the National "Internet Plus" Program, which meant any entrepreneurships and innovations on Internet-related industries were advocated. Fourth, most investors preferred blockbuster entrepreneurship on mobile Internet as they had low risks and quick earnings, in particularly comparison to aerospace, bio-medical, and new materials domains.

Northern Light_co-founder: "…Beijing is rich in 'soft' things but short of 'hard' things."

Interviewer: "The 'soft' thing you mean is the software?"

Northern Light_co-founder: "Not exactly. As with cloud computing, semiconductors, integrated electronic system, and electronic design that Shanghai and Shenzhen might be more competitive, Beijing cannot have all industries. Comparably, I mean Beijing's mobile Internet industry has been in the lead in the global. The bloom of mobile Internet industry will stop in the future when no other emerging industries arise. Specifically, the collision and combination between different industries can produce new things, which can sustain Zhongguancun development. Therefore, for our governments, how to diversify industries and moreover upgrade industry distribution became a big challenge."

In summary, the high-impact entrepreneurships (e.g., 66 unicorns until January 2018) emerged from Zhongguancun EE were locked into mobile Internet industry. These unicorns in this industry consisting of investment preference, accumulated talents, polies, strong mobile Internet culture, established social networks are hardly reversible. They are complementary and mutually reinforced and restrained the emergence of other disruptive innovations.

4.4 Adaption to environment/far from equilibrium

According to Auerswald and Dani (2017), Zhongguancun EE was on the transition from "exploitation" to "conservation", a development stage that all EE agents interactions were not too

loose or too chaotic. Firstly, the diversity and connectedness of EE components had been increasing. *"I think a most important puzzle Zhongguancun missed several years ago was the robust entrepreneurial services, such as market statistics and information providers, legal consultancy, IP rights protection, fund-raising guarantee, specialized media propagation and so on. But fortunately, they developed fast since 2010 and started to catalyze with Zhongguancun actors, especially mass entrepreneurs. This seems a good signal." (Tsinghua Holdings_chairperson).* Based on these, ambitious entrepreneurs can realize their innovative ideas quickly, though there was a high competition for entrepreneurial resources. As 36kr_co-founder emphasized, "…we are now standing at a wild developing state. You cannot delay but move as fast as possible…". Secondly, yet the strong interdependencies among EE components, Zhongguancun had never reached a climax point where entrepreneurial resources utilization by entrepreneurs shifted from increase to maintenance, or a state vulnerable to internal or external disturbances. As respondents illustrated:

> *"…Zhongguancun Administrative Commission needs to proactively think about Zhongguancun's future as we cannot predict what happened tomorrow. In fact, after the economic benefits of promoting mobile Internet stagnate, the real systemic risks come. However, preparing for future development in turn entails revolutionizing all factors in Zhongguancun, like infrastructure, culture, talents, and even policies from top-level design." (Zhongguancun Administrative Committee_section chief).*

> *"The current prosperity of Zhongguancun is superficial and fragile, if we compare it to U.S. Silicon Valley. They are always worried about future, and think and execute ahead of others, such as investing future biotechnologies. And many investors have patience to these high-risks investments, which is not the case for Beijing investors." (Northern Light_co-founder)*

Therefore, Zhongguancun EE improved their ability to defend against internal and external struggles for systemic fitness. First, the deep integration among EE components promotes more entrepreneurship in a sustainable way, especially considering the high-performance entrepreneurships need high synergies among them (Nylund & Cohen, 2017). For example, over 100 incubators/accelerators located in Zhongguancun allied themselves to support entrepreneurs or start-ups, in order to make use of complementary capabilities and resources. *"…the incubator platform built by Zhongguancun Administrative Commission is forward-looking…for example, 3w café introduced a nice entrepreneurial project to Microsoft Azure accelerator, who is more suitable to give one-to-one niche-targeting services. We also collaborate with AAMA to provide trainings to all members…" (Microsoft Azure_co-founder).* In addition, many angel capitals (as well as between governments and venture capitals) followed the same way.

