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Whirlwind model of entrepreneurial ecosystem path dependence

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Abstract The body of literature on entrepreneurial ecosystems (EEs) is rapidly expanding, but few studies have simultaneously examined their complexity, dynamics, and context. To better understand how they evolve, we introduce the notion of EE path dependence based on an original combination of an evolutionary approach and complex adaptive system theory. We thus present a whirlwind model that takes the form of subecosystems and that integrates a structural approach with attributes and a dynamic approach with sequences. Context is addressed through narratives and entrepreneurial stories. We conducted a case study on the EE of Montpellier, France. To characterize the subecosystems, we quantified the attributes using NVivo software, showing their links and evolution over time. The results shed light on the subecosystems that contributed the most to the entrepreneurial dynamics. This study contributes to extending path dependence theory to EEs. The results may help policymakers rethink their development strategies by setting priorities in accordance with the drivers of their EEs.

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Plain English Summary We propose a whirlwind model of entrepreneurial ecosystem (EE) path dependence to comprehensively explore the complex, dynamic and contextual nature of an EE. Based on the narratives of EE actors and entrepreneurial stories from a specific region, we identify significant attributes and decompose the ecosystem into subecosystems. The dynamics are understood through the links between the attributes and their evolution over time. This work allows us to characterize the specific aspects of the EE and to identify the drivers of this evolution. The subecosystems operate like EE markers according to a logic of coevolution. This detailed understanding of the trajectory constitutes a strategic asset for projecting into the future with the ability to identify development priorities for EE stakeholders.

Keywords Entrepreneurial ecosystems · Path dependence · Complex adaptive system (CAS) theory · Dynamics · Subecosystem

JEL classifications L26 · M13 · P00 · R58

1 Introduction

Entrepreneurial ecosystems (EEs) seem to be everywhere. Although the term originally designated iconic regions such as Silicon Valley (Bahrami & Evans, 1995), it is now liberally applied regardless of the state of local development. Most studies focus on particularly dynamic EEs (Acs et al., 2017; Han et al., 2019), but greater attention to the emergence and development processes in regions with fewer resources seems warranted. Thus, the dynamics of entrepreneurship and innovation in these contexts have been explored in EEs in emerging countries (Cao & Shi, 2020), rural areas (Miles & Morrison, 2020), and small- or medium-sized cities (Roundy, 2019). We explored the dynamics of an EE in this last context.

Most studies examine EE structures, highlighting dimensions (Isenberg, 2011) or attributes (Spigel, 2017), but some note that EE dynamics have been overlooked (Cao & Shi, 2020; Roundy et al., 2018). To highlight development phases, the trajectory (Mack & Mayer, 2016; Radinger-Peer et al., 2018; Voelker, 2012) and life cycle (Cantner et al., 2020; Colombelli et al., 2019) concepts seem to be an emerging trend, but the analyses remain either fairly descriptive or relatively linear, with little characterization of trajectories. Complex adaptive system (CAS) theory may address this gap (Han et al., 2019; Phillips & Ritala, 2019; Roundy et al., 2018) because it provides an interpretive framework open to the notion of path dependence (Roundy et al., 2018). Han et al. (2019) emphasized the importance of sensitivity to initial conditions but highlighted that environmental adaptability is a condition for EE viability. CAS theory may thus be useful for conceptualizing EE path dependence by incorporating continuity and change. The theory owes much to Simon's (1962) pioneering work, which powerfully influenced evolutionary authors (Nelson & Winter, 1982) and those focused on entrepreneurial systems (Van De Ven, 1993; Stam & Van De Ven, 2021). A system's dynamics can be understood by first decomposing it into its elementary components and then analyzing its interactions. We developed a whirlwind model of subecosystems (Malecki, 2018; Regele & Neck, 2012; Theodoraki & Messeghem, 2017) to represent EE path dependence. The subecosystems operate like EE markers in a logic of coevolution. Our model integrates a structural approach to attributes and a dynamic approach to sequences, with EE path dependence being decomposed into hierarchical, specific, or transversal subecosystems that drive the system via sequences of significant attributes. The sequences start at different times and have varying durations and phases of impulse, creation, and structuring, just like many change processes.

This qualitative study examines the EE in Montpellier, a mid-sized city in southern France. To characterize the subecosystems, we quantified the attributes, showing their evolution. We describe the main subecosystem and entrepreneurial support (Theodoraki & Messeghem, 2017) and highlight two others, one transversal and the other specific. This research enriches the EE literature by proposing a dynamic decomposition into subecosystems, and with the concept of EE path dependence, it contributes to evolutionary approaches to research.

We first review the EE literature and show how path dependence provides a dynamic perspective on a complex system in the form of a trajectory. We then present our whirlwind model and methodology and our results, which reflect the distinctive characteristics of EE evolution in Montpellier. Finally, we conclude with implications for policy decisions to foster EE development in the direction of drivers, with greater interaction and inclusion.

