

Modeling complex processes in entrepreneurship: A method for designing agent-based simulation models using bibliometric procedures

Jaehu Shim

Australian Centre for Entrepreneurship Research,
Queensland University of Technology, Brisbane, Australia

Martin Bliemel

School of Management, University of New South Wales, Sydney, Australia, and

Myeonggil Choi

School of Business Administration, Chung-Ang University, Seoul, South Korea

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Purpose – This study aims to suggest a bibliometric method for designing agent-based models (ABMs) in entrepreneurship research. The application of this method is illustrated with an exemplary agent-based modeling and simulation (ABMS) regarding early venture growth process. This bibliometric approach invigorates the utilization of ABMS as a viable research method in process-oriented entrepreneurship research.

Design/methodology/approach – In the bibliometric method, a domain corpus composed of scholarly articles is established and systematically analyzed through co-word analysis to discern essential concepts (i.e. agents, objects, and contexts) and their interrelations. The usefulness of the bibliometric method is elucidated by constructing an illustrative ABMS.

Findings – The bibliometric method for designing ABMs identifies the essential concepts in the entrepreneurship literature and provides the context in which they are interrelated. The illustrative ABMS based on these concepts and interrelations accurately and consistently reproduces the emergence of power-law (PL) distributions in venture outcomes consistent with empirical evidence, implying further merit to bibliometric procedures.

Practical implications – The proposed method can be used not only to build simple models with essential concepts, but also to build more complex models that take a large number of concepts and their interrelations into consideration.

Originality/value – This study proposes a bibliometric method for designing ABMs. The proposed method extends similar procedures that are limited to thematic or cluster analysis by examining the semantic context in which the concepts co-occur. This research suggests that ABMS from bibliographic sources can be built and validated with empirical evidence. Several considerations are provided for the combined utilization of the bibliometric method and ABMS in entrepreneurship.

Keywords: Agent-based modeling and simulation, Bibliometric procedure, Entrepreneurial process, Power-law distribution, Complexity

Paper type: Research Paper

Introduction

There is increasing consensus that agent-based modeling and simulation (ABMS) is a viable research method in entrepreneurship research (McKelvey, 2004; Yang and Chandra, 2013), especially for the process-oriented approach (McMullen and Dimov, 2013; Crawford *et al.*, 2015). ABMS is regarded as a tool for establishing theories about processes by reproducing phenomena using computer simulations (Gilbert and Terna, 2000).

ABMS is a major research method of complexity science and has some uses in business and management studies (Fioretti, 2013). The complexity perspective views a macro-level phenomenon can emerge through multiple agents' micro-level behaviors in the process of interest. In ABMS research, simulation models are built consisting of essential agents and their behavioral rules. This enables investigation of the temporal or dynamic effects of individuals' behaviors that generate their aggregate outcome. Using an agent-based simulation model, the sudden disappearance of Anasazi civilization around AD 1350 was finally explained (Diamond, 2002). In the simulation model, the dynamics of the population and settlement size over time (AD 800-1350) were reproduced based on the people's plausible behaviors and known environment. Such ABMS are particularly useful if the phenomenon is not easily explained by conventional methods, and when field data is hard to obtain and hard to replicate across different contexts.

Despite the fact that ABMS is a promising research method in entrepreneurship, it is difficult to find applications of ABMS in this research field (e.g. McDonald *et al.*, 2015). Only recently, papers applying ABMS have begun to be published in entrepreneurship (e.g. Bhawe *et al.*, 2016). This underutilization may be associated with a lack of understanding of how to design the conceptual models upon which the ABMS are based. Designing ABMS involves identifying (i) essential concepts (e.g. agents, objects, and contexts) and their relationships, and (ii) the agents' plausible behavioral rules in a way that is consistent with the literature. However, such comprehensive consideration can be cognitively overwhelming, particularly for new adopters of ABMS and for newcomers to a given literature.

To tackle these challenges, this study suggests a bibliometric method that uses co-word analysis to discern essential concepts and their relationships. Bibliometric analysis has been used to automate the synthesis and analysis of large volumes of scientific publications and identify central authors and core themes (e.g. Martens *et al.*, 2016). In bibliometric analysis, the literature is regarded as an important means of delivering knowledge. For a given area of interest, the bibliometric method extends beyond listing core concepts to identify their interrelationships using co-word analysis (Moed, 2006), followed by content analysis to better understand the context in which the concepts co-occur. Co-word analysis facilitates analyzing a large corpus to identify essential concepts and their relationships. When co-occurring concepts are reviewed in context of the corpus, they describe “who is related to whom” as well as “what (process) they do.” These descriptions then provide a guide for researchers to develop valid ABMS. This article illustrates the bibliometric procedure to identify the agents, objects, and their (interactive) contexts with regards to early venture growth process. The conceptual insights from the procedure are then translated into an illustrative ABMS. The main purpose of the ABMS is to make the guidelines for creating ABMS using the bibliometric procedure more concrete. The additional purpose is to accurately reproduce the emergence of power-law (PL) distributions as a stylized fact of entrepreneurship.

This study offers three contributions. The main contribution is the presentation of the bibliometric method as a means to find essential concepts and their relationships for designing of ABMS in entrepreneurship research. The secondary contribution is an illustration of how to apply the procedure to identify essential concepts (agents, object, and contexts) for the purpose of developing ABMS, with the example of studying the emergence of PL distributions in early venture growth process. This contribution is reinforced by validating the simulation results against empirical observations. Tangentially, this ABM may provide a baseline model upon which entrepreneurship researchers can develop more refined versions of the ABM for their simulation studies.

ABMS and entrepreneurship research

The rationale for using ABMS in entrepreneurship is gaining in recognition in the literature (McKelvey, 2004; McMullen and Dimov, 2013; Yang and Chandra, 2013; Crawford *et al.*, 2015) and will only briefly be reviewed here to frame the proposed bibliometric method. ABMS has ability to simultaneously reproduce each agent's micro-level behaviors and their interactive processes, while enabling observation of the emergence of macro-level empirical facts over time. As noted by Yang and Chandra (2013), ABMS and entrepreneurship have shared conceptual foundations, such as agents' autonomy, heterogeneity, bounded rationality, and their capabilities to learn and adapt under environmental uncertainty. In aggregate, these individual behaviors result in the emergence of patterns at the level of the (social) system, such as the distribution of venture outcomes and their growth rates in a population (McKelvey, 2004; McMullen and Dimov, 2013; Crawford *et al.*, 2015). This ability to link micro-level behavior to aggregate outcomes can span multiple levels, including individual, regional, and national levels (Kozlowski *et al.*, 2013). Generally, ABMS studies start with finding a stylized fact of a phenomenon at the macro level and result in reproducing the underlying processes and behaviors of individual agents at the micro level that produce the stylized fact.

From a theory perspective, ABMS may be used as a predictor when it is used to forecast something using existing theories. ABMS may also be used as a generator to develop or refine theories where there is a lack of understanding about the underlying processes of a phenomenon (Davis *et al.*, 2007; Heath *et al.*, 2009). From a practical perspective, simulations provide researchers with the ability to adjust and control all the variables in the ABMS and efficiently perform large numbers of repetitive tests (Anderson, 1999; Davis *et al.*, 2007) that are impractical to do using lab experiments or interventions in the field. These simulated tests may include what-if analyses, where researchers can simulate plausible or even extreme scenarios (Harrison *et al.*, 2007). Overall, ABMS fits entrepreneurship research where theory refinement is required, as the findings from simulations can help unfold the process behind a larger scale phenomenon.

Essential concepts for ABMS

There are invaluable primers for ABMS in entrepreneurship research (e.g., Davis *et al.*, 2007; Crawford and McKelvey, 2010; Yang and Chandra, 2013). However, they often overemphasize the agents without clearly differentiating objects (e.g. resource, opportunity) in the system and the contexts of the system.

This is a concern, considering that what agents do and how they interact is highly contingent on available objects and the contexts in which the manipulation of the objects creates value.