> *"…it is always difficult for angel capitals to individually pinpoint the best venture investment projects due to their limited resources and experiences, which promote them to cooperate with angel peers. We sit together and choose entrepreneurial projects with satisfying investment returns. The investing efficiency is thus enhanced and investing risks are reduced…in our usual practices, we establish a mutual fund joining all intended angel or venture capitals to invest a mobile Internet project. It is turned out such union model is fruitful. The assessed market value of many invested entrepreneurial projects has tripled or more…even for those promising ones with possible political struggles, we will invite governments." (River_co-founder)*

Second, a common sense is gradually shared with all EE finance agents: *"union turns impossible into possible"*, which functions as the entrepreneurial culture (investing norms, values, practices, and entrepreneurship narratives (Feld, 2012; P. Roundy, 2016)) guiding all EE agents in Zhongguancun. *"Every people will sacrifice himself to his or other related entrepreneurial projects because helping others equals to helping yourself. This [union culture] is powerful as it resonates with many potential entrepreneurs and investors, even for newcomers who will be quickly infected. " (Cheku Café_co-founder).*

4.5 Emergence

Zhongguancun EE has typically become a breeding ground to unicorns. Their emergence in these years, though unforeseeable by any individual agent, was generally observable (i.e., focusing on mobile Internet products/services, fast-growing, new business model, world-wide niche market, and huge social and environmental benefits), based on and in turn influencing numerous entrepreneurs, coherent entrepreneurial activities and actions, and injection of new EE resources (P. Roundy et al., 2018). First, numerous ambitious entrepreneurs, no matter what their education backgrounds, gender, or age, urged to materialize their innovative ideas with social, economic, and environmental effects. *"Most of them [entrepreneurial ideas] are irrelevant to money, but more to achieving self-value or pure desires to change the society…"(Cheku Café_co-founder).* Moreover, ambitious entrepreneurs and other involved EE agents behaved according to shared Zhongguancun identity, self-conscious norms, failure tolerance and union culture, and inclusive values.

Second, all agents united to create *"influential companies"* as no one knew or even was able to predicted what blockbuster entrepreneurships looked like and by no means created them individually. For this aim, each EE component consciously performed their own duties. *"for those entrepreneurs nobody do not understand their intended ideas, we will accept these 'weird' guys and provide supports as much as possible. Because we firmly believe what they want to do just goes beyond conventional innovation logics and practices. Probably they will be the future big ones" (3w Café_co-founder); "An interesting phenomenon of Zhongguancun is that academic entrepreneurs spring up. This is because universities have changed their attitudes to them. We see many scholars speed up the transformation of scientific research."(Tsinghua Holdings_chairperson); "we set our role as the resource depot rather than the ruler…" (Zhongguancun Administrative Committee_section chief).*

Third, Zhongguancun EE development benefited from U.S. Silicon Valley EE. A prominent trend was that since 2000 more overseas returnees (scholars and investors) moved from Silicon Valley to Zhongguancun to explore entrepreneurial opportunities, because of the availability of young talents, technology infrastructure, complete entrepreneurial services, supportive governments, closness to mass markets, and energetic entrepreneurship networks. Their injection diversified EE components and promoted EE evolution with heterogeneous technologies, concepts, knowledge, and more importantly shaped established EE culture These largely helped Zhongguancun EE's capability to avoid evolutionary path dependence (on way of mobile Internet). An example illustrated.

> *"…Tian [founder] considered collaborating with Yizhuang local governments to introduce cloud-computing technologies. Local governments welcomed the idea and facilitated our Cloud Valley's foundation. Tian further created six new companies ranging from Cloud software to end cloud-computing marketing, based particularly on the constructed cloud-computing platform. After these endeavors, Tian usually returns to Silicon Valley several times every year, attempting to absorb new knowledge, technologies, and concepts out there. Currently the cloud-computing industry begins to take shape…Our cloud-computing platform works for a start-up, who ambitiously apply gyro technologies into two-wheel cars. We feel optimistic to them and then supply money, technologies, and management services to them. They grow very fast." (Cloud Valley_CEO)*

Fourth, a change was that Zhongguancun highlighted more on developing 'hard' core technologies than 'soft' business model innovation. They made such a transition because they increasingly felt unicorns from mobile Internet were not sustainable and competitive than technological start-ups from emerging industries (e.g., biomedical) in the long-term, which exactly was the emphasis by other EEs in Shanghai, Wuxi, and Shenzhen. Consequently, this macro-level Zhongguancun behavior might have an overarching effect on current EE components. Specifically, investors will changed their investment strategy; governments will rethink about their entrepreneurial policies and infrastructure construction; research institutes and universities will modify their talents education systems. Moreover, these changes started to impact entrepreneurs and relevant culture elements.