2 Conceptual framework

2.1 Entrepreneurial ecosystems: from a structural to a dynamic framework

The EE concept now has a solid place in the entrepreneurship literature (Acs et al., 2017; Alvedalen & Boschma, 2017; Cao & Shi, 2020; Malecki, 2018; Theodoraki et al., 2018), making it easier to both account for the role of context (Van De Ven, 1993; Welter & Gartner, 2016) in entrepreneurial dynamics and emphasize the roles of entrepreneurs (Acs et al., 2017; Stam, 2015). The term appeared in the mid-1990s to explain the dynamics of iconic regions such as Silicon Valley (Bahrami & Evans, 1995) and began spreading in the early 2000s (Cohen, 2006). Studies first sought to provide an ecosystem map by determining the categories of actors, with seminal studies stratifying ecosystems into interdependent layers (Van De Ven, 1993; Neck et al., 2004). The managerial literature, especially starting with Feld (2012) and Isenberg (2011), popularized the notion in academic and professional circles. For example, Isenberg (2011) highlighted six main components: an enabling culture, supportive policies and leadership, the availability of appropriate financing, quality human capital, markets open to new businesses, and a range

Table 1 Lineages of the path dependence approach

Evolutionary economic perspectives	Organizational	Technological	Institutional	Geographical
Authors	• Nelson and Winter (1982) • Teece et al. (1997)	• David (1985) • Arthur (1989)	• North (1990) • Schneiberg (2007) • Strambach (2010)	• Boschma and Frenken (2006) • Martin and Sunley (2006)
Founding concepts	• Contingent events • Self-reinforcing mechanisms • Lock-in effects			
Specific concepts	• Routines • Dynamic capabilities	• Increasing returns • Network externalities	• Paths not taken • Path plasticity	• Adaptive process • Multiple paths • Path interdependence
Perception of change	• Biological metaphor with routines playing the same role as genes	• Discontinuous and exogenously driven	• Long process of continuous change and adaptive learning	• Multiplication of mechanisms at work

of institutional and infrastructural support. Spigel (2017) preferred the term attributes, grouped around three broad categories that support and reinforce each other: material, social, and cultural.

In addition to a structural perspective, time is essential to understanding the emergence and institutionalization of EEs. However, as Alvedalen and Boschma (2017) noted, few authors have designed studies from a dynamic perspective to explain how EEs evolve, even though the preference for a static reading has been criticized by many (Mack & Mayer, 2016; Mason & Brown, 2014; Spigel, 2017). The dynamic approach to ecosystems is rooted in Van De Ven's (1993) studies on entrepreneurship infrastructure, which showed that an infrastructure does not emerge from a few events or the actions of a few entrepreneurs. He encouraged a historical reading to understand the processes and components of the entrepreneurship infrastructure.

From a theoretical perspective, several approaches may be relevant for exploring EE dynamics. Roundy et al. (2018) suggested CAS theory, which takes into account nonlinear dynamics and feedback effects linked to the interdependence between EE components (Han et al., 2019). This characteristic implies another property of complex dynamic systems: sensitivity to initial conditions. Thus, Roundy et al. (2018) mobilized an essential concept from evolutionary approaches, path dependence. As Boschma and Frenken (2006) noted, the complexity approach in the social sciences can be seen as a branch of evolutionary economics (or vice versa). To explain the evolution of an EE or, more broadly, a region (Evenhuis, 2017), several authors have taken an evolutionary approach and referred to this theory implicitly (Cohen, 2006; Neck et al., 2004; Voelker, 2012) or explicitly (Evenhuis, 2017; Mack & Mayer, 2016; Radinger-Peer et al., 2018). However, these works used the path dependence concept in a metaphorical and restricted way without considering the possibilities for theoretical advances.

2.2 Contributions of evolutionary approaches

The social sciences use evolutionary approaches to understand the trajectories of phenomena as different as organizations, technologies, institutions, and regions (Magnusson & Ottosson, 2009). Four perspectives (Table 1) have progressively contributed to extending the scope of path dependence.

The organizational perspective is based on the seminal work of Nelson and Winter (1982), who acknowledged an "intellectual debt" to Schumpeter and Simon (Nelson & Winter, 1982, p. IX). Path dependence enables us to analyze a firm's evolution, as a path develops based on the nature of the "routines" that take shape over time. Continuing with the biological metaphor to explain change, routines have a role similar to that of genes—hence the term "organizational genetics." "Dynamic capabilities" extend the thinking on how firms "integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece et al., 1997, p. 516).

The seminal work of David (1985) and Arthur (1989) prepared the way for the technological perspective. Technological spread is explained by increasing returns and network externalities. A canonical model of path dependence (Martin, 2010, p. 4; Henning et al., 2013; Evenhuis, 2017) was articulated around three characteristics: a stochastic process, with small random initial events or historical accidents having significant long-term effects on economic structures; development, limiting alternative paths by a lock-in effect if the initial events were reinforced through various self-reinforcing mechanisms; and a pattern that remains stable until disrupted or dislodged by an external shock.

North's (1990) institutional perspective is particularly important. It emphasizes the need for a specific model of institutional change. Processes such as the "recombination of resources" (Stark & Bruszt, 2001) and "paths not taken" (Schneiberg, 2007) enriched the notion, and institutions are no longer considered a succession of steady states created at critical exogenous and periodic junctions. "Path plasticity" (Strambach, 2010) was also an advance, highlighting the coevolution of structures and actors to encourage innovation without causing a break in the path.

Finally, research at the geographical level[1] is more recent. It seeks to understand the influence of path dependence on the decline, recovery, or resilience of regional economies and the restructuring of industrial clusters (Zhu et al., 2019, p. 651). The idea of the path dependence of an entire region has been challenged, especially given the increasing complexity. Criticisms, such as the hypotheses of the virgin market (Witt, 2003) or virgin land (Martin, 2010), emphasize the lack of consideration of pre-existing exchanges and structures in understanding the evolution of an economic space. Notably, Martin and Sunley (2006, p. 413) suggested "'path interdependence', that is situations where the path-dependent trajectories of particular local industries are to some degree mutually reinforcing."

The founding works, particularly that of Nelson and Winter (1982), make it possible to focus on the microfoundations, particularly from the perspective of routines. On the other hand, other perspectives are more oriented towards the meso or macro levels; thus, they deal less with the question of routines (Boschma & Frenken, 2006). These evolutionary approaches all emphasize the value of addressing both continuity and change and better taking complexity into account. We thus propose a model of EE path dependence that fits with CAS theory.