At their core, ABMS include multiple agents, each with diverse capabilities, experience, and cognition patterns, which are used to adapt to their environments over time (North and Macal, 2007; Yang and Chandra, 2013). The majority of entrepreneurship studies have mainly focused on the “entrepreneur” or “firm” (Martinez *et al.*, 2011) as a sole agent. However, other agents engaging in the process (e.g. “investor”, “customer”) may be simultaneously considered in ABMS (McMullen and Dimov, 2013), as appropriate to the process being studied (e.g. person to nascent entrepreneur, nascent entrepreneur to firm, firm growth, and industry emergence).

The second type of essential concept for ABMS are the diverse objects that are being acted on by the agents, including tangible objects such as “resource” and “product” and intangible objects like “opportunity” or “knowledge.” In some previous studies, these entities have been treated as agents or attributes thereof (e.g., Yang & Chandra, 2013). However, it is more useful to categorize these passive entities as a separate component of ABMS, especially when they can exist independently of the agents and do not have any autonomous behavior.

The third type of essential concept for ABMS is the context. In an entrepreneurial process, how agents interact and manipulate objects is affected by temporal or spatial contexts. The context refers to environmental settings (and their changes) that have an impact on entrepreneurial activities (Aldrich, 2009), such as “industry”, “institution”, and “country” (including as a proxy for culture). Despite the importance of contexts in entrepreneurship research, it is rare to find such contextual variables in entrepreneurship studies (Martinez *et al.*, 2011).

Bibliometric approaches to designing ABMs

Bibliometric methods are increasingly used to make sense of large sets of publications. They are typically used as an advanced form of systematic literature reviews as a relatively objective means of identifying central publications, scholars and themes within a body of knowledge. Notable examples include analysis of the information sciences (Börner *et al.*, 2003), nanobiopharmaceuticals (Chen and Guan, 2011), strategic management (Furrer *et al.*, 2008) and entrepreneurship (Martens *et al.*, 2016), as well as across multiple academic disciplines (Leydesdorff, 2007). While there is variance across algorithms and methods, they generally seek to identify who or what is central by way of frequency counts and network centrality measures based on associative or relational networks among the publications. As such, they are particularly useful in identifying concepts for ABMS and provide a starting point for understanding how the concepts are interrelated. These bibliometric methods have transformed how systematic literature reviews are conducted, causing a shift from manual coding of a limited sample and inter-coder reliability testing to semi-automatic analysis of massive samples. By a similar token, these methods are particularly well suited to shifting away from qualitative or manual approaches to designing ABMs to more quantitative or computational approaches. Despite this potential, these bibliographic methods have focused on visualizing the literature (e.g., Stegmann and Grohmann, 2003), and not yet on identifying essential concepts and their behavioral rules for ABMS.

Qualitative approaches to developing ABMS often draw on the researcher's personal knowledge of the literature, combined with input from other experts and research participants. The strength of qualitative methods is that they can elicit nuanced behavioral rules with which to define interactions between concepts in the ABM. For instance, North and Macal (2007) suggested structured interviews as a way to identify the agents that make up the ABM, and investigated the behavioral rules of each agent. Building on such structured interviews, Garcia (2005) suggested cognitive mapping as a method to specify the agents, the environments, and the rules. Likewise, Rand and Rust (2011) emphasized the necessity of specifying for agents' properties and behaviors.

In comparison, bibliometric approaches to designing ABMs use computational methods (Börner *et al.*, 2003; Stegmann and Grohmann, 2003; Leydesdorff, 2007; Chen and Guan, 2011) to identify the key agents, objects, and contexts. Each bibliometric approach starts with building a large corpus in a computer file, which typically consists of journal articles or patents but also web pages or news articles. Relations between documents in the corpus may be derived in a variety of ways, including use of co-authorship data, (co-)citation data, or semantic analysis. The benefits of the bibliometric methods are that they can be used to examine the accumulated domain knowledge in a very short period of time. The drawback is that the computationally produced overviews often lack nuances of the arguments in the sources and interpretations offered by their authors. While imperfect, bibliometric methods therefore help “collate previous empirical research and facts, e.g. cases, surveys, histories, events” and help “review the literature in the domain of interest to identify the agents, their attributes and environment” (Yang and Chandra, 2013, p. 222).

The next activity in building ABMS that bibliometric methods can help with is to “identify the agent relationship and specify a theory of agent interaction” (*ibid.*). Here too, the activity can be done manually, or it can be computationally assisted by bibliometric procedures to remove some of the subjectivity and can increase the scope of the literature drawn on while shortening the time required to do so. As a starting point, occurrences and co-occurrences of concepts provide an indication of how or why concepts may interact (e.g., Martens *et al.*, 2016). Quantitative semantic similarity measures can now be used automate the process that previously required manually interpreting and coding each text with keywords representing concepts, and exploring the similarity of the concepts using multidimensional scaling (e.g. Furrer *et al.*, 2008).

Suggesting a bibliometric method for designing ABMs

This study suggests a bibliometric method that commences with co-word analysis to find essential concepts for designing ABMs, including essential agents, objects, contexts, and their combinations. Using the method, all potential agents, objects, and contexts related to a process of interest are extracted. This

method then focuses on key interactions between agents and other concepts by exploring the textual context in which the concepts are co-mentioned. This latter step, involves content analysis of statements identified using the co-word analysis to establish the agents' behavioral rules about "who is doing what (with whom)." Lastly, these key statements and rules from the literature are then translated into the agents' behavioral rules in the ABM.

As explained in greater detail in the next section, the bibliometric procedure proposed in this study follows four steps: (i) building a domain corpus regarding the process of interest; (ii) using frequency analysis to identify major concepts within the corpus including agents, objects, and contexts; (iii) using co-word analysis to tabulate the relationships among the agents and the other concepts; and (iv) developing a conceptual map for ABMS by investigating their uses in the texts where concepts co-occur. This procedure is presented in the next section in combination with an example of discerning concepts and developing a conceptual map in regard to the early venture growth process. The next major section then provides an illustrative ABMS based on the conceptual map.

Building a domain corpus

A domain corpus is a collection of documents related to the phenomenon of interest. In order to build a domain corpus the researcher should confine which documents to collect into a database. For instance, the collection may consist of abstracts that include specific keywords that are related to the process of interest. Analogous to the process in Vlieger and Leydesdorff (2011), word lists are created according to their frequency of appearance in the corpus. During this process any multi-word nouns found in a dictionary or multi-word patterns frequently observed in the corpus are registered as one-word terms (e.g. "venture" "capital" becomes "venture capital"). Any stop-words, such as articles (e.g. "a", "the") and prepositions, are excluded from a list of candidate terms. Also, plural forms of nouns are merged into their basic forms; that is, a stemming or lemmatization process is performed (e.g. "entrepreneurs" merges into "entrepreneur"). This step can be partially automated using various text analysis tools, including ones by Leydesdorff (Vlieger and Leydesdorff, 2011) or commercially-available software such as T-Lab.

To illustrate this step, a domain corpus related to the venture growth process was established. This was done by collecting the abstracts of a decade of articles which were published in the *Journal of Business Venturing* (JBV) and *Entrepreneurship Theory and Practice* (ETP) from 2005 to 2014. These journals are recognized as the representative journals in entrepreneurship. The abstracts were included in the corpus if they contained the word “venture(s)” or “venturing”, and captured 301 articles, as summarized in Table 1.

Table 1. Counts of venture-related articles

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
ETP	6	15	23	11	18	13	9	16	18	12	141
JBV	15	17	14	12	16	17	18	18	14	19	160
Total	21	32	37	23	34	30	27	34	32	31	301

Identifying agents, objects, and contexts

This corpus was then imported into a text analysis program, T-Lab 9.0.1,¹ through which the 301 documents were broken down into segments, tokens, words, and basic words. As summarized in Table 2, the text “segments” are sentences where the lengths are limited to 400 characters. The “tokens” are the cumulative frequencies of all words in the corpus. The “words” include all unique tokens, including all forms of basic words. The “basic words” are words that occur in the corpus after lemmatization (e.g. “decisions” merges into “decision”).

