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The logic of innovative value proposition: A schema for characterizing and predicting business model evolution

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Chester K.M. To*#, K.P. Chau*, Chi Wai Kan*

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* Affiliation: The HK PolyU, Hong Kong

Send correspondence to Chester K. M. To, ITC, Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, telephone/fax: 852-27666499/852-27731432, (chester.to@polyu.edu.hk).

Abstract Innovations in business models involve a dynamic process that makes business values resilient against market and technology changes. We propose a schema that supports predicting the effect of innovation on business model values. The schema redefines the value proposition logic in business model innovations with five primary variables: business dependence structure, business value dominance, innovation dynamics, innovation domains, and innovation-resources-agility. Based on the schema, we have tested a set of hypotheses for 474 cases of business model innovations in four textile processing technology markets. We have estimated and modeled the data using two techniques: Cox modeling and temporal qualitative comparative analysis. The former predicts the business model that is destructed by innovation over time and the latter assesses the configurative conditions for innovation during the destruction period. The findings offer insights for predicting business model innovation as a value creation platform and for predicting innovative business models in industrial technology markets.

Keywords: Business model innovation; dynamics of innovations; semiparametric Cox analysis, temporal QCA.

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1. Introduction

In contemporary innovation research, two streams of literature present the explanatory ontology of market-wide innovation mechanisms and predict the effects thereof on the entire business ecology. The first stream involves *business model innovation*; this theme has been particularly noteworthy in the literature on entrepreneurial management since the past decade. The key underlying principle of the business model herein is the portrayal of a hypothesized business value proposition and its delivery in a structural business system. As such, reconceiving or restructuring the structural elements can offer essential insights for uncharted business value creation. These structural elements comprise key business actors and stakeholders, processing activities, resources, and anticipated market demand (or revenue). In theory, radical changes of the key structural elements can even create an entirely new market (Calia, Guerrini, & Moura, 2007; Chesbrough & Rosenbloom, 2002; Osterwalder & Pigneur, 2010).

The second stream of literature deals with technological management corresponding with the concepts of business model innovation from the perspective of technological disruption. In this case, a newly introduced technology with non-primary business values could gain a niche market in the initial stages, but overpower and defeat established technologies in later stages (Adner, 2002; Christensen, Anthony, & Roth, 2004). The non-primary business values are often inferior and neglected by business incumbents at the time of market entry. However, their continuous evolution can reshape business values with greater competitiveness, and thus dominate mainstream market preferences in future (Sood & Tellis, 2005).

Nevertheless, the two streams of literature above employ distinct logic when predicting the potential of business innovation. However, two broad theoretical issues arise:

First, defining business innovation—or the innovativeness of a new business—is challenging because of the tautological issues of causes and effects inherent to an innovation process (Zott, Amit, & Massa, 2011). In business model innovation, the focus is on causative properties, such as new functionalities, value standards, and ownership of an innovation. Contrariwise, technological management concerns the consequential effects that business actors and users may experience from new innovation values. Hence, the two streams of study imply different assessments and predictions of business innovation (Clauss, 2016). The logic of business innovation should be readdressed to offer convincing predictions or choices of prospective business models.

Second, the sources of business model innovation are ambiguous, and their effects are unclear. Within an innovative business model, model elements such as business actors, agents, value creation platforms, resources, and governance affect new business values in multi-morphological forms. Changes in one model element cannot guarantee innovative business values, whereas changing the very configuration of the model element may do so (Woodside, 2013, 2017). New processing agents and technological development, or even the emergence of market needs, cannot be judged as discrete, prominent sources for innovation. In the extant literature, Crossan and Apaydin (2010) and Sood and Tellis (2011) identified three main sources (*domains*) in which business model innovations can occur: technological innovation domain (new performance), actor–agent–user innovation domain (new organization relationship/new value chain), and market innovation domain (new definition of value proposition). However, the method to attribute these three domains to business model innovation is still under scrutiny (Foss & Saebi, 2017).

To address the two issues highlighted above, we redefine the logic of innovation for business values and reconceive new variables to assess the causes and outcomes of business model innovation. We also extend four questions for predictive purposes: 1. How can a new business model redefine business values with respect to the entire business ecosphere? 2. Whether or how can a business model innovation dominate a market? 3. What leads a business model toward innovation? 4. Given an innovative business model, how can business actors predict the new model's consequences? To answer these questions, we conduct an empirical survey and design a new method of analysis.

First, we revisit the logic of value proposition that underpins business model innovation and identify a set of predictive variables and hypotheses for analysis. The primary variables include innovation domains, innovation dependence structures, dominance of business values, innovation dynamics, and innovation resource-agility.

Second, we collect data from four technology markets in the international textiles industry, and then model the effects of these primary variables over the time span of the business model innovation.

Third, the methods of measurement and analysis draw on two discrete analytic techniques: Cox analysis and temporal qualitative comparative analysis (QCA). The former estimates the variable properties based on time-driven variance theories, whereas the temporal QCA identifies the antecedent–outcome relationship using set-theoretic analysis. Both techniques explain the temporality properties of testable variables. The implications and complementarity of the two techniques are explained in detail, followed by a discussion of the final analytic results.

2. Theoretical framework

2.1 Value proposition logic in business model innovation

Within this decade, the discussion on and theories of business models have become more visible in the literature on technological management and entrepreneurship (Osterwalder & Pigneur, 2010; Spieth, Schneckenberg, & Ricart, 2014; Storbacka, Windahl, Nenonen, & Salonen, 2013). We also find evidence of the private and public sectors putting these theories into practice (Müller, Buliga, & Voigt, 2018; Shafer, Smith, & Linder, 2005). In most cases, at least four categories of model elements help illustrate business models: product concepts (value propositions to users), business process channels (mechanisms of delivering values in hypothesized business systems), actors, users and agents (value networks to co-define the final business values), and cost-and-benefit (resources and gains to sustain model performance). However, this ontological description is inadequate for management to address questions about the predictive purposes of business model evolution.

To illustrate the above points, we refer to the cases of digital textile printing technologies that have existed in markets for thirty years. We find that business actors and consumers do not consider such technologies to be “inventive.” However, because of the continual breakthrough in ink compositions and print-head designs at the micron level, the digital printing process can now be applied almost to all types of substrates for fashion, home textiles, signage, construction materials, and electronic circuits at remarkably high speed and resolutions. These technologies can also create products in much reduced batch sizes and efficiently disrupt the conventional printing and finishing technology markets. Today, such technology envisions the greatest potential for production reshoring and personalization of end goods. The nature and size of the business ecosphere is changing dramatically, elevating business values to the global level. This case illustrates the value proposition logic in business model innovation.

Most times, firms apply different processes, skills, and technologies to produce a variety of value-differentiable products or services. In principle, any new ideas of product features, functions, and performance can be inventive—or technologically innovative—but may not be considered business model innovations. Sawhney, Wolcott, and Arroniz (2011) contend that myopic management that neglects focus on new value cannot lead to innovation for customers. They proposed a practical framework called an “innovation radar” to assess innovation through 12 dimensions. Whether a business model is inventive or innovative is determined by the significance of the newly created business values that reshape existing business realms (Chesbrough, 2010; Zott & Amit, 2010). Based on this logic of value-driven business model innovation, this study defines a business model as a platform built on a discrete field of technological knowledge and factor inputs through which firms develop and manufacture a specific category of values to serve a discernable market. Based on this definition, we propose a schema to explain the theories of value proposition in business model innovation and lay a foundation to test and predict the hypothesized outcomes of business model innovation. The variables in this predictive schema include business model dependence structure, business value dominance, innovation domains, innovation dynamics, organizational resource capability, and action agility. We explain these variables in detail in the following subsections.

