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Uncovering business model innovation contexts: A comparative analysis by fsQCA methods

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Abstract:

Business model innovation purports to create new business values in uncharted market ecologies. In addressing questions of how business contexts can shape and impose urgency on business model innovation, this research reviews and puts forth five classes of contextual antecedents, namely, business eco-networks, the business actors' behavioral orientation, mastery of technology, rules and governance, and business complexity. The research also posits that the configurations of these contextual antecedents mediate two business model performance outcomes: adaptive agility, and resource capability. This research conceives the antecedents that mediate outcomes in complex multiconfiguration contexts, and analyzes their relationships using fuzzy-set qualitative comparative analysis (fsQCA) methods. Using data from an empirical survey of 42 innovation start-ups, this research corroboration concludes with relevant implications for managing business model innovation. The research results identify seven antecedent configurations multimorphologically leading to the same outcomes. As uncovered by the analysis, the mastery of technology and business complexity are the most salient, necessary antecedents. This research contributes to the business strategy literature, as well as to innovation management, by characterizing the configurative conditions for the effective pursuit of business model innovation.

Keywords:

Business Model Innovation, Adaptive Agility, Resource Capability, fsQCA, Set-theoretic Context Analysis

1 Background

For more than a decade, the literature on business strategic planning has extensively discussed the concepts of business model innovation, and model reconfiguration (Battistella et al., 2017; Magretta, 2002; Shneider & Spieth, 2013; Teece, 2010; Wirtz, et al., 2016). These theoretical discussions seek a management characterization different from that of business model innovation as strategy planning. More precisely, business model innovations are more structuralist, acting as key mediating tools for converting business strategies into blueprints for business changes (Teece, 2010). The core motivation of a business model is to define the structural elements of business ecosystems within an integrated framework. From this structuralist perspective, business models should portray value systems, actors and stakeholders, actor-business interactions, operational processes, and performance in resource utilization (Achtenhagen et al., 2013; Osterwalder & Pigneur, 2010). Business model innovation means reconceiving model components within new business frameworks, offering uncharted business values and processes to create brand new market ecologies (Zott & Amit, 2007). The underlying beliefs are twofold. For established business actors, an innovative review of business models can induce more sustainable capabilities for responding to changing market contexts. As such, a more integrated business strategy can evolve. For new start-ups, business model innovation facilitates the pursuit of uncharted business opportunities in fiercely competitive ecosystems (Boken et al., 2014; Schaltegger et al., 2012). Analogous to contemporary perspectives in the innovation literature, a systematic analysis and redevelopment of business concepts in firms can fuel cycles of cross-disciplinary learning, ultimately triggering overarching innovation over whole business ecospheres (Prendeville et al., 2017).

The potential for such innovation is broad, creating the expectation that it will entail the right response to ecologically framed business challenges, such as disruptive technological advancement, socioeconomic crisis downturn, business network collapses, etc. Stated succinctly, business model innovation purports to elevate strategic thought from value propositions to market propositions (Storbacka & Nenonen, 2011). Although this literature has clarified the management values gained from business model innovation, there remain many unanswered fundamental questions, such as how business model innovation emerges, and provides implications for managing dynamic business environments, how a business context provides an alert for reconfiguring a more effective business model, and what key antecedents can provide the preconditions for business model innovation.

These research questions reveal much concern over determining which contextual antecedents are important, that is, the determination of the innovation conditions that can shape entire business concepts, process components and boundaries. In this regard, the research studies conducted in a business innovation context have observed many cases, and reported a number of determining factors that can mediate the success in conceiving new business models (Battistella et al., 2017; Morris et al., 2005; Storbacka & Nenonen, 2011). However, these research results often show that the factors are patchy, or occur uncertainly from case to case. There are no concrete, corroboratory explanations of how new business models can arise from these factors (Ko et al., 2011; To, 2016; Santoro, Borges & Rezende, 2006). Managing the contextual antecedents, and mediating factors to support business model innovation remains one of the most vexing challenges in today's business innovation discussion.

In addressing these challenging issues, this research reviews five salient classes of contextual antecedents, namely, the business eco-networks, the business actors' behavioral orientations, the mastery of technology, rules and governance, and business complexity. The research also elucidates two potential outcomes, namely, adaptive agility and resource capability, which may occur over the course of business model innovation. This research conceives the antecedents, mediating outcomes, and their relationships in complex multiconfiguration contexts that are analyzed using fuzzy-set qualitative comparative analysis (fsQCA) methods. An empirical industry survey of 42 innovation start-ups provides the data source. The research results identify various antecedent configurations that multimorphologically lead to the same performance outcomes. This research contributes to the business model literature, as well as to innovation management, by characterizing the configurative conditions for the effective pursuit of business model innovation.

2 Literature review

In this decade, the literature on business model innovation has attempted to conduct closer examinations of the characteristics of business contextual antecedents rather than merely to represent the business models' structural contents. These antecedents include firm behavior (Maynard, et al., 2012), market orientation (Baker & Sinkula, 2007; Schalteegger et al., 2012), knowledge backgrounds (Taylor & Greve, 2006), organizational interests (Jiménez-Jiménez & Sanz-Valle, 2011), and cultural values (Urry, 2005). Cavalcante, (2014), Morris, Schindchutte and Allen (2005), Krishnan and Loch (2005), Ko, To, Zhang, Ngai, and Chan (2011), and To (2016) have also identified some other factors at the industrial level, such as technological development, rules and regulations, and task complexity.

From the perspective of strategic thought, an examination of business model antecedents encourages business actors to determine when, and by which means management should alter an operating business model. Achtenhagen, Melin, and Nakdi (2013), and Cavalcante (2014) explained whether a business could sustain its innovativeness by adapting different business models in changing business environments. Business actors should also remain alert to the dynamics between contextual antecedents and outcomes (Dul & Ceylan, 2014; Teece, 2007). Prevalently discussed in the literature, adaptive agility, and resource capability are the two key classes of post hoc performance used for assessing the outcomes of business model innovation (Battisella et al., 2017). Adaptive agility refers to a set of capabilities for business actors to anticipate business competitions, to seize emerging opportunities, and to capitalize on learning processes in the course of innovation ventures (Battisella et al., 2017; Beckman & Barry, 2007; Doz & Kosonen, 2010; To et al., 2009). Such capabilities can overcome innovation barriers resulting from types of misperceptions of business ecosystems (Johnston, 2009), inertia to challenges in changing environments (Hamel & Valikangas, 2003; Wirtz et al., 2016), and misinterpreted, or ill-defined business values (García-Fernández et al., 2018; Weick & Sutcliffe, 2007; Chesbrough, 2010). Resource capability refers to an alternative set of capabilities through which business actors mobilize business resources and actions to respond contingently to

external emerging challenges (Fartash et al., 2012). Business actors characterized by such strategic capabilities are sensitive to a set of internal dimensions, for instance, leadership and governance (Teece, 2010), resource fluidity (Johnston, 2009), a clear vision of the customers' value propositions (Helfat et al., 2007), a mastery of hands-on technology and innovation knowledge (Chang et al., 2012), and shared perspectives (McGuire, 2006; To, 2016). Stated succinctly, these two performance classes facilitate an awareness of the business ecosystem's emergence, and the deployment of appropriate business resources to cope with this emergence. These two performance classes lay the foundations for the successful pursuit of business model innovation, and reconfiguration. Focusing on these performance outcomes can help business actors to associate with, and analyze the relevant antecedents that are contextually embedded within business model innovation. The following sections attempt to review the relevant antecedents leading to successful adaptive agility and resource capability.