Table 2. The composition of venture-related corpus

Documents	Segments	Tokens	Words	Basic words
301	913	35,299	4,342	3,309

¹ Retrieved from <http://tlab.it/>

In order to identify the essential concepts (i.e. agents, objects, and contexts) from the corpus, candidate terms are selected from among these words, including consideration of their frequencies. To do so, the complete word list is reviewed for nouns which are potential candidates for main concepts. However, the word list contains nouns from the documents that are not necessarily even concepts related to the phenomenon of interest (e.g., nouns like “paper” and “study” occur with regular frequency). Therefore, it is recommended that the full word list is reviewed, by first focusing on only the nouns, from which to then select potential candidates for the main concepts among the more general nouns. This may be done by almost anyone who has some degree of expertise in the field or knowledge of the phenomenon. This study started with the 1,000 most frequently appearing words in the corpus which were lemmatized by T-Lab into 450 basic words. From this list of 450 basic words, two early career researchers (the authors) independently identified and cross-examined each other’s selection of candidate terms. As a result, 53 nouns were agreed on as candidate concepts that may be relevant to the venture growth process.

These 53 candidate concepts were divided into agents, objects, and contexts. Of the concepts, agents are the most essential to generate an ABM. The agents are individuals or cohesive groups who can perform active behaviors; objects cannot perform active behaviors. For example, the “entrepreneur” (agent) can actively access or modify a “resource” (object). This selection can be done considering the uses of the candidate terms in each source text in the corpus.² This step can be regarded as a process of coding, where the expert accepts the candidate term as being relevant to agents, objects, or contexts of a specific phenomenon. In case of conceptual uncertainty, the reliability of the coding can be evaluated by calculating the inter-coder reliability among multiple experts. Following these steps, the 53 candidate terms were divided into agents, objects, and contexts, as summarized in Table 3.

² Concordance analysis tools like AntConc can be used to search for how a single word is used across a large number of text segments within a corpus; freely available at <http://www.laurenceanthony.net/software/antconc/>

Table 3. Candidates for essential concepts in the venture-related corpus

Type of concept (Count)	Candidate concepts
Agent (32)	agency, angel, board, business, capitalist, CEO, company, customer, director, employee, enterprise, entrepreneur, entrepreneurial firm, executive, family, firm, founder, investor, man, manager, member, organization, owner, small- and medium-sized enterprise (SME), team, team member, Top management team (TMT), university, venture, venture capital firm, venture capitalist, woman
Object (15)	capital, corporate venture capital (CVC), equity, finance, fund, human capital, information, market, network, opportunity, product, resource, social capital, technology, venture capital
Context (6)	country, economy, environment, industry, institution, system

To identify the agents engaging in the early venture growth process from Table 3, the uses of these terms in the corpus were investigated. Some of the candidate agents were eliminated, such as (i) terms that did not represent agents actively involved in the creation of new ventures and which were used primarily as adjectives (e.g. agency, customer, director, enterprise, family, and university), (ii) agents that were mainly active in later stages of the venture growth (e.g. board, CEO, employee, executive, manager, owner, SME, TMT), (iii) terms that were too general (e.g. capitalist, company, man, member, organization, woman), and (iv) terms that were composites of the above cases (e.g. business, firm, venture). The remaining agents were considered actively involved in the early venture growth process. Some of the candidate object terms were eliminated, such as terms where the meaning was mainly used to reflect an agent's behavior (e.g. *finance* and *fund* being used as verbs, not as nouns, and their noun form being encapsulated by *capital*). Among the context's candidate terms, the term "system" was eliminated because this term was not used as a context of the agents. The uses and meanings of these terms could be confirmed by reviewing them in the context of the surrounding words in the text segment. Nine agents, thirteen objects, and five contexts were discerned as the essential concepts in the venture creation process. Table 4 shows the final list of agents, objects, and contexts of the process.

Table 4. Essential concepts in the venture creation process

Type of concept (Count)	Essential concepts
Agent (9)	angel, entrepreneur, entrepreneurial firm, founder, investor, team, team member, venture capital firm, venture capitalist
Object (13)	capital, CVC, equity, human capital, information, market, network, opportunity, product, resource, social capital, technology, venture capital
Context (5)	country, economy, environment, industry, institution

Tabulating relationships among the essential concepts

Once the relevant agents, objects, and contexts have been selected, the next step is to tabulate the relationships among the agents and other concepts to find the interrelations among them. Key relationships can be found by investigating the co-occurring pairs of agents within text segments. In order to investigate the co-occurring words within segments, the predetermined definition of each segment is used (i.e., a sentence where the length is limited to 400 characters). After segmenting the corpus, a normalized index for the frequency of co-occurring words is calculated and used to detect key relationships. Because some words occur more frequently than others, and these words have more chance to co-occur with any other word, it is therefore not sufficient to compare the absolute frequencies of co-occurrences.

An effective means to create a normalized index of co-occurrences is to calculate the cosine coefficients between any two words, especially when analyzing a large corpus. The cosine coefficient is one of the bibliometric indexes used to measure the strength of relationship between two words. The cosine coefficient (cos_coeff) is calculated as follows (Eck and Waltman, 2009).

$$\text{cos_coeff}(w1, w2) = \frac{\text{co_occ}(w1 \text{ and } w2)}{\sqrt{\text{occ}(w1) \times \text{occ}(w2)}}$$

In this expression, $w1$ and $w2$ represent two different words in the corpus, $\text{occ}(w)$ represents the frequency of segments in which the word (w) occurs, and $\text{co_occ}(w1 \text{ and } w2)$ represents the frequency of segments in which the two words ($w1$ and $w2$) co-occur. If two specific words always occur together

within text segments, the cosine coefficient of these two words becomes 1. If they never co-occur within any text segment, it becomes 0. By normalizing the co-occurrence frequencies, all the agents can readily be tabulated against their co-occurring agents, objects, and contexts.

These tables aid in providing an overview of the co-occurring concepts and may be used as a basis for more detailed investigations. As a result of the co-word analysis of the early venture growth process, Table 5 shows the essential agents, objects, and contexts that seem to interact in the process. The left hand columns in Table 5 list the essential concepts and the number of text segments (TS) where the concepts occur. This is followed by columns of cosine coefficients among the agents and other concepts (listed alphabetically). The cells where the cosine coefficients are more than 0.1 are shaded in grey. By confining the coefficient values above a certain threshold, less important relationships are filtered out and a more parsimonious model can be derived. This tabulation and filtering is useful when generating an ABM composed of the focal concepts and their key interactions.

Table 5. The tabulated relationships among agents, objects, and contexts

	TS	ANGEL	ENTREPRENEUR	ENTREPRENEURIAL FIRM	FOUNDER	INVESTOR	TEAM	TEAM MEMBER	VENTURE CAPITAL FIRM (VCF)	VENTURE CAPITALIST
Agents:										
ANGEL	15		0.110			0.237				
ENTREPRENEUR	199	0.110		0.035	0.054	0.140	0.052	0.020		0.055
ENTREPRENEURIAL_FIRM	15		0.035			0.066				0.096
FOUNDER	43		0.054			0.140	0.075	0.042		
INVESTOR	58	0.237	0.140	0.066	0.140		0.032		0.060	0.025
TEAM	67		0.052		0.075	0.032		0.305	0.056	0.071
TEAM_MEMBER	13		0.020		0.042		0.305			
VENTURE_CAPITAL_FIRM (VCF)	19			0.096		0.060	0.056			0.088
VENTURE_CAPITALIST	27		0.055			0.025	0.071		0.088	
Objects:										
CAPITAL	24	0.105		0.102	0.031	0.080			0.094	
CORPORATE_VENTURE_CAPITAL (CVC)	22					0.028				0.041
EQUITY	20	0.058	0.048	0.112	0.102	0.117	0.027			0.043
HUMAN_CAPITAL	28		0.121		0.058	0.025	0.162		0.043	0.036
INFORMATION	34		0.061	0.043	0.026	0.090	0.063	0.048	0.039	0.066
MARKET	71	0.092	0.101		0.018	0.078	0.058		0.027	0.046
NETWORK	60		0.174	0.032		0.034	0.016			0.050
OPPORTUNITY	71		0.143	0.059	0.054	0.031	0.072	0.033		0.023
PRODUCT	17		0.052		0.037	0.076	0.030			
RESOURCE	75		0.205	0.029	0.053		0.056			0.067
SOCIAL_CAPITAL	21		0.108		0.033		0.027			
TECHNOLOGY	31		0.013		0.027		0.022			0.035
VENTURE_CAPITAL	70	0.123	0.051	0.090	0.036	0.126	0.073		0.137	0.253
Contexts:										
COUNTRY	31		0.089						0.041	0.104
ECONOMY	18		0.050	0.118						0.045
ENVIRONMENT	46		0.136	0.111	0.045		0.036	0.041	0.034	0.057
INDUSTRY	36		0.047	0.083	0.051	0.066	0.041			0.128
INSTITUTION	10		0.045	0.079						0.122