2.3 Whirlwind model of EE path dependence

The authors suggest that EEs are CASs (Han et al., 2019; Phillips & Ritala, 2019; Roundy et al., 2018; Sheriff & Muffatto, 2018). According to Roundy et al. (2018), they exhibit six properties: self-organization, open but distinct boundaries, complex components, nonlinear dynamics, adaptability through dynamic interactions, and sensitivity to initial conditions. EE path dependence is thus nonlinear, sensitive to initial conditions, subject to endogenous and exogenous influences, and the result of the dynamic interactions between complex components within the framework of self-organization.

The challenge is to determine the elementary components and how their dynamics shape path dependence. Simon's (1962) studies on complex systems address the first issue by suggesting decomposition into a hierarchy of subecosystems. According to Simon (1962, p. 468), "By a hierarchic system, or hierarchy, I mean a system that is composed of interrelated subsystems, each of the latter being, in turn, hierarchic in structure until we reach some lowest level of elementary subsystem." In the ecosystem literature, this decomposition occurs in terms of dimensions or attributes (Isenberg, 2011; Spigel, 2017; Stam & Van De Ven, 2021) or subsystems (Dubina et al., 2017) or subecosystems (Harrington, 2017; Malecki, 2018; Regele & Neck, 2012; Theodoraki & Messeghem, 2017). We propose decomposition based on these complementary approaches and define a subecosystem as "a local subsystem that is composed of material, social and cultural attributes, that is open and interacts with other subecosystems of the EE, and that is led by or connected to an actor or group of actors contributing to the dynamics of innovation and entrepreneurship."

To understand how the evolutionary dynamics of subecosystems contribute to EE path dependence, Simon's work is once again appropriate. In The Architecture of Complexity, Simon (1962) insisted on

[1] Geographical in the sense of a wide variety of types and scales of economic space, the definition, delimitation, and opening of which depend on the empirical study.

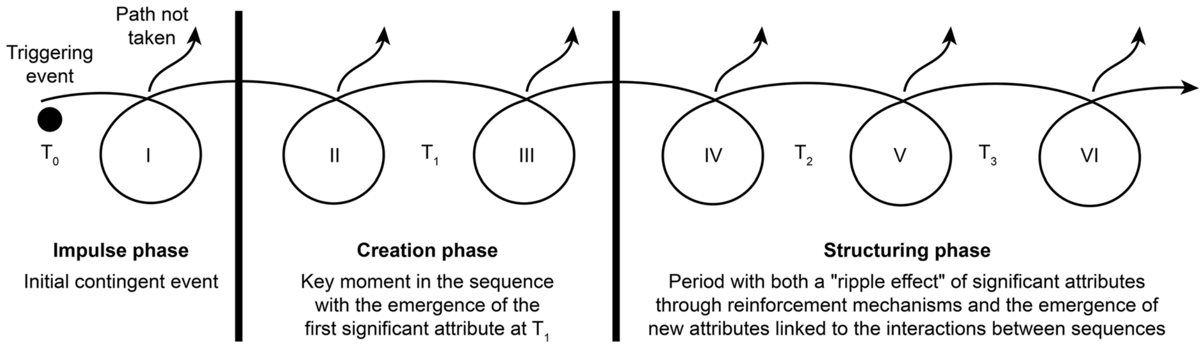

Fig. 1 (Quasi-)decomposition of a sequence. I, II, III, etc.: loops of successive experiments

the hierarchical aspect of complex systems and their decomposition: "In their dynamics, hierarchies have a property, near-decomposability, that greatly simplifies their behavior. Near-decomposability also simplifies the description of a complex system, and makes it easier to understand how the information needed for the development or reproduction of the system can be stored in reasonable compass" (Simon, 1962, p. 482).

The dynamics of each subecosystem can be decomposed and analyzed in terms of sequences (Fig. 1). The whirlwind movement of a sequence is inspired by sociological work on the process of technological innovation (Akrich et al., 2002) and results from successive experiments. The path is often winding (Martin & Sunley, 2011; Radinger-Peer et al., 2018), and the "paths not taken" (Schneiberg, 2007) may play a subsequent role or join other sequences. Each sequence is composed of chronologically significant attributes, where a significant attribute is an attribute in Spigel's (2017) sense and its role within the ecosystem is notable with regard to EE actors. Thus, the elementary unit of the hierarchy is an attribute embedded in a sequential process (Abbott, 2001). The starting point of each sequence varies depending on the dated attributes.

Based on the founding concepts of path dependence, three phases within each sequence were retained: impulse, creation, and structuring. The impulse phase is a trigger event that represents an initial contingent event. However, it is not limited to a "small" random event or a "historical accident": "Path dependence may be triggered by 'bigger' events or even strategies as well" (Sydow et al., 2009, p. 693). Here, we find the sensitivity of CASs to initial conditions (Roundy et al., 2018). The creation phase corresponds to the emergence of the first significant attribute and sets the tone, the beginnings of the sequence being built. This period may display many loops, directs the movement, and may represent an inflection point or a major bifurcation. It is characterized by strong plasticity, as all paths are still possible. The structuring phase focuses on the reinforcement mechanisms at work in sequence development. The significant attributes that compose it are linked by the themes of their activities or by how each attribute creates the conditions favorable or necessary for the next, which we refer to as the "ripple effect" of significant attributes. However, novelty and invention are possible, especially due to the interactions between sequences. These interactions are part of the processes for escaping the lock-in effect. The "paths not taken" also participate in recombination processes: "[…] the presence of these legacies suggests that change can emerge within existing pathways from a number of endogenous institutional processes, ranging from DIY, recombination or the assembly of fragments of alternative industrial orders, to the borrowing, transposition and elaboration of more or less coherent and established secondary paths" (Schneiberg, 2007, p. 70).

