Industrial and Corporate Change, 2019, Vol. 28, No. 4, 941–959
doi: 10.1093/icc/dtz034
Advance Access Publication Date: 16 June 2019
Original article

Entrepreneurial dynamism and the built environment in the evolution of university entrepreneurial ecosystems

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Abstract

University-centered entrepreneurial ecosystems (UCEEs) are complex webs of entrepreneurs, researchers, institutional support structures, and the built environment. We study the relationship between the built environment and the dynamism of the behavior of ecosystem agents in the evolution of UCEEs. Drawing upon data from interviews with ecosystem agents, as well as documents associated with the planning and development of purpose-built facilities (the built environment), we show how planned ecosystem evolution strategies differ from realized strategies. In particular, we develop a model of emergent response mechanisms to ecosystem dynamism and munificence, which include *coping*, *learning*, and *adapting*. We discuss UCEE evolution within a connectionist framework to better address the dynamic interaction of agents, institutions, and the environment.

JEL classification: O3, I25, I23, M13, M10, O10

1. Introduction

Scientific progress and downstream commercialization are unpredictable in knowledge-intensive domains. The combination of technological uncertainty, high discovery costs, specialized knowledge requirements, and long gestation periods favors entrepreneurial ecosystems anchored by stable institutions such as large research universities. Entrepreneurial ecosystems are "*combinations of social, political, economic, and cultural elements within a region that support the development and growth of innovative startups*" (Spigel, 2017: 50). These ecosystems are characterized by the interconnectedness of actors, organizations, institutions, and infrastructure (Brown and Mason, 2017). Entrepreneurial ecosystems are not static; they evolve based on the dynamic characteristics and interactions between and among agents and institutions (Pitelis, 2012).

This interconnectivity is embedded within and around the built environment. Broadly defined, the built environment is the human-made space in which people live, work, and recreate on a day-to-day basis. It includes urban design, land use, buildings, and spaces, and encompasses patterns of human activity within and between the physical environment. For example, a research university is defined by its built environment of buildings and spaces, where individuals work and directly engage with general physical structures such as laboratories, clinics, classrooms, learning, and meeting spaces. Purpose-built facilities are constructed for specialized activity within a scientific domain, including efforts to translate basic science into early commercialization activity. These facilities are noteworthy because entrepreneurial ecosystems serve to link technological innovations to commercial practice and market adoption through agents in the ecosystem.

With the emergence of the entrepreneurial university (Urbano and Guerrero, 2013), a university-centered entrepreneurial ecosystem (UCEE) forms when knowledge spillovers, including technology transfer, generate a cluster of entities associated with a specific technology field or sector. The formation and evolution of UCEEs are particularly interesting because universities have gained recognition as engines of technological advancement and economic development, and such ecosystems appear to be responsive to policymaking associated with public funding (Acs *et al.*, 2017). Despite the growing interest in UCEEs (e.g., Miller and Acs, 2017; Hayter *et al.*, 2018), the role of the built environment has received surprisingly little attention. Research has demonstrated importance of microlevel effects in university entrepreneurship (Bercovitz and Feldman, 2008; Wright *et al.*, 2012), but UCEE agents work in and around physical structures that may enable or constrain beliefs, capabilities, choices, and behaviors. In this study, we explore how the behavior of agents interacts with the built environment in the evolution of UCEEs.

We focus our effort on regenerative medicine (regenmed), a nascent technology sector with high capital intensity and high technological and market uncertainty. These charactersitics have resulted in long-term research universities taking the lead in both foundational regenmed research as well as early commercialization activity. We study commercialization activities at two public research universities: University of Edinburgh, United Kingdom (UK) and University of Wisconsin-Madison, United States (US). We use a mixed-methods approach to investigate the relationship between the built environment and individual behaviors. We explore how this relationship drives the evolution of UCEEs. Findings reveal that the emergent characteristics of the ecosystem could not be attributed to planned outcomes of investments in the built environment. We develop a model for the emergent dynamism of the ecosystem based on three mechanisms: *coping*, *learning*, and *adapting*. We find that high and low dynamism ecosystems respond differently to the built environment, which is often manifested as a form of resource munificence.

First, we discuss existing research on UCEEs to clarify the gap in theory associated with ecosystem characteristics and the built environment. Second, we briefly profile the UCEEs selected for the study, including the relevant purpose-built regenmed facilities (built environment). We then discuss the datasets, comprising both a series of documents associated with the planning of the built environment as well as a series of narrative interviews. We examine the relationship between planned and emergent characteristics of the ecosystems using computer-aided text analysis (CATA) on the built environment documents and our interviews. Qualitative analysis of the interviews reveals the response mechanisms employed in each ecosystem, yielding distinct characteristic profiles. We then discuss implications for future research as well as innovation policy.

2. University-centered entrepreneurial ecosystems

UCEE are complex, somewhat vaguely defined constellations of agents, entities, institutions, and processes (Spigel, 2017). Triggered by knowledge spillovers, the development of UCEEs depends on the behaviors of individual entrepreneurs and organizations (Wright *et al.*, 2012). Entrepreneurial culture at the core institution influences how ecosystem agents navigate technology transfer and commercialization (Huyghe and Knockaert, 2015). It might seem obvious that the built environment would play a critical, if not defining role in the evolution of UCEEs, given its importance to universities and knowledge production (Griffiths, 2004). While studies have addressed the effect of infrastructure on entrepreneurial activity (e.g., Jain and George, 2007; Audretsch *et al.*, 2015; Audretsch and Belitski, 2017), they have not explored the specific impact of the built environment on UCEE evolution.

The university as opportunity engine

A university provides a natural environment for new opportunities through knowledge spillovers, networks, and entrepreneurial culture. Teaching, research, and external engagement generate knowledge transfer and spillovers, essential ingredients in the identification of entrepreneurial opportunities (e.g., George, 2005; Breznitz and Feldman, 2012). The university also connects people with common interests, knowledge, and capabilities. Collaborations facilitate knowledge spillovers and the development of absorptive capacity (Alnuaimi and George, 2016) as well as opportunities for commercialization of emerging technologies (e.g., Schillebeeckx *et al.*, 2016). Networks play an important role, especially in technology-intensive areas that require collaboration across scientific domains (Kotha *et al.*, 2013). Strong network ties and diverse network participants can reduce perceived uncertainty, facilitate resource assembly, and accelerate venture formation (De Vaan, 2014; Schillebeeckx *et al.*, 2016). This has led to the recognition of the "entrepreneurial university" (Urbano and Guerrero, 2013) as a hub for venturing activity.

The emergence of the entrepreneurial university has required some universities to explicitly address the role of institutional culture, including the legitimization of entrepreneurial behavior as an acceptable outcomes of scientific research (Wright *et al.*, 2012). The entrepreneurial culture of the institution directly impacts commercialization efforts (Huyghe and Knockaert, 2015). Academics that engage in commercialization activities often experience tension between academic research policies and commercially oriented activities (Jain *et al.*, 2009). In this high risk—high uncertainty context, scientists and entrepreneurs face a paradox: continued effort and investment are essential but necessarily result in high rates of failure. To maintain consistent effort toward scientific and commercial progress, individuals and organizations need to be refreshed with new ideas and resources, and manage both technological and institutional uncertainties.