Developing a conceptual map for ABMS

Identifying the focal concepts and their implicit relationships using co-word analysis provides a foundation for a conceptual map of which concepts are interrelated in the system. The co-occurrence coefficients help identify hierarchical relationships (e.g. “angel investor” is a type of “investor”), as well as behavioral relationships (e.g. “investors” invest in “entrepreneurs”). In our illustrative example, the most frequently mentioned agent from the literature is “entrepreneur” (in 199 segments), but mentions of “team” (67) and “investor” (58) are also frequent. This highlights that the early venture growth process is not solely due to the actions of a single agent (i.e. a sole “entrepreneur”; see also Dimov, 2007), but rather due to a process from the interactions of several different agents (e.g. “team”, “investor”). The nine agents discerned in this study can be broadly classified into three groups: entrepreneur, investor, and team. By focusing on these groups of agents and their relationships, a foundation of a conceptual map can be derived:

- i. The agents in the *entrepreneur* group. The main agent in this group is “entrepreneur” (199). The “founder” (43) and their “entrepreneurial firm” (15) are conceptually similar to “entrepreneur.”
- ii. The agents in the *investor* group. The main agent in this group is “investor” (58), and this group includes “angel” (15) as a subtype. The agents such as “venture capital firm” (19) or “venture capitalist” (27) do not frequently co-occur with any other agent of the early venture growth process.
- iii. The agents in the *team* group. The main agents in this group are “team” (67) and “team member” (13), and the agents in this group mainly co-occur with the “human capital” object (0.162).

This study identified thirteen objects that may be involved in the early venture growth process. The essential objects can be broadly classified into two groups: opportunity and resource. By focusing on these groups of objects and their relationships, the foundation for a conceptual map is developed further:

- i. The objects in the *opportunity* group. The “opportunity” (71) is the sole object in the group. This term frequently co-occurs with “entrepreneur” (0.143), but any detailed concepts or relationships

with “opportunity” were not found. This result may be related to the elusiveness of the “opportunity” concept in entrepreneur research (Davidsson, 2015; Dimov, 2011).

- ii. The object in the *resource* group. The main object in this group is “resource” (75), and this group includes “venture capital” (70), “human capital” (28), and “social capital” (21) as subtypes. In this group, the “resource”, “human capital”, and “social capital” frequently co-occur with the “entrepreneur” agent.

This study also identified five context-related terms (“country”, “economy”, “environment”, “industry”, and “institution”) that may affect the venture growth process. These concepts mainly co-occur with the agents of “entrepreneur”, “entrepreneurial firm”, or “venture capitalist.” Among the terms regarding contexts, relatively general terms, such as “environment” (0.136), co-occur with the focal agents. This result may be related to the lack of previous studies that take more detailed contextual variables into consideration. In order to translate this conceptual map into an ABMS, the relationships between concepts need to be made more explicit and brought forward by analyzing the text where concepts co-occur. To illustrate this step, this study improves upon the conceptual map and broad example above to provide a more concrete illustrative example followed by an ABMS analysis of that example.

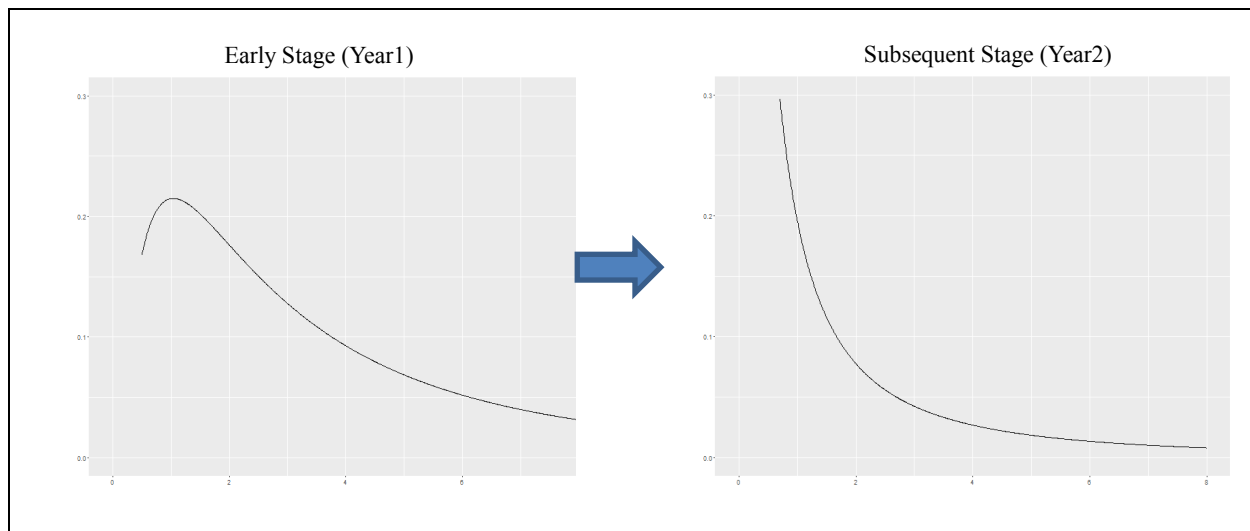
Illustrative ABMS

The above example explored essential agents, objects, and contexts related to early venture growth. This section recommences the bibliometric approach with the same corpus, but with a more specific research question targeted at a stylized fact of the process (Step 1). This is followed by determining the essential concepts (Step 2); identifying plausible behavioral rules (Step 3); and performing ABMS with these concepts and behavioral rules (Step 4-6).

Step 1: Defining a research question from a stylized fact

A stylized fact is defined as a simplified presentation of an empirical finding (Cooley and Prescott, 1995). It may be a newly discovered fact from empirical data or an empirical finding already reported in the literature. In either case, it mainly describes a macro-level phenomenon. Examples of stylized facts include the S-curved temporal diffusion pattern of new products (Mahajan *et al.*, 1990), the residential pattern of racial segregation (Clark, 1991), and the ecological behavior of birds' flocking (Heckbert *et al.*, 2010). The stylized fact becomes a guide for creating and analyzing the corpus leading to the ABMS and it serves as a criterion of macro-level validation.

Figure 1. Empirical distribution of venture outcomes



For the more concrete illustrative example of the bibliometric procedure and ABMS, the stylized fact was selected that early venture outcomes are highly skewed. These distributions in entrepreneurship have been shown to converge into PL distributions, as shown in Figure 1 (Crawford *et al.*, 2015; Davidsson, 2016; Shim, 2016) – there are a small number of billionaire entrepreneurs who become richer over time, while the majority attains more modest outcomes. The emergence of PL distributions in the early venture growth process can be regarded as a stylized fact of entrepreneurship since this distribution is commonly observed in various datasets in entrepreneurship. This stylized fact was selected in order to address

research questions regarding how the underlying micro-level interactions of the focal agents produce this macro-level stylized fact.