2.1 Value creation networks

Business modeling implies an integrated framework that portrays business activity processes for developing and transferring business values across a relevant group of business actors and stakeholders (Feldman et al., 2005). Epistemologically, business models exist in the form of networks that unite collaborative individuals, as well as organizational units, to cocreate mutually beneficial business interests. In other words, value cocreation stems from the formation of heterogeneous repositories built by interconnected business actors (Mačiulienė & Skaržauskienė, 2016). In modeling such business networks, business actors should understand the composition and affiliation of the nodes of resources, and processing that can exercise either symbiotic or inhibitory effects on the whole business model (Engel et al., 2017). Business model innovation driven by such value creation networks can provide clustered business actors with two substantive benefits. (1) Networks intensify knowledge distribution, refinement and diffusion. Resources, including capital and labor, become more 'nimble', and flexibly emancipated through network ties. Networks thus enhance efficiency in light of economies of 'external' scale (Huynh et al., 2017). (2) Diverse knowledge and competence within networks provide complementary sources of new value necessary to form, and reform viable value chains in existing business models. Such diversities in networks spur business actors to be ecologically adaptive, and responsive to new environmental challenges. Networked knowledge actors focus on adaptation competence rather than on merely their individual strength over that of others (Benavides-Espinosa & Ribeiro-Soriano, 2014; Tsai, 2001).

2.2 Business actors' behavioral orientation.

Analogous to all types of human behavior, networked actors judge their own interests and gains in the course of business model innovation. Hienerth, Keinz, and Letti, (2011) and von

Hippel and Katz (2002) explored factors for successful business model implementation from the perspectives of users' roles and motivations. The findings emphasized two key issues: (1) the means and consequential rationales for attracting and engaging users in core business model processes; and (2) the effective tactics and mechanisms to overcome internal rivalry and resistance to business model innovation. From the perspective of organization science, business actors decide behavioral orientations in the expectation of reciprocal benefits gained from interacting with stakeholders in business models (Lyon et al., 2000; Maynard et al., 2012). Very often, complex business ecosystems cannot guarantee fair economic returns or types of social rewards to every business stakeholder in the course of business model innovation. Such reciprocity is an issue of uncertainty in managing the actors' interactions and collaboration (Pinto, Pinto & Prescott, 1993). Segregated, even opposite, behavioral orientations would hinder business actors sharing business model interests and values collaboratively. As such, management should review business model structures, and adapt mechanisms to align every actors' incentives and commitments; otherwise, renovating business models might not bring fruitful, desirable results, although the new business model could portray its intended visions and value propositions (Hammermesh at al., 2002; Hienerth et al., 2011).

2.3 Mastery of technology

Technology aspects have long been regarded as key determining antecedents for effective business processes (Carayannis et al., 2014), organization changes (Chang et al., 2012), and business systems reconfiguration (Calia et al., 2007). The mastery of technology concerns the development, adoption, and deployment of processing, and information technologies to accomplish effective business systems. Such technological mastery is an organizational learning, aimed at the perfection of business systems (Anderson & Tushman, 1991). In the course of business model innovation, business actors should build relevant knowledge repositories, and technological platforms for sharing and for sustaining interactions among business stakeholders (Chesbrough & Rosenbloom, 2002). Di Stefano, Gambardella, and Verona (2012) provided a detailed discussion of the motivations for innovation, and highlighted a technology push as the key contingency to innovate demand-driven business model values. In facilitating interactions among business actors, technology-based information and processing systems are necessary, especially when business models are open, and colossally scaled to an unanticipated level (Santoro, Borges & Rezende, 2006). Appropriate and sufficient adoption of technology and factors that support knowledge is an indispensable antecedent to conduct effective, harmonious cross-functional innovation.

2.4 Rules and governance

For management, organizational rules and governance incorporate the essence of regulations and accountability, and are the antecedents that shape the appropriate controls over the forms, patterns, and directivity of interactions among business model components, i.e., activities, actors, value interests, and resources (Pertusa-Ortega et al., 2009; Pinto et al., 1993). Very often in reality, actors participating in new business ventures or innovation might not know the extent to which their contributions are needed or how much responsibility their involvement will entail. This is especially true during the early period of strategic planning and resource budgeting. To mitigate these uncertainties, proper rules and governance instruments should facilitate effective interactions among new business model actors, and stakeholders (Johnston et al., 2011). Rules and governance state the relevant mechanisms to assure how a business model prepares assets, and how far the scope of a business model can go in a business ecology. From institutional perspectives, rules and governance imply the prespecification of a business process and entail the legitimization of the process' innovation. However, it would inevitably restrict the contingent changes (Brones & de Carvalho, 2015). Conceiving an appropriate list of businesses and cowork policies, rules and governance within an innovative business model should be situation-adaptive. A minor adjustment or a reconfiguration of a part of an operating business model would trigger changes in the whole business process and values over an unanticipated period in future. Rules and governance must be tested, and reviewed regularly with respect to changing business models and value interests. Rules and governance are prevalently theorized antecedents leading to successful business model innovation under the complexity of business ecologies (Chesbrough, 2010; Zott & Amit, 2007).

2.5 Business model innovation complexity

A key principle underlying business modeling is to portray a whole business ecosystem as one in an integrated framework. Such a framework therefore becomes a strategic reference for defining and launching new business values and interests for all relevant business actors and stakeholders. As such, business model innovations concern entrepreneurial responses to dynamic, complex market forces. Vasconcelos and Ramirez (2011) discussed this issue, and proposed ontologically three vertices of complexities: procedural complication, transactional entanglement, and contextual complexity. These three complexities exert influences concomitantly on business model innovation, leading to cycles of system refinement and redefinition in nested, reiterated patterns (Iansiti & Levien, 2004; Woodside, 2014). Meanwhile, the layers of work tasks increase inevitably in complexity with massive technical and administrative difficulties (Johnston, et al., 2011). Business actors and stakeholders cannot anticipate confidently their participation in most stages of business modeling processes (Sherperd et al., 2013). Under highly complex conditions, the successful pursuit of business

model innovation should undergo a process of unremitting review and refinement for new business solutions and value creation (Smith et al., 2010). Based on such premises, this research theorizes context complexity as a key antecedent shaping business model innovation.

All of these captioned antecedents occupy business ecospheres, and determine the effectiveness of new business model development. Notably, the consequence does not arise simply from the combined net effects of these antecedents, as presented in a linear regression model; instead, the effects are configurational with *equifinal* consequences (Huarng, 2015; Rihoux & Ragin, 2008). From this research perspective, this research attempts to test a causal relationship regarding how well alternative configurational structures of these antecedents explain outcomes of business model innovation (Ragin, 1994; Sculze-Bentrop, 2013). In particular, this research hypothesizes the business model innovation process as a flow path with the following three-stages: (1) the mixing of the various business model innovation antecedents; (2) the catalyzing and smoothing of the dynamic innovation process; and (3) the yielding of effectiveness as reflected by sufficient adaptive agility and resource capability for business model innovation. Figure 1 illustrates the antecedent-outcome isomorphic flow path, which is composed of the prerequisite antecedents, the mediating effects, and consequences during the course of business model innovation. The flow path is characterized by the parsimony of the context variables, as discussed in this section of the literature review.

Figure 1 here

This research corroborates these context-oriented business model innovation hypotheses within a complexity paradigm (Fiss, 2007; Urry, 2005), and it posits sets of configurational antecedents that can lead to business modeling outcomes and performance. Analogously explained, the research dwells on contemporary thoughts of network connectivism, in which business models pursue performance results collectively much greater than the results from simply totaling individual model component competencies and contributions. This view has been especially prevalent in areas of organizational redevelopment and innovation/venturing management (Bennis & Biederman, 1998; Benavides-Espinosa & Ribeiro-Soriano 2014; Teece, 2010). The next section on the research plan and methodology elaborates in detail how the antecedents are constructed and analyzed.