2.1 From entrepreneurial university to university-centred entrepreneurial ecosystem

Venturing activity within and around a university meets the definition of an entrepreneurial ecosystem: an interconnected set of actors, entities, and infrastructure that supports opportunity exploitation (Brown and Mason, 2017). Emerging research on entrepreneurial ecosystems provides a valuable frame for studying venturing activity at the university-industry (U-I) boundary. Because much of the entrepreneurial activity will result from knowledge spillovers associated with sophisticated and specialized scientific expertise, understanding UCEEs requires careful consideration of the cognition and behavior of the individuals participating in venturing activities at the U-I boundary.

The cognition of ecosystem agents, which organizes and orders behavior, will impact the development of both organizational and ecosystem-level dynamic capabilities (Helfat and Peteraf, 2015). The development of ecosystem characteristics will depend on behaviorally anchored dynamic capabilities, namely (1) sensing and shaping opportunities and threats; (2) seizing opportunities; and (3) reconfiguring and transforming assets, resources and capabilities to maintain competitiveness (Hodgkinson and Healey, 2011). In particular, the specific processes associated with opportunity exploitation and capability development will be influenced by entrepreneurial orientation (EO) (Moss *et al.*, 2015). While EO is primarily understood as an organizational construct, it is useful to address EO as a more general characteristic, relevant to individuals, groups, and even an ecosystem (c.f. Ferreira *et al.*, 2015). EO has been shown to be an important narrative element, which can influence both behavior and action (Wolfe and Shepherd, 2015). Understanding EO at the U-I boundary can help us understand the mechanisms that entrepreneurs use during venture creation in UCEEs.

2.2 The built environment: hiding in plain sight

Research on the interconnected cultural and behavioral drivers of entrepreneurial behavior around universities have not consistently addressed either the built environment or the links between agent behavior and institutional artifacts (Hayton and Cacciotti, 2013). Studies exploring the built environment span a diverse range of fields, including urban planning, health policy, and transportation. While the built environment shapes human behavior and outcomes for those actors who are directly confined to that specific environment, studies have also confirmed that outcomes are influenced by actors associated with but *not* solely confined to that built environment (Gordon-Larsen *et al.*, 2006).

We are unaware of studies explicitly addressing the built environment and entrepreneurial ecosystems. This is unfortunate given the obvious link between entrepreneurial ecosystems, which emphasize the interconnectedness of organizations and institutions, and the built environment, which emphasizes the interactions of human activity with urban design, land use, physical buildings, and spaces. This is especially relevant for UCEEs, precisely because de novo venturing activity around a university potentially requires scientist entrepreneurs to leave the heavily resourced (and familiar) university built environment for the unfamiliar built environment of commercial activity.

Entrepreneurial activity is influenced by infrastructure; this includes private and public resources, and physical buildings such as purpose-built facilities (Woolley, 2013). The availability and complementarity of infrastructure resources drives the development and success of entrepreneurial ecosystems (Audretsch and Belitski, 2017), particularly within scientific domains (Clayton *et al.*, 2018). Research on the role of infrastructure in UCEEs has addressed university incubators (Kolympiris and Klein, 2017), science parks (Phan *et al.*, 2005), and university accelerators (Pauwels *et al.*, 2016). UCEE infrastructure clearly drives entrepreneurial behavior and venturing processes (Barbero *et al.*, 2014). As prior studies have addressed individual and organizational levels of analysis, the next step is to explore the impact of infrastructure on the development of entrepreneurial ecosystems.

Prior research, therefore, leaves two key issues unresolved. First, these studies address the impact of general, non-sector specific infrastructure. As such, impacts and outcomes on entrepreneurial behavior and venturing activity are necessarily spread across multiple sectors and overlapping ecosystems. Second, there has been no comparison between the underlying strategic intent of the infrastructure investment and emergent behavior. This is important because UCEE evolution is a dynamic and multifactorial process (c.f. Porter, 1991). The response behavior of individuals and organizations, including the emergence of strategically valuable dynamic capabilities, depends on the cognitive and behavioral capabilities of ecosystem agents (Helfat and Peteraf, 2015). We suspect that UCEE evolution will depend significantly on both munificence, represented in part by the built environment, and the dynamism of the agents within the system. The relationship between the built environment and individual behavior can improve our understanding of UCEE evolution.

2.3 UCEEs and the built environment: the case of regenerative medicine

Regenerative medicine belongs to the field of life sciences and is defined as the *"process of creating living, functional tissues to repair or replace tissue or organ function lost due to age, disease, damage or congenital defects"* (NIH, 2006). Regenmed is a nascent industry; there are relatively few industrial clusters to support commercial activity. Industry development, including major pharmaceutical activity, has been hindered by market uncertainties relating to funding, regulations, intellectual property (IP), manufacturing, and distribution (Ledford, 2008). These uncertainties limit entrepreneurial planning, hinders identification of capabilities and prevents *ex ante* validation of business models. At the same time, the high capital requirements of regenmed commercialization favor entrepreneurial activities with explicit links to university infrastructure. As a result, commercialization has been driven by scientists and clinical entrepreneurs rather than established life science companies, and these commercialization activities within UCEEs are highly uncertain and challenging (Johnson and Bock, 2017). As a response, some universities have invested in purpose-built facilities (Woolley, 2013). The scope and cost of these projects necessitates institutional planning and consensus-building around strategic purpose and long-term outcomes.

3. Study context, data, and methods

3.1 Study context

UCEE selection was based on four criteria: (1) institutions where science commercialization activities are common; (2) institutions that are driving regenmed research and have a separate purpose-built regenmed facility; (3) institutions across two regions to allow for comparison; and (4) access to relevant documentation and participants. Two institutions met our criteria: The University of Wisconsin-Madison (UW-Madison), US, and The University of Edinburgh (UoE), UK. These institutions rank comparably in terms of global rankings and stem cell/regenmed research outputs.

3.1.1 University of Wisconsin – Madison: Wisconsin Institute for Discovery

UW-Madison is a public, land-grant institution located in Madison, Wisconsin. Founded in 1848, the University has become one of the largest research universities in the United States, with an annual research budget exceeding $1.2 billion. UW-Madison Professor James Thomson derived the first human and primate embryonic stem cell lines, and the first human induced pluripotent stem cell lines, establishing the University as a global leader in regenmed research. The university's technology transfer office (WARF) is generally credited with the world's most foundational patent portfolio covering stem cell and regenmed technology. At the center of UW-Madison's translational activities in regenmed is The Wisconsin Institute for Discovery (WID). This purpose-built faculty was proposed in 2004 and completed in 2010 at an investment of US $210 million.

3.1.2 University of Edinburgh: Scottish Centre for Regenerative Medicine

Founded in 1583, the University of Edinburgh is the sixth oldest university in the UK. Located in Edinburgh, the capital city of Scotland, the university has an established history of stem cell research, made famous by Dolly the sheep.

Dolly was the first mammal cloned from an adult somatic stem cell, culminating extensive research at Edinburgh led by Professor Sir Ian Wilmut. In 2012, the University opened the £54 M Scottish Centre for Regenerative Medicine (SCRM). Housing scientists and clinicians, this purpose-built facility is charged with accelerating world-class regenmed research and translating this to industry and the clinic.

3.2 Data

The mixed method study utilizes two distinct but related datasets. The “built environment dataset” is a set of documents associated with the planning, development, and construction of the purpose-built science commercialization facility at each institution (WID at Wisconsin and SCRM at Edinburgh). The “narrative interview dataset” is a series of narrative interviews conducted with agents within the UCEEs associated with regenmed translational activities.