2.1.1 Predictive schema

In the logic of a value-driven business model, innovation redefines a business value boundary or disrupts an existing value boundary. The potential of business model innovation should be assessed based on the logic of value creation and transformation. Grounded in this premise, we reconceive a schema with a set of hypothesized variables that help predict value changes in business model innovation. These hypothesized variables are explained below.

Innovation domains: As explained in the example of textile processing innovation, business model innovation can occur within any knowledge domain—from the realms of science and engineering to those of management. However, knowledge innovation cannot be interpreted equivalently to new business values. We construe the domains of business model innovation based on a new value proposition and new value boundary. Three domains of business model innovation are specified—process, organization, and market—and in each domain, innovation generates the effects of value discretely.

Process innovation occurs when a new form of business process can effectively challenge the existing, applied process. This innovation domain emphasizes the efficiency, or responsiveness, with which business actors can outperform one another (Levinthal, 1998).

Organization innovation occurs when a business model innovation leads an organization to stronger positions and larger market shares. This innovation domain implies market acceptance and dominance—That is, organizations can better use resources and respond to rivalry in markets with more agility (Achtenhagen, Melin, & Naldi, 2013).

Market innovation occurs when a business model innovation entails competent business actors to win leadership of and gain supremacy over a market. The business actors can potentially capture the other "competence-relevant" markets (Kilkki, Mäntyläa, Karhua, Hämmäinena, & Ailistob, 2018). The innovation enhances competition in and increases dominance over more markets.

Based on the effects and boundaries of business value, we define the innovation domains as the main variables for estimating business model innovation.

Business dependence structure: Business actors, users, and relevant stakeholders co-define and co-create the final business value in a hypothesized business model. Such a model conjures an analogical business process that passes desired resources and commitment to networked business actors. The business actor should coherently assure both performance and interests of other dependent actors, or *vice versa*. Therefore, a business model will not be successful without well-defined interrelationships and dependence among actors—that is, a coherent transfer of values and interests. In such a case, a business model innovation implies a restructuring of the existing structural dependence that aligns it with the new value and interest propositions. Successful business model innovation should trigger a more constructive change of interdependence (Kim & Lui, 2015). Being aware of the roles and contributions of networked members implies the quality of the constructive structure when new business model values are being developed (To, 2016). Hence, the predictive schema defines a business dependence structure as a variable that measures and predicts business model innovation.

Business value dominance: From the view of organizational learning, we know that organizational knowledge, prowess, or even corporate prestige are strategic values that help firms dominate markets (Lloria & Moreno-Luzon, 2014; Nonaka, 1994). Business actors who can dominate markets with mainstream business knowledge and capabilities are better placed to defend their market shares or to build game rules that protect their business interests (Baraldi, Gressetvold, & Harrison, 2012; Leonard, 1995).

Business value dominance determines the performance of competition. However, in business modeling innovation, the management prioritizes the conditions for value proposition and co-creation (Lindič & da Silva, 2011; Payne, Storbacka, & Frow, 2008). An innovative business model leads to dominating values only when a new concept or breakthrough can be exploited to expand business values or attract more participation by business actors, agents, users, and stakeholders. Such a business model innovation generates the diffusion processes of new value co-creation. This co-created value diffusion could also indicate a firm’s likelihood of attaining market dominance. Contrariwise, a business value can only be secondary when the corresponding business model cannot convene more business actors to participate. Hence, this predictive schema defines business value dominance as a variable to signify the business value extension and diffusion. An innovation of a business model would then mean creating a larger and/or better participatory value.

In most cases, participatory actors anticipate the growth of business interests and reward redistribution through effective model business innovation. In economic terms, a desirable change of value dominance indicates a higher output level in the value production system. A larger co-created value becomes an incentive; it drives business model innovation. This schema defines the positive marginal gain of all business actors and users to measure whether a business model innovation is valid.

Innovation dynamics: The literature on innovation and technology management attributes business model innovation to a number of market opportunities and threats such as emergence of technology disruptions, competition across different technology industries, regulatory changes, and market turbulence (Lichtenthaler, 2009; Huarng, 2013). All these opportunities and threats stem from uncertainty in technology and market continuities (Hung & Chou, 2013). In terms of technological disruption, technology innovation will trigger unexpected and fast results; it will eventually suspend customer preferences in a well-established market. Its effects can even propagate across other technology-related industries (Achtenhagen et al., 2013; Sood & Tellis, 2011). However, an innovation may disrupt technological business in one industry, but not in another industry. Business actors should not simply explain business model innovation based on the dynamic effects of techno-economic changes, but also based on the momentum of environmental and social changes.

An emerging innovation value does not arise to immediately replace incumbent businesses; rather, it will exert its influence over time (Willemstein, van der Valk, & Meeus, 2007). Business model values that stem from these three dynamic components can be complementary or competitive at different points in time. This predictive schema defines business model innovation as a platform for dynamic responses to chained, temporal effects arising from external and internal changes. The schema further identifies three dynamic responses closely relevant to business model innovation, namely, techno-economic, environmental, and social dynamics.

Innovation resource and agility: The literature on management conventionally assumes that organizational resources and capabilities affect business model innovation (Zott & Amit, 2007). Logically, innovation should meaningfully deploy and reconfigure discrete resources in dynamic organizational contexts (Teece, 2007). The innovation resources should be heterogeneous across business innovation cases and incongruent with varying innovation orientations, scales, and interests (Barreto, 2010). Measuring the empirical effects of the resource on innovation involves instability. However, Eisenhardt and Martin (2000) argue that innovation resources can exhibit commonalities across innovation cases and organizations (analogous to the so-called “best practices”). The justification of the commonality is based on a view that innovation resources, in line with agile actions, represent the propensity of business actors to sense opportunities or threats, and thereby adopt relevant competencies that can target the envisioned innovative business values. Hence, this predictive schema defines innovation resource-agility as a key variable to reflect innovative business value creation and diffusion.

2.1.2 Research hypotheses

To answer whether business model innovation can redefine business values as a competitive response to the entire business system, we examine the likelihood of new business models challenging and overturning the business dominance in incumbent markets.

When developing an innovation in the technological process domain, business models are likely to focus on improving business functions to change the value chain operations (Willemstein et al., 2007). For an innovation in the organization domain, business actors are likely to reconfigure organizational relationships or remodify partnership commitments to capture a larger market share (Tacer, Ruzzier, & Nagy, 2018). Extending this logic to the market domain innovation, all business entities and their interacting structures should be rebuilt and retested iteratively until the innovative business model can gain a position in new market realms. These arguments suggest that:

Hypothesis 1 Business model innovation is relevant to the destruction of business values in incumbent business networks and overturning respective entity dependence structures.

To answer whether or how business actors can dominate markets through business model innovation, we test the dominance that a business actor can exploit to call for larger value creation and greater value boundary during business model innovation (Lloria & Moreno-Luzon, 2014). For better business performance and market reinforcement, business actors would devote most of their resources and capability to incumbent business models (Teece, 2007). When these actors dominate a sizable market share, the business model innovation would be routinized or kept in the process domain innovation. Such established routines do not encourage much exploration of unknown, innovative values or of unfamiliar markets with high uncertainty.