As shown in Fig. 2, EE path dependence is composed of a small number of subecosystems, i.e., n, the number of subecosystems such that $n \geq 1$. Each subecosystem is composed of a certain number of sequences, i.e., i, the number of sequences such that $i \geq 1$. Each sequence is composed of a chronological suite of significant attributes, i.e., p, the number of significant attributes such that $p \geq 1$. Each attribute is associated with a phase. Thus, attribute A_I corresponds to an attribute that occurred during the impulse phase.

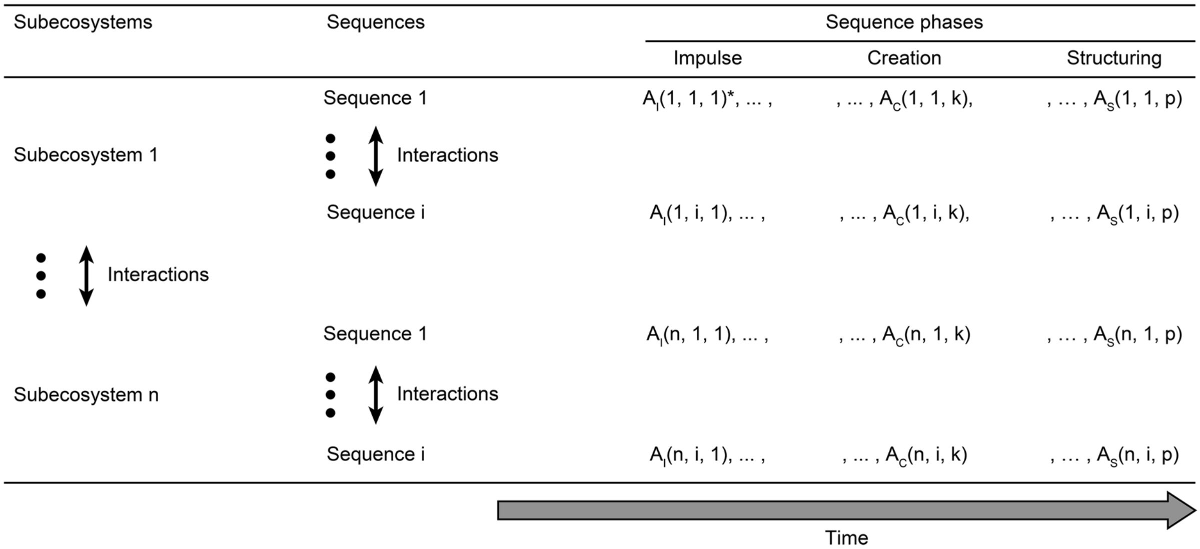

Fig. 2 EE path dependence. *A_{PHASE} (subecosystem, sequence, significant attribute): elementary entity of EE path dependence where $A_C(n, i, k)$ is the *k*th attribute of sequence *i* associated with the creation phase and belonging to subecosystem *n*

Therefore, EE path dependence appears to be processual, historical, and geographical, encompassing sequentially interacting processes involving events, actions, and decisions favoring or constraining system evolution.

3 Methodology

We opted for a mixed approach with qualitative sources, the quantification of attributes, and the identification of the links between significant attributes. The use of qualitative and/or mixed methods for studying EEs has been supported by several authors (Fuster et al., 2019; Roundy et al., 2018). Here, we detail our approach to data selection, collection, and processing.

3.1 Data selection

Our case study focused on Montpellier and its surrounding areas.[2] According to the Global Entrepreneurship Network (GEN) 2020 report, Montpellier is not listed among the 140 most successful startup ecosystems in the world report (Gauthier et al., 2020). However, this city has resources and a strong structural and institutional environment (Theodoraki & Messeghem, 2017). That is, between the proliferation and scarcity of entrepreneurial logics are intermediate situations that are more ordinary but little explored. Moreover, Montpellier is interesting because of its contrasting situation. We have indicators on business creation and regional attractiveness that point to a dynamic EE, but unemployment and poverty indicators show a difficult context (see Table E1 in the Electronic Supplementary Material for the socioeconomic indicators). To understand the evolution and real scope of EEs, these ordinary and dissonant cases warrant further attention.

3.2 Data collection

Our data were mainly drawn from 23 semistructured interviews, participatory observations at key EE events, and various types of secondary data (news articles, activity reports, calls for tenders, online audio and video recordings, patent archives, and historical sources). These secondary data were fundamental for gaining more in-depth knowledge on certain periods and particular organizations or persons. They also enabled us to test certain statements and thus facilitated data triangulation (Mathison, 1988).

[2] Essentially centered on Montpellier but also including Metropolitan Montpellier with extended borders, according to EE actors (e.g., the criterion of French Tech Capital, uniting all actors within a 1-h drive from the city center).

The primary data were collected during face-to-face interviews with 23 entrepreneurs or key players in the Montpellier EE (Table 2). The people interviewed represented the major components of the EE, as classified by Isenberg (2011), to which we added the category of entrepreneurs. The interviewees all had dozens of years of business experience and extensive experience with the Montpellier EE. We thus were able to collect qualitative data on the genesis and development of the EE. The interview guide focused on professional backgrounds, experience within the EE, relationships with a range of actors in the EE, perceptions of significant events, and representations of an idealized future. Overall, the interviews were structured to closely follow the dynamics of the EE based on resources, interactions, and governance (Cao & Shi, 2020). They were conducted by the two authors, together or individually. The interviews lasted 1 h and 30 min on average and were recorded and fully transcribed to allow coding and data processing with NVivo 12 software. The collection of secondary data ended when no new significant attributes appeared, indicating saturation.