3 Research plan and methodology

This research corroborates a context-driven innovation theory and model antecedents versus outcomes under a paradigm of configurational complexity (Weick & Sutcliffe, 2007; Sculze-Bentrop, 2013). The paradigm posits that a set of antecedent combinations (models in various

configurational conditions) can isomorphically lead to expected outcomes in business model innovation. The research focuses on the predictive purposes of innovation and ecosystem management (Huarng, 2015; Jiménez-Jiménez & Sanz-Valle, 2011; Roig-Tierno et al., 2017). Apart from empirical descriptions, this research also evaluates business model innovation by using qualitative comparative (configurational) analysis (QCA) methods (Ragin, 1994, 2008). Notably, the data are empirical, although the analysis is set-theoretically driven. In methodological thinking, QCA amalgamates both the merits of qualitative study for theory corroboration and those of quantitative study for empirical affirmation, which is more appropriate for studies at the organizational or institutional level.

Rather than putting forth an analysis of phenomenal variables, this research conceives the antecedents and mediating consequences for business model innovation, as done in multifaceted complex contexts. The causal relations between outcomes and antecedents are configurationally constructed: an individual antecedent x_i does not necessarily show its effects on y, but a set of configured x_i does. The relations are configurationally metamorphic, still leading to the same outcome, which is a phenomenon of equifinality (Ragin 2008). The magnitude of this relationship is also not symmetrically anchored: the same set of data x_i in various configurations can relate to y positively, negatively, or even not at all. In business model innovation, classes of context antecedents considered for analysis include value creation eco-networks, business actors' behavioral orientations, mastery of technology, business ecosystem rules and governance, and complexity. All of these factors can determine the potential and efficacy of business model innovation.

3.1 Case selection and data collection

As discussed in the previous section, business model innovation can apply to a set of intricate configurations built by various management antecedents within whole business ecosystem contexts. To investigate the implications of the captioned antecedents, this research conducted an industrial survey in Hong Kong. The research examined the registration lists from public sector agents that initiated public-private joint innovation research and research spin-off ventures. Using the registration information, the research invited 116 new corporate ventures, small/medium enterprises and new start-ups to respond to this empirical survey. All of these companies once attempted to examine and transform their business values into new business models. Over an initial six-month period, 42 companies returned their feedback, and provided details about their motivations and orientations for business model innovation. Table 1 summarizes the 42 cases, their business nature and operating years. In general, the companies could be categorized into two orientation types for business model innovation: science-based and service-based value innovation. Of these companies, ten belonged to science-based new ventures

or technology-driven start-ups. Twenty-eight companies focused on service innovation, and sought new service values for various end markets, for instance, industrial goods supply in food, textiles, packaging systems, furniture, consumer services for wedding event business, video-blogging, beauty, health care training service, product design, etc. Four companies claimed to be oriented toward both new science and service value innovations. The cases represented the diverse nature of business models and ventures, seeking innovative approaches to deliver new value to customers.

The survey imposed three criteria to justify the validity of these companies' responses. First, the founders or the CEOs of these companies had profound knowledge of their business models and ventures, being in the right position to provide direct survey data. Second, the companies performed business model innovation as key mechanisms in planning business resource utilization, key management programs for organizational learning, and business breakthroughs from existing business environments. Third, the companies could explain their business value chains, the loci of their business competitiveness, and measures for sustainable growth. The last criterion assessed the validation of the judgment data provided by the companies.

Table 1 here

3.2 Measurements

In assuring the data and measurement integrity, this research followed up the returned questionnaire with behavioral-event interviews (McClelland, 1988). Appendix A lists the corresponding interviewing focuses, by which the measurements of business model innovation antecedents and relevant outcomes were verified. The next subsection further discusses the measurements. In the six-month investigation period, narrative scripts of more than 26,000 words were collected. A content analysis was applied in parallel with a fuzzy-based comparative analysis to reason and evaluate the analyzed results. In testing likely measurement differences between the sample cases for the two innovation orientations (science-based and service-based innovation), Levene's tests and t_s show weak amounts of variability, insignificant for most of the theorized outcomes and antecedents (only for Adaptive Agility, Levene's Sig = 0.009 and t Sig =0.033 are significance at <0.05). As such, the research should have treated all of the measurements as coming from one single pool of sample cases in the variance analyses (see Appendix B for the descriptive statistics). However, the QCA methods advised very contradictory analysis results, which are explained in the next subsection, '3.3 Antecedent conditions and configuration analysis'.

To measure outcome values and various antecedent conditions in the course of business model innovation, the research treated each responding company as an analytic case sample. The

research finally accessed a small (N=42) case data set in which all of the cases were concerned with the customers' new ideas and values derived from business model redevelopment. In these cases, the research set forth a set of focal questions to explore the nature and scale of the outcomes, and the conditional antecedents perceived for business model innovation. Owing to the measurements mainly originating from the respondents' perceptual views and experience, the data were recorded psychometrically using seven-interval Likert scales. The collected data were affirmed by behavioral-event interviews (McClelland, 1988). The interviews asked the companies' founders and CEOs to examine, reason, and verify their previous responses in the survey. Of the 42 cases, six respondents (14%) kept the response data unchanged in the follow-up interviews. Twenty-six respondents (62%) adjusted their data moderately (with less than 20% of question responses being adjusted). Ten cases (24%) revised the data more than twice in subsequent interviews. When the case respondents requested reviews and revisions of previous measurement ratings or comments, the interviews continually examined the measurements until the responses to most of the items (≥ 90%) were judgmentally stable and certain.

3.2.1 Outcomes (adaptive agility and resource capabilities)

In this research, the measurements of the post hoc performance of business model innovation focus on two dimensions: adaptive agility and resource capability. Adaptive agility concerns the extent to which business actors sensitively observe the whole business ecosphere and anticipate rapid actions for business model adaptations. Adaptive agility can be regarded as an innovation capability to seize emerging business opportunities. In the meantime, unified leadership and coordination are necessary to align all business actors' visions and actions. This dimension concerns the respondents' perceptions about their strategic sensitivity, responsiveness and leadership for business model changes. Accordingly, the survey referred to the studies of Doz and Kosonen (2010), and Battistella, de Toni, de Zan, and Pessot (2017), developing a four-item battery to assess this dimension ($\alpha = 0.881$) (as illustrated in Appendix B).

The measurement of resource capability builds on the extent to which business model innovation can maintain management momentum to identify, consolidate, and redistribute networked business resources. Business models characterized by such strategic capability can be sensitive to internal resource strength, namely, resource fluidity (Johnston, 2009), hands-on organizational knowledge and technologies (Chang et al., 2012), resource alignment (Doz & Kosonen, 2010), sharing (To, 2016), networked assets and resource integration (Helfat et al., 2007). On the premises of these studies, the research developed four items to measure the dimension ($\alpha = 0.545$). The measurement is rated with a seven-interval Likert scale.

3.2.2 Causal antecedents

In venturing network perspectives, value creation networks shape connections and interactions among business actors, agents, and stakeholders (Larson, 1991; Chen et al., 2015). Business actors participating in networked cycles believe in faster information and resource accessibility. In the face of adversity, business actors can strategically dissolve their networked relations for a greater likelihood of adaptation. The value creation networks generate an antecedent factor accountable for activity coherence along value chain processing. This research adopts four items to indicate the essence and scale of such contextual antecedent effects (see Appendix A). Respectively, the four items representing the antecedents' characterization are synergetic value (Engel et al., 2017; Mačiulienė & Skaržauskienė, 2016; Tsai, 2001), interdependence (To et al., 2009), perspective taking (Huynh et al., 2017; Johnston et al., 2011), and sharing (Huynh et al., 2017; To & Ko, 2015). Although the four items characterize complementarily the antecedents of the value creation network, their proximities are well discerned, showing that the indicative items are reliable for the conception of value creation networks. The standardized alpha is 0.742.