Hypothesis 2 Incumbent business actors favor innovations in the process/organization domains, which have advantageous business value dominance.

Continual innovation of business models can help perfect business values and reshape an entire business ecosystems. New entrants with less dominant market positions manage to occupy niches with novel dimensions of business values and expect to eventually outperform business incumbents (Balboni, Bortoluzzi, Pugliese, & Tracogna, 2019)

Hypothesis 3a New business entrants favor market domain innovation.

Hypothesis 3b New business entrants sustain better through innovating secondary (non-dominating) dimensions of business values.

To answer what leads to business model innovation, we examine the business contingency for changes; in other words, the responses to market dynamics become the incentives for changes of business concepts (Lichtenthaler, 2009; Huarng, 2013). For incumbent business actors, an innovation entails better operational efficiency and market reinforcement. For new business entrants, it is a new platform to challenge incumbent businesses. In each situation, business actors and even customers ought to be aware of the changes in existing market deficiency (e.g., obsoleting product functionalities), inefficiency (e.g., too much processing costs), environmental concerns (e.g., inclusion of ecological cost), or social aspects (e.g., better corporate social accountability). A business model innovation with better responses to market dynamics can mediate market recognition and acceptance (Kilkki et al., 2018; Scridon, Achim, Pintea, & Gavriletea, 2019).

Hypothesis 4 Responses to market dynamics positively mediate business model innovation.

Under sound business model development, the management can identify the appropriate resource capabilities as well as agile actions to be employed in a business process, which can, in turn, equip business actors with better competitiveness that would enlarge or help confront the incumbent market (Teece, 2010; Zott & Amit, 2007). In most cases of market domain innovation, the initial innovative products are not feature-rich and focus primarily on a few dimensions of business values. However, after receiving market feedback, the business innovation model modifies the products as well as itself. Such changes will discontinue the capabilities and agilities of incumbent business players and set the business value onto a new path. Unless the business capacity, that is, market boundary, is restricted (e.g., by regulation or customer loyalty), business model innovations that can convene more value in markets have more advantages to sustain the business in long run (To et al., 2018).

Hypothesis 5 Business model innovation explains shifts of organizational resource capabilities and agility actions over time. Innovative business models claim higher levels of value provision in markets.

Controlled variables: To estimate the hypothesis tests, we conduct an empirical analysis of the textile processing industries now challenged by industrial digitalization (Ko, To, Zhang, Ngai, & Chan, 2011). New market players from cyber-technology realms confront incumbent business actors with two extolled business values: processing site reshoring and product personalization (McCarthy, Puffer, & Lamin, 2018; Ribau, Moreira, & Raposo, 2019). In the hypothesis tests, we take the two value dimensions—propensity to reshoring and value personalization of finished goods—as our controlled variables.

The propensity to reshoring is the capability of an innovation to promote the relocation of processing systems back to consumption endpoints. In the last three decades, globalization has emphasized the economic consideration of factor input optimization, which has polarized a substantial amount of manufacturing in developing countries as well as consumption in developed ones (Li, Huang, Xu, & Yu, 2018). However, this polarization has also led to complaints of environmental and social sustainability in every aspect. Processing system reshoring can significantly reduce the processing scales, but still maintain the factor input efficiency as well as use less nature resources. The value personalization of finished goods involves enhancing customer experience by tailoring finished products or service. With the advent of industrial digitalization, personalization of goods and services has become more cost-and-time responsive. Hence, the predictive schema proposes the two value dimensions above as the controlled variables.

In summary, the schema explains five value-based innovation variables, namely, the domains of innovation, business dependence structure, business value dominance, dynamics of innovation, and innovation resource-agility. The predictive schema also proposes two controlled variables, propensity to reshoring and value personalization of finished goods, to estimate the results. Based on this premises, the schema proposes a set of hypotheses that support the prediction of business model innovation and the respective innovation potential.

3. Method

3.1 Sample cases

We observe business model innovation in industrial market contexts. The data can estimate a broader scope of managerial implications for managing business model innovation. First, the concerns of business model innovations change throughout all value chains. Such innovations run with sizable investment too. The returns also spread over a longer span of time. The data provided in industrial markets can better reflect the dynamic characteristics of business model innovation over time.

Second, the conventional view of innovation dynamics is driven by techno-economic advancement, which focuses on the use efficiency of factor costs and market responses. However, in this millennium, *sustainability*—including every aspect of environmental and social effects—becomes more central to innovation decisions. The observation of industrial markets allows a thorough examination of all three concomitant innovation dynamics at the earliest phases of business model changes.

Third, besides the variables to be analyzed, the data of the controlled variables can be better identified and measured. For instances, in this study, the hypotheses tests identify two controlled variables—propensity to reshoring and value personalization of finished goods. Considering the requirements of our analysis, the data collection processes are still manageable, both in terms of consistency and data integrity.

Throughout the field survey, we measured four closely relevant technology markets in the textiles industry: innovations in digital textile printing, wide-format digital printing, direct-to-garment digital printing, and textiles finishing technologies. Although these technology markets are "close" in proximity within the global fashion and textiles value chains, their business model innovation behavior—that is, competition characteristics, innovation realms (scientific and engineering disciplines), stakeholders, and business strategies—are remarkably distinctive. Table 1 reports the sources and profiles of the sample cases in the four markets relevant to this study.

[Table 1 here]

We used the industrial survey to collect the primary data, which span the five summer months of 2018. The survey sorted the prospective respondents from the membership lists of international trade and business federations, references from trade agents, publicly funded innovation centers, and trade councils. The survey also collected secondary data from technical and trade journals, papers from public institutions, annual reports on company profiles, and statistics from consultancy companies.

We compiled and targeted 131 companies for data provisions through the survey at first and finally consolidated 474 innovation factsheets (i.e., cases) in 61 companies. Parts of the data in individual sample cases were provided by the affiliated business agents of the companies. The measured data do not represent all phenomena in the international printing businesses. However, the scope of measurements should adequately represent the realities of the business model innovation. Table 1 reports the profiles of the sample cases. In summary, the survey recorded sample cases in 61 companies from 24 business territories for the latest five years, censoring the period from 2013 to 2018.

We observed the three primary aspects of innovation dynamics: techno-economic performance, environmental management, and social accountability. Table 1 distinguishes these innovation dynamics using the superscripts of “a,” “b,” and “c,” respectively. As anticipated, the companies claimed their key concerns on techno-economic performance. However, the environmental and social innovation aspect are still significant. In each column of the subtotal in Table 1, the numbers marked with the superscript “α” refer to the innovations that focus on mainstream business values in markets. The number of observed cases is 313 (66%). The numbers with the superscript "β" refer to innovations serving markets by secondary and radically developing business values. The number of observed cases is 162 (34%), reflecting a relatively high proportion of innovation cases related to non-mainstream, less dominating innovation concepts. This explains why the technology markets evolve their business models so radically and aggressively (In the next subsection, we will evaluate and represent the data using time-dependent Cox analysis).

To verify the sample cases, we invited three independent reviewers (industrial practitioners working in the fields for more than ten years) to participate in the survey and elicited their views and judgment of the innovation cases and results. These expert judgments helped us verify the accuracy and consistency of the data.