Step 2: Determining essential agents, objects, and contexts

The agents may act upon their co-occurring objects in their co-occurring contexts. Instead of including every co-occurring concept in the co-word table, researchers may restrict the boundary of the ABM by selecting a subset of focal agents and only including those focal agents' relationships from the table. This reduction can be done in order to pursue the most parsimonious or elegant set of elements and rules that explain the stylized fact. The illustrative example here confines analysis to two agents (“entrepreneur” and “investor”) and two objects (“opportunity” and “resource”). This confinement addresses the practicality that (i) these concepts occur most frequently, implying that these concepts are most essential regarding the venture growth process; and that (ii) the main purpose of this model is to provide an easy to follow illustrative guide to implementing an ABMS regarding the early venture growth and the emergence of PL distributions.

Step 3: Identifying plausible behavioral rules

To identify plausible behavioral rules of the agents for the emergence of PL distributions, the interactions among the selected agents (“entrepreneur”, “investor”) and objects (“opportunity”, “resource”) are investigated by reviewing the text segments and related literature in which the concepts co-occur. From these sources, each agent's behavioral relationships with other concepts are inferred. Although, all relationships among all agents and concepts can be explored exhaustively, it is more practical to focus on the more essential relationships and to continue the investigation only until consistent patterns are revealed across co-occurrences.

As verified in Table 6, “entrepreneurs” seek funding from “investors”, mainly from “angel” investors. The “venture capitalist” or “venture capital firm” can be another specific form of “investor”, but only rarely co-occurs with the other agents in the venturing process. Therefore, the angel and the other

informal investors can be understood as the most significant investors during the early venture growth process.

Table 6. Identification of relationships among agents

Agent pairs (cos_coeff)	Usage in corpus	Identified relationship
Entrepreneur & Investor (.140)	“ <i>Entrepreneur</i> seeking early-stage financing from either a specialist or a generalist <i>investor</i> ...” (Schwienbacher, 2013)	Entrepreneur <i>seeks financing</i> from Investor
Entrepreneur & Angel (.110)	“Nascent ventures [<i>entrepreneurs</i>] seeking business <i>angel</i> [investor] funding in the...” (Parhankangas and Ehrlich, 2014)	Entrepreneur <i>seeks</i> Angel funding

To add more detail to the behavioral processes, the behavioral relationships among the selected agents and objects are investigated by reviewing the text segments in which the agents and objects co-occur, resulting in the behavioral relationships shown in Table 7.

Table 7. Identification of relationships among agents and objects

Agent-Object pairs (cos_coeff)	Usage in corpus	Identified relationship
Entrepreneur & Opportunity (.143)	“ <i>Entrepreneurs' opportunity</i> perceptions mediate between objective characteristics of the environment and the entrepreneurs' efforts to start a new venture...” (Edelman and Yli-Renko, 2010)	Entrepreneur <i>perceives</i> Opportunity (mediator)
Entrepreneur & Resource (.205)	“Access to <i>resources</i> is a key challenge facing <i>entrepreneurs</i> during early venture development...” (Sullivan and Ford, 2014)	Entrepreneur’s <i>access</i> to Resources (key challenge)
Angel [Investor] & Capital [Resource] (.105)	“Women (entrepreneur)'s access to <i>capital</i> from private equity <i>angel investors</i> ...” (Becker-Blease and Sohl, 2007)	Angel <i>has</i> Capital (Entrepreneur <i>accesses</i> it)

These relationships among the essential concepts and their interactive mechanisms discerned in the literature provide a basis from which to identify plausible behavioral rules that may lead to the PL distributions of venture outcomes. The segments in Table 7 reveal that “entrepreneurs” perceive “opportunities”, but the pursuit of the “opportunities” requires committing a certain level of “resource” investment. Additionally, and more specifically to our interest in PL distributions in entrepreneurship as

an illustrative example, researchers suggest that a multiplicative effect may be a generative mechanism of these distributions (Crawford *et al.*, 2015; Shim, 2016). In the multiplicative mechanism, the added value of an entrepreneurial activity is not only determined by the activity value but also multiplicatively affected by the venture's current value. If we regard an "opportunity" as a multiplying chance for the venture's current value, a venture's greater stock of "resources" enables greater "resource" investment, and committing more "resources" will increase the likelihood of the venture returning a greater reward. This results in the Behavioral Rule 1 for Entrepreneurs.

Behavioral Rule 1: *Entrepreneurs* seek and take affordable business *opportunities* in a way that each *opportunity* requires a certain level of *resource* investment and the return will be multiplicative for the investment.

Furthermore, in absence of their own resources, Table 7 shows that entrepreneurs will attempt to access other's resources, notably angel investors. Angel investment is not automatic and requires convincing the angels of the value of the venture. In relation to PL distributions, it is suggested that the preferential attachment may be another generative mechanism of these distributions (Barabási, 2009; Crawford *et al.*, 2015). In the preferential attachment mechanism, a Matthew Effect can be observed, where the rich get richer. Logically, investors will only invest commensurate with the current valuation of the business. This can mean investors can put a small amount of capital into the venture, but no more than the investor thinks the venture is worth. This results in Behavioral Rule 2 for Investors.

Behavioral Rule 2: *Investors* may invest in *Entrepreneurs* who seek financial *resources*. This investment occurs *stochastically* in a way that the upper limit of an investor's investment will be proportional to the venture's present *resource*.

Step 4: Implementing an ABM

This section describes the ABM of the early venture growth process based on the essential concepts and their identified behavioral rules. This section follows the principles of the Overview-Design-Details (or

ODD) protocol to describe the ABM. The ODD protocol was proposed for a rigorous representation of ABMs and consists of seven subsections of the three general categories (Grimm *et al.*, 2006; Grimm *et al.*, 2010):

1. Purpose of the ABM – The purpose of the ABM is to explain the micro mechanism of the early venture growth process that generates the PL distributions of venture outcomes.
2. Entities, state variables, and scales – This ABM has two types of agents (i.e. Entrepreneur and Investor) and two types of object (i.e. Opportunity and Resource). The amount of Resource was modeled as state variables of Entrepreneurs and Investors.
3. Process overview and scheduling – Initially, multiple Entrepreneurs, Investors, and Opportunities are randomly located in the simulation space. The Entrepreneurs' efforts to grow their ventures were modeled as their movements within the simulation space. All Entrepreneurs randomly move to one of eight nearby locations in the hope of finding Investors or Opportunities. Each movement can end up in an empty space or at the location of an Investor or an Opportunity. If an Investor is found, 30% probability of a successful investment was assumed, and the amount of the investment is up to the venture's present resource. If an Opportunity is found, the Opportunity can be exploited if the venture can make the required investment. In that case, the return value from the Opportunity is determined by the multiplication of the investment (assumed as a random value which is 1.0-1.5). The Entrepreneurs continue to search for Investors and Opportunities in the simulation space.
4. Design concepts – This ABM is based on the essential concepts obtained from the bibliometric method and on the behavioral rules inferred from the entrepreneurship literature. If the identified behavioral rules successfully reproduce the stylized fact of entrepreneurship, the behavioral rules will have the macro-level validity.
5. Initialization – At the outset the 1,000 Entrepreneurs are randomly located in a simulation space with 10,000 locations (100 x 100). Across this space are also located 300 Investors and 300 Opportunities. At this time, each Entrepreneur is assumed to have one Resource, and each Investor is assumed to

have three Resources to invest. Also, each Opportunity is assumed to require a certain amount of investment between 0 and 10.

6. Input data – This ABM does not assume the variations of input variables thus it does not use empirical input data.
7. Submodels – This ABM has three submodels that have different configurations. The main submodel tests the roles of Investor (preferential attachment mechanism) and Opportunity (multiplicative effect mechanism) simultaneously, while the other submodels test the effect of Investor or Opportunity separately.

It must be noted that precise parameterization of the model is not required and defeats the purpose of using simulations to explore plausible or even extreme ranges of variables. Using simulations is faster and less disruptive than conducting in-situ experiments across different contexts and across policies.

Additionally, the parameters primarily need to be internally consistent, and can be scaled to different contexts or currencies later. For example, instead of specifying the investment in dollars, generic units suffice to provide variance of investment required to pursue each opportunity commensurate with units of available capital.