The actors' orientations and behaviors determine the business actors' judgments, preferences of values, and interests likely gained during the course of business model innovation. This research proposes four items to represent the effects of the actors' behavioral interests: altruistic support (Hienerth et al., 2011), autonomous judgment (Hienerth et al., 2011; Taylor & Greve, 2006), interest rationalization by causal judgment (Hoang & Rothaermel, 2005; Taylor & Greve, 2006), and assurance of mutuality and transparency (Bennis & Biederman, 1998). Mainly from the perspectives of deontological preference and consequentialist rationalization, these four items capture the extent to which the business actors' behavioral preferences and orientations determine the effectiveness of business model innovation (To, 2016). ($\alpha = 0.662$)

The mastery of technology concerns the development, control, and deployment of processing and information technologies. Facilitating business model innovation, business actors should build relevant knowledge repositories, provide technological platforms for sharing and interactions among business stakeholders, and assure highly efficient, sustainable operational systems (Calia et al., 2007; Carayannis et al., 2014; Chang et al., 2012). This research therefore adopts two items to reflect the causal influence on business model innovation ($\alpha = 0.732$).

Rules and governance reveal a leadership and administration dimension that shapes an organization's legitimacy and accountability for each unit of function (Pertusa-Ortega et al., 2009; Pinto et al., 1993). Rules and governance are also regarded as prevalent antecedents for appropriate control over forms, patterns, and the directivity of interactions among business model components, i.e., activities, actors, value interests, and resources. This research sets forth two items to measure the antecedent effect: characterizing business model work contexts (Pinto et al., 1993, Ko & To, 2015), and restrictiveness to contingency (Chesbrough, 2010) ($\alpha = 0.701$).

In designing and reconfiguring business models, a business model's value would not simply result from internal processes and capabilities for value proposition and creation (Iansiti & Levien, 2004). Indeed, business actors cannot perceive and discern the potential of business model innovation without cycles of refinement and redefinition of business model components. The complexity is outward expanding, significantly affecting the whole performance of business models in business ecospheres. Vasconcelos and Ramirez (2011) proposed three vertices of complexities: procedural complication, transactional entanglement and contextual complexity. This research adopts three measurements to reflect complexity: task complications (Prendeville et al., 2017; Urry, 2005), perceptual complexity (Smith et al., 2010), and the stochasticity and capriciousness of the business ecosphere (Pertusa-Ortega et al., 2009) ($\alpha = 0.643$).

3.2.3 Measurement calibration

All of the measurements are reflectively rated using seven-interval Likert scales. The research calibrated the raw measurements into fuzzy membership scores ranging from 0 to 1. Table 2 summarizes the observed outcomes, the antecedent variables, and their calibrated fuzzy membership values. The independent t-test results show the insignificant variability between the means of the two groups of measurement data, namely, science-based and service-based business model innovation. The research should have assumed the inseparability of all cases in the variance analysis. However, the QCA process finds very contrary solution results in the two sample groups. The results manifest the particular properties explored in a set-theoretic comparative analysis. The next section elucidates these analytic properties and results in detail (Jenson et al., 2016; Ragin, 2008).

Table 2 here

3.3 Analysis of antecedent configurations

This research hypothesizes analytic tests by which five management and contextual antecedents precondition successful pursuits of business model innovation for producing two performance classes: adaptive agility and resource capability. The five antecedents—value creation networks, business actor behavioral orientation, mastery of technology, rules and governance, and business model innovation complexity—must be the supersets of the two outcomes. Fuzzy-based QCAs permit tests of whether all of the conditional antecedents are necessary and sufficient for business model innovation to be sustained. The research therefore tests all of the possible combined effects of the five antecedents with respect to the two outcomes. In the set-theoretic analysis, the antecedents are regarded as necessary conditions when any single consistency value of the five antecedents is higher than the 0.85 threshold. The

consistency values in necessary condition tests exceed the threshold to uphold the assumption of necessity for causing the theoretic outcomes (see Table 3).

Table 3 here

In the fuzzy-based QCA, the truth table lists the numbers of cases in the same sets of different configurations of possible causal antecedents. However, not all of the possible theoretic configurations would occur in the research observations. The research must analyze cases with different configurations of reasonable occurrence rates (see Table 4). In the research, in light of the recommendation for small-N theoretic analyses, the minimum frequency cutoff is two for specifying the analyzing cases (Ragin, 1994 & 2006).

Table 4 here

Proportional reduction in inconsistency (PRI) tests any hidden asymmetry in which a QCA of hypothesized conditions can show sufficient consistency values for both the presence and absence of designated outcomes. These contradictory results challenge the logicality of the interpretation. Table 4 shows that all of the PRI consistencies exceed the threshold (0.5). There are no negated, contradicting outcomes observed over the corresponding threshold. The results indicate that the illogical set-theoretic relations do not occur in the observations.

In QCA, an antecedent will be treated as a sufficient factor for an outcome when the factor consistently occurs in an antecedent condition: the membership scores of business model innovation performance (i.e., adaptive agility and resource capability) are consistently the superset in relation to the membership scores of the testing configurations among the five antecedents (i.e., combinations among value creation networks, actor behavioral orientation, mastery of technology, rules and governance, and innovation complexity). Alternatively, the membership scores of combinations of antecedents are consistently less than the scores of outcomes. Ragin (2008) explained a value of consistency purportedly implying how proximate, or how reliable, a subset relationship that exists is. This research tests this set-theoretic relationship with a conservative threshold at 0.8 for minimum raw consistency.

3.4 Analysis results

Table 5 illustrates the consistency and the coverage scores for the overall immediate solution sets. The scores of raw coverage and unique coverage measure how much of an outcome is covered (i.e., explained) by each solution term and by the whole solution. The raw coverage values indicate the proportions of membership scores in the respective outcomes explained by

each term of the solution. The raw coverages indicate the empirical significance, and are similar to the meaning of R^2 in statistical regression processes. The unique coverages indicate that the membership proportion values with respect to the outcome are solely accounted for by each solution term and each particular configuration. All of the measures are greater than the recommended threshold of 0.5.

Table 5 here

The research identified different critical configurative conditions for science-based and service-based business model innovations (see Table 5). The QCA results provide an implication of dissimilarity of conditions between the two business innovation orientations. In the meantime, although the two outcomes, adaptive agility and resource capability, describe two independent management performance classes, management should consider both outcomes to judge the accomplishment of business model innovation (solution coverage = 0.69895, solution consistency = 0.99068 for adaptive agility immediate solutions; solution coverage = 0.75069, solution consistency = 0.98679 for resource capability immediate solutions).

Table 5 lists the immediate solutions for the two performance outcomes in the two business innovation orientations. Regarding science-based business model innovation, high solution consistency values imply that configuration solutions sufficiently lead to the two performance outcomes. Raw coverages for the three configuration conditions are all greater than 0.65, showing that each term of the solution can account for a large proportion of the performance outcome in business model innovation processes. The fuzzy-based QCA results in the three configurations as follows:

(1) VNF*TSF*RRF*CYF ←AA;

(2) BBF*TSF*RRF*CYF ←AA; and

(3) VNF*TSF*RRF ←RC,

where AA and RC denote the two theorized dimensions of adaptive agility and the resource capability; VNF, BBF, TSF, RRF, and CYF indicate correspondingly the fuzzy membership values of value creation network, business actors' behavior, technology mastery, rules and governance, and innovation complexity.