3.2 Cox analysis and qualitative comparative analysis (QCA)

We apply two discrete analyses to represent the hypothesized variable data: Cox proportional hazard estimation and set-theoretic QCA. The Cox analysis explains the cases based on time-driven variance theories; it tests the stated hypotheses by predicting the "destructed" time of the business model during the innovation process (Cox & Oakes, 1984; Therneau & Grambsch, 2000). The QCA identifies the configurational antecedent–outcome relationships in the dynamic contexts of business model innovation (Ragin, 2008). It also analytically considers temporality.

The two analyses above belong to two different data representation paradigms. However, together, they can corroborate empirical properties, where neither can fully envisage the theoretic logic that underpins business model innovation.

In other words, we estimate the properties of the variables with respect to the observed timeframe using Cox analysis. This type of analysis—also known as survival, time duration, or hazard analysis—can model data wherein the dependent variable is the time that has elapsed from one specific time point to a time point at which a change of event or interests has occurred or "hazarded" (Blossfeld, Hamerle, & Mayer, 2014; Park & Russo, 1996). The result of the analysis is a prediction function that estimates the chances of the event or interests occurring over a given time. In this study, we estimate whether incumbent and emerging models can sustain over time and whether the incumbent business model would change when a business model innovation enters into competition. In the Cox analysis, the business models are "hazarded" by innovation.

Set-theoretic comparative analysis is also called QCA or qualitative configurative analysis. The paradigm posits that a set of antecedent combinations (models in various configurational forms) can isomorphically lead to an expected outcome, that is, a business model innovation destructing incumbent business values (Misanyi et al., 2017; Ragin, 1994, 2008). The method focuses on the predictive purposes of the "recipe" formation for business model destructing, that is, the conditional configurations of the dynamic variables leading to business model innovation (Jiménez-Jiménez & Sanz-Valle, 2011; To, Au, & Kan, 2019).

3.3 Cox analysis

We develop a test model characterized as follows: A business model dynamically responds to some challenges in markets, possibly because of "unsatisfied" demands or the evolution of any technological, environmental, and social aspects. Alternatively, some new business actors who are more sensitive to innovation potential develop innovative business models. Anticipating potential threats from this innovation, incumbent business actors review the existing—perhaps dominating—business models to secure themselves from challenges posed by these new entrants. During such courses, incumbent business models can no longer survive; in other words, the business models are destructed (or hazarded in Cox terminology) and conflated with the innovation factors of 1. dependence structure changes, 2. competence improvements (for resource deployment and action agility), and 3. changes in the primary (mainstream) business values. In Cox modeling, innovations destruct value propositions in incumbent business models—This phenomenon is a dynamic response to a set of exogenous variables of techno-economic, environmental, and social changes. The effects of innovation can be confined within the domains of technological processes, organizations, and markets. In this study, the Cox model estimation is limited to the industrial business contexts in which innovations destruct incumbent business model in an especially short time. The Cox analysis models the destructing function with the variables as follows:

$$h(t) = h_o(t) \times \exp(\beta_1 Inn_{dom_i} + \beta_2 Inn_{valu_i} + \beta_3 Inn_{dyn_i} + \beta_4 Depend_{stri} + \beta_5 Resource_i + \beta_6 Agility_i + \beta_7 Reshore_i + \beta_8 Personaliz_i)$$

In the above equation,

- $\mathrm{h_o(t)}$ is the baseline function, corresponding to the value of the business model destruction, if all the variables are 0 in the beginning;
- $\mathrm{Inn_{dom_i}}$ is the quantity variable for innovation domains, which is measured on a five-point Likert interval scale, where "5" indicates that an innovation case occurs in the types of innovation domains to the highest extent, whereas "1" indicates the least extent. An innovation can occur across markets (Inn_dom_M), within organizational levels (Inn_dom_O), and within technological processes (Inn_dom_P) at the time of launch;
- $\mathrm{Inn_{valu_i}}$ is the quantity variable for dimensions of innovation business value, which is measured on a five-point Likert scale, where "5" indicates the highest business value in a business model innovation, whereas "1" indicates the least value. A business model mainly proposes two dimensions of business values: an innovation enhances an existing, mainstream business value, that is, the primary value (Inn_valu_P); and the innovation aims at new effects on markets using non-mainstream, emerging business values, that is, the secondary (very often less superior) values (Inn_valu_S);

- $\mathrm{Inn}_{\mathrm{dyn}_\mathrm{i}}$ is the quantity variable for the dynamic response, which is measured on a five-point Likert scale, where "5" indicates that a business model innovation can respond effectively to markets to the highest extent, whereas "1" indicates the least extent. An innovation can concur with a new business model for environmental performance (Inn_dyn_E), social performance (Inn_dyn_S), and for techno-economic performance (Inn_dyn_T);
- $\mathrm{Depend}_{\mathrm{str}}$ is the category variable for dependence structure changes in a new business model, which is 1 if an innovation results in substantial changes of relational structure among business actors, users, and stakeholders, whereas 0 if the innovation does not do so;
- $\mathrm{Resource}_\mathrm{i}$ is the quantity variable indicating efficiency of resource deployment, which is measured on a five-point Likert scale based on respondents' views and opinions on an innovation;
- $\mathrm{Agility}_\mathrm{i}$ is the quantity variable indicating agility and mobility of business actors to enact an innovation, which is measured on a five-point Likert scale based on respondents' views and opinions on an innovation;
- $\mathrm{Reshore}_\mathrm{i}$ is the controlled category variable of potentiality for an innovation leading to process reshoring, which is 1 if the innovation intends for reshoring operational processing, whereas 0 if the innovation does not do so;
- $\mathrm{Personaliz}_\mathrm{i}$ is the controlled category variable of personalization value from an innovation, which is 1 if the innovation intends for value personalization of finished goods, whereas 0 if the innovation does not do so; and
- The subscripts i and t are the sample cases and timing of business model innovation, respectively.

3.3.1 Results

Visual diagnostics of proportionality assumption: We collected the sample cases from international technological markets. The companies developed and produced emerging technological capital (i.e., printing systems) to industrial processing companies (i.e., printing mills). These companies needed to interrupt and redesign their process structures and activities to deliver new values to end markets. Conventionally, business incumbents are mainly located in industrialized countries, whereas new business entrants come from spin-off subsidiaries of large corporates or newly emerging industrial areas.

The Cox analysis measures the business model innovations and the respective destructing effects on incumbent business over the latest five years, from 2013 to 2018. We thus estimate the destructing functions (i.e., hazard curves in Cox terminology) and ratios using SPSS v.25. To validate the Cox model variable measurement, we checked the partial residuals of the variables. The proportionality of the Cox models assumes that the residuals are independent of time. A non-random pattern of residuals over the censoring time evidences the violation against the Cox's proportionality conditions. This leads to the individual destructing functions crossing each other significantly. Figure 1 illustrates the graphical diagnostics of β_i residual patterns insignificantly varying over time. The patterns and fit lines of each variable are not evidently violating the proportionality property. The validity is thus assumed.

[Figure 1 here]

Analysis of hypotheses: The four technology markets exhibit an unprecedented and overwhelming trend: The innovative businesses values redefine market boundaries radically. These new boundaries, in turn, trigger another new wave of dynamic innovation. Table 2 reports the descriptive statistics of the collected data. Of all the four markets, the average percentage of destructed business models is 26.6%. The phenomenon is particularly obvious in the wide-format digital printing business (33.6%), indicating that one-third of the business model concepts proposed in incumbent business models would be abandoned over the five years.