Step 5: Conducting simulations

The illustrative ABM constructed here is used to simulate the dynamics of the venturing process that generates the PL distributions of venture outcomes. In particular, three submodels are tested – the effects of investors, opportunities, and their interactions. For each of the three submodels, 100 simulations were performed using a commonly used ABMS program, NetLogo 5.3.1.³ The outcome distributions over the simulations were analyzed at 100, 200, 300, 400, and 500 iteration time steps (ticks).

Step 6: Analyzing the simulation results

³ Retrieved from <https://ccl.northwestern.edu/netlogo/>. A copy of the NetLogo model for this study is available upon request.

In order to check whether the simulation outcomes fit the PL distribution, each outcome distribution's goodness-of-fit for the PL model was estimated, as was a calculation of the proportion of points that fit the PL model. The goodness-of-fits were measured by the Kolmogorov-Smirnov (KS) statistic, which measures the maximum distance between the empirical or simulation results and the PL model in the cumulative distribution function. Lower KS statistics mean greater fit. A second fit measure was used because, for most empirical or simulation distributions, only a portion of the distribution follows the PL model (Clauset *et al.*, 2009). The second fitness measure involved counting the number of data points that fit the PL model (n_{tail}), and the proportion of the fitted number can be easily calculated since the total number of Entrepreneurs is 1000 in a simulation ($n_{tail} / 1000$). Values of n_{tail} close to the whole data points (1000) mean greater fit.

Figure 2 shows an outcome distribution of one of the simulations, and Table 8 shows the goodness-of-fits (KS) for PL model and the proportion of fitted data points (n_{tail}/n) for all simulation results. Table 8 shows that all three submodels have satisfactory goodness-of-fits (KS) for PL model (0.035-0.071) and the proportion of fitted data points (n_{tail}) is increasing over the process. Overall, these simulation results are highly congruent with the stylized fact of entrepreneurship.

Figure 2. Reproduction of venture outcome distribution by the ABMS

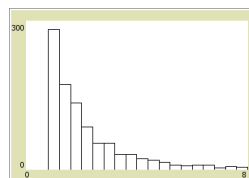


Table 8. Goodness-of-fits (KS) for PL distributions and the proportion of fitted data points (n_{tail}/n).

Submodels	100 ticks	200 ticks	300 ticks	400 ticks	500 ticks
Goodness-of-fits (KS)					
Opportunity & Investor	0.055	0.046	0.040	0.036	0.035
Opportunity-only	0.071	0.059	0.050	0.044	0.042
Investor-only	0.061	0.060	0.062	0.059	0.060
Fitted data points (n_{tail}/n)					
Opportunity & Investor	18.5%	24.3%	27.5%	36.4%	44.2%
Opportunity-only	12.2%	19.0%	23.3%	30.7%	31.8%
Investor-only	18.5%	22.3%	22.8%	23.5%	21.7%

- Values are represented by averages of 100 simulations per each submodel.

- The n_{tail} denotes how many data points fit to the PL model, thus n_{tail}/n shows the proportion of the fitted number ($n=1000$).

- The KS statistic measures the goodness-of-fit between an empirical distribution and a theoretical model, which is the maximum distance between the empirical data and the theoretical model in the cumulative distribution function.

To visualize how quickly each submodel converges towards a PL distribution, Figure 3 and 4 contrast the three submodels and their fitness measures. As Figure 3 shows, the opportunity-only and investor-only models show different effects on the goodness-of-fits (KS) for the PL distributions during the process of venture growth. Similarly, Figure 4 shows the different effects of opportunity and investor on the number of fitted data points. The investor-only model plateaus around 20% of 1000 outcomes fitting the PL distribution, while in the opportunity-only model, the proportion of outcomes that fit the PL distribution eventually exceeds 30% but shows a tendency towards a plateau. In comparison, the combined submodel initially follows the investor-only model, with an initial plateau around 20%, but then outperforms both other submodels to exceed 40%, and climbing.

Figure 3. PL distributions' temporal changes of goodness-of-fits (KS) by submodel.

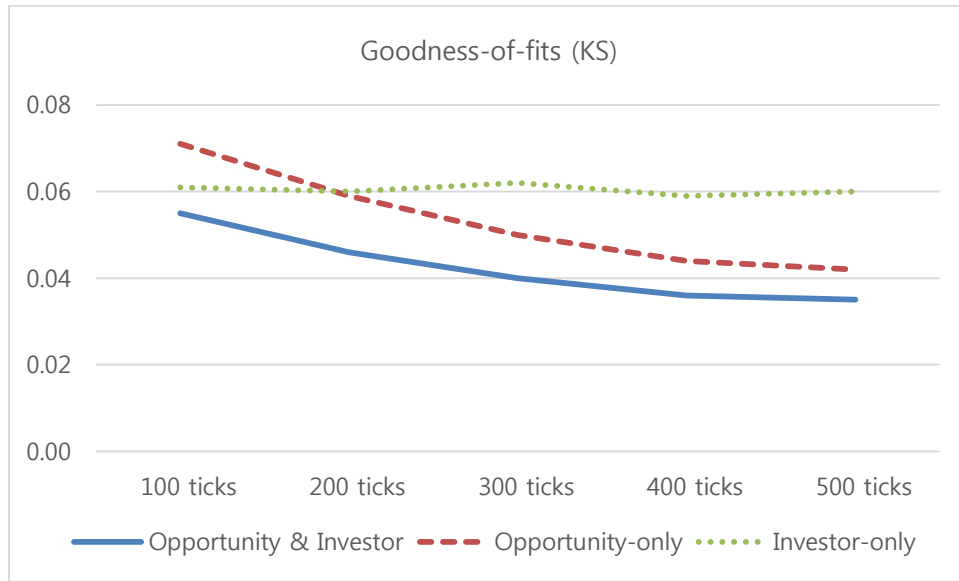
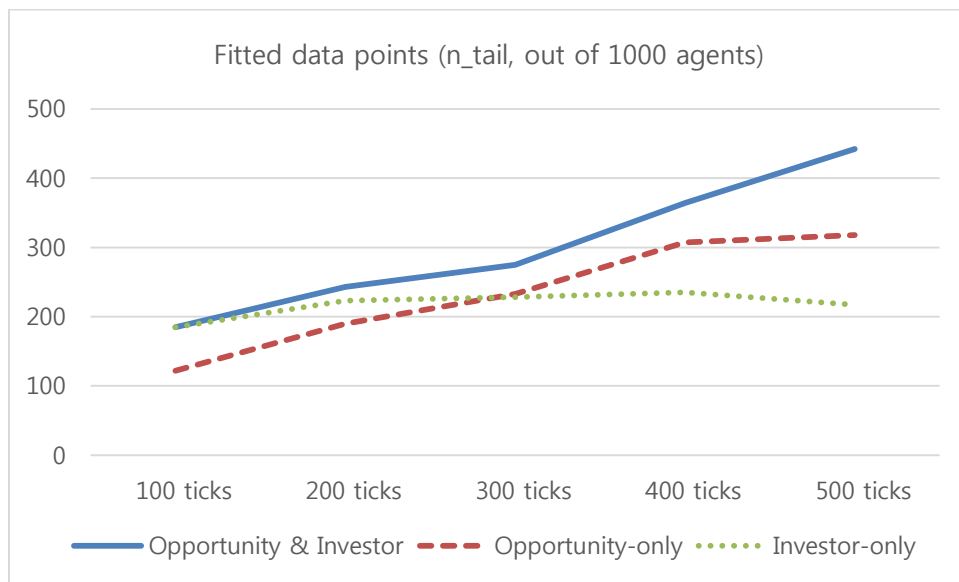


Figure 4. PL distributions' temporal changes of fitted data points (n_{tail}) by submodel.



Overall, the illustrative ABM successfully reproduces the PL distributions of venture outcomes with a minimal set of concepts and behavioral rules, as identified through the bibliometric procedure. The simulation results therefore confirm the usefulness of the bibliometric method and the macro-level validity of the behavioral rules. With additional investigations, the micro-level validity of the behavioral rules may be secured.