3.3 Data analysis

The data analysis, closely articulated with the whirlwind model of EE path dependence, was based on an iterative procedure (see Fig. E1 in the Electronic Supplementary Material for the flowchart of the data process) and used qualitative materials and quantitative processing of EE attributes (Table 3). We then

Table 2 Overview of the interviewees

Item	Date	No. of inter-viewers	Main role of the interviewee	Belonging to EE compo-nents	Code	Duration (min)
1	05–12-19	1	Journalist	Culture	Journalist, culture 1	65
2	11–06-19	2	Vice president, media	Culture	Vice president, culture 2	92
3	18–12-19	1	President of networks	Culture	President, culture 3	65
4	26–04-19	1	CEO, digital	Entrepreneur	CEO, entrepreneur 1	76
5	23–01-20	1	Cofounders, entrepreneurship service provider	Entrepreneur	Cofounders, entrepreneur 2	145
6	20–05-19	1	Vice president of networks & cofounder, digital	Entrepreneur	Cofounder, entrepreneur 3	80
7	04–12-19	1	Member networks management & CEO digital	Entrepreneur	CEO, entrepreneur 4	54
8	23–05-19	1	CEO, venture capital	Finance	CEO, finance 1	56
9	03–12-19	1	Director, innovation	Finance	Director, finance 2	65
10	22–08-19	1	President, capital investment	Finance	President, finance 3	129
11	02–12-19	2	Director, capital investment	Finance	Director, finance 4	123
12	29–08-19	1	Director, network	Human capital	Director, human capital 1	85
13	30–08-19	2	Director, research	Human capital	Director, human capital 2	111
14	06–12-19	1	Coach & network correspondent	Human capital	Coach, human capital 3	78
15	02–12-19	1	Cofounder, open innovation	Markets	Cofounder, markets 1	75
16	03–09-19	1	President of networks & founder	Markets	President, markets 2	89
17	16–09-19	1	Manager, entrepreneurship	Policy	Manager, policy 1	59
18	28–03-19	2	Director, networks	Policy	Director, policy 2	87
19	08–10-19	2	Manager, economic growth	Policy	Manager, policy 3	88
20	28–08-19	2	Vice president, economic development	Policy	Vice president, policy 4	111
21	03–07-19	1	Director, incubator	Supports	Director, supports 1	66
22	25–04-19	1	Director, innovation agency	Supports	Director, supports 2	93
23	19–12-19	1	Director, incubator	Supports	Director, supports 3	87

Note: 11 women, 12 men.

Table 3 Process for data coding

Attribute types	No. of quotations	%	Avg. % of coverage
Total cultural attributes	528	16	15
Supportive culture	347	11	20
Histories of entrepreneurship	181	5	11
Total social attributes	1102	34	16
Worker talent	97	3	6
Investment capital	392	12	23
Networks	552	17	33
Mentors and role models	61	2	4
Total material attributes	1651	50	19
Policy and governance	559	17	35
Universities	266	8	15
Support services	490	15	28
Physical infrastructure	133	4	8
Open markets	203	6	11

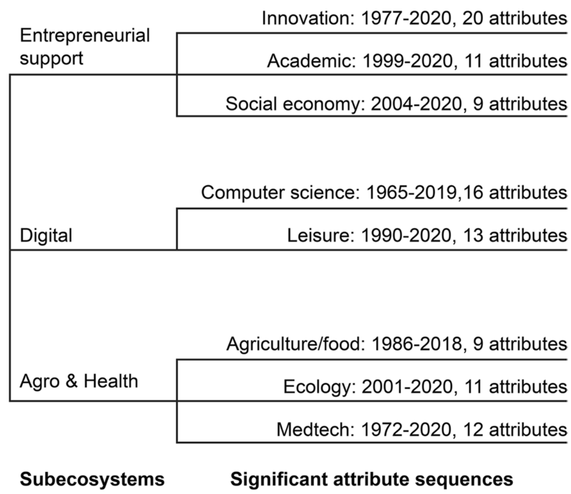

Fig. 3 Path dependence of the Montpellier EE

focused on the links between these attributes. Similar to Motoyama and Knowlton (2017), we were interested in the connections between the EE components. Sequences were constructed by linking the attributes by interdependence and relational dynamics. We were attentive to the chronological sequence of events, actions, and decisions. Relationships were identified through the accounts given by the interviewees, the documents collected, and the presence of people in several groups, thus providing data on social processes. Sequences were grouped into subecosystems based on the intensity of interactions between the sequences and the shared identity and logic of action between them. Across the iterations, we discussed the result of the ecosystem path dependence until a consensus was reached.

In total, 3281 quotations; mean coverage of 17%

4 Path dependence of Montpellier's EE

Path dependence in Montpellier's EE was decomposed into three subecosystems and eight sequences (Fig. 3). We present the sequence dynamics of each subecosystem and then an overview of the evolution of the EE (see Table E2 in the Electronic Supplementary Material for the denominations of the significant attributes).

4.1 Entrepreneurial support: the main and transversal subecosystem

Entrepreneurial support is a particularly dynamic subecosystem, with three sequences and numerous material attributes (Fig. 4). The impulse phases are of a political nature, the creation phases result from institutional work to produce infrastructures that integrate support services for business creators, and the structuring phases are long chains of highly diverse significant attributes.