3.2.1 Built environment dataset

The WID and SCRM are purpose-built life science facilities. They represent the physical building infrastructure of the built environment. Both facilities were planned and funded as public-private partnerships between the respective universities and government agencies to promote regenmed research, translation and commercialization, reflecting the munificence of the respective ecosystems. We secured access to planning and development documents related to the vision, intended outcome, and construction plans for WID and SCRM. Total documentation exceeded 400 pages and 125,000 words.

3.2.2 Narrative interviews

The narrative interviews reflect the emergent, realized evolution of the UCEE, and the human behavioral aspect of the built environment. The narrative interview is a technique that encourages interviewees to tell a story (Jovchelovitch and Bauer, 2000). The narrative approach allowed informants the freedom to report their own regenmed commercialization journeys, focusing or avoiding topics based on their interpration of what was relevant and meaningful. This helps reduce staged responses and social desirability bias that could be generated with highly focused questions. Target informants across both ecosystems represented three categories: (1) regenmed entrepreneurs and firms (E/RMF); (2) regenmed academic scientists (AS); and (3) regenmed/life science support entities (SE). The dataset included 34 narrative interviews: 13 from Madison and 21 from Edinburgh. Table 1 summarizes informant data.

All interviews were conducted face-to-face by the lead author. Interviews in Edinburgh were conducted between November 2012 and September 2013. Interviews in Madison took place between March and May 2014. Other than the request for informants to discuss their commercialization journey, informants were given complete freedom to direct the flow and topic of the narrative. In some instances, following the end of the informant response, the interviewer prompted the informant to provide additional information on specific topics discussed during the narrative. Field notes were generated during and immediately following each interview and were used in the inductive analysis. The duration of interviews ranged from 15 minutes to 85 minutes. The interview transcriptions ranged in length from 1074 to 14,226 words, in total exceeding 188,000 words.

3.3 Methods

Mixed methods approaches have demonstrated value in studies of the built environment. A qualitative approach enables grounded theory-building, this is relevant as “much built environment research is still largely exploratory. The use of qualitative methods allows for unexpected development that may arise.” (Amaratunga *et al.*, 2002: 24). We adopt a mixed methods approach to gain the benefits of more transparent quantitative tools. Specifically, we generated a CATA of both the built environment documents and narrative interviews across Madison and Edinburgh. We then used this CATA data to perform Mann-Whitney non-parametric tests of the built environment documents and interviews. This quantitative analysis complemented our comparative situational analysis of the Madison and Edinburgh UCEEs, which was performed via qualitative, inductive analysis of the regenmed narrative interviews (Straus and Corbin, 1990).

3.3.1 Computer-aided text analysis (CATA) of the built environment

Linguistic inquiry word count (LIWC) is a type of CATA software to analyze narrative content. While LIWC allows for testing across dimensions, we focused on emotional, cognitive, and EO dimensions. The emotional dimension consists of both positive and negative emotions. The cognitive dimension comprises of words that organize and are associated with behavioral processes. We evaluate the full set of five EO dimensions (i.e., autonomy, innovativeness,

Table 1. Study informant and organization information

Informant #		Category	Informant role	Organization type
Edinburgh	1	SE	Executive	Provides support to the regenmed community. Government-backed initiative.
	2	E/RMF	Founder	Main operations are in tools/diagnostics. Offer services to other organizations and are actively developing in the cell therapy space.
	3	E/RMF	Manager	Involved in providing stem cell technical support and services.
	4	E/RMF	Founder	Providing stem cell training and consultancy.
	5	AS	Manager	University academic scientist (Principal Investigator).
	6	SE	Manager	Governmental organization to encourage economic growth in Edinburgh.
	7	SE	Executive	Supports academic innovation and commercialization.
	8	SE	Manager	Supports technology transfer and innovation.
	9	AS	Executive	University academic scientist (Principal Investigator).
	10	E/RMF	Founder	Operates in regenmed products and services.
	11	SE	Manager	Economic growth for Scotland through life sciences industry.
	12	SE	Manager	Supports a healthcare community and enables innovation.
	13	E/RMF	Founder	Operates in the regenmed tools and diagnostics space.
	14	E/RMF	Founder	Biotechnology and stem cell services organization.
	15	SE	Executive	Establishing a cell therapy industry and community.
	16	E/RMF	Executive	Products and services organization with operations in stem cells.
	17	SE	Manager	Supports innovation and economic development in Scotland.
	18	SE	Manager	Supports economic growth in Edinburgh and Scotland.
	19	SE	SR Manager	Supports technology transfer and company formation.
	20	SE	SR Manager	Supports technology transfer and company formation.
	21	E/RMF	Founder	Operates in the regenmed diagnostics space.
Madison	22	SE	Manager	Supports technology transfer and company formation.
	23	E/RMF	Founder	Operates in the regenmed tools space with therapeutic potential.
	24	E/RMF	Founder	Operates in the regenmed tools space with therapeutic potential.
	25	SE	Manager	Supports regional economic growth.
	26	SE	Executive	Supports scientific and technological innovation.
	27	SE	Executive	Supports new venture creation and growth.
	28	E/RMF	Founder	Operates in the tools and diagnostics space. Also, developing stem cell therapeutics.
	29	SE	Manager	Supports technology transfer and innovation.
	30	AS	Executive	University academic scientist (Principal Investigator).
	31	AS	Manager	University academic scientist (Principal Investigator).
	32	SE	Executive	Supports technology transfer and innovation.
	33	SE	SR Manager	Supports company investments.
	34	SE	SR Manager	Support company investments.

proactiveness, competitive aggressiveness, and risk taking) to be consistent with prior studies (Short *et al.*, 2010; Wolf and Shepherd, 2015).

The dictionary for the positive emotional dimension consists of 406 entries and the negative dimension dictionary contains 499 entries (see Pennebaker *et al.*, 2001). The cognitive dimension contains 730 unique individual behavioral words, such as *think*, *consider*, *perhaps*, *could*, and *always*. Since LIWC does not contain a pre-defined dictionary for EO, following Wolfe and Shepherd (2015), we developed an EO dictionary using the dictionary constructed by Short *et al.* (2010). This consists of 244 words that are grouped into the five EO dimensions, including an additional dimension—*additionally inductively derived words*. The inductively derived words category reflects words that do not fall within the other five EO dimensions but still reflects EO. Using LIWC, we analyzed the built environment documents and interviews for emotional, cognitive and EO dimensions, including testing for an overall EO dimension (*EOcombined*), which is a total calculation of the six EO sub-dimensions combined. Previous studies have shown LIWC to be useful in investigating the cognitive, behavioral, emotional, and EO dimensions of narratives (Moss *et al.*, 2015; Wolfe and Shepherd, 2015).

Quantitative analysis was performed using Mann-Whitney non-parametric tests. Mann-Whitney is a rank-ordering test to determine whether two independent groups are significantly different from each other. First, we analyzed the differences between the built environment documents and interviews within Madison and within Edinburgh to understand whether the planned strategy for the evolution of UCEEs was realized. Second, we analyzed the differences between the Madison and Edinburgh ecosystems to compare how the ecosystems evolved.