Discussion

The main purpose of this study is to suggest a bibliometric method to discern essential agents, objects, and contexts for ABMS studies in entrepreneurship. The bibliographic procedure is implemented with an illustrative AMBS study regarding the venture growth process. The illustrative example shows how ABMS can be built through the bibliometric procedure. Although the concepts identified in the illustrative example do not seem to be novel, their familiarity with entrepreneurship scholars also lends significant face validity to the method. These concepts and this model may provide a foundation for future ABMS in entrepreneurship research including more concepts and interrelations with which to explore more complex phenomena or more nuanced theories. That said, while ABMS are capable of modelling extremely complex systems, the essence of ABMS can be seen as finding the minimum plausible set of agents, objects and interactions with which to provide new insights about a complex process; so more is not necessarily better.

The example also shows how to deepen our understanding of the generative process of a phenomenon using the ABMS. It was recently reported that almost all variables in entrepreneurship follow PL distributions (Crawford *et al.*, 2015), but the generative process of the PL distributions was not clearly presented. The illustrative ABMS shows that the PL distributions of venture outcomes can emerge by the preferential attachment of resources and the multiplicative effect of opportunities. In addition, the ABMS clarifies the sequential effects of these two mechanisms. With further refinement of the concepts and rules to include from the bibliographic procedure, the simulation results may trigger further theory development approaches regarding the venture growth process.

In the illustrative example, scholarly articles were used to extract and suggest the essential agents, objects, and contexts for ABMS in entrepreneurship research. The scholarly articles can be regarded as a good source for the bibliometric procedure, because they are composed of well-defined concepts and relationships among the concepts. Yet there may be a limitation in building a process model based on scholarly articles, because in most cases each article does not directly show the sequence of the agents'

behaviors. To overcome this limitation, researchers may also consider chronological data sources describing a process, such as entrepreneurs' diaries or blogs, as well as the panel dataset, including the Panel Study of Entrepreneurial Dynamics (PSED) or Comprehensive Australian Study of Entrepreneurial Emergence (CAUSEE) (Davidsson and Gordon, 2012).

This study has focused on the beneficial features of the bibliometric procedure. However, this procedure should be regarded as one of diverse approaches to designing ABMs. The bibliometric procedure is particularly supportive of objective research when applied under specific conditions. (1) The approach is applied in a domain that has a suitable volume of reliable documents from which to generate a corpus, including multiple concepts and relationships with respect to a phenomenon of interest. (2) Two or more competent experts in the field are available to review the candidate concepts from the method and verify their interrelationships in the text segments in the corpus.

While the bibliometric procedure can reduce subjectivity in the process of generating ABMS, some limitations remain. Even if all agents and other concepts engaging in a process of interest are found by the procedure, and the procedure presents text segments that describe the behavioral rules, some interpretation is still required to verify the suggested concepts and interrelationships, and to translate them into behavioral rules for the ABMS. Precise parameterization of the behavioral rules within plausible ranges is not automatic.

Concepts, rules and ranges may be chosen from the evidence in the corpus using the proposed procedure, or they may be explored using complementary methods, including case studies, experiments, role-playing games, or rule-specific meta-analyses. The case study method has already been widely used in entrepreneurship and management fields, and this method may be effectively combined with the bibliometric procedure. In case studies the bibliometric procedure can also be utilized to analyze the documents obtained from entrepreneurs or firms. Specifically, entrepreneurs' diaries or blogs can be a good source for the bibliometric procedure to understand their activities during their venture creation and growth processes (Kato and Wiklund, 2011). Likewise, experiments have already been used in entrepreneurship and management studies. In particular, conjoint analysis can be used as a method to

understand agents' behavioral rules in a specific context. Conjoint analysis enables researchers to experiment the conditions in which entrepreneurs perceive a business opportunity, the time when they would start their business venture, and how much and in whom investors would invest. The decision-making criteria found by the conjoint analysis can then be utilized to parameterize the relationships in the conceptual model and ABM. Although role-playing games have been regarded more as an educational tool rather than a research method they have begun to be used as a research procedure in entrepreneurship studies (e.g. Arend, 2016). The case study is closer to the phenomenon of interest, but it has the disadvantage of taking large amounts of time and money to conduct. Meanwhile, experiments enable researchers to understand the clear causal relationships in the controlled setting; however, it can be pointed out that it is different from actual decision-making situations. Role-playing games have the advantage of reducing time and money, while providing participants with realistic decision-making contexts. Overall, it can be said that the proposed bibliometric procedure complements the various existing agent-based modeling methods rather than replaces them.

Conclusion

ABMS is increasingly regarded as a viable research method that fits characteristic features of entrepreneurship research. To invigorate the application of ABMS in entrepreneurship, this study proposes a bibliometric procedure, which can further be utilized to design ABMs, and analyzes essential concepts. To illustrate the utility of the procedure, a corpus was analyzed regarding venture growth to identify essential concepts and their interrelations. From this analysis, an illustrative ABM was produced that accurately reproduces the PL distributions of venture outcomes. As complexity perspective views a macro-level phenomenon can emerge through micro-level interactions of relatively small number of essential agents and objects, thus it is critical to discern the essential agents and objects to build a plausible ABM. We argue that the proposed bibliometric procedure is a useful tool to discern the essential concepts regarding a process of interest.

Bibliometric methods have proven useful in objectively automating the synthesis and analysis of large volumes of scientific publications and identify central authors and core themes. While the proposed bibliometric procedure does not entirely remove subjectivity from the early steps of ABMS (i.e., steps 1 and 2 of Yang & Chandra, 2013), it can substantially decrease it. As a result of using the proposed bibliometric procedure, we hope that ABMS research in entrepreneurship may be more approachable by novices in the method and that the procedure may add a layer of validity checks to counter subjectivity in building the models. In other words, the proposed method is practical for early stage scholars and practitioners who have not yet been socialized into the literature to reconstruct a relatively simple model that reflects core theories in a given domain. Further, the method may be practical for those more knowledgeable in the literature to develop more complex models with which to explore more nuanced theories.

References

- Aldrich, H.E. (2009), “Lost in space, out of time: why and how we should study organizations comparatively”, in King, B.G., Felin T. and Whetten, D.A. (Eds), *Studying Differences between Organizations*, Emerald Group Publishing Limited, Bingley, pp. 21-44.
- Anderson, P. (1999), “Perspective: complexity theory and organization science”, *Organization Science*, Vol. 10 No. 3, pp. 216-232.
- Arend, R.J. (2016), “Entrepreneurs as sophisticated iconoclasts: rational rule-breaking in an experimental game”, *Journal of Small Business Management*, Vol. 54 No. 1, pp. 319-340.
- Barabási, A.L. (2009), “Scale-free networks: a decade and beyond”, *Science*, Vol. 325 No. 5939, pp. 412–413.
- Becker-Blease, J.R. and Sohl, J.E. (2007), “Do women-owned businesses have equal access to angel capital?”, *Journal of Business Venturing*, Vol. 22 No. 4, pp. 503-521.
- Bhawe, N., Rawhouser, H. and Pollack, J.M. (2016), “Horse and cart: the role of resource acquisition order in new ventures”, *Journal of Business Venturing Insights*, Vol. 6, pp. 7-13.