Again, these three configurations cover approximately 70% of the accomplishment of adaptive agility performance and explain sufficient consistency of approximately 0.9. The results show an epitomized understanding that not all five antecedents are present for the two theorized outcomes. Configuration (1) implies that the presence of a value creation network, high levels of technological mastery, regulated rules and governance, and high skills for handling innovation

complexity can lead to the anticipated business model innovation. Configuration (2) also shows that the presence of clear business actors' behavioral orientations, high levels of technological mastery, regulated rules and governance, and high skills in handling innovation complexity can explain similar outcomes, with slightly smaller raw coverage values. Configuration (3) suggests an antecedent structure proximate to that of configuration (1), but in the absence of innovation complexity, it can account for resource capability. Of all these three configurations, the mastery of technology, and the rules and governance antecedents are structurally coupled for the accomplishment of business model innovation. It is understandable that the mastery of advanced technologies, and venturing rules and regulation are critical for science-based innovation and venturing.

Contrarily, the QCA analysis results for a service-based business model innovation predict five different configurations with varying consistency values:

(a) VNF*BBF*TSF ←AA;

(b) VNF*TSF*RRF ←AA;

(c) BBF*TSF*RRF*CYF ←AA;

(d) VNF*TSF*CYF←RC; and

(e) BBF*TSF*CYF←RC.

The solution coverages have high score values ≥ 0.83. The raw coverages are all greater than 0.7. Notably, although the business models are service based, mastery of technology is still the prominent antecedent, occurring in the five configuration solutions. The value creation network is a key solution term accounting for the outcome of adaptive agility. For the outcome of resource capability, the key solution term is the innovation complexity handling.

Of all these solutions, only the configuration solution (c) of BBF*TSF*RRF*CYF (i.e., business actors' behavioral orientations, mastery of technology, rules and governance, and innovation complexity) occur for both science-based and service-based business model innovation. The QCA results lead to a totally different angle for examining the causal effects of antecedents for business model innovation. As mentioned in the previous section, the independent t-test results and correlations return insignificant variability between science-based and service-based businesses. The Levene's test between the two company categories for all of the theorized antecedent variables shows no significance of equality of variance (the least Sig, 0.187). Similarly, the sample t_s returns the least significance at 0.16. In checking the scale tests with Cronbach's values, the reliability levels of individual variables are high (max α, 0.741; min α, 0.641). These two categories of business model innovation are distinct but, however, have a less distinguishable characterization from the perspective of variance-based theories. These results show that the science-driven and service-driven companies share the same theorized

antecedents but are characterized under different conditions (the combinations of antecedents) with respect to the pursuit of success in business model innovation.

In summarizing these analyzed relationships between the contextual antecedents and outcomes, Figure 2 visualizes a flow path model that represents the alternative, dynamic progress of business model innovation and the cascade of antecedent interactions resulting in corresponding outcomes (i.e., adaptive agility, resource capability, innovation success, or innovation hindrance).

Figure 2 here

4. Interpreting the analysis results

A closer look at the cases reveals three notable implications for developing and innovating business models. First, the research investigated two categories of cases: companies funded by public agents to support science and technology-driven innovation; and companies managing to compete in markets with highly advantageous, innovative services. Regardless of the categories to which the companies belong, both the companies aim at strategic thinking to shift their value propositions toward market propositions (Storbacka & Nenonen, 2011). In other words, the business model innovations aim at overarching value propositions to compete *for* whole markets. Therefore, apart from the static context structures, business model innovation should make these companies aware of the dynamic interactions of whole market context factors. The QCA provides this logic and analytic corroborations. These antecedent analyses imply today's research priority in the business model literature, which focuses on the 'recipes' of antecedents accountable for phenomenal outcomes rather than on the variance effects of individual antecedents, as in linear regression processes (Achitenhagen et al., 2013; Caryannis et al., 2014; Hammermesh et al., 2002; Smith et al., 2010). The prediction by a set of independent variables' variance effects tends to neglect the asymmetric, multiconjunctive properties of perceptual antecedents, and they provide no account of the conditionality to which the predicted outcome can be related (Armstrong, 2012; Soyer & Hogarth, 2012; Woodside, 2013; Woodside et al., 2018).

Second, the QCA results show the high levels of necessity for all five antecedents leading to the two outcomes in business model innovation. However, not all five account essentially and simultaneously for the outcome occurrences. In reference to the QCA's immediate solutions for the sufficiency of antecedent configurations, the occurrence of the two outcomes can result from various antecedent configurations. Table 5 shows that, of the seven configuration solutions, only one configuration solution (i.e., BBF*TSF*RRF*CYF) occurs for adaptive agility in both science-based and service-based innovation companies. Further, of the seven configuration

solutions, five are composed of three antecedent terms only. All of these configurations are logical but represent multiconfigurative sets, showing that single context complexes cannot predict or manifest the potential of business model innovation.

Third, the analysis results from QCA immediate solutions show two prevailing demands for the cautious management of technology, namely, 'TS', innovation complexity, and 'CY', with the antecedents leading to a strong facilitation or to effects hindering innovation performance, adaptive agility and resource capability. Technological mastery is the most critical, necessary solution term in the QCA results. From epistemic viewpoints, technological mastery empowers business actors to gain benefits from access to applied knowledge or from improvements in processing efficiency. Innovation complexity is the second critical antecedent shaping the context of companies' model innovation. In managing innovation complexity, companies envision future innovation potentials that will facilitate correspondence to entrepreneurial commitments to resolving all types of intertwining difficulties and uncertainty. All of the cases explain these two antecedents unanimously. In parallel with the QCA data analysis, the content analysis of the case interview scripts supports these two antecedents' prominence. In this regard, the research examines the respective script content. The following excerpts provide the relevant affirmation.

> *Online data crawling, meta-level data categorization and interpretation are the key business directions in consumer data analytics. These support consumer relationship management, product offers, communication, and pricing from minute to minute. Technologies determine our boundary of business activities, directions, and also the capability for business growth. We rely on types of new algorithmic development, new data-processing hardware, mediating technologies like energy systems, data vaults, clouding networks, etc., to model our core business values and directions. [Case 3 in consumer data analytics – mastery of technologies for science-based innovation]*

> *I am a freelance designer for intimate wear items—now full-fledged PLMs, Product Life Management systems, can do almost all planning jobs from product graphical design, illustration, merchandising, and costing to retail process simulation. Without such advanced, sophisticated technologies, I cannot sell my ideas nor retain my business partners. [Case 19 in intimate wear design and wholesales—mastery of technology for service-based innovation].*

> *Our business models and core services have been reviewed several times since we started the venture two years ago. At the time, we saw the emerging demand for data vault services in international corporations; we believe in the potential of such technology-*

driven business. Initially, we approached the clients, and proposed services to remodel their databases and retrieval systems. Later, we built our cloud facilities and security; further, we re-standardized and maintained data from all types of clients' legacies. All these caused us to redefine our work tasks, from hardware design to systems coding. Therefore, our higher-ups call for meetings anytime, and regulate follow-up projects. The complexity is indeed far beyond our initial imagination. [Case 5 in data vault modeling business – business innovation complexity in science-based innovation]

Our sister company is an integrated textile-processing corporate group, having manufacturing operations in five countries. In this decade, we are very concerned about issues of sustainability and environmental management. For example, we estimate using two to seven kilograms of chemicals to treat one kilogram of cotton in the dyeing and wet finishing processes. We can imagine a large proportion of these chemicals being disposed of as waste somewhere (rivers or sea). Eight years ago, our corporation teamed up with a group of experts to audit and provide blueprints to reconfigure all of the processing methods and resources to address the issue. However, our corporation's business is about billions of capital investment, and employs more than 40,000 staff worldwide. Our tasks are so complex and undiscernible. We need to reengineer every nut and bolt. Sometimes, we face a lot of resilience from other units and divisions. To handle all these, we need to remodel our functions first, and to demonstrate our innovative consultant values to each counterparty prudently. We cannot underestimate the complexity in remodeling our processing, [Case 10 in textiles finishing consultancy - innovation task complexity in service-based innovation]

This script content analysis provides an interpretive means to affirm the QCA results. Regarding the investigated cases, the content analysis provides a strong behavior-based data source to confirm the validity of perceptual data measurements from the surveys. The captioned extracts exemplify the complementarity of content analysis with QCA methods in studying configurational context management.