3.3.2 Inductive qualitative analysis of the narrative interviews

We completed an inductive, qualitative coding of the narrative interviews to unpack cognitive and behavioral processes within a framework of grounded theory-building (Charmaz, 2006). First-level constructs were open-coded to generate the widest set of expressed ideas. We followed a standard protocol for organizing the coding results (Strauss and Corbin, 1990). We utilized an iterative process to generate second-level constructs by grouping the first-level constructs based on logical connections expressed in the interviews. This involved reviewing both sentence-level and contextual information in the interviews. Finally, we generated a set of theoretical dimensions to reveal the higher-level cognitive processes associated with the expressed ideas and behaviors (Strauss and Corbin, 1990). Throughout this process we utilized field notes and the original audio files for depth and context to allow themes to emerge from the data. The qualitative coding utilized NVivo software.

4. Results

First, we present the findings from the quantitative analysis of the built environment documents and the narrative interviews. We then report findings from the inductive analysis of the interviews.

4.1 Quantitative analysis of the built environment documents and interviews

In Table 2, we report the Mann-Whitney findings comparing built environment documents against interviews for Madison and for Edinburgh. In Table 3, we report the Mann-Whitney findings comparing Madison to Edinburgh for built environment documents and for interviews. Within each table, we report the test statistics arising from performing the Mann-Whitney statistical analysis within SPSS, showing the Mann-Whitney U values, *Z* values, and significance. For simplicity, we do not show the results for *AddWrds*, which are words that could not be placed into the main categories, and we only report those findings that are significant (≤ 0.01).

4.1.1 CATA analysis: planned and emergent behavioral strategies

Table 2 reveals the differences between the built environment documents (planned strategy) and interviews (emergent strategy) within each UCEE respectively. In the Madison ecosystem, comparing the built environment documents to the interviews shows significant differences for *Innovativeness*, *Proactiveness*, *EOCombined* (Entrepreneurial

Table 2. CATA test results for Madison (MSN) and Edinburgh (EDI): built environment document vs. interviews

	Madison (MSN): Built environment documents vs. interviews		Edinburgh (EDI): Built environment documents vs. interviews	
	Mann-Whitney U	Z (Sig. two-tailed)	Mann-Whitney U	Z (Sig. two-tailed)
Innovativeness	0.0	−4.584 (0.000*)	35.0	−1.234 (0.217)
Proactiveness	14.0	−4.029 (0.000*)	10.0	−3.042 (0.002*)
EOCombined	1.0	−4.544 (0.000*)	20.0	−2.319 (0.010*)
Positive emotion	40.5	−2.976 (0.003*)	49.0	−0.217 (0.828)
Cognitive mechanisms	0.0	−4.583 (0.000*)	0.00	−3.766 (0.000*)

*$P \leq 0.01$.

Table 3. CATA test results for built environment documents and interviews: Madison (MSN) vs. Edinburgh (EDI)

	Built environment documents: Madison (MSN) vs. Edinburgh (EDI)		Interviews: Madison (MSN) vs. Edinburgh (EDI)	
	Mann-Whitney U	Z (Sig. two-tailed)	Mann-Whitney U	Z (Sig. two-tailed)
Innovativeness	42.0	−0.165 (0.869)	50.0	−3.069 **(0.002*)**
EOCombined	30.0	−1.156 (0.248)	53.0	−2.960 **(0.003*)**

*$P \leq 0.01$.

Orientation combined), *Positive Emotions*, and *Cognitive Mechanisms*. In the Edinburgh ecosystem, comparing the built environment documents to the interviews reveals significant differences in *Proactiveness*, *EOCombined*, and *Cognitive Mechanisms* dimensions. The CATA results suggest that the planned, intended strategy of the built environment differs from the realized and emergent behavioral strategies reflected in the narrative interviews.

4.1.2 CATA analysis: ecosystem evolution

Table 3 compares the built environment documents in Madison to the built environment documents in Edinburgh, as well as the interviews in Madison to the interviews in Edinburgh. Comparing the built environment documents across ecosystems revealed no significant differences in the LIWC analysis. That is, the built environment documents in Madison and Edinburgh were indistinguishable across the linguistic categories of interest. In contrast, CATA of the interviews found significant differences for *Innovativeness* and *EOCombined* between Madison and Edinburgh. In other words, although the planned ecosystem outcomes from the built environment were comparable across ecosystems, the emergent behavioral strategies were quite different across the Madison and Edinburgh ecosystems.

4.2 Inductive analysis: data coding of narrative interviews

The data structure emerging from the qualitative analysis of the narrative interviews is shown in Table 4. We briefly discuss the key constructs revealed by the inductive-driven analysis of the narrative interviews. Illustrative examples are provided to emphasize key elements. Analysis of the narrative interviews reflects how UCEE agents approach venturing activities at the U-I boundary, and the emergent evolution of the UCEE.

4.2.1 Coping

The *academic context*, *technology transfer policies*, and *environmental dynamism and munificence* support and challenge UCEE evolution. The development of UCEEs is partly dependent on the motivations of the academic entrepreneur, but tensions and conflicts at the U-I boundary challenge research translation and UCEE evolution. In particular, we witness the tensions between academics engaging in commercialization activities alongside their research and teaching roles:

> "[A]cademics are judged by their papers and their grants…Spinouts take a lot of time and a huge amount of work…group leaders find that extremely difficult because that's time that they're not doing their academic work. And ultimately they will be judged with the current metrics much more on their academic work than they will on their commercialization work." (Informant #9 - Edinburgh)

These commercialization activities are driven partly by the technology transfer policies, which may assist or hinder commercialization activities. For example, policies that favor licensing deals may have detrimental effects on spinout venture formation. While licensing deals are an important aspect of commercialization activities, the evolution of UCEEs will ultimately depend on spinout venture formation. In the following example, we witness the policies in place at the Edinburgh Technology Transfer Office (TTO) that directly affect spinout venture formation:

> "…we looked to create a spin out company…Because of the sort of links to the university and regenmed, we wanted to get the university engaged – that was a bloody nightmare…my negativity probably is a bit harsh to some extent…its the reason that universities don't do spin out companies." (Informant #7 - Edinburgh)

Table 4. Emergent coding structure from ecosystem-based narrative interviews

First-order codes	Second-order categories	Theoretical dimensions
Academic conflicts	Academic context	Coping
Academic metrics		
Academic motivations		
Emotion-based coping	Coping strategy type	
Problem-based coping		
Types of facilities within the ecosystem	Built environment	
Institutional/TTO goals, activities, processes & commercialization models	Technology transfer policy	
Current resources	Environmental dynamism and munificence	
Ethical challenges		
Funding issues		
Manufacturing, scale-up & distribution uncertainties		
Regulatory uncertainties		
Reimbursement uncertainties		
Risk		
Scientific uncertainties		
Communication	Proactive knowledge formation	Learning
Knowledge transfer		
Networks		
No limits to venturing	Entrepreneurial narratives	
Promising signs of venturing		
Vulnerability of ecosystem agents		
No clear path to commercialization		
Exchanges for funding purposes	Exchanges at the U-I boundary	Adapting
Exchanges for legitimacy building		
Exchanges for process improvement		
Exchanges for sharing of resources		
Business models	Entrepreneurial process	
Commercialization timeframes		
Innovation		
Imaginable industry structure		
Regional investment and growth		
Spinout venture formation		

In another example, we see the process and structures in place at the TTO for commercialization activities. These are important since they have a direct influence on venturing activity at the U-I boundary. In the excerpt below, we observe the importance of the TTO structure in assisting venturing at the U-I boundary:

> "Our [technology transfer office] has three groups. Two are permanently based here. One is the IP managers. The other are the licensing managers…IP manager will sit down with them and seek to understand the nature of their work and their possible invention…they have a very strong idea as to what is patentable and what isn't…Once they understand it, they'll get a licensing manager involved. So the primary job of the licensing manager is to license technology, but they will take a look at the marketability of this technology…They'll look at what kind of a product would this enable, how far away is it, how much risk there is?" (Informant #22 - Madison)

Our findings also reveal the importance of resources for venturing. Limited slack resources challenges venture development, which is likely to have implications for UCEEs. In Edinburgh, our findings reveal the importance of access to financial capital for venture development:

> "…they haven't had the oomph financially to take it to the next level. So they try and do as much as they can with as little resources as possible." (Informant #14 - Edinburgh)

We also witness high levels of uncertainty surrounding manufacturing, scale-up, and distribution:

> "…so you have all sorts of problems as to how you scale out and manufacture…" (Informant #2 - Edinburgh)

At the same time, regenmed ventures also face high levels of regulatory uncertainty, especially unresolved IP rights issues:

> "Not only is the regulatory path as expensive as a pharmaceutical with a potentially smaller market, it's also got a huge amount of uncertainty." (Informant #10 - Edinburgh)

As a result of the high levels of uncertainty and venturing challenges surrounding regenmed venturing, our findings revealed UCEE agents engaging in coping responses to address environmental dynamism and munificence. More specifically, analysis of the narrative interviews highlighted the implementation of two *coping strategy types*: emotion-based coping or problem-based coping mechanisms. An emotion-based coping strategy either avoids uncertainty or accepts that nothing that can be done to mitigate uncertainties. In the following example, we see an academic entrepreneur who chose to avoid uncertainties surrounding their university spinout venture. As a result, the venture failed:

> "So we took the initiative and the three of us set up a company on our own, we re-mortgaged houses, we sold children, you know, whatever! We took a big financial risk…It was not easy…we put personal money into it quite a lot, we also thought we would fund it by offering a service making monoclonal antibodies for people. We did that and we had some limited success…we made a little bit of money but it never really took off…I've been on a steep learning curve and looking back at it we were so naïve. We had no money to do any marketing, we had no expertise, we had no experience in selling/marketing…What we did brought in a bit of money, and people were happy with the service that we provided and the prices, but it never really got going. So I think it never got going for two reasons: one because of what I've just said about no money and no experience, and no expertise in how to sell and how to market. But the biggest reason I think – we didn't have the time to do it properly." (Informant #21 - Edinburgh)

In contrast, problem-based coping strategies seek knowledge to try and actively reduce the uncertainties. In the illustrative example below, we observe an (academic) entrepreneur, with no prior entrepreneurial experience or training, seeking knowledge to directly address venturing uncertainties. This entrepreneur realized the need to connect with seasoned entrepreneurs and venture capital (VC) investors, and to be active within the venturing scene in Madison. In doing so, this would reduce knowledge gaps and assist the entrepreneurial process:

> "So, I'm kind of learning myself. I am expecting to get more advice from people who are in this world and who are in this business…And I've never been so excited about something for a long time like this… A lot of things haven't worked so far…And I think we're going to make a run of it…in a whole area of life that I'm not fully appreciative of. But also at the same time, not only just learn something but have a little bit of fun along the way." (Informant #23 - Madison)

In another example of problem-based coping, we witness an academic involved in a spinout venture failing to raise Series B venture financing. Rather than dwelling on this, the venture altered their business model and then began raising smaller-scale funds in order to progress the venture:

> "…we were interested in raising Series B…And the challenge was that we were going to need to raise about $20 million to get all of these technologies developed…And we ended up instead of raising the $20 million we needed to get all the products done, we ended up doing a much smaller raise and changing the business plan…and we've raised enough to keep the company alive for another couple of years and we have collaborations now established with strategic partners that are building towards potential acquisition over the next year or two. So that process was a tremendous learning experience for me." (Informant #31 - Madison)

4.2.2 Learning

Findings highlighted agents *learning* by *proactive knowledge formation* and collaborating for knowledge. When the university favors commercialization activities at the U-I boundary, greater U-I exchanges were evident. This is especially critical, since this drives knowledge collaboration. In the example below, we see a UW-Madison-linked organization supporting knowledge collaboration through a range of networks, programs, and knowledge transfer:

> "So our [network] connects entrepreneurs and others through a variety of programs. Tomorrow we will have a program at which four relatively new faces in the university tech transfer ecosystem will be featured. And we'll have a hundred plus people who will be there to hear what it's about… Our Angel Network is a network of largely angel investors but also some smaller funds,

venture funds, early stage funds and some corporate investors. And one of the things we do is make sure the deal flow comes in front of them so that they're able to see the newest, greatest, best ideas that are spinning off of [UW] campus or elsewhere. And we do a variety of things help existing angels' best practices… Our conferences are also built around the notion of giving companies and entrepreneurs a chance to intersect and for investors to have a chance to take a look at some emerging companies…." (Informant #26 - Madison)

Entrepreneurial narratives are important for venturing at the U-I boundary and demonstrate learning (or the lack of learning) during venturing. Findings illustrated signs of heroic entrepreneurship. In the excerpt below, we see a founding entrepreneur describe how they developed a nascent venture, spun-out of UW-Madison, despite the inherent challenges associated with venturing in regenmed. In this example, we witness how the entrepreneur overcome the odds of venturing in this highly uncertain sector, showing no limits to the venturing uncertainties, and learning as they progressed their business model and venture:

"You know, it's funny, I think in the early days we thought we had challenges in raising that early seed capital and securing our million dollar check for the state. And you know, building this base out and adding a few people, really I think getting your company started is not as hard as keeping one going….So, I guess I don't feel like there were any insurmountable problems. It was just the confluence of lots of things to consider. So, the science, the business, was there a viable business plan here? Convincing investors that there was one, finding talented people to get us off the ground who are willing to take a risk. Trying to decide what things we needed for the lab and what things we didn't need and what needed to be new and what could be used in operational kind of things like that. But you know, nothing really insurmountable, just educating ourselves and learning as we went." (Informant #28 - Madison)

In contrast, we saw evidence of tragic/flawed entrepreneurship. Here, we witnessed the vulnerability of UCEE agents, with no real clear paths to commercialization:

"I went to a meeting in India with the company, I did some seminars and things there; I've done all sorts of things this year but things are not progressing very well this year, and really if things don't really start picking up I really need to think about perhaps doing something else." (Informant #4 - Edinburgh)

4.2.3 Adapting

Our findings reveal agents searching for new opportunities and adjusting resources, behaviors, and structures. In high-tech sectors, *exchanges at the U-I boundary* are critical to leverage key resources:

"…we got them to meet some companies through our network…to find out what they're doing, swap information, so that kind of activity, I mean, it's community building, access to funding and access to partners for collaboration would be the strap line." (Informant #12 - Edinburgh)

In particular, we see exchanges at the U-I boundary to improve particular scientific processes:

"…the idea is that we work with them and take some of the processes and tune them up for proper manufacturing." (Informant #15 - Edinburgh)

At the same time, these exchanges enable sharing of resources:

"…so we have access to the cell lines, or at least some of them, from [company name]." (Informant #3 - Edinburgh)

We also observed externally focused interactions to drive the *entrepreneurial process* and progress venture business models and support spinout venture formation:

"So our next immediate business model milestone to spin out is raising for venture capital. We have never raised venture capital. We've raised \$6.35 million in angel financing, and we've got another \$3.75 million in grants from either SBIR or from state." (Informant #28 - Madison)

In some instances, we saw ventures adapt their business models to exploit market opportunities:

"…we altered our business…what we did is move away from a company that was almost a service company to one that would have product or products based on IP in one form or another, whether patented or not, that we could then market." (Informant #7 - Edinburgh)

Some were doing this, and shifting from a business model based on therapeutics to one based on services or tools/diagnostics, due to the unattractive commercializing timeframes (and costs) of therapeutics:

> "…[the] time horizons of a VC investment just don't fit the time horizons of a development of a therapeutic…" (Informant #10 - Edinburgh)

Our findings reveal how UCEE agents approach venturing activities at the U-I boundary. In particular, we witness evidence of *coping*, *learning*, and *adapting* frames. We now reflect on these in further detail.