4.6 Co-evolution/Multidimensionality

Zhongguancun, actually a 220- meter avenue geographically consisting of complete EE components including 50 established big firms, 45 entrepreneurship services agencies, 50 research institutes and

universities, and around 2000 investment agencies, played as the EE epicenter with the most dynamic entrepreneurial activities.

Around the EE center, there were several other smaller EEs. *"…yeah, Zhongguancun is a big ecosystem, while our AAMA is an embedded smaller one. Because we are able to produce influential entrepreneurships and innovations, with advantages in abundant human and finance resources. I guess this is also applicable to many other big incubators or accelerators. We only share the same policies by governments and other entrepreneurial services…"* In addition, the informant continued, *"Tsinghua University is also a small research-based ecosystem. First, as a world-famous technical university, Tsinghua is powerful in R&D. This means attracting entrepreneurs and investors is relatively easy for them. Second, they have a lot of alumnus dispersed in global areas, who have connected other entrepreneurial resources out of Zhongguancun. Third, a dynamic interaction among CEOs from well-known firms and academia makes Tsinghua look like a place producing innovative ideas…" (AAMA_secretary general).*

However, beyond the Zhongguancun entrepreneurship epicenter, over 20 specialized epicenters were in parallel distributed within Beijing. They have close interactions in exchanging entrepreneurial resources, despite the geographical distance. Moreover, Zhongguancun Administrative Commission even set their sub-commission agency in global EEs (e.g., Silicon Valley, London, Paris, and New York), where they were active to aggregate local talents, finance resources, emerging technologies, and leading management experiences to further help Zhongguancun EE develop sustainably.

5 Discussion

While there is increasing focus on EE theorization in the literature (e.g., Zoltan J. Acs et al., 2017; Autio et al., 2018; Cohen, 2006 ; Feld, 2012; Isenberg, 2011; E. Stam, 2015), there are increasing calls that it is important to unfold EE complexity (Autio & Levie, 2017; Brown & Mason, 2017; Goswami et al., 2018; P. Roundy, 2016). Insights into EE complexity might moderate the conceptual ambiguities and empirical problems in three EE schools we summarized, and based on which allow for regional policymakers' better interventions. Against this backdrop, we have examined how an emerging EE, *Zhongguancun EE*, in Beijing reveled six main CAS properties, drawing on extant CAS work on conceptualizing inter-organizational phenomena (Aydinoglu, 2013, Choi et al., 2001, Peltoniemi, 2006; Russell & Smorodinskaya, 2018; Surie, 2017), and, particularly recent literature theorizing EEs with CAS perspectives (Carayannis et al., 2018; P. Roundy et al., 2018). As a result, we contribute to current EE knowledge by adapting the CAS theory to present an empirical model of CAS-based EE, including key constructs and their coherent relationships.

5.1 Theoretical contributions

Related to our first contribution, we deepen a nuanced understanding of CAS-based EE components, consisting of large number of diversified but unified agents and entrepreneurial resources. First, although previous EE research has categorized how diversified and coherent EE agents and entrepreneurial resources make a vibrant EE (Cohen, 2006; Isenberg, 2011; Mason & Brown, 2014; Neck et al., 2004; F. C. Stam, & Spigel, B., 2016), our findings go beyond them by revealing the nonlinearity among them without distinct component boundaries. Specifically, investors (finance component) often provide entrepreneurial training and social networking services, which are main functions of incubators or accelerators (infrastructure component), to entrepreneurs, and vice versa. Second, in addition that the synergetic interactions among components render certain EEs outperform others (Ghio, 2017; Radinger-Peer et al., 2018; Spigel, 2015; Theodoraki et al., 2017), we further clarify these synergies are produced in a nonlinear fashion. That is, the amplifying (positive feedback loops) synergies among agents speed up high-impact entrepreneurships that promote EE development, while the dampening (negative feedback loops) synergies restrain it. Therefore, we propose successful EEs depend more on positive feedback loops than negative feedback loops among EE components.