The densest sequence concerns *innovation*. Georges Frêche, the mayor of Montpellier for 27 years and then president of the region until 2010, left his imprint by resolutely focusing on support for business creation. In the 1980s, he initiated a policy of encouraging and supporting innovation through the creation of an incubator, which was done to promote economic activity in a region that was severely affected by unemployment and that was relatively unindustrialized but richly endowed with researchers. "It was the visionary and pioneering side of Georges Frêche because he … I mean, Cap Alpha, so the incubator, now the BIC [business & innovation centre], it's been more than 30 years since it was created. You had to be really daring" (CEO, Entrepreneur 4). The incubator was founded in 1987 and still plays a central role in Montpellier's relational dynamics. It confirms the positioning of new entrants and participates in the strategizing of various support actors.

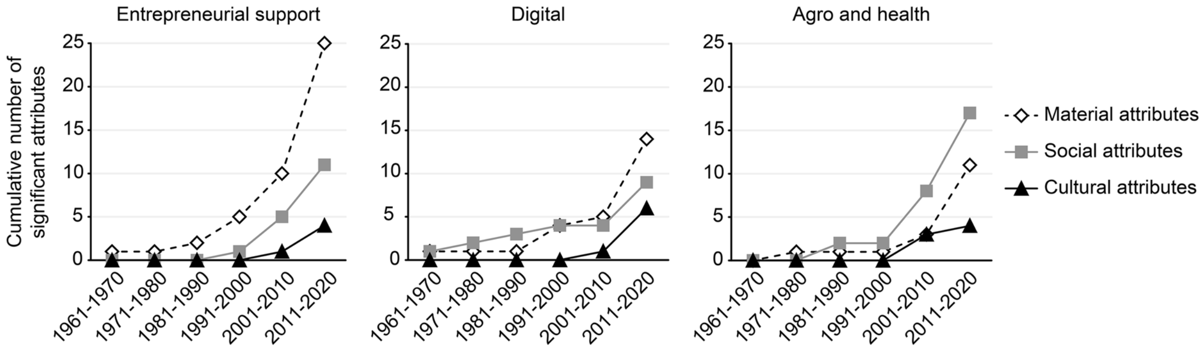

Fig. 4 Evolution of significant attributes based on the EE subecosystems

During the structuring phase, many businesses were created, but attention was also paid to improving the survival rate of young businesses beyond the critical threshold of 3 to 5 years and assisting them in growing. The LeadeR network emerged under the impetus of business leaders who were keen to exchange views and be a source of proposals to institutions. "In the 2000s, there was a willingness to reorganize business support services in line with the business life cycle. So, this service was created to focus more on the operating methods to support business creators and buyers, and even sellers, and the financial tools that had to be created, designed and implemented" (Manager, Policy 1).

The *academic* sequence began in the late 1990s with the Allègre law.[3] The rise in European projects raised questions about how to use research findings, and the French National Center for Scientific Research (CNRS) Innovation program was the first to respond. At this point, institutional initiatives for technology transfer and business creation entered the world of research. However, significant disagreements regarding how to use the findings arose, and compromises were made on a case-by-case basis. "For example, INSERM does not like startups. They prefer to market IP [intellectual property], and they have economic reasons because creating a startup in biotech or drugs is super long and very risky, and the chances of crashing are enormous. But once you have sold to Sanofi or Pfizer, it's done. There you go. And they're right. But we are… locally, we say we're here, our families are settled here, our children work here, we'd rather try to create a startup here" (director, Human Capital 2).

The *social economy* sequence was a pioneer in France with the creation of the "first regional social innovation incubator" in 2007, followed by collectives for pooling services and accelerating projects. The call for projects from the European Social Fund to combat employment discrimination and inequalities especially resonated with the support services in the region. This sequence was the start of an experiment to support activities in response to major societal challenges and favoring businesses, taking a collective approach to their internal functioning and stakeholders. "The region had already acted politically and understood that social economy projects were vectors of jobs that couldn't be relocated, unlike high-tech projects that soon fled. So, we wanted to keep jobs and wealth in the territory" (director, Supports 3). During this structuring phase, however, the movement failed to boost the status of cooperative enterprises, and the social economy more often favored traditional enterprises.

4.2 Digital: a transversal subecosystem

The digital subecosystem was also composed of mostly material attributes. IBM's arrival in 1965 initiated the *computer science* sequence of Montpellier's EE when it established a factory to manufacture mainframe computers. The creation phase marked the start of education in this field and an inflection point insofar as those trained in computer science could

[3] Law no. 99–587 initiated by Claude Allègre then minister of research and technology. The law promotes the transfer of technologies from public research to the economy and the creation of innovative businesses.

now work in Montpellier. The structuring phase was also fruitful with an exemplary laboratory that has continued to train talented entrepreneurs and scientists who are much sought after by industry. Dell arrived in 1992, and IBM's strategic shift led to the construction of a major data storage facility and the opening of a dedicated quantum computing hub. Technological "treasures" were also emerging, leading to the first generation of mentors or multientrepreneurs and allowing investors to remain. "When a company sells for 75, 120, 200, 500 million euros, you make millions in capital gains and ensure your investment for a couple of years. You need these treasures" (President, Finance 3). Finally, obtaining a national label (Metropolis, then French Tech Capital) has encouraged decision-makers and entrepreneurs to promote Montpellier's EE, first by publicizing hypergrowth IT and Montpellier companies and then by building a wider network.