5. Discussion

We focus our discussion around three topics. First, we combine the results of the quantitative CATA and qualitative inductive analyses to show how UCEEs evolve. In particular, we discuss the relationship between the planned strategy of the ecosystem, as reflected in the built environment documents, and the resulting emergent strategic outputs demonstrated within the narrative interviews. More specifically, we discuss the interaction between the built environment and individual-level behaviors in the evolution of UCEEs. Second, we extend our discussion on the evolution of UCEEs through consideration of a connectionist learning approach, which can better characterize the path dependencies of UCEEs. Finally, we discuss policy and practice implications for UCEE evolution and development in the context of our findings.

5.1 Evolution of UCEEs: planned strategies and emergent ecosystem outputs

Table 2 compares the built environment documents to the interviews within each ecosystem. The planned strategy of the built environment documents differs from the emergent characteristics and behavior described within the narrative interviews. Both observed ecosystems have entrepreneurial characteristics that are different from what was envisioned in the commissioning of the built environment facilities.

It is important to note, however, that although both ecosystems demonstrate divergent characteristics from what was envisioned in the respective planning documents, they also diverge from each other. First, Table 3 shows that the built environment documents in Madison and Edinburgh are linguistically indistinguishable. The commissioning of the built environment facility in both ecosystems was predicated on remarkably similar expectations for entrepreneurial characteristics and behaviors. As stated, the characteristics of the interviews in both ecosystems differed from the planning documents, but the revealed cognitive and behavioral characteristics in Madison differ from those in Edinburgh. In other words, the ecosystems have evolved differently.

This leads to a methodological conclusion as well as a valuable theoretical conclusion. From a methodological perspective, the CATA analysis demonstrates the ability to discriminate linguistic content between and across datasets. We note below that future research should consider qualitative semantic coding to extract further information from the ecosystem datasets. However, the analysis provides a clear basis for drawing conclusions independent of the qualitative analysis. From a theory-building perspective, the CATA results show that ecosystem evolution is determined by more than the institutional resources and planned behavioral strategies. Otherwise, given the similarity in resources and behavioral strategies, the cognitive and behavioral characteristics of the interviews across ecosystems should also have been relatively indistinguishable.

We now turn to the findings from the qualitative analysis. The qualitative coding of the narrative interviews unpacks the underlying behavioral approaches and patterns of agents within entrepreneurial ecosystems. The dynamism of the agents influences individual responses to navigate the munificence of the ecosystem. As a consequence of these responses, emergent strategies evolve and the realized strategy and evolution of the UCEE differs from what was planned. With this in mind, we explore the mechanisms of agent responses in the ecosystem. Based on the inductive qualitative analysis, we discuss the *coping*, *learning*, and *adapting* frames across individual, organizational, and ecosystems levels. This is a novel contribution exploring the interconnectedness of (university-centered) entrepreneurial ecosystems by investigating the dynamism of agent behavior.

The inductive analysis suggests that within different ecosystems, which are operating under differing levels of dynamism and munificence, the decision-making abilities of ecosystem agents is challenged. Entrepreneurs either address uncertainties directly via a problem-based coping response or chose to ignore these uncertainties and act through an emotion-based coping mechanism. Similarly, the universities, ventures, and ecosystems are presented with uncertainties that cannot be solved via simple, linear processes.

The first critical stage of framing in UCEE evolution utilizes various *coping* mechanisms and processes employed to respond to the dynamism and munificence within the ecosystem. Individuals and organizations rely on narratives to organize and interpret information, events, and outcomes (Phillips *et al.*, 2013). Under high uncertainty, knowledge is necessarily contextual and interpreted through connections to other entities. The second critical stage of framing is *learning*, in which UCEE agents utilize a dominant coping process to impose meaning onto a set of observed circumstances and anticipate outcomes of choices. The final stage of framing is *adapting*, in which agents seek to adjust resources, behaviors, processes, and even exogenous structures to their advantage. Adaptation requires internally driven exploration and externally focused transactions within the broader entrepreneurial context.

Coping: At the individual level, effective coping requires problem solving. While emotion-based coping is a viable short-term psychological strategy to address uncertainty, in the long-term it supports the entrepreneur at the expense of the long-term success of the venture and the evolution of the UCEE. At the venture level, effective coping is accomplished through testing markets. Effective UCEE coping, however, requires recycling the failed efforts of entrepreneurs and ventures back into the resource base of the ecosystem. Failure is an inevitable outcome, at every level, within the ecosystem. Healthy ecosystems recycle the residual resources and capabilities toward new opportunities and business models, rather than allow those valuable elements to be tied up indefinitely in half-dead entities.

Learning: Entrepreneurs learn via the development of managerial skills in the context of opportunity recognition and venture growth. In high-uncertainty sectors, such as regenmed, ventures learn by collaborating for knowledge. These knowledge collaboration processes are critical to the development of capabilities and exploration of distant opportunities (Kotha *et al.*, 2013; Schillebeeckx *et al.*, 2016). In scientific projects, learning through collaboration leads to capability development over time as coordination costs reduce (Kotha *et al.*, 2013; Vural *et al.*, 2013). At the UCEE level, learning is evidenced via distribution of available resources, including knowledge spillovers and failure residuals into ongoing research and development activities.

Adapting: At the individual entrepreneur level, adaptation is the continuous search for new opportunities. At the venturing level, adaptation is the continuous exploration of viable business models. At the UCEE level, however, the process of adaptation requires extending the boundaries of the ecosystem via market-facing networks.

Table 5 presents the framework for the evolution of UCEEs. In particular, this includes ecosystem dynamism profiles resulting from the levels of EO and innovativeness, and the emergent response mechanisms to these particular ecosystem profiles. More specifically, our analysis reveals that when EO and innovativeness is low, as is the case in Edinburgh, we witness a UCEE focused on emotion-based coping responses. As such, individuals and ventures learn within this ecosystem profile via externalization. In this ecosystem, individuals and ventures adapt to the dynamism and munificence through perseverance, where new opportunities are exploited by adapting to new processes and resources. In contrast, in Madison, we observe high EO and innovativeness linked to an ecosystem that emphasizes problem-based coping. In this situation, individuals and ventures learn by collaboration, in order to build knowledge and capabilities. In turn, individuals and ventures adapt to the dynamism and munificence through pivoting, where opportunities are exploited by exploring new solutions and business models.