As the second contribution, we add empirical knowledge to emerging EE evolutionary dynamics, resulting particularly from the large number of diversified EE agents and their nonlinear interactions. First, EE evolution depends on initial conditions in aspects of its established infrastructure, talents, dominant culture, and early history factors. The accumulated positive feedback loops among initial conditions result in EE irreversibility in evolution process, and therefore high-impact

entrepreneurships by ambitious entrepreneurs locking into one industrial or relevant domain(s) (e.g., Auerswald & Dani, 2017). Comparing to EE having single industries or dominated by several established firms (e.g., Spigel, 2015), this path-dependence is less evident in EEs with diversified emerging industries. Second, complementing to EE's linear life cycle from birth to decline (Colombelli et al., 2017; Mack & Mayer, 2016; Spigel & Harrison, 2018), we observe that EE develops over time in an adaptive life cycle. On the one hand, EE develops fast with increasing diversified and coherent EE agents, which accordingly increase EE adaptability by solving internal entrepreneurial struggles collectively. On the other hand, the climax in agents' diversity and connectedness/coherence means much vulnerable to external disturbances. In line with Auerswald and Dani (2017), EE thus reorients by introducing new agents and resources and avoiding path-dependent interactions between agents, in order not to fall into static (decline) phase.

With the third contribution, our study contributes to a better understanding of EE governance, from the CAS perspective. Some scholars think that EE governance is more related to "bottom-up" approach, as the EE agents can hardly predict or intentionally organize the birth of high-impact entrepreneurships (e.g., Isenberg, 2011, 2016). In contrast, others insist the "top-down" governance approach by involving established big firms, multiple incubators, and even powerful policies gives rise to blockbusters or unicorns (e.g., Bhawe & Zahra, 2017; Spigel, 2016). Our findings are consistent with the "bottom-up-top-down" approach by Colombo et al. (2017) and Stam (2015). Specifically, the production of high-impact entrepreneurships results mainly from self-organized ambitious agents (especially the entrepreneurs), high fluidity of entrepreneurial resources, coherent entrepreneurial actions among EE agents, and injection of new agents or resources from outside. During this process, the high-impact entrepreneurships regarded as the EE collective behavior gradually emerge, which is observable but unpredictable for EE agents. Moreover, the emergence of collective behavior in turn will guide EE agents to readjust to create future high-impact entrepreneurships. However, 'top-down' tools such as policies can consciously change infrastructure conditions, finance preferences, and human capital, while seem difficult to change cultural and social elements shared by mass entrepreneurs. Therefore, top-down approach is sufficient rather than necessary in generating unicorns.

In addition, EEs could be geographically considered in different levels at the same time. Most studies analyzing EE phenomena concentrate on bounded city or region level (Cavallo et al., 2018; Malecki, 2018). There is, however, an increasing awareness that EE governance boundaries setting should be flexible, especially taking into account the role of digital infrastructure and technologies (Autio et al., 2018; Sussan & Acs, 2017). Our study takes a further step to reveal the multidimensionality feature of EE, similar to "nested geographies" mentioned by Brown and Mason (2017). In our case, Zhongguancun EE contains many smaller EEs (e.g., university-based EEs) and meanwhile is embedded into larger EEs (e.g., the national EE). First, EEs in different levels are identified, not only by distinct socio-cultural characteristics (Brown & Mason, 2017; P. Roundy et al., 2018), but also with an epicenter, the place where the most dynamic entrepreneurial activities happen. Second, EEs are not developing separately, but coevolve each other.