[Table 2 here]

Table 3 reports the test results of the Cox analysis. The Cox model is significantly representative (ρ-value = 0.00, *minus-2 Log likelihood* = 2602.6, and χ^2 = 314.9). Among the numerical variables, the secondary business value dimensions (*Inn_valu_S)*, resource capability (*resource_cap*), action agility (*agility)*, technological processing innovation domain (*Inn_dom_P)*, and environmental/ social/techno-economic innovation dynamics (*Inn_dyn_E/Inn_dyn_S/Inn_dyn_T)* are significant (ρ-values ≤ 0.005). Particularly, the effect coefficients of the three innovation dynamics—innovation responses to environmental *(Inn_dyn_E)*, social *(Inn_dyn_S)* and techno-economic *(Inn_dyn_T)* dynamics—are all remarkably significant (ρ-values = 0.000, 0.030, and 0.000, respectively). The coefficients of the category variables (i.e., structural dependence changes, innovation domains, and innovation dynamics) and the controlled variables (i.e., processing reshoring and finished goods personalization) are negative, implying that the factors have negative effects of destructing incumbent business models. The variables of corporate agility and resource capability are also two key factors for innovating business models in the industry technology markets (both ρ-values = 0.000). The destructing ratios (or censoring ratio in the SPSS term), *exp(β)*, are the effect sizes of individual variables. For instance, the variable of structural dependence changes *(Depend_str)*, which has a ratio at 1.092, implies an increase in the destructing effect by a factor of 0.092 or 9.2%. The effect is neither strong nor significant. The variable of secondary dimension of business value *(Inn_valu_s)* has a destructing ratio of 1.117, which implies that an additional time unit (monthly based) increases the innovation destructing effects on incumbent business models by a factor of *exp(β)* =1.117 or 11.7%, given all other variables are constant. The innovation in the secondary dimension of business values exhibits its marginally significant effects on business model evolution (ρ-value = 0.05).

[Table 3 here]

The hypothesized tests explains the entire innovation ecology. Figure 2 illustrates the graphical results of the survival and destructing function curves for the four technology markets. For each market, the function curves are further estimated in the three innovation domains (i.e., market, organization, and technological process). The estimated Cox functions in the individual market follow similar patterns, but the cumulative destructing (hazard) ratios are different. The vertical axes indicate the cumulative destructing ratios, implying the effect sizes of the variables (i.e., the exponentiated coefficients) of the business model destructing at the points in observation time. The destructing ratios of the business models in wide-format digital printing markets are relatively higher than those in the other markets. The ratios imply higher risk of destructing for incumbent business model values. The direct-to-garment digital market has the least cumulating destructing effects over time.

[Figure 2 here]

Hypothesis 1: We hypothesize that business model innovation is positively associated with the destruction of incumbent business networks and overturning dependence structures among business entities. The hypothesis test implies that business model innovation is concomitant with the destruction of incumbent business value offers. The relationships between business actors, users, and stakeholders would then be restructured into new relationships. The destructing effect is positive; however, the changes in the business dependence structure ($Depend_{str}$) can only induce weak effect size on incumbent business models and values ($\beta = 0.088$; $e^{\beta} = 1.092$); the ρ-value of 0.595 indicates its insignificance on the destructing function (standard error, $\sigma = 0.165$, with 0.79 and 1.51 as the 95% lower and upper confidence interval bounds).

Hypothesis 2: This hypothesis predicts that incumbent business actors focus on the primary dimension of business value, that is, mainstream business concepts and values in markets. The innovation in mainstream business values intends to reinforce the market acceptance of this value. The functionality performance is the key innovation concern. This is particularly obvious when an organization attains successful rewards from incumbent business models. In the Cox analysis, the variable of technological process innovation domain (*Inn_dom_P)* is significant, with $\beta = 0.282$, $e^{\beta} = 1.326$, and ρ-value = 0.000. The innovation in the technological process domain can induce business model destruction by a factor of 1.326 per monthly time unit, given all other variables are constant. The variable of primary business value (*Inn_valu_P*) is not significant during business model innovation, with $\beta = -0.102$. Moreover, $e^{\beta} = 0.903$ indicates an effect size of 0.9 or 10% reduction on the destruction. However, the secondary dimension of business values is significant, with $\beta = 0.111$, $e^{\beta} = 1.117$, and ρ-value = 0.05. These Cox coefficients imply that incumbent business actors favor innovation in the technological process domain, but not necessarily for the primary, dominant dimension of business values. The secondary dimension of business values *(Inn_valu_S)* that are emerging radically change in the markets; they are key considerations for business model innovation.

Hypothesis 3a: Table 3 reports the insignificant effects of innovation in the market domain (*Inn_dom_M)* on business model evolution, with the coefficient $\beta = 0.031$ and ρ-value = 0.589. The results of the Cox analysis do not support the estimation of Hypothesis 3a. Conventionally, the entrepreneurial and innovation management holds that new business entrants are sensitive to market-wide potential or ephemeral market niches, so they conceive innovation at the market domain level. New entrants build their business model through trial-and-error, which requires continual review of business realities. It then requires businesses to adjust their responses to competitive challenges. The path of business development is similar to how the effectuation concept explains an entrepreneurial process (Sarasvathy, Kumar, York, & Bhagavatula, 2014). However, the Cox analytic results in this study do not consistently predict this theory. Instead, technology market business actors are still concerned with innovations in the basic techno-economic domain ($\beta = 0.282$, $e^{\beta} = 1.326$, and ρ-value = 1.326).

Hypothesis 3b: Hypothesis 3b estimates that new entrants who can anticipate some secondary dimensions of business values are more keen on entering into competition, and they even perform better. However, the variable of secondary dimension of business value *(Inn_valu_S)* is significant (ρ-value = 0.030 and $e^{\beta} = 1.144$) to business incumbents and entrants. The Cox results estimate no particular advantages for new entrants to adopt secondary, radically changing business model values. Figure 3 illustrates the destructing functions stratified by the two groups of market players: New entrants would face a relatively higher destructing ratio curve than business incumbents over the studied period. The stratified Cox functions return a higher χ^2: 3364 (initial non-stratified $\chi^2 = 2955$). The stratified functions do not estimate better than the initial functions, possibly because of unobserved heterogeneity. Thus, Hypothesis 3b is not evidenced statistically.

[Figure 3 here]

Hypothesis 4: This hypothesis predicts that the innovation dynamic responses (Inn_{dyn_i}) destruct incumbent business model values. The Cox analysis results support this hypothesis. All the three types of innovation dynamics (i.e., environmental, social, and techno-economic dynamics) induce increase existing business model destruction (the destructing ratios, $e_3{}^{\beta} > 1$, with $e_3{}^{\beta Inn\_dyn\_environ} = 1.323$, $e_3{}^{\beta Inn\_dyn\_social} = 1.144$, and $e_3{}^{\beta Inn\_dyn\_techno\text{-}econ} = 2.301$). Among all the hypothesized variables, the techno-economic dynamic response ($Inn_{dyn_{techno\_econ_i}}$) explains the most significant effects on the Cox function, with $\beta = 0.833$, ρ-value= 0.000, $e^{\beta} = 2.301$, and 95% lower and upper confidence interval bounds (1.997 and 2.652). The results imply particularly high destructing effects on incumbent business models and values. All three innovation dynamics predict strong relationships with business model innovation ($\beta_3^{Inn\_dyn\_nviron}$ = 0.28 $\beta_3^{Inn\_dyn\_social}$ = 0.135, and $\beta_3^{Inn\_dyn\_techno\text{-}econ}$ = 0.833).