The *leisure* sequence was driven by local people involved in activity sectors associated with leisure, such as video games, cinema, and extreme sports. Ubisoft arrived in Montpellier in 1994 due to two loyal Montpellierains who returned to develop the Rayman project. This relatively discreet creation phase was then amplified by the company's growing success, the establishment of an animation school, audiovisual production in the region, and postproduction studios near filming sites. Another sector of leisure-related activities followed the same general pattern with the creation of a flagship event, which enhanced Montpellier's reputation for experimentation in the sports field, particularly in services (marketing, organization, distribution) and innovative digital solutions. Thus, a network of actors and an incubator dedicated to this economic sector emerged from this structuring phase.

4.3 Agro and health: a specific subecosystem

This subecosystem comprised three sequences with numerous social attributes. The *agriculture/food* sequence began with an association (Agropolis) involved in structuring a scientific community around agricultural research for development. The history of regional wine production and the National School of Agriculture confirmed the long-standing links between the region and agriculture. The creation phase began with the Qualiméditerranée competitiveness cluster, which signaled entry into an entrepreneurial logic. Indeed, efforts were aimed at collaborative projects and the development of Mediterranean agricultural products and their associated processes. The structuring phase strengthened this logic with exemplary companies, a network of researchers, and designation as a "Convergence Lab."[4]

The *ecology* sequence began in the early 2000s with the entrepreneurial project of four students' intent on developing software for agriculture, which ultimately led to an incubator created on their training premises. The structuring phase was characterized by an important geographical factor: the proximity of the Mediterranean coast to local water and environmental professionals. An opening up to the international scientific community was also important, with the University of Montpellier's Department of Ecology becoming top ranked in the Shanghai rankings of 2018 and 2019. Exemplary startups can be noted, and the digital transformation of agriculture continued with the creation of a private accelerator.

The *medtech* sequence has an interesting history, as Montpellier is home to the oldest medical school in the Western world. From an entrepreneurial perspective, the arrival of Sanofi's R&D laboratories in 1972 was a key event. The creation phase was embodied by the creation of the company ABX in the field of in vitro diagnostics. When ABX became a subsidiary of the Japanese group Horiba, former company executives helped develop spinoffs, which in turn were very successful. The structuring phase included startups whose founders became mentors and who have continued to help repeat the entrepreneurial experience. Research networks were organized, especially to pool cutting-edge tools. Montpellier positioned itself in the health sector to raise state funds for innovation, enabling it to start a biotech incubator within its university hospital center. Sanofi created a digital manufacturing laboratory on its premises in partnership with the University of Montpellier's Department of Digital Technology. Other movements to structure research were articulated around agriculture, the environment, and health.

[4] The call for "Convergence Labs" projects was launched in 2016 by the state to structure large-scale multidisciplinary scientific sites with high visibility.

Table 4 Characteristics of the path dependence of the EE

	Entrepreneurial ecosystem of Montpellier and the surrounding area
Longevity	55 years
Number of sequences	8
Number and type of subecosystems	2 transversal (entrepreneurial support and digital) and 1 specific (agro and health)
Main subecosystem	Entrepreneurial support
Predominant attribute	Material

4.4 Characteristics of the structure and evolution of Montpellier's EE

Five characteristics describe the structure and evolution of an EE (Table 4). We also present the evolution of significant attributes for each subecosystem (Fig. 4).

The *longevity* of the Montpellier EE indicates its maturity. In France, it also indicates its early start in the mid-1960s. The first triggering event was the arrival of IBM in 1965. The longevity of the Montpellier EE is partly due to Montpellier's embrace of digital technology and the creation of an incubator in the late 1980s, stimulated by the forward-looking vision of its political class. The curves in Fig. 4 show strong growth dynamics for all subecosystems starting in the 2000s.

The *number of sequences* is an indicator of an EE's vitality. Each started at a different time between 1965 and 2004 (the call for projects from the European Social Fund) and continues to this day. All point to a diversity of initiatives by equally diverse actors (individuals, collectives, policymakers). Although Montpellier is not highly industrialized, IBM and Sanofi have had significant impacts, with repercussions that are still being felt. The interactions between the sequences reflect a dynamism that can be identified through, for example, the links between digital technology and agriculture, between entrepreneurial support and research, and between the social economy and health or digital technologies. In other words, the main drivers are highly relational for specific subecosystems and *material* for transversal subecosystems.

The *number and type of subecosystems* tell us about both the structure and dynamic of EEs. Two transversal subecosystems characterize the Montpellier EE: entrepreneurial support and digital. These subecosystems have permeated and boosted all entrepreneurial activities. They are currently considered almost essential for EE development and are found in most EEs. Figure 4 also shows the predominance of material attributes within this type of subecosystem. A specific subecosystem, agro and health, is also part of the Montpellier EE. It fits into the region's historical context because the agriculture and health sectors predate the advent of the EE. This type of subecosystem also refers to a predominance of social attributes and underlines the decisive role of social networks.

The *main subecosystem*, entrepreneurial support, is the most influential in terms of trajectory. In Montpellier, it contains the largest number of significant attributes and has particularly helped develop the entrepreneurial skills of people "already there" so that they can create and sustainably develop their businesses in the region. The sequences are characterized by policy initiatives, followed by the creation of support infrastructures and structured by professional networks.

Finally, the predominant attribute indicates the type of resources most frequently found in the EE. Here, 50 out of 101 significant attributes are material attributes. This result is related to the many higher education institutions, research labs, incubators, and accelerators.

5 Discussion

Despite the growing literature on EEs (Acs et al., 2017; Malecki, 2018; Cao & Shi, 2020; Stam & Van De Ven, 2021), research articulating concepts of complexity, dynamics, and context through a holistic approach remains limited (Acs et al., 2018; Colombelli et al., 2019; Radinger-Peer et al., 2018; Roundy et al., 2018). We thus mobilized the literature on EEs, evolutionary perspectives through path dependence, and a case study of Montpellier to develop a whirlwind model of EE path dependence. We were able to characterize the evolution of this EE through a small number of subecosystems, specific or transversal, driving the EE through a number of sequences. These sequences started at different times, had varying durations, interacted, and were composed of three phases (impulse, creation, structuring). Our results make theoretical contributions to both the EE literature and path dependence theory and provide useful policy implications.