- Börner, K., Chen, C. and Boyack, K.W. (2003), “Visualizing knowledge domains”, *Annual Review of Information Science and Technology*, Vol. 37 No. 1, pp. 179-255.
- Chen, K. and Guan, J. (2011), “A bibliometric investigation of research performance in emerging nanobiopharmaceuticals”, *Journal of Informetrics*, Vol. 5 No. 2, pp. 233-247.
- Clark, W.A. (1991), “Residential preferences and neighborhood racial segregation: a test of the Schelling segregation model”, *Demography*, Vol. 28 No. 1, pp. 1-19.
- Clauset, A., Shalizi, C.R. and Newman, M.E.J. (2009), “Power-law distributions in empirical data”, *SIAM Review*, Vol. 51 No. 4, pp. 661–703.
- Cooley, T.F. and Prescott, E.C. (1995), “Economic growth and business cycles”, *Frontiers of Business Cycle Research*, Vol. 39, pp. 64.
- Crawford, G.C., Aguinis, H., Lichtenstein, B., Davidsson, P. and McKelvey, B. (2015), “Power law distributions in entrepreneurship: implications for theory and research”, *Journal of Business Venturing*, Vol. 30 No. 5, pp. 696-713.
- Crawford, G.C. and McKelvey, B. (2010), “Using simulation experiments to build and test entrepreneurship theories”, *Frontiers of Entrepreneurship Research*, Vol. 30 Iss. 20, Article 3.
- Davidsson, P. (2015), “Entrepreneurial opportunities and the entrepreneurship nexus: a re-conceptualization”, *Journal of Business Venturing*, Vol. 30 No. 5, pp. 674-695.
- Davidsson, P. (2016), *Researching Entrepreneurship: Conceptualization and Design* (Vol. 33), Springer.
- Davidsson, P. and Gordon, S.R. (2012), “Panel studies of new venture creation: a methods-focused review and suggestions for future research”, *Small Business Economics*, Vol. 39 No. 4, pp. 853–876.
- Davis, J.P., Eisenhardt, K.M. and Bingham, C.B. (2007), “Developing theory through simulation methods”, *Academy of Management Review* Vol. 32 No. 2, pp. 480-499.
- Diamond, J.M. (2002), “Archaeology: life with the artificial Anasazi”, *Nature*, Vol. 419 No. 6907, pp. 567-569.
- Dimov, D. (2011), “Grappling with the unbearable elusiveness of entrepreneurial opportunities”, *Entrepreneurship Theory and Practice*, Vol. 35 No. 1, pp. 57-81.

- Dimov, D. (2007), "Beyond the single-person, single-insight attribution in understanding entrepreneurial opportunities", *Entrepreneurship Theory and Practice*, Vol. 31 No. 5, pp. 713-731.
- Eck, N.J.V. and Waltman, L. (2009), "How to normalize co-occurrence data? An analysis of some well-known similarity measures", *Journal of the American Society for Information Science and Technology*, Vol. 60 No. 8, pp. 1635-1651.
- Edelman, L. and Yli-Renko, H. (2010), "The impact of environment and entrepreneurial perceptions on venture-creation efforts: bridging the discovery and creation views of entrepreneurship", *Entrepreneurship Theory and Practice*, Vol. 34 No. 5, pp. 833-856.
- Fioretti, G. (2013), "Agent-based simulation models in organization science", *Organizational Research Methods*, Vol. 16 No. 2, pp. 227-242.
- Furrer, O., Thomas, H. and Goussevskaia, A. (2008), "The structure and evolution of the strategic management field: a content analysis of 26 years of strategic management research", *International Journal of Management Reviews*, Vol. 10 No. 1, pp. 1-23.
- Garcia, R. (2005), "Uses of agent-based modeling in innovation/new product development research", *Journal of Product Innovation Management*, Vol. 22 No. 5, pp. 380-398.
- Gilbert, N. and Terna, P. (2000), "How to build and use agent-based models in social science", *Mind & Society*, Vol. 1 No. 1, pp. 57-72.
- Grimm V., Berger U., Bastiansen F., Eliassen S., Ginot V., Giske J. and DeAngelis D. (2006), "A standard protocol for describing individual-based and agent-based models", *Ecological Modelling*, Vol. 198 No. 1, pp. 115-126.
- Grimm V., Berger U., DeAngelis D., Polhill J., Giske J. and Railsback S. (2010), "The ODD protocol: A review and first update", *Ecological Modelling*, Vol. 221 No. 23, pp. 2760-2768.
- Harrison, J.R., Lin, Z., Carroll, G.R. and Carley, K.M. (2007), "Simulation modeling in organizational and management research", *Academy of Management Review*, Vol. 32 No. 4, pp. 1229-1245.

- Heckbert, S., Baynes, T. and Reeson, A. (2010), “Agent-based modeling in ecological economics”, *Annals of the New York Academy of Sciences*, Vol. 1185 No. 1, pp. 39-53.
- Heath, B., Hill, R. and Ciarallo, F. (2009), “A survey of agent-based modeling practices (January 1998 to July 2008)”, *Journal of Artificial Societies and Social Simulation*, Vol. 12 no. 4, p. 9.
- Kato, S. and Wiklund, J. (2011), “Doing good to feel good – a theory of entrepreneurial action based in hedonic psychology”, *Frontiers of Entrepreneurship Research*, Vol. 31 No. 4, p. 1.
- Kozlowski, S.W., Chao, G.T., Grand, J.A., Braun, M.T. and Kuljanin, G. (2013), “Advancing multilevel research design capturing the dynamics of emergence”, *Organizational Research Methods*, Vol. 16 No. 4, pp. 581-615.
- Leydesdorff, L. (2007), “Visualization of the citation impact environments of scientific journals: an online mapping exercise”, *Journal of the American Society for Information Science and Technology*, Vol. 58 No. 1, pp. 25-38.
- Mahajan, V., Muller, E. and Bass, F.M. (1990), “New product diffusion models in marketing: a review and directions for research”, *The Journal of Marketing*, Vol. 54 No. 1, pp. 1-26.
- Martens, C.D.P., Lacerda, F.M., Belfort, A.C., and Freitas, H.M.R.D. (2016), “Research on entrepreneurial orientation: current status and future agenda”, *International Journal of Entrepreneurial Behavior & Research*, Vol. 22 No. 4, pp. 556-583.
- Martinez, M.A., Yang, T. and Aldrich, H.E. (2011), “Entrepreneurship as an evolutionary process: research progress and challenges”, *Entrepreneurship Research Journal*, Vol. 1 No. 1, pp. 1-28.
- McDonald, S., Gan, B.C., Fraser, S.S., Oke, A. and Anderson, A.R. (2015), “A review of research methods in entrepreneurship 1985-2013”, *International Journal of Entrepreneurial Behavior & Research*, Vol. 21 No. 3, pp. 291–315.
- McKelvey, B. (2004), “Toward a complexity science of entrepreneurship”, *Journal of Business Venturing*, Vol. 19 No. 3, pp. 313-341.

- McMullen, J.S. and Dimov, D. (2013), "Time and the entrepreneurial journey: the problems and promise of studying entrepreneurship as a process", *Journal of Management Studies*, Vol. 50 No. 8, pp. 1481-1512.
- Moed, H.F. (2006), *Citation Analysis in Research Evaluation* (Vol. 9), Springer Science & Business Media.
- North, M.J. and Macal, C.M. (2007), *Managing Business Complexity*, Oxford, New York.
- Parhankangas, A. and Ehrlich, M. (2014), "How entrepreneurs seduce business angels: an impression management approach", *Journal of Business Venturing*, Vol. 29 No. 4, pp. 543-564.
- Rand, W. and Rust, R.T. (2011), "Agent-based modeling in marketing: guidelines for rigor", *International Journal of Research in Marketing*, Vol. 28 No. 3, pp. 181-193.
- Schwienbacher, A. (2013), "The entrepreneur's investor choice: the impact on later-stage firm development", *Journal of Business Venturing*, Vol. 28 no. 4, pp. 528-545.
- Shim, J. (2016), "Toward a more nuanced understanding of long-tail distributions and their generative process in entrepreneurship", *Journal of Business Venturing Insights*, Vol. 6, pp. 21-27.
- Stegmann, J. and Grohmann, G. (2003), "Hypothesis generation guided by co-word clustering", *Scientometrics*, Vol. 56 No. 1, pp. 111-135.
- Sullivan, D.M. and Ford, C.M. (2014), "How entrepreneurs use networks to address changing resource requirements during early venture development", *Entrepreneurship Theory and Practice*, Vol. 38 No. 3, pp. 551-574.
- Vlieger, E. and Leydesdorff, L. (2011), "Content analysis and the measurement of meaning: the visualization of frames in collections of messages", *The Public Journal of Semiotics*, Vol. 3 No. 1, pp. 28-50.
- Yang, S.J.S. and Chandra, Y. (2013), "Growing artificial entrepreneurs: advancing entrepreneurship research using agent-based simulation approach", *International Journal of Entrepreneurial Behavior & Research*, Vol. 19 No. 2, pp. 210-237.