Hypothesis 5: Based on the hypothesized theories, the business models of organizations should concur with the resource capability and action agility. A business model innovation can change the resource capability and agility for more value proposition. The Cox analysis results support Hypothesis 5. In conventional management, competition results in exploration of better processing efficiencies or administrative effectiveness. Since the last decade, organizations have become more aware of the types of sustainability requirements that concern the use of economic and nature resources. Business actors should also consider social development such as human health, social class mobility, and work dignity. They should equip themselves with sufficient resource and management capability to deal with the necessary business model innovations. They should also be alert to business uncertainties and take agile actions whenever necessary. The resource-based organization theories echo this view and identify a number of resource capabilities and agilities in highly dynamic business climates (Engel, Kaandorp, & Elfring, 2017). The Cox results estimate the coefficient of β^{resou_cap} = 0.360, with $e^{\beta resou\_cap}$ =1.374, and of $\beta^{agility}$ =0.319, with $e^{\beta agility}$ = 1.374 (both ρ-values = 0.000).

3.3.2 Predictive power

Figure 4 illustrates the graphical plot of the Receiver–Operating–Characteristic (ROC) curve estimates of the Cox analysis (Gönen, 2007). In principle, the prediction is more accurate when the curves of the estimating variables move closer to the top-left area in the plot. The areas-under-the-curve (AUC) indexes the predictive power of the Cox estimation to discriminate those business model values that are positively destructed by innovation from those negatively destructed by innovation. A truly ambiguous prediction, that is, no better than any to predict innovation effects, has an area of 0.5. A perfect prediction will show an area close to 1.0. Table 4 reports the AUC tests on the variables' results. The variables of innovation for secondary business values (*inn*$_{valu\text{-}S}$) and value personalization of finished goods (*Personaliz*) weakly predict the innovation destructing effects on business models (the AUC = 0.5, Sig = 0.987 for innovation for secondary business values; and AUC = 0.542, Sig = 0.428 for value personalization). All other variables provide significant predictive accuracy for the Cox analysis.

[Figure 4 here]

[Table 4 here]

3.3.3 Pattern of business model innovation

Table 5 reports the estimated durations (time before destructing) of business models in the four industrial technology markets. In the table, the estimated durations are further stratified according to the types of domains in which the innovations occur. The overall average duration of business models in these four markets is 40.55 months out of the censoring period of 60 months. The business models rapidly change in approximately three years. In the domain of technological process innovation, business models for the direct-to-garment digital printing have the smallest duration mean (17.7 months). Contrariwise, the business models for the conventional textile finishing innovation have the largest mean (49.07 months). As mentioned in section 2.1, the digitalization of textile printing and finishing processes allows feasible relocation of processing sites close to consumer end markets. Such operation reshoring would become more intensive and prevailing, leading to short durations for incumbent business model. This is contrary to the case of conventional finishing, which still prefers to maintain steadier business models in global supplies.

[Table 5 here]

The results explain some patterns of business model innovation that are noteworthy. First, in view of the destructing rates, the business model innovations have some special implications. Figure 5 illustrates the innovation destructing function curves—that is, the means of the variables of destructing functions—on the business models. The destructing effects in the wide-format digital printing and textile finishing technologies are particularly significant at the end of the censoring period—nearly double of those in the digital textile printing and direct-to-garment digital printing markets. Although the four market are technologically relevant, the destructing functions are still discernably different.

The four destructing function curves are non-linear and progressively significant. Particularly, the wide-format digital printing has extended its applications from conventional textiles toward some other businesses such as finishing material (e.g., flame-retarding agents, light-reflecting agents, and bio-medical micro-capsules) that can be printed on function-specific textile substrates, metal-based coating, metallized substrates for construction materials, and signage with electro-ink. All these functions and end uses are radically expanding. Such phenomena echo the theoretic schema of value-based business model innovation, which predicts the shifting and reshaping of business models in new business ecospheres.

[Figure 5 here]

Second, of the two types of business players, business incumbents had a higher destructing percentage than business entrants did (see the descriptive remark in Figure 3). The proportion of destructing incumbent business models should not be less than that for new business entrants. However, the Cox analysis results as illustrated in Figure 3 indicate that the destructing rates are significantly different over the observation period. This destructing rate implies the evolution of the business model to respond to dynamic business ecosystems over time. As shown, compared with business incumbents, business entrants are predicted to have a higher destructing rate of business values because of innovation. New business entrants are inclined toward innovation because they seek to improve initial non-dominating, secondary business values. These secondary business values need continual improvement until new business values and concepts can prevail in the market more effectively. Business entrants with new business model values have a higher destructing rate for business model values.

Third, innovations do not persist smoothly over time (see Figure 5), but still follow a pattern of cumulative distribution. The Cox functions of wide-format digital printing and conventional textile finishing innovation are relatively slanting compared with those in the other two technology markets. The Cox functions reflect the relative responsiveness of business model changes without being reliant on the historical periods. Contrary to the conventional view of innovation management, business model innovations are at most time-dependent, but not time-varying (i.e., timing itself is a variable; see the random effects over time in Figure 1). The business model innovations are determined by whether the business actors can respond to the business climates of techno-economic, environmental, and social changes as well as how large the scope of innovation can be, that is, the innovation boundaries for technological processes (resource efficiency), organizations (management/administration effectiveness), and market wide performance (novel value creation).

Finally, although the four industrial markets are closely related because of their similar science and engineering foundations, their survival and destructing natures are different. The Cox analysis predicts the destructing functions cutting across one another sporadically over the 60-month censoring period. The results violate the assumption of proportionality and evidence the heterogeneity among the innovation destructions in the four markets. Although the analysis assumes that the variables uphold the condition of time independence in individual market types, this assumption may not be applicable across the “neighboring” markets. To explain this phenomenon, we speculate that business model innovation in individual markets have propagating effects across each other, that is, unspecified exogenous effects.

3.4 Temporal QCA

In the Cox analysis, the estimations treat the variables and the related net effect sizes over a number of cases of business model innovation destruction. This method tests the hypothesized variables and predictive effects based on the deductive logic for theoretic generalization. However, the analysis process does not allow for explanations encompassing different combinations of the conditions (i.e., the variables in variance analysis) or even absence of some conditions that can be comparatively related to the time-dependent situation or the situations over the time period. In short, the case-oriented QCA can appropriately cope with the explanation for such conjunctive causality problems (Fiss, 2007; Mas-Verdú, Ribeiro-Soriano, & Roig-Tierno, 2015). However, the conventional setting of QCA does not explicitly explain, or compare, cases of antecedent–outcome relationships in a temporal sequence of events. Especially, the truth table algorithm in QCA does not represent prospective configurations of conditions for non-commutative events over time (Schneider & Rohfing, 2013). To address this temporality issue, we redefine the dimensionalities of the hypothesized variables and incorporate time-related conditions over sequential points of time.