Table 5. Emergent response mechanisms for UCEE evolution

Ecosystem dynamism profiles	Emergent response mechanisms		
	Coping	Learning	Adapting
Profile 1: Edinburgh low EO / innovativeness	Emotion-based coping	Externalization driven by perceived limitations in implementation	Perseverance: new processes and resources to address similar problems
Profile 2: Madison high EO / innovativeness	Problem-based coping	Collaborative knowledge and skill-building, via market-facing networks, to expand implementation options	Pivoting: new solutions and business models to address new problems

In Tables 6a and 6b we report excerpts from the narrative interviews from each UCEE as exemplars of the *coping*, *learning*, and *adapting* emergent response mechanisms. Our findings show that UCEEs evolve and develop from the combination of planned investments in the built environment and the behavior of ecosystem agents. These behavioral *coping*, *learning*, and *adapting* frames do not present a linear process of increasing importance or success. For any given "problem," UCEE agents may employ one or more of the framing stages simultaneously or serially. Framing processes may progress from any stage to any other stage. In addition, the successful implementation of the *adapting* frame to navigate and resolve a given problem does not predict the success of any given organization or UCEE.

Table 6a. Emergent response mechanisms for UCEE evolution: Madison examples

Emergent response mechanisms	Interview example	Navigating environmental dynamism and munificence
Coping	". . ..the business - was there a viable business plan here? Convincing investors that there was one, finding talented people to get us off the ground who are willing to take a risk. . .And it just took time to build that. . . I hired someone to be the head of diagnostics. . .He just has a different pedigree than I have. . .He's raised 170 million dollars in venture capital. He's taken one [venture] public and got another one acquired. . .He is probably the right person to lead the company in the next section of our lifetime. . .Not to say that I'm leaving, I will just move into a different seat. But what we do is recognize when we have to have a different set of talents."	"I think in the early days we thought we had challenges in raising that early seed capital and securing our million dollar check for the state. . .So, I guess I don't feel like there were any insurmountable problems. It was just the confluence of lots of things to consider. So, the science, the business, was there a viable business plan here? Convincing investors that there was one, finding talented people to get us off the ground who are willing to take a risk. . .But you know, nothing really insurmountable."
Learning	"Our Wisconsin Innovation Network is designed to connect entrepreneurs and others through a variety of programs in and around the State. . .we brought all those people to the table, including outsiders who are not university related, who'll hear about what's going on. . . And that's going to help [the ecosystem], at least in an indirect way, further that notion of tech transfer."	". . .the business school has a business clinic. They provide training in developing businesses, not business plans so much, but market assessments and looking at the strategic feasibility. We have a law clinic that looks at the legal side. We have a mentor group that's outside of the university officially but pretty much tied in with access to the university. WARF has a number of training programs. . .so we have quite a diversity of things."
Adapting	"And the challenge was that we were going to need to raise about $20 million to get all of these technologies developed. . .And we ended up instead of raising the $20 million we needed to get all the products done, we ended up deciding to do a much smaller raise and changing the business plan. . .and we've raised enough to keep the company alive for another couple of years and we have collaborations now established with strategic partners that are building towards potential acquisition over the next year or two. So that process was a tremendous learning experience for me."	"When the company started it was entirely novel-there were some business plans, but they weren't very mature. . .we're exploring interactions with strategic partners. . .we had interactions early on with venture capital folks. . .we had to identify the initial technical staff, we had to determine what the focus of the company was going to be, what were we going to effectively do with the initial venture financing? How were we going to explore, how were we going to develop a company focus? We had a really exciting platform that could do many things, but we didn't have a story, we didn't know the market that we were going to identify and target. . .So we continued to develop the technology. . .we found out very quickly what the risks were. . . And we went from being not a lifestyle company, but also not a product discipline company, to becoming a laser-focused-product discipline company."

Table 6b. Emergent response mechanism for UCEE evolution: Edinburgh examples

Emergent response mechanisms	Interview example	Navigating environmental dynamism and munificence
Coping	"…it's really quite difficult for a company like mine-but there's not really any money coming in from most of this, so that's going to be something that's going to close the company if I don't find something soon."	"You're to try and predict where the market opportunities are, and that's very difficult because we're ahead of the curve in terms of demand…it's not a great business model in the traditional sense - normally you produce a product for which there's going to be a market demand. Here, it's a classic case of having the capability and no market. But you're anticipating, and the difficulty is actually the timing of getting to the point when the demand starts to ramp up? I'll be honest in saying that I'm still convinced this demand is going to come through. My difficulty is I don't know whether it's going to be this year or next year, and the challenge from the company point of view is how do you maintain the business itself and how do you remain viable while this is going on? So our choices were pretty simple, either we said well okay, we've missed the boat or we're ahead of the boat…I guess we could've closed it…I guess we woke up and said well hang on a minute, before we do that, before we close the door so to speak, is there an opportunity here to see if we can develop something for ourselves that is unique…that could be viable we can actually sell…"
Learning	"We have a bit of a focus here on hepatocytes, so we're very good at turning our stem cells into hepatocytes in 2D culture, and we're now progressing a lot of projects which are going to move that kind of 2D stuff into 3D, and we've done a lot of learning… partially it's from doing commercial work with 3D scaffold manufacturers, and partly it's from just doing collaboration work on R&D projects that we've learned as we're going along – we seem to be getting better at it…"	"…we have to try and find new ways of either generating that money ourselves or collaborating with people who've already got it…and we will try to get some of our potential cell therapies into this pipeline."
Adapting	"So the entire business model, manufacture and supply chain model is significantly different from what biotech and big pharma understands as their business model…There are new business models required in these therapies…"	"…but that's how we deviated from what was our original business model to what we're trying to do now, and there's some other developments, we're doing some other stuff that the guys are working on at the moment…"

5.2 A connectionist learning approach to entrepreneurial ecosystem evolution

The successful development of similar purpose-built regenmed facilities in the Madison and Edinburgh UCEEs suggests comparable institutional contexts for entrepreneurial activity. The interview data, however, suggests that the common aspirational EO of the built environment documents is not replicated in practice. The development of EO characteristics in the UCEE is not tightly linked to infrastructure and resources at the entrepreneurial university. UCEE evolution is a multifactorial process (Wright *et al.*, 2017). As such, a connectionist learning perspective provides an alternate framework for understanding UCEE evolution.

An ecosystem can be viewed as a configuration of elements (resources, activities, infrastructure, norms, people, etc.). The components of EO are contextualized at multiple levels. Emergent behavior or outcomes at all levels are possible without direct coordination among those elements. In a connectionist learning framework, a major investment, such as a purpose-built physical facility, represents a *discontinuity*, rather than simply an additional resource. It is effectively an exogenously driven shock, because it does not emerge organically from extant ecosystem resources and capabilities. Discontinuities can lead UCEEs to grow and evolve, or to regress to a prior stable state. In the connectionist learning lens, the configuration of elements within the UCEE has a "memory." This is important, precisely because a memorized configuration of elements may be a more likely response to discontinuity than a novel, "preferred" configurational change. Similar results have been shown from simulation of business model configurational change (George and Bock, 2012).