5 Discussion

Business model innovation intends to review, and redefine a whole business system as one in a new, integrated framework. The innovative model framework can create new interests and new value for customers as a means, and can propose a new market for all stakeholders as an end. Management must obtain a clear understanding of whole business contexts to achieve

success in business innovation. With such views, this research attempts to contribute to the literature on business model innovation and business venturing in two relevant aspects. First, the research helps to uncover the contexts, in terms of relevant antecedents, for determining performance in business model innovation. The research results show the indistinctive prominence of five contextual antecedents to both science-driven and service-driven business innovation and venturing. These antecedents consist of value creation networks, the business actors' behavioral orientations, technological mastery, rules and governance, and innovation complexity. The research also theorizes two performance outcomes in business model innovation, namely, adaptive agility and resource capacity. Notably, in the research's empirical results, the five antecedents' causal relationships with the two theoretic outcomes are significant and distinct. This finding supports a view of the generality of the causal relationships among the antecedents and consequences in the course of business model innovation. In more closely examining the configurative conditions in the observed cases, the QCA research provides an account of specificity in which none of the antecedents exert effects on the outcomes with fixed scales, i.e., with coefficients of symmetrical effect sizes. The antecedents' importance or occurrence can vary over different situations and times. Therefore, the analytic approach might not simply rely on conventional variance analysis, which estimates average extents (mean values) of causal interrelationships for every independent variable toward predicted ones. Different configurative conditions can result in the same outcomes, i.e., the characteristics of conjunctivity and equifinality in large puzzles of causal factors (Rihoux & Ragin, 2008).

Second, this research recommends context analysis as a complementary technique in line with QCA methods. These two distinct methods can advance more substantive explanations for the antecedents' combined effects on business model development and innovation. The research theorizes the five antecedents repeatedly: value creation networks, the business actors' behavioral orientations, mastery of technology, rules and governance, and innovation complexity. In light of these five antecedents' empirical analysis, mastery in relevant technology and innovation complexity have particular importance. The other three antecedents—value creation networks, actor behavioral orientation, and rules and governance—can also peripherally explain performance for business model innovation. In almost all the observed cases, the relevance of technological mastery and innovation task complexity articulate the phenomena of 'focus-in' management orientations. These two antecedents concern the organizations' own capabilities that inherently build on entrepreneurial envisioning and commitments to new business values. Contrarily, the other three antecedents concern the contextual aspects stretching out over the whole business ecosphere. A value creation network indicates collaboration among networked members to propose new business interests and values. This antecedent is dynamic, subject to the characteristics of network ecosystems and the reciprocity among networked participants. This

antecedent echoes with another antecedent, rules and governance, which regulate and characterize decisions and actions among business actors within the whole business ecosphere. The business actors' behavioral orientations (i.e., preferential decisions and actions for various business interests) are very intertwined with the two dynamic antecedents. These three antecedents exert many discernible influences on business model innovation. In business ventures, entrepreneurs would regard these three contextual antecedents as 'focus-out' deliberations of business value innovation. In regarding these two views of 'focus-in' and 'focus-out' for business model innovation and venturing, the research enlightens issues of how management explores and evaluates patterns of combining all antecedents to accomplish anticipated business outcomes. Apart from simply exploring the causal elements that would be related to the predicted consequences, the research suggests a theoretical means to determine how the importance of particular configurative causal condition accounts for a business process arising from a 'recipe' perspective.

6 Conclusion

This research provides empirical results regarding whether and how business contexts can shape business model innovation. This research reviews the relevant literature on innovation and venturing management and, to study business model innovation, posits five classes of contextual antecedents: business value creation eco-networks (denoted in VN), business actors' behavioral orientation (BB), the mastery of technology (TS), rules and governance awareness (RR), and business complexity (CY). The literature reviews also facilitate theorizing about two potential outcomes, namely, adaptive agility and resource capability, in the course of business model innovation. The analysis focuses on the configurations of these five contextual antecedents mediating the two outcomes. An empirical survey of 42 start-ups and entrepreneurs provides the analysis data. The data analysis employs the fsQCA method, a set-theoretic analysis technique, in line with a content analysis of interview scripts as the follow-up (behavioral-event) data elicitation method. This research corroborates the characterization for measuring the antecedents and the mediating outcomes.

Eventually, the analysis results show seven configurations multimorphologically leading to desirable outcomes. Regarding the fsQCA analysis in science-based business models, two prominent contextual configurations sufficiently entail the innovation outcomes of adaptive agility: {VN*TS*RR*CY} and {BB*TS*RR*CY}. The outcome of resource capability is entailed by one single configuration: {VN*TS*RR}. In service-based business models, three configurations sufficiently entail the innovation outcome of adaptive agility: {VN*BB*TS}, {VN*TS*RR}, and {BB*TS*RR*CY}. Two configurations entail the resource capability: {VN*TS*CY} and {BB*TS*CY}. The analysis implies that two antecedents, mastery of

technology (TS) and business complexity (CY), are particularly critical, necessarily leading to strong facilitating or hindering effects on all of the model innovations in science and service businesses. This research contributes to the business strategy literature, as well as to innovation management, by characterizing the contexts of business model innovation in the conjunctivity terms of causal antecedent factors. Business practitioners can therefore examine the patterns combining all of the contextual antecedents, accomplishing the anticipated innovation outcomes.

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Appendix A: Measurement focus

Adaptive agility refers to the ability of business actors to anticipate business competition, to seize emerging opportunities and to capitalize on learning processes in the course of business innovation. Very often, business actors must adjust or redefine business performance, tactics and even orientation in response to the dynamic climates of the business ecosphere.

- Business model innovation enhances strategic sensitivities to emerging changes in markets (Doz & Kosonen, 2010);
- Business model innovation maintains business momentum and mobility for ad hoc changes (Battistella et al., 2017);
- Business model innovation allows process contingency to different types of market disruptions (Battistella et al., 2017; Carayannis, et al., 2007);
- Business model innovation facilitates business leadership realignment among business ecosystem actors (Teece, 2010; Ulrich & Smallwood, 2004).

Resource capabilities refer to the ability of business actors to define and utilize business resources and actions to respond dynamically to external emerging challenges.

- Business model innovation entails the strategic deployment of internal business resources and authority (Teece, 2007; Hammermesh et al., 2002; Stalk et al., 1992);
- Business model innovation reviews and revises leadership and governance to streamline resource efficiencies and fluidity (Ulrich & Smallwood, 2004);
- Business model innovation includes envisioning the transformation of intangible resources, such as new knowledge and intellectual technologies, into business assets (Helfat et al., 2007; Stalk et al., 1992);
- Business model innovation fosters the sharing and internalization of new business visions and new business values (Santoro et al., 2006; To, 2016).

The following statements can be used to characterize the antecedents of business model innovation. Please indicate

the extent to which these statements apply to your understanding of envisioning, building and validating business model innovation.

Value creation network

- Business model innovation associates its potential with symbiotic business collaboration and value sharing (Engle et al., 2017; Mačiulienė & Skaržauskienė, 2016; Tsai, 2001);
- For business model innovation, the actors' performances are interdependent. Networked cycles collectively account for innovation outcomes (To et al., 2009);
- Each business actor and stakeholder considers the perspectives of others and is accountable for the performance of each collaborating actor and process (Huynh et al., 2017; Johnston et al., 2011);
- Each business actor is active in the exchanges of views, opinions, data, and knowledge and in the exploration of uncharted business values and opportunities (Huynh et al., 2017; To & Ko, 2015).