5.2 Policy implications

This study has implications for policymakers to consider EE complexity in formulating innovation and entrepreneurship policies. First, various regional innovation and entrepreneurship polices should keep their continuity and coordination. The policy continuity stands to reason that favorable regional policies often would not obtain instant satisfied results, due mainly to the disproportional rate from entrepreneurial inputs to outputs, if the regional economy aim is creating blockbusters or unicorns, not limited to new firms creation (Brown & Mason, 2017). Besides, policy coordination is required, as collecting and diversifying all EE components do not mean a recipe for a successful EE. In particular, the nonlinear dampening interactions between EE components will slow EE development down. This is always happened to between infrastructure and talents. EE development needs improved housing and skilled human resources. The more talents promotes the higher housing price, the negative interactions between them will drive talents out of EE, which cause problems for EE development. Therefore, it posts a great challenge to policymakers to make such a balance.

Second, another emphasis of regional innovation and entrepreneurship policies should be placed on avoiding EE evolutionary path-dependence. In general, the increasing diversity and their synergetic connectedness of EE agents and resources will speed up EE development, and enhance EE

adaptability to struggles in producing high-impact entrepreneurships. However, some dominant types of high-impact entrepreneurships will be mutually reinforced and thus drive other potential types out, causing EE evolution under path-dependent component interactions, to a peak point where EEs might easily vulnerable to external shocks (e.g., transitions of technology paradigm). Reminded by Radinger-Peer et al. (2018), when EE reaching to this critical 'point', we therefore suggest policymakers should take a more active role in dealing with external disturbances they cannot control or predict, through breaking up rigid agents interactions and providing more protections on new potential high-impact entrepreneurships.

A third key insight for policymakers is mindful of their intervention boundaries into high-impact entrepreneurship emergence. On the one hand, most high-impact entrepreneurships come out in a bottom-up fashion, considered that policymakers could not organize them intentionally. In this sense, equating full political participation into EE development with a successful EE might be misleading. Political interventions, such as initiating incubators/accelerators, introducing high-profile actors, finance subsidies, have effectiveness in improving 'hard' things (e.g., infrastructure, talents education, investing preference), while become incompetent to change 'soft' things (e.g., entrepreneurial culture). Often, the latter changes in a gradual way, depending on self-organized ambitious entrepreneurs. On the other, policies making should not be geographically bounded but spans different levels (regionally, nationally, and even internationally). The importance of multidimensional thinking in making entrepreneurship and innovation solutions is that high-impact entrepreneurship possibly emerges with interactions between different EEs in different levels, rather than in a closed physical area.

5.3 Limitations and future directions

This study has some inherent limitations, which also inform future research avenues. First, we revel the non-linear interactions among EE components and distinguish two nonlinearity mechanisms: positive and negative feedback loops, which promote and decelerate EE development. However, we only presume the economic outcomes result from these two mechanisms. In fact, in the long run, both have "dark side" in societal aspects (e.g., social inequality, increasing cost of living, driving out of other employment etc.) that increasing research has paid less attention in emerging economics (exceptions, Guerrero & Urbano, 2017; Spigel & Harrison, 2018). We encourage future work focuses on this topic from CAS perspective.

Moreover, our findings come from one specific empirical setting: Zhongguancun, an emerging EE that produced many unicorns. In order to ensure case appropriateness, we purposefully put our research focus on the period since 2009 and therefore our captured data might not fully accommodate all relevant CAS properties. In our model, we identified the adaptive life cycle from "exploitation" to "conservation" phase that Zhongguancun EE situated, with the fact that the increasing EE component diversity and coherence. Nonetheless, our results cannot provide robust evidence in terms of how EE reorients itself from "release" to "reorganization" phase, because we did not observe any critical external shocks rendering such adaptive process. Such EE evolutionary dynamics are useful to help unfold EE complexity nature: adaptability or resilience. Thus, future research can extend our study with a longitudinal research design that specially covers the role of influential external shocks.

Finally, the EE multidimensionality/co-evolution in different levels is tested from the Zhongguancun EE perspective. Whether this feature (i.e., mutual interactions on the ecosystem-level) applied to other productive EEs that our collected data did not include remains unanswered. Future work can contribute to EE co-evolution knowledge from CAS perspective by considering different EEs in different regional scales, such as university-based EE, Zhongguancun EE, national EE including Shanghai and Shenzhen, and the international EE (Valley Silicon). More comprehensively, scholars have opportunities to enhance our model generalizability (Yin, 2013) with a comparative case analysis that simultaneously involves similar emerging EEs (e.g., Bangalore).