5.1 Theoretical contributions

The first contribution is the priority given to EE dynamics over a long time period. Lévesque and Stephan (2019) underlined the importance of taking into account temporal perspectives (past, present, future) in entrepreneurship research, and doing so has important methodological implications. EE trajectories are more sinuous and unpredictable (Martin & Sunley, 2011; Radinger-Peer et al., 2018) than life cycle models suggest (Mack & Mayer, 2016). To represent their dynamics, we were inspired by the notion of a whirlwind from sociological work on the processes of technological innovation (Akrich et al., 2002). Composed of successive experiments, paths not taken (Schneiberg, 2007), and multiple interactions, this concept helped us gain a nonlinear understanding of EE evolution. From an empirical perspective, this approach requires qualitative materials emphasizing the chaining of significant attributes.

The second contribution relates to the decomposition of the ecosystem into subecosystems. The concept of hierarchy in complex systems (Simon, 1962) is still rarely taken into account, and a hierarchical approach differs from a multilevel approach (micro, meso, macro) to each subecosystem. The decomposition into subecosystems echoes a concern stated by Spigel (2020, p. 148): "By building new models of ecosystems, we can begin to see which aspects of ecosystems are related to universal aspects of the entrepreneurship process and which are connected with local specificities." This concept enabled us to reveal specific and transversal subecosystems.

The third contribution is the extension of path dependence theory to ecosystems. The rise in complexity of research objects investigated from evolutionary perspectives (organizations, technologies, institutions, and regions) suggests the need to revisit this concept in terms of ecosystems. The "path plasticity" (Strambach, 2010), "paths not taken" (Schneiberg, 2007), "multiple paths," and "path interdependence" (Bergek & Onufrey, 2014; Martin & Sunley, 2006; Stark & Bruszt, 2001) concepts point to advances in path dependence theory that have prevented it from being locked into processes of reproduction. This idea resists a concept of path dependence that would systematically lead to a lock-in effect. We propose a sequential approach, with each sequence being composed of three phases consistent with the founding concepts of path dependence: an impulse phase with a triggering event, a creation phase with the emergence of the first significant attribute, and a structuring phase with self-reinforcing mechanisms. This conceptualization makes it possible to reconcile continuity and change through the coevolution of several sequences and their interactions. From the impulse phase to the structuring phase, the sequences result in EE path dependence. It would be interesting to explore in greater detail the microfoundations of EE path dependence by highlighting the routines and dynamic capabilities (Cunningham et al., 2019; Roundy & Fayard, 2019) that are constructed along the way, particularly in the interactions between EE actors. The work of Nelson and Winter (1982) and their extensions with regard to notions such as dynamic capabilities (Teece, 2007; Teece et al., 1997) could contribute to a better understanding of the processes that contribute to the structuring phase.

5.2 Policy implications

This study presents three main policy implications. First, policymakers should set priorities based on the drivers of their EEs. This means focusing on the strengths of an EE to have a more meaningful impact. For example, Montpellier's policymakers supported the emergence of an incubator early on to stimulate business creators, who are more numerous in the region than captains of industry. More recently, they asked a group of entrepreneurs to respond to a call for tenders dedicated to digital technologies and, in doing so, obtain a state label with many ramifications for all EE actors. This strategy called for a form of shared governance.

Second, policymakers should stimulate interactions between subecosystems. Doing so between a specific subecosystem and a transversal subecosystem develops coevolutionary processes and results in a more viable EE. In Montpellier, the interaction between agro and health and digital is an example that energized the EE. It may also be relevant for encouraging interactions between the sequences of a subecosystem.

Third, policymakers should make EEs more inclusive. Montpellier shows two parallel worlds that rarely communicate: priority areas and entrepreneurship support. The national French Tech Tremplin program was launched in 2019 to optimize the chances of underrepresented populations through funding, training, and a mentoring system. This initiative appears insufficient given the extent of the distance between these two worlds, but we can imagine proactive approaches to these populations.

5.3 Limitations and future directions

This study also has limitations. First, we focused on a single study case, which did not allow us to harness the full comparative advantage of a sequential analysis. For example, with more sequences and distinctly different EEs, we might have used algorithms for sequence comparisons. Second, we ended our interviews in January 2020 just before the first COVID-19 confinement. It would be interesting to conduct a second series of interviews with our respondents after the global COVID-19 crisis to understand how it impacted the EE's evolution. However, the relative inertia of EEs leads us to imagine that the current trajectory will continue, especially with an amplification of the digital subecosystem and an adaptation of entrepreneurial support to those entrepreneurs who have struggled.

6 Conclusion

How do "ordinary" EEs develop over time? To date, researchers have not fully explored their complex, dynamic, and contextual nature. We therefore turned to path dependence theory, CAS theory, and the EE literature to examine the case of the Montpellier EE using a whirlwind model of EE path dependence. This model, understood as both method and representation, helped us identify a small number of subecosystems whose trajectories depend on the coevolution of several sequences. The interactions between the sequences and the paths not taken were all factors for the creativity displayed by the EE. These results highlight the drivers of the evolution of subecosystems. By revealing Montpellier's EE path dependence, our work provides useful information for policymakers to promote the potential of EEs and to energize and improve their impact.

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Declarations

Conflict of interest The authors declare no competing interests.

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