Actor orientation and behavior

- Business model innovation supports business actions altruistically and intersupportively. Business processes align with each other consistently and congruently (Hienerth et al., 2011);
- Business model innovation embraces high levels of independency, allowing business actors to make decisions and undertake action in effectuation patterns (Hienerth et al., 2011; Taylor & Greve, 2006);
- Business model innovation envisions the whole innovation landscape and values of each model stakeholder. It considers all of the actors' perspectives within a system boundary and a holistic business ecosphere (Hoang & Rothaermel, 2005; Taylor & Greve, 2006);
- Business model innovation allows for value cocreation and propositions. Business model innovation therefore allows for fairness and transparency of the corresponding values and rewards to each stakeholder (Bennis & Biederman, 1998).

Technological and knowledge supports

- Technological and knowledge repositories provide sufficient assets and infrastructures to sustain continuation along value chains built by business model innovation (Carayannis et al., 2014; Chang et al., 2012);
- Business model innovation must be organized from a systematizing, technologically driven perspective (Calia et al., 2007).

Rules and governance

- Rules and procedures provide business model operations with policies and formalities as governing requirements and standards of mutually anticipated work results (Johnston et al., 2011; Pinto et al., 1993, Ko & To, 2015); and
- Rules and procedures provide alerts regarding performance deviation but inevitably restrict contingent changes (Chesbrough, 2010, Hamel & Valikangas, 2003).

Business model innovation complexity

- The scale of task work is undiscernible (Prendeville et al., 2017; Urry, 2005);
- Business process innovation can only be perceived by a few experts and ecosystem initiators (Smith et al., 2010);
- Business ecosystems are highly stochastic and capricious (Pertusa-Ortega et al., 2009).

Appendix B:

The descriptive statistics of the measurements

Variable	Mean	Std. Dev.	Cronbach's α	Standardized α
AA	4.827	1.592	0.883	0.881
RC	4.85	1.4855	0.460	0.545
VN	4.44	1.5655	0.731	0.742
BB	4.47	1.3825	0.678	0.662
TS	5.607	1.951	0.732	0.732
RR	4.976	1.3855	0.699	0.701
CY	4.833	1.1216	0.648	0.643

The descriptive statistics of the fuzzy membership values

Variable	Mean	Std. Dev.	Minimum	Maximum	N cases	Missing
AAF	0.6896238	0.1872851	0.3214	1	42	0
RCF	0.7108857	0.1093272	0.5	0.9643	42	0
VNF	0.5405643	0.1137493	0.2963	0.7778	42	0
BBF	0.6318048	0.1442371	0.3214	0.9286	42	0
TSF	0.8010071	0.1222609	0.5	1	42	0
RRF	0.7023714	0.1776657	0.2857	0.9286	42	0
CYF	0.6791286	0.131878	0.3333	0.9524	42	0

Group statistics (science-based versus service-based business model innovation)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
AA	Equal variances assumed	7.478	0.009	2.201	44	0.033	0.88817	0.40361	0.07475	1.70159
	Equal variances not assumed			2.547	40.059	0.015	0.88817	0.34875	0.18336	1.59299
RC	Equal variances assumed	0.015	0.904	-0.571	44	0.571	-0.14086	0.24651	-0.63766	0.35594
	Equal variances not assumed			-0.567	27.244	0.575	-0.14086	0.24843	-0.65039	0.36867
VN	Equal variances assumed	0.285	0.596	1.776	44	0.083	0.58062	0.32695	-0.07831	1.23957
	Equal variances not assumed			1.856	31.196	0.073	0.58062	0.31276	-0.05710	1.21836
BB	Equal variances assumed	1.223	0.275	-2.389	44	0.021	-0.72043	0.30152	-1.32811	-0.11275
	Equal variances not assumed			-2.198	22.735	0.038	-0.72043	0.32769	-1.39876	-0.04211
TS	Equal variances assumed	1.794	0.187	0.683	44	0.498	0.1860	0.2723	-0.3628	0.7348
	Equal variances not assumed			0.753	35.804	0.456	0.1860	0.2470	-0.3151	0.6871
RR	Equal variances assumed	2.721	0.106	0.039	44	0.969	0.0151	0.3864	-0.7637	0.7938
	Equal variances not assumed			0.035	21.160	0.973	0.0151	0.4340	-0.8872	0.9173
CY	Equal variances assumed	0.105	0.748	-1.426	44	0.161	-0.40502	0.28406	-0.9775	0.16746
	Equal variances not assumed			-1.502	31.826	0.143	-0.40502	0.26968	-0.9544	0.14441

Note:

AA denotes the theorized dimension of adaptive agility; RC denotes resource capability; VN denotes the value creation network; BB denotes the business actors' behavioral orientation; TS denotes technology mastery; RR denotes rule and governance; and CY denotes innovation context complexity

Table 1: Cases (42 start-ups running as of 30 Nov 2017)

	Sectors	Cases	Innovation orientation	Operating period (# of years)
1	Material development	Research institution spin-off	Science oriented	3
2	Material development	Research institution spin-off	Science oriented	4
3	Consumer data analytics	Research institution spin-off	Science oriented	2
4	Textile finishing chemicals	SME	Science oriented	11
5	Data vault modeling	Innovation fund start-up	Science oriented	2
6	Software development	University research spin-off	Science oriented	6
7	Software development	Innovation fund start-up	Science oriented	3
8	Packaging material printing	Private venturing	Science oriented	10
9	Laboratory services	University research spin-off	Science oriented	15
10	Textile finishing and sustainability consultancy	Corporate division venturing	Science oriented	8
11	Business service center	Private venturing	Service oriented	1
12	House services	Publicly subsidized SME	Service oriented	4
13	Project management	Social enterprise	Service oriented	2
14	Wedding event consultancy	Private venturing	Service oriented	9 months
15	Software development	Private venturing	Service oriented	6
16	Food	Private venturing	Service oriented	12
17	Food	Private venturing	Service oriented	3
18	Apparel design	Private venturing	Service oriented	1
19	Intimate wear design	Freelance venturing	Service oriented	3
20	Interior design project	Private venturing	Service oriented	6
21	Interior design project	Freelance venturing	Service oriented	2
22	Retail	Private venturing	Service oriented	1
23	Retail	Private venturing	Service oriented	1
24	Marketing/ promotion	Freelance venturing	Service oriented	3
25	Blogging	Freelance	Service oriented	2
26	Social media promotion	Private venturing	Service oriented	2.5
27	Packaging material supplies	Corporate venturing	Service oriented	7
28	Toy design	Freelance venturing	Service oriented	3
29	Transportation	Franchised operations	Service oriented	1
30	Transportation	Franchised operations	Service oriented	1
31	Beauty service	Private venturing	Service oriented	3
32	Architecture consultancy	New private venturing	Service oriented	6 months
33	Food packaging	Public funded social enterprise	Service oriented	3 months
34	Metalsmithing – furniture	Private venturing	Service oriented	8
35	Yarn design and supply	Private start-up	Service oriented	1
36	Insurance consultancy	SME start-up	Service oriented	2
37	Financial service consultancy	SME start-up	Service oriented	2
38	Health training center	SME private venturing	Service oriented	8
39	Chinese medical service	Publicly funded social enterprise	Both science and service oriented	2.5
40	Construction material supply	Corporate division venturing	Both science and service oriented	12
41	Cosmetic product design	Corporate division venturing	Both science and service oriented	4
42	e-Portal system design	Innovation fund start-up	Both science and service oriented	3

Table 2: The descriptive statistics of fuzzy membership values

Variable	Mean	Std. Dev.	Minimum	Maximum	N cases	Missing
AAF	0.6896238	0.1872851	0.3214	1	42	0
RCF	0.7108857	0.1093272	0.5	0.9643	42	0
VNF	0.5405643	0.1137493	0.2963	0.7778	42	0
BBF	0.6318048	0.1442371	0.3214	0.9286	42	0
TSF	0.8010071	0.1222609	0.5	1	42	0
RRF	0.7023714	0.1776657	0.2857	0.9286	42	0
CYF	0.6791286	0.131878	0.3333	0.9524	42	0

Denotations and remarks:

AA denotes the theorized dimension of adaptive agility; RC denotes resource capability; VN denotes value creation network; BB denotes business actors' behavioral orientation; TS denotes technology mastery; RR denotes rules and governance; and CY denotes innovation context complexity. "~~F" refers to a fuzzy membership value deducted on a standardized scale for each theorized contextual dimension, assuming that $0 \leq \sim\sim F \leq 1$ (0 = absolute value for exclusion; 1 = absolute value for inclusion; and 0.5 = crossover threshold value).