6 Conclusion

How can we moderate (or even deal with) existing conceptual ambiguities, paradoxes, and even practical challenges in EE literature? We argue scholars underexplore a better understanding of EE complexity nature. To this end, we combine three streams of EE literature and insights from CAS theory to demonstrate six integrated complexity properties a successful EE possess, in particular

though a qualitative case: Zhongguancun EE. Our results provide new empirical insights into EE nonlinear component interactions, adaptive evolutionary dynamics, and governance boundaries. Such complex nature definitely requires concerted policymaking attention.

7 Reference

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Figure 1 the staged pattern of Zhongguancun EE development (1980-Current) (source: by authors)

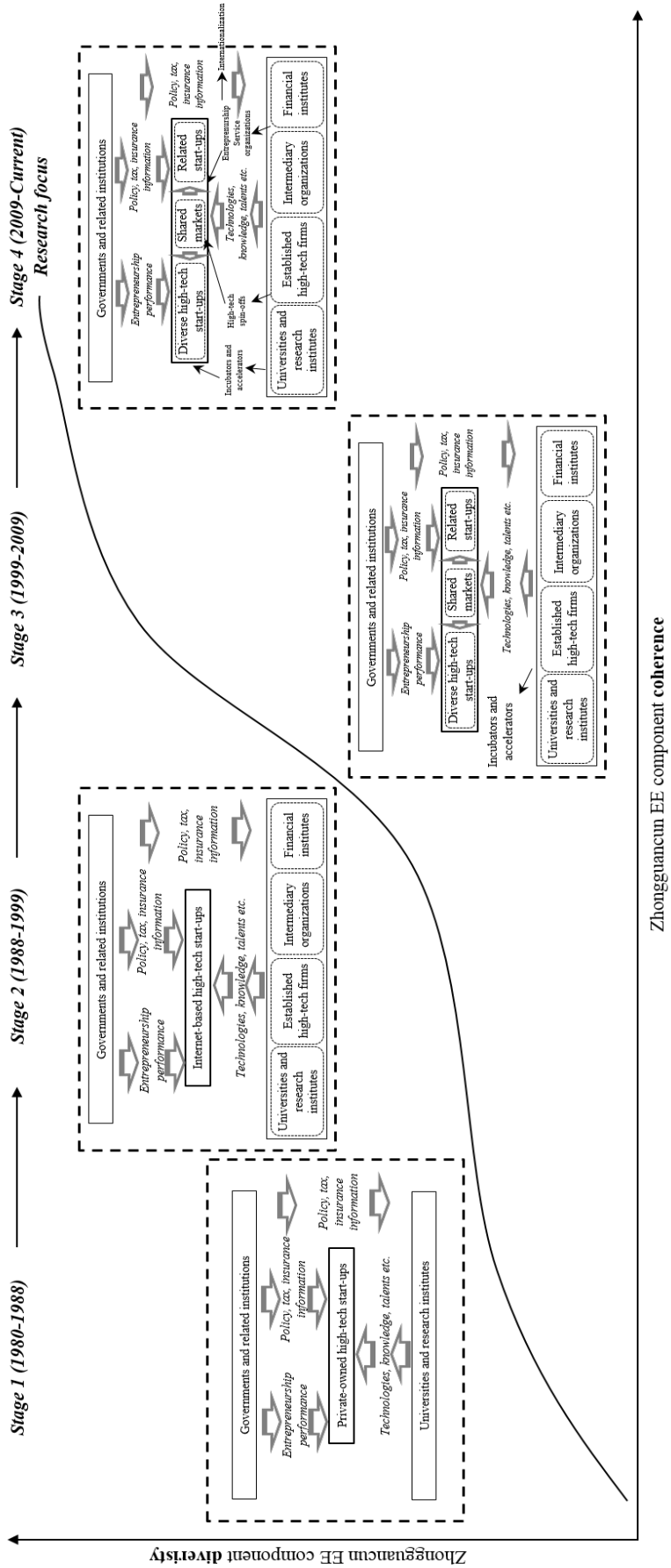

Table 1 an overview of focus group interviews

Item	*Date*	*Number of interviewers*	*Code (institution_ interviewee position)*	*Belonging to EE components (Isenberg, 2011)*	*Duration (minutes)*
1	2014-05-15	3	*Microsoft Azure_co-founder*	Culture (accelerator)	110 min
2	2014-05-15	5	*Cheku Café_co-founder*	Culture (incubator)	90 min
3	2014-05-15	3	*3w Café_co-founder*	Supports (incubator)	100 min
4	2014-05-27	3	*River_co-founder*	Finance (venture capital)	100 min
5	2014-05-29	3	*Maxtrix Partners_co-founder*	Finance (venture capital)	80 min
6	2014-06-19	5	*Hackerspace_founder*	Supports (incubator)	70 min