The QCA takes the temporality logic through which the consistencies of the hypothesized conditions explain the outcomes at specific points of time series, that is, the *survival status* of a business model. The QCA first assesses the necessary and sufficient conditions. It assumes the exclusion of an antecedent for truth table minimization when the consistency scores exceed the threshold of 0.9 as a necessary condition. Table 6 reports the consistency scores of individual antecedents under the presence and absence of the outcomes. All the antecedents meet the requirements of "sufficiency but not necessity" for theory dependence. However, the two antecedents—innovation with primary and secondary value dimensions—have particularly low consistency scores corresponding to the presence of an outcome ($Consistency_{Inn\_valu\_P}$ = 0.2671, $Consisteny_{Inn\_valu\_S}$ = 0.1175). These two hypothesized antecedents are related to the entrepreneurial choice of innovation paths, but may not be consistently relevant to the status of business model incumbency. Although these conditions are independent of time, as explained in the Cox analysis, their relevance to the outcome would be temporally unstable. Therefore, the necessary test suggests excluding them for temporal QCA.

[Table 6 here]

Further, the antecedents are categorized into two contexts: business and organizational. The former is conditioned by the macro-factors of the business climate, which include the three innovation domains that bound the scope of innovation and the three innovation responses to business dynamic feedback from markets at points in time. The latter is conditioned by the organizational factors, which include structural dependence changes, resource capability, agile actions, processing reshoring, and value personalization of finished goods. These organizational antecedents are hypothesized to enable, or disable, the status of business model incumbency; in other words, the occurrence of the destruction to incumbent business models by innovation.

The QCA identifies the cases not directly based on the individual samples of innovation. Instead, the temporal QCA treats the censoring time points as the proxy cases. The "cases" refer to the timing of business model innovation occurrence and are stated according to the points over the 60-month censoring period. The QCA operationalizes the distinction among the configurative conditions that entitle the innovations sufficiently at each point in the censoring time. Such distinctive configurations of conditions become the valid, longitudinal panel data to explain the temporality in the QCA method (Fisher & Maggetti, 2017). This approach is appropriate when the points in time are relatively limited, with reference to the small-N algorithmic assumption in the QCA's partial inductive evaluation. Table 7 reports the excerpts of the causal and temporal QCA results. The key causal conditions (i.e., solution sets of antecedent configurations) are explained in line with the censoring time in which the business models evolve through innovation.

[Table 7 here]

Causality: In Table 7, the results are based on the intermediate solutions by fsQCA algorithms (Ragin, 2008). The intermediate solutions return set-theoretically viable conditions with user-supplied information to assume the counterfactual cases. The intermediate solutions allow reduction of complexity of all identified sufficient configurations of antecedents. To explain the sufficiency of analyzed solutions, Table 7 lists out the critical solution sets in the four markets, which can multi-morphologically lead to the predicted outcome, that is, the status of business model incumbency. To control the robustness of the QCA results, the analysis sets the cut-off threshold at 2 to discriminate the single cases with configurations of their own conditions. The proportional reduction in inconsistency (PRI) measurement threshold is set at 0.5 to discriminate those solutions with the low degrees of consistency for odd cases that allow both $x \leftarrow y$ and $x \leftarrow \sim y$. All the stated solutions provide raw coverages equal to or greater than 0.3 (i.e., the configurative solutions explaining at least 30% of the business model to be destructed by innovation).

The four types of industrial technology markets have their distinctive contextual antecedents leading to status changes by business model innovation: Three sufficient solutions are identified in the digital textile printing market, two in the wide-format digital printing, and one respectively in the direct-to-garment and textile finishing technologies. Particularly, in the business context, the antecedent of innovation occurred in market domain (as denoted by *Dom_M* in the table) is nearly absent, with a negated sign to imply that its absence would be common, or relevant, to business model innovation. The only exemption occurs in the market of direct-to-garment digital printing. The results advise the contradictory solutions against the belief of market-oriented innovation impinging on the entire business ecosystem.

Business model innovation occurring at organization levels (as denoted by *Dom_O*) is sporadic. The antecedents of innovation for technological processing (*Dom_P*) and dynamic response to techno-economic climate changes (*Dyn_T*) are evidently prominent. Of the four technological markets, only direct-to-garment digital printing can explain its business model innovation by all the solution terms. That is, all the business contextual antecedents sufficiently account for the anticipated outcome (the raw coverage, 0.71; solution coverage, 0.7714, and the solution consistency, 0.9). Contrariwise, the business models in the textile finishing technology markets do not seem sensitive to the business contextual antecedents. Of the six business solution terms, only dynamic response to techno-economic climate changes (*Dyn_T*) is present; all the other solution terms are in negated sign. Compared with the other three market types, business model innovations in the textile finishing market are less sufficiently accounted for by the hypothesized antecedents (with solution consistency at 0.5286).

In the organizational context, the antecedents exert various encompassing effects in the four industrial technology markets. The results reveal no repeated configurative solutions leading to destructed incumbent business models. The antecedents of structural dependence changes (*Depend_str*), organizational resource capability (*Resou_cap*), and action agility (*Agility*) are sporadically associated with the QCA solutions. Particularly, the organizational action agility exhibits a weak, paradoxical relationship between the antecedents and predicted outcome in all the market types. Action agility (*Agility*) and its absence(*~Agility*) in organizations is set-theoretically irrelevant to the business model innovation, which is contrary to the conventional view of resource-based management (Helfat et al., 2007; Zott & Amit, 2007). The antecedents of processing reshoring (*Reshore*) and value personalization of finished goods (*Personaliz*) are conditioned sufficiently in the markets, except the textile finishing technology market. Innovations in this market conventionally emphasize mass volume processing to enable an economy of production scale. Small batches of business value proposition by personalization would not necessarily benefit business performance in terms of operational efficiency and stability. Hence, the solution terms of structural dependence changes (*Depend_str*) and personalization (*Personaliz*) are negated in the analysis. Contrariwise, of all the organizational configurative solutions, the antecedents of *Depend_str*, *Reshore*, and *Personaliz* in the direct-to-garment digital printing market are strongly relevant to business model innovation, as indicated by the raw coverage (0.9143), solution coverage (0.9714), and solution consistency (0.8718).

Temporality: The QCA results trace the explanatory conditions in the sample cases with reference to the time points at which the business models are destructed by innovation. That is, the truth table algorithm generates the sequential points over the business model censoring time as the analyzing case units. These "temporal" cases with the same and sufficient configurative conditions can be traced and classified into batches of solutions. For instance, in the digital textile printing market, the three critical solutions in the business context are:

1. *~Dom_M*Dom_P*~Dyn_S*Dyn_T* ← month-6 to month-24 (Raw-con, 0.5030);
2. *~Dom_M*Dom_P*Dyn_E*Dyn_T* ← month-6 to month-20 (Raw-con, 0.5091);
3. *Dom_O*Dom_P*~Dyn_S*Dyn_T* ← month-18 to month-36 (Raw-con, 0.3515);

where solution 1 entails the occurrence of business model destruction through innovation in a time span from 6 to 24 months; solution 2 entails it from 6 to 20 months; and the solution 3 from 18 to 36 months. Solution 3, *Dom_O*Dom_P*~Dyn_S*Dyn_T*, explains the relevant business models with higher tendency for innovation than the other two.

Such solution sets do not advise which business contextual conditions are predicted better than the others in the management of business model innovation. Instead, the business contextual conditions imply different possible time spans for business models to make innovative changes. As shown in this instance, the innovation responding to dynamic environmental aspects, *Dyn_E*, is "critically relevant" to the incumbent status of business models (with the shortest destructing time in a range of 6 to 20 months). The *Dyn_E* is considered the imperative.