Based on the underlying dynamism of the ecosystem agents, a discontinuity may "lock in," rather than change, the prior configuration of UCEE characteristics. In this interpretation, the purpose-built facilities reinforce the extant characteristics of the ecosystem configuration. Viewed within this framework, the low EO/Innovativeness observed in the Edinburgh interview data suggests that even significant and explicit resource investments do not easily change entrenched patterns of behavior, especially in the context of high uncertainty, nascent technologies. The investments that support healthy evolution in one UCEE may be ineffective or even counterproductive in another, by locking-in undesired or suboptimal characteristics from prior configurations.

5.3 Practice and policy implications

University entrepreneurial ecosystem analysis has emerged as a flashpoint for practice and policy focused on new venture-driven economic impact. In contrast with industrial clusters that emphasize competition and efficiency, entrepreneurial ecosystems emphasize innovation and new venture creation. Policymakers have been quick to embrace the coordination-based frameworks for UCEE development (c.f. Etzkowitz, 2004). In high-uncertainty contexts, however, these coordination frameworks necessarily suffer from high transaction costs while overstating the influence of university and government incentives in technology-intensive ecosystems. Combined with inherently high failure rates, policies that seek to coordinate and "guide" innovation across institutions are unlikely to succeed.

For example, an institutional approach to risk management within a weak entrepreneurial environment points toward higher diligence and fewer investments (Degroof and Roberts, 2004). Such policies run counter to the needs of a healthy ecosystem. The innovation rate of a healthy ecosystem is positively related to failure rate for individuals and organizations. In other words, institutions that apply their own risk profile to the process of opportunity identification and exploitation will most likely hinder the effective allocation of resources and spillovers within the ecosystem. In reality, loosening requirements for technology-driven startup activity facilitates entrepreneurial self-selection and allows market forces to determine venture outcomes. Ventures that succeed shape the ecosystem; ventures that fail impart population level learning to the ecosystem (Miner *et al*., 1999). Such policies likely increase the rate of startup failure, which may be difficult for TTOs and universities generally to accommodate. The challenge for institutional practice and policy is recognizing that failure is a necessary element of a healthy UCEE.

Additionally, formal entrepreneurial training mechanisms that emphasize business skills are unlikely to prepare research academics for organizational contexts where uncertainty dramatically hinders analytical decision-making. Entrepreneurial universities attempt to establish and control resource-rich microclimates at the U-I boundary, including skills-based training. UCEE agents, however, engage with commercialization activities within entrepreneurial and narrative frames. Experiential training, which assists entrepreneurs in coping with uncertainty and even failure, may help in these entrepreneurial universities.

Finally, coping strategies appear to be an important characteristic of UCEEs, closely linked to knowledge collaboration processes that are essential in knowledge-intensive and high-technology sectors. The evolution of the ecosystem depends more on the socio-cultural framework for response to stress than specific resource availability or available translational skill-sets. The emergence of dominant narratives and the path of ecosystem evolution will be driven by preferential coping and knowledge collaboration strategies. As such, policy makers must recognize the importance of microlevel factors in the development of UCEE in technology-intensive sectors at the U-I boundary. More specifically, the interaction between the microfoundations of UCEE and the built environment is important for the evolution and development of UCEEs. Yet, while these recommendations may have important consequences to assist with the evolution and development of UCEEs, we must be cognizant that the ecosystem and built environment has many stakeholders. These diverse range of agents often have differing (and sometimes, competing) goals, norms, standards and values, and they operate within distinct contexts. This complexity challenges "best practice" policy toward the evolution and development of UCEEs (Wright *et al*., 2017).

While these findings pose directions for new research, we must recognize the limitations to this study. The datasets are relatively small and limited to two ecosystems. Larger datasets of interviews and information about ecosystem activity would improve our understanding of the hidden connections and complex interactions within ecosystems as they evolve. Since the data is cross-sectional, we cannot assess the rate of UCEE change. The study does not address outcome or performance measures of ecosystems, so we are unable to confirm whether specific ecosystem profiles are directly correlated with the success of UCEEs. One important limitation of the study was analyzing the built environment documents only with the CATA software. An open-coded, qualitative, semantic level analysis of such documents would have enabled more direct comparison with the qualitative interview analysis. Whenever a mixed-method approach is used, it is appropriate to recognize the limits of comparing different analytical methods. In this case, however, it is useful to note that the CATA analysis found significant results when comparing ecosystem-specific datasets (built environment documents vs. interviews), and when comparing the interview datasets across ecosystems (Edinburgh vs. Madison) but *not* when comparing the built environment documents across ecosystems (Edinburgh vs. Madison). In other words, while semantic level analysis might have added further depth to these results, the word-level analysis generated discriminatory results. Further research is clearly needed. The framework generated through our analysis of the dataset should be tested and refined through additional empirical research. A large-scale, multi-site quantitative study could test microlevel characteristics in UCEEs and ecosystem development processes. In-depth case studies also have the potential to provide a deeper understanding of UCEE formation.

6. Conclusion

We studied the interaction between the built environment and the microfoundations of UCEEs to understand how ecosystems emerge from the combination of planned investments in the built environment and the behaviors of ecosystem agents. Research universities often rely on direct institutional drivers such as policy and the built environment to facilitate and encourage entrepreneurial activity. While universities may develop purpose-built facilities with a key focus on technology transfer and commercialization, our findings suggest that ecosystem creation is far more complex than a simple sum of its parts.

This study provides an unique window into how the built environment and entrepreneurial ecosystems are deeply interconnected. We contribute to the literature on entrepreneurial ecosystems by, first, highlighting the potential role of the built environment in the evolution of UCEEs. This represents a new level of analysis for the impact of infrastructure and environment on entrepreneurial outcomes; prior research has primarily focused on outcomes at the individual and organizational levels. By bringing in the built environment into the management and innovation literatures, we highlight the potential effects of how "human-made" space affects innovation and commercialization. Our study shines a light on how urban design, buildings, and infrastructure can affect entrepreneurial activity, and showcases some implications of human connectedness to the physical environment.

We contribute further by conceptually linking the built environment and the behaviors of ecosystem agents. To our knowledge, this is the first study to link microlevel behavior and the built environment to the evolution and development of UCEEs. Extending prior studies that have explored dynamism, munificence, and the microfoundations of capabilities (e.g., Helfat and Peteraf, 2015), we show that UCEE evolution depends on both munificence (in the built environment), and the dynamism and behavioral responses of agents in the ecosystem. Finally, we develop a framework of how ecosystems evolve—through *coping*, *learning*, and *adapting*. We propose a configurational perspective for understanding the evolution of an ecosystem, and our comparative data show how these ecosystems could have the same starting built environment conditions but their evolutionary pathways differ based on the behaviors of agents within these ecosystems. Taken together, our study showcases the importance of the relationship between microlevel behavior and the built environment in the evolution of UCEEs. With a shift to a sharing economy and collaborative working-living facilities to promote entrepreneurship, our study highlights the university's central role in these entrepreneurial ecosystems and the need to consider how agent's innovative and commercialization behaviors are shaped by the built environment.

Acknowledgements

We thank the co-editors of the special issue, Maryann Feldman, Don Siegel and Mike Wright, and the reviewers for their comments and guidance. This work was supported by The Economic and Social Research Council (grant number ES/J500136/1) and Research and Development Management (RADMA). We are also grateful for institutional support from the Holtz Center for Science and Technology Studies at The University of Wisconsin-Madison and The Wisconsin School of Business at The University of Wisconsin-Madison. Gerard George gratefully acknowledges the support of the Lee Kong Chian Chair Professorship from the Lee Foundation.

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