7	2014-06-19	2	*Legend Star_director*	Supports (incubator & accelerator)	105 min
8	2014-06-19	4	*36kr_co-founder*	Supports (entrepreneurship service provider and incubator)	130 min
9	2014-06-24	5	*Tsinghua Holdings_chairperson*	Finance (venture capital)	130 min
10	2014-06-24	4	*Cheers_co-founder*	Markets (mobile Internet social APP)	90 min
11	2014-06-24	5	*Yidao Yongche_founder*	Markets (car-sharing service)	80 min
12	2014-07-04	4	*Northern Light_co-founder*	Finance (venture capital)	90 min
13	2014-07-18	2	*Zhongguancun Administrative Committee_section chief*	Policy (Zhongguancun Administrative Committee)	80 min
14	2014-07-24	4	*Great Wall Consultant_senior consultant*	Human capital (research institutes)	100 min
15	2014-07-30	4	*51wan_CEO*	Markets (online gaming)	80 min
16	2014-07-30	4	*Cloud Valley_CEO*	Supports (incubator)	120 min
17	2014-08-01	4	*AngelCrunch_vice president*	Finance (venture capital)	100 min
18	2014-08-01	4	*AAMA_secretary general*	Supports (chamber of commerce)	85 min
19	2014-08-29	3	*Bank of Beijing_president assistant*	Finance (commercial bank)	110 min
20	2014-08-29	2	*Leader IP_co-founder*	Supports (legal service)	76 min
21	2014-09-03	3	*Shichuang Tongsheng_CEO*	Supports (financing guarantee/service)	70 min
22	2014-10-28	3	*Times Group_CEO*	Markets (high-tech electrics)	90 min
23	2014-11-05	3	*Tsinghua X-lab_Executive director*	Human capital (research institutes)	80 min