Table 3: The subset/superset analysis

Outcome	AA			RC		
	consistency	raw coverage	combined	consistency	raw coverage	combined
VNF*BBF*TSF*RRF*CYF	0.997478	0.686886	0.824631	0.997744	0.666519	0.812314
VNF*BBF*TSF* RRF	0.997497	0.692186	0.827807	0.997761	0.671660	0.815441
VNF*BBF*TSF*CYF	0.993355	0.723655	0.846415	0.997867	0.705200	0.835553
VNF*BBF*RRF*CYF	0.997478	0.686886	0.824631	0.997744	0.666519	0.812314
VNF*TSF*RRF*CYF	0.996695	0.716346	0.842130	0.993193	0.692479	0.827982
BBF*TSF*RRF*CYF	0.935769	0.736530	0.849588	0.990078	0.755968	0.865106
VNF*BBF*TSF	0.993415	0.730188	0.850227	0.997886	0.711537	0.839298
VNF*BBF*RRF	0.997497	0.692186	0.827807	0.997761	0.671660	0.815441
VNF*BBF*CYF	0.993355	0.723655	0.846415	0.997867	0.705200	0.835553
VNF*TSF*RRF	0.996762	0.731147	0.850785	0.993330	0.706838	0.836522
VNF*TSF*CYF	0.992786	0.754072	0.864021	0.993559	0.732088	0.851333
VNF*RRF*CYF	0.996698	0.717078	0.842560	0.993200	0.693190	0.828407
BBF*TSF*RRF	0.917167	0.750920	0.853459	0.986447	0.783486	0.880711
BBF*TSF*CYF	0.929411	0.779283	0.869428	0.989216	0.804620	0.892510
BBF*RRF*CYF	0.927054	0.736530	0.845242	0.987067	0.760755	0.867840
TSF*RRF*CYF	0.924272	0.807635	0.885102	0.949204	0.804613	0.887987
VNF*BBF	0.993415	0.730188	0.850227	0.997886	0.711537	0.839298
VNF*TSF	0.993004	0.777643	0.877420	0.989551	0.751762	0.862696
VNF*RRF	0.996765	0.731879	0.851211	0.993337	0.707548	0.836942
VNF*CYF	0.992793	0.754804	0.864440	0.993565	0.732798	0.851745
BBF*TSF	0.899997	0.799014	0.875816	0.986113	0.849283	0.916946
BBF*RRF	0.906245	0.750920	0.849048	0.980654	0.788272	0.883397
BBF*CYF	0.918604	0.779283	0.869428	0.986435	0.811797	0.896482
TSF*RRF	0.896954	0.869290	0.908750	0.913498	0.858845	0.912732
TSF*CYF	0.913574	0.868880	0.918049	0.932164	0.860044	0.918065
RRF*CYF	0.907137	0.815030	0.884550	0.939623	0.818968	0.895873
VNF	0.993010	0.778375	0.877833	0.989561	0.752472	0.863103
BBF	0.872135	0.799014	0.862023	0.973078	0.864830	0.925301
TSF	0.847145	0.983970	0.935806	0.856707	0.965315	0.937249
RRF	0.861985	0.877918	0.893815	0.883785	0.873200	0.905984
CYF	0.891489	0.877922	0.913250	0.917790	0.876790	0.922218

Consistency refers to the extent to which an antecedent is necessary for a designated outcome.
Raw coverage refers to the relative size between an antecedent set and the corresponding outcomes set.
Combined refers to the necessity for the combined conditions to explain the business model innovation outcomes.

Table 4: Truth table and PRI scores

Truth Table (outcome=AA)

VNF	BBF	TSF	RRF	CYF	Number	AAF	Cases	Raw consist.	PRI consist.	SYM consist.
1	1	1	1	1	18			0.997443	0.994197	0.998459
0	1	1	1	1	8			0.935555	0.824789	0.834515
1	1	1	0	1	5			0.99274	0.974148	0.974148
1	0	1	1	1	4			1	1	1
0	1	1	1	0	1			0.974262	0.888273	0.895304
0	1	1	0	0	1			1	1	1
0	1	1	1	0	1			1	1	1
0	0	1	1	1	1			0.994739	0.981909	1
1	0	1	0	0	1			1	1	1

Truth Table (outcome=RC)

VNF	BBF	TSF	RRF	CYF	Number	RCF	Cases	Raw consist.	PRI consist.	SYM consist.
1	1	1	1	1	18			0.997713	0.99452	1
0	1	1	1	1	8			0.9997298	0.992003	1
1	1	1	0	1	5			1	1	1
1	0	1	1	1	4			0.994616	0.974115	1
0	0	1	0	0	1			1	1	1
1	0	1	0	0	1			1	1	1
0	1	1	1	0	1			1	1	1
0	0	1	1	1	1			1	1	1

Denotations:
AA denotes the theorized dimension of adaptive agility; RC denotes resource capability; VN denotes value creation network; BB denotes business actors' behavioral orientation; TS denotes technology mastery; RR denotes rules and governance; and CY denotes innovation context complexity.
"~~F" refers to a fuzzy membership value deducted on a standardized scale for each theorized contextual dimension, assuming that $0 \leq \sim\sim F \leq 1$ (0 = absolute value for exclusion; 1 = absolute value for inclusion; and 0.5 = crossover threshold value).

Table 5: Configuration solutions

Science-based business model innovation conditions (immediate solution sets)

Hypothesized model	AAF = f(VNF, BBF, TSF, RRF, CYF)		RCF = f(VNF, BBF, TSF, RRF, CYF)
Configuration solutions	VNF*TSF*RRF*CYF	BBF*TSF*RRF*CYF	VNF*TSF*RRF
Raw coverage	0.653508	0.643634	0.750769
Unique coverage	0.0553187	0.045445	0.750769
Consistency	1	0.989886	0.986789
Solution coverage	0.698953		0.75069
Solution consistency	0.990679		0.986789
Frequency cutoff	2		2
Consistency cutoff	0.989551		0.98555

Service-based business model innovation conditions (immediate solution sets)

Hypothesized model	AAF = f(VNF, BBF, TSF, RRF, CYF)			RCF = f(VNF, BBF, TSF, RRF, CYF)	
Configuration solutions	VNF*BBF*TSF*	VNF*TSF*RRF	BBF*TSF*RRF*CYF	VNF*TSF*CYF	BBF*TSF*CYF
Raw coverage	0.762779	0.75855	0.750769	0.716726	0.812262
Unique coverage	0.0297963	0.025562	0.750769	0.015523	0.111059
Consistency	0.991175	0.995625	0.986789	0.99596	0.985761
Solution coverage	0.838457			0.827785	
Solution consistency	0.920184			0.984978	
Frequency cutoff	2			2	
Consistency cutoff	0.919093			0.996432	