Similarly, from the results in organizational contexts, the solution set encompasses:

4. *Resou_cap*~Agility* ← month-12 to month-24 (Raw-con, 0.5151);
5. *Reshore*Personaliz* ← month-6 to month-20 (Raw-con, 0.4606);

where the business model innovation is particularly evident in the organizational contexts pervaded by the process operation reshoring (*Reshore*) and finished goods personalization (*Personaliz)*.

Observing all the QCA solutions, we find that business model innovations are skewed toward the early phase of the business model launch over the censoring period of 60 months. The results indicate that business models sustain themselves over a rather short term. Further, the digitization process significantly impinges on the industrial business models and business ecology.

4. Discussion

We proposed a schema that predicts the time-dependent behavior of business model innovation, particularly in the contexts of industrial business environment. We first reviewed the theories in the research on value proposition by business models and proposed a number of time-dependent variables relevant to business model innovation. Specifically, the schema redefines the variables, namely, innovation domains, innovation dynamics, business model dependence structure, organizational resources, agility, business value dimensions, business strategies of reshoring, and value personalization. All these variables and their time-dependent effects were tested through Cox regression analysis. As the Cox analytic method is based on the empirical net effect sizes of each variable, the regression results cannot provide sufficient implications for predicting the causality of these contextual variables. In particular, the net effect size analysis cannot unfold the properties of various variable combinations leading to the same, or contradictory, consequences. Very often, these variables cannot produce the momentum for business model innovation alone as the necessary causes, but can do so in combination with a set of others as the sufficient-but-not-necessary causes. Therefore, we further proposed a QCA to explain the causality of the antecedent–consequence relationship. This QCA is also temporally based, which can further explain the timing of the cause configurations. The merits and limitations of combining these two distinct analyses will be discussed to examine the scope of its applicability.

First, the central logic of business model innovation is to explore unknown business values and uncharted market realms. However, the majority of the existing literature focuses on model structures, value proposition processes, or key system components built for hypothesized performance. The research does not underpin, or only party underpins, the time-dependent analysis applicable for predictive purposes at the initial business development stages. As illustrated in this study, the findings provide implications that are controversial to the conventional views of business model innovation:

- Business model innovation is not too concerned with, or relevant to, the changes of business entity dependence (interrelationship) for new value proposition.
- Secondary business values that are often non-dominant in markets are the key considerations for business model innovation.

- New business entrants are susceptible to business model innovation in market domains; radically changing new business model values cannot assure success for business entrants.
- The external factors (business dynamic forces) are the main factors that push for innovating business values.

Second, the central result of the Cox analysis provides the predictive function curves that estimate the chances of business model to be destructed by innovation. Based on a survey spanning a period of 60 months and covering 474 sample cases in four technology markets, we found an average of 26.6 destructing percentage (from the lowest of 21.6% in direct-to-garment digital printing to the highest of 28% in textile finishing technologies). However, these results may not be empirically comprehensive. The digitization of conventional processing is not a standalone innovation within a technology market or a few neighboring markets along a value chain. Digitalization of an industry encompasses a wide array of science and engineering innovations that can apply across many other markets. Because of limited resources to collect a comprehensive dataset, we selectively collected the sample cases in the four technology markets. For robustness in data evaluation, analytic methods from theoretic realms are preferred. We attempted to illustrate the complementarity of two analytic paradigms: time-dependent Cox regression and temporal QCA. In future, the robustness of combining different analytic paradigms could support further investigations.

Third, the Cox functions in this study technically represent the baseline destruction (hazard) of the business models in the surveyed companies. However, from the theoretic points of view, the destruction of business model innovation can be better modeled with two simultaneous Cox estimations, namely, destruction to business value and destruction to technology:

$$h^{Bv}(t) = h_o(t) \times \exp(\theta_1 Inn_{dom_i} + \theta_2 Inn_{valu_i} + \theta_3 Inn_{dyn_i} + \theta_4 Str_{dependi} +$$

$$\theta_5 Resource_i + \theta_6 Agility_i + \theta_7 Reshore_i + \theta_8 Personaliz_i + \epsilon^{Bv});$$

$$h^{tech}(t) = h_o(t) \times \exp(\alpha_1 Inn_{dom_i} + \alpha_2 Inn_{valu_i} + \alpha_3 Inn_{dyn_i} + \alpha Str_{dependi} +$$

$$\alpha_5 Resource_i + \alpha_6 Agility_i + \alpha_7 Reshore_i + \alpha_8 Personaliz_i + \epsilon^{tech});$$

where ϵ^{Bv} and ϵ^{tech} are the error terms of the destruction function with respect to the business model values and technologies, respectively.

The two error terms are distinct, but correlated. Theoretically, the two functions should have been estimated as in a system of interdependent functions with joint normality. However, such an estimation would consume more research efforts and time for the respondents to differentiate the two innovation logics, and then report the data with sufficient heterogeneities. For consistency, the Cox functions in this analysis predict only the characteristics of the value-dependent business model innovation. The interdependence of multiple Cox functions will be the main issue of future research.

Fourth, like the other statistical inference methods, the Cox analysis estimates the net effect sizes of each hypothesized variable. This is a deductive process. The results cannot advise any implications of multiconjunctivity among these variables leading to the predicted outcomes. In reality, the destruction of a business model by innovation does not necessarily depend on the occurrence of all these variables at the same time. Such cases also occur for temporal events, as investigated for business model innovation destructing in this study. The QCA method can addresses such issues of causality and temporality. However, the QCA is a partially inductive process and is restricted by the issue of "limited diversity" (Ragin, 2008). It needs to place theoretic propositions to limit the number of configurations, and thus reduce the possible solution set into a manageable size. In light of such restrictions, the temporal QCA separates the analysis of points in time into two contextual conditions: business and organizational. The inspection of their similarity and differences across the solution conditions can systematically explain the time-relevant solution consistency. Like the conventional causality analysis, the temporal QCA is subject to the availability of data that are contextually stable over time: that is, the causes and outcomes are independent of time; and the manageability of the number of points in time.

5. Conclusion

We conceived a predictive schema that helps identify the patterns and outcomes of innovating business models in four industrial technology markets. The predictive schema draws on the logic of innovation destructing incumbent business model values; in other words, new value propositions and delivery evolve through business model innovation.

With this schema, we predicted the destructing rates of business models with a set of related hypotheses over time. The statistical tests by the Cox analysis reveal the significant effects of the variables, which include innovation of non-dominating (secondary) values; three innovation responses to environment, social, and techno-economic dynamics; resource capability; and action agility. A temporal QCA complementarily explains the causality and temporality of the business model innovation. The set-theoretic analysis exhibits that the antecedents of innovation that occur for market domain and the responses to social dynamics are absent terms, that is, they are nearly irrelevant to the consequence of business model sustainability. This result is contrary to the initial hypotheses. We believe that the findings and discussions provide a novel methodological procedure to research business model innovation, especially when the innovation cases are examined from the perspective of timing of business value emergence.

As discussed in the previous section, the Cox analyses were only confined to one harzard function estimation, owing to the restriction of research time and resource. The analysis results could be more implicative when a system of multiple baseline function estimations are applied simultaneously. In future, the study will enhance the schema structure and measurements to further characterize the interdependence of multiple Cox functions. The analysis method will also address to the phenomena of business value evolution across different technological markets, that is, the propagation of destructive innovation across different technological realms, or an emergence of totally uncharted technological market. As such, the predictive schema in Cox analysis and complementary QCA can allow a formal procedure to predict the outcomes and patterns of innovative business models.

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