Figure 2 the data structure: CAS-based Zhongguancun EE

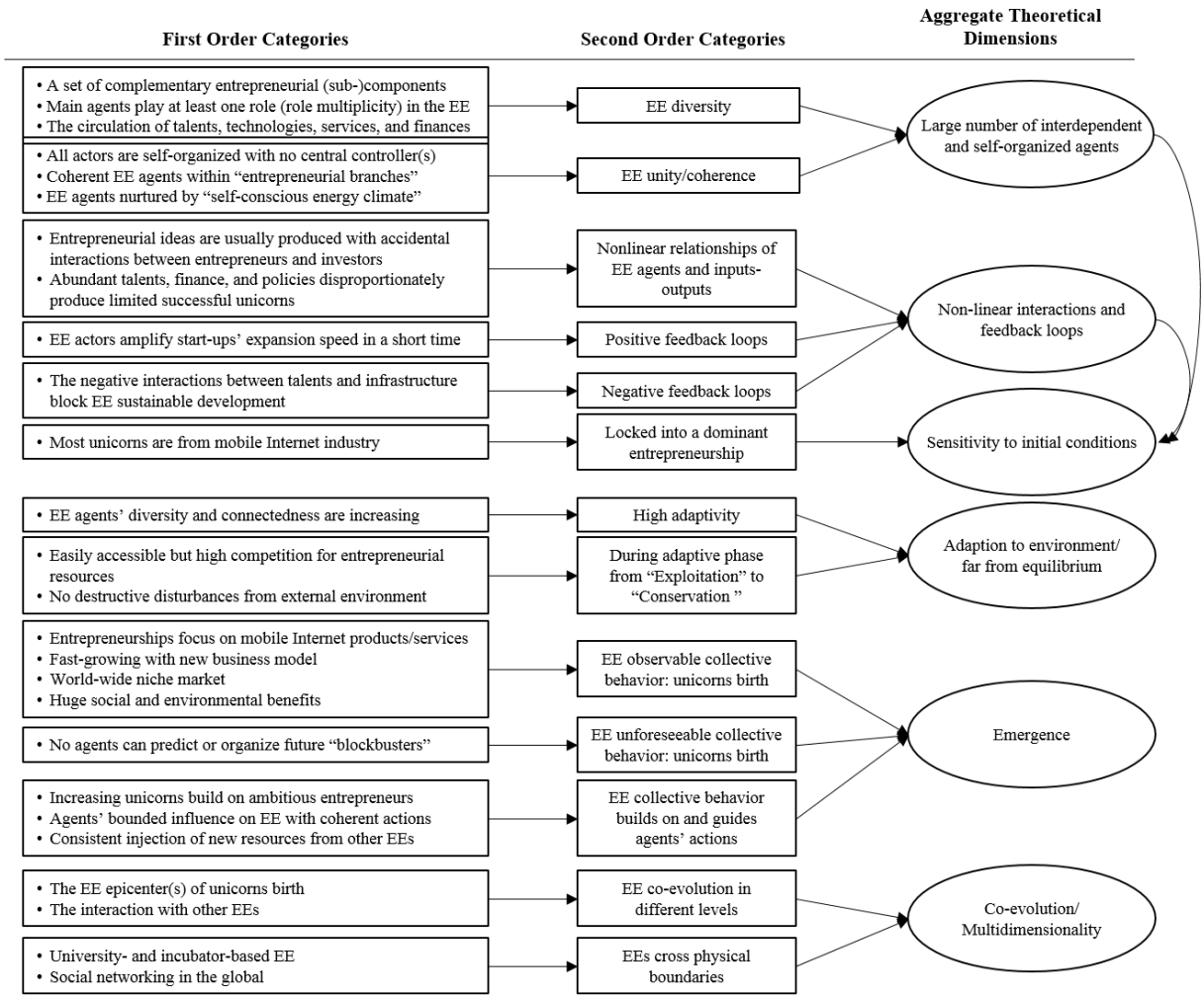

Figure 3 the integrated model of the CAS-based Zhongguancun EE

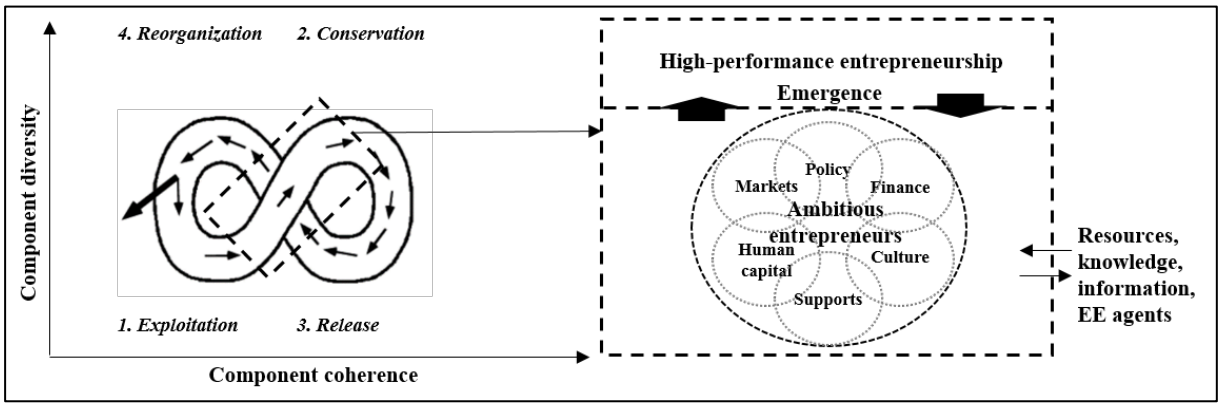

Figure 4 the entrepreneurship resources circulation in Zhongguancun EE (source: by authors)