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Business model design in the case of complex innovations: a conceptual model

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ABSTRACT

Current literature presents the antecedents of business model design as a given managerial choice. In complex and uncertain environments, there might not be enough information for the managers to make choices as the options for creating and capturing value have to coevolve with emerging innovations. We argue for how business model design and its antecedents differ and develop a process model that shows how and when a firm can generate business model designs in complex innovation. Through the principles of design under complexity, our model develops a non-predictive approach that connects emerging complex-innovations to the antecedents of their business models, whereby a focal firm engages in the collaborative generation of business model design alternatives. Thereby we extend the understanding of the business model design and its antecedents under complex and uncertain environments.

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1. Introduction

An appropriate Business Model (BM) should be employed to create and capture value from the underlying innovation – be it technological, radical, open, or sustainable (Baden-Fuller and Haefliger 2013; Ritala and Sainio 2014; Saebi and Foss 2015). Literature has presented Business Model Design (BMD) as a choice that firms make (Casadesus-Masanell and Ricart 2010) to align with their innovation strategies (Saebi and Foss 2015). Viewing BMs as a managerial choice whereby the right technology or BM leads to the other's development (Teece 2010) portrays a linear, predictive, and planned view of decision making. This is particularly suitable when firms face little uncertainty or resource constraints (Wiltbank et al. 2006; Packard and Clark 2019). However, when it comes to 'complex-innovations' (Dougherty and Dunne 2011), the relationship between BMs and the innovations may not be entirely linear. Complex-innovations are broad, paradigm-changing, and emerge unpredictably over considerable periods at the intersection of knowledge resources within an ecology of organisations, institutions, and as yet unknown and dispersed actors (Dougherty and Dunne 2011, 2012; Dunne and Dougherty 2016). Given that the BMD should reflect the underlying nature of the innovations (Saebi and Foss 2015), we argue that BMD choices emerge concurrently with complex-innovations.

BMs are an interconnected and structured set of organisational activities performed by a firm to create and capture value (Zott, Amit, and Massa 2011). It has been argued that the design of BMs could be traced back to given antecedents, both internal and external, that a designer has chosen

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from a given range of available options (Amit and Zott 2015). Amit and Zott (2015) have proposed considering the antecedents of BMD as a means for various stakeholders to strengthen their overall value proposition. However, they have discussed antecedents as a design content – an alternative from which managers choose. For complex-innovations that emerge from non-linear interactions between diverse stakeholders along long and uncertain technological trajectories, the locus of which reside outside the focal firm (Dougherty and Dunne 2011, 2012), the antecedents of BMDs cannot be a given, but need to be part of an emergent process that leads to BMD alternatives. This means that the choices are not preexisting alternatives for managers, but rather an emergent property (Yoo, Boland, and Lyytinen 2006; Boland Jr et al. 2008). However, BM literature has not captured the antecedents of BMD entirely when technological innovations are emergent (Russell and Smorodinskaya 2018). Consequently, the existing literature is not sufficient to explain the relationship between innovations and BMs fully. Thereby, we ask the question, how and when can a firm engage in generating BMDs to create and capture value from complex-innovations?

In answering the research question, we develop a process model of the emergence of BMD alternatives based on a theoretically grounded conceptualisation. We present BMD as complex problem-solving (Simon 1960; Nickerson and Zenger 2004, 619; Rai et al. 2017), whereby the complexity of a design problem is embraced instead of reduced (Brown and Eisenhardt 1997). First, we contribute to the BM literature by extending the understanding of BMD and its antecedents (Zott and Amit 2010; Frankenberger, Weiblen, and Gassmann 2014; Amit and Zott 2015) under complex and uncertain environments (Dougherty and Dunne 2011, 2012). Thereby we conceptualise the link between BMD and innovations as one where they emerge in interaction through non-predictive design (Simon 1996; Packard and Clark 2019), rather than the predominant linear view in which one leads to the other (Teece 2010; Baden-Fuller and Haefliger 2013). Second, we conceptualise environmental constraints as important antecedents that, when leveraged and reshaped given the dynamic capabilities of a firm, could be an enabler towards generating BMD alternatives. In this regard, we depart from existing literature (Amit and Zott 2015) in providing a more dynamic view of how constraints act as BMD antecedents.

2. Complex-innovations, their emergence and value appropriability

Complex-innovations are prevalent in industries such as new energy systems, transportation, biotechnology, and financial services (Dougherty and Dunne 2011; Niosi 2011; Nair and Paulose 2014). The knowledge required for the emergence of complex-innovations is beyond a single organisation. Instead, they emerge through the social practices of knowledge orchestration, strategizing, and public policy development across the innovation ecology. They are characterised by integrated collaboration, co-created shared value, cultivated innovation ecosystems, and unleashed exponential technologies and extraordinarily rapid adoption (Dougherty and Dunne 2011).

Every firm, either by design or default, employs a BM. The process of BMD enables a firm to create compelling value propositions to be delivered appropriately for the customers with advantageous cost and risk structures and to capture the resultant value (Teece 2010) significantly. Based on design literature (Boland and Collopy 2004), Amit and Zott (2015) derived four BMD antecedents that include goals, templates, stakeholder activities, and environmental constraints. They further show how the design antecedents foster a particular design theme that connects the content, structure, and governance of a BM. Such a conceptualisation shows a linear relationship between the given antecedents and the design that they lead to, which might not be relevant when it comes to complex-innovations that thrive on inherent uncertainty and prevalent non-linearity (Dougherty and Dunne 2011, 2012).

BMs were able to capture the changing nature of technological innovations due to the design principle of modularity (Baldwin and Clark 2000). Baden-Fuller and Haefliger (2013) argue that modularity, cognitively and practically links 'the stage of technology development with the organisation of innovation and customer engagement,' thereby bridging the 'changing customer demands and technological evolution for the BM.' However, the fundamental nature in which complex-innovations diverges from a linear conceptualisation of innovation means that BMD principles based on modularity is not relevant. Modularity requires that the innovation problem be sub-divided into independent modules to enable collaborative interactions (Surie and Hazy 2006). However, complex-innovations are different in that as the complexity of an evolving innovation problem increases, it becomes increasingly difficult for it to be decomposed into its constituent parts and thereby modularised (Dougherty and Dunne 2012). Modularisation, an attempt to manage the complexity as they allow for integrated design efforts by multiple actors (Ethiraj and Levinthal 2004), will serve to 'constrain the natural emergence and flow of innovation processes' (Garud, Tuertscher, and Van de Ven 2013). To create and capture value from complex-innovations, organisations should then attempt to embrace and harness complexity instead of reducing them.

3. The problem-solving perspective of BMD and their taxonomy

In this section, we develop a taxonomy of BMD that shows three design choices with increasing complexity (Table 1). The design of a BM depends on the nature of the design problem dealt with by the designer. From the perspective of design as complex problem-solving (Simon 1995) a problem's complexity is 'a function of the degree to which the individual design choices, which define a solution, are either independent or interdependent in their contribution to the solution value (Nickerson and Zenger 2004, 619; Simon 1960).' The designer might not have control over the design choices required towards the solution of the problem since the knowledge resources required for making these choices reside external to the firm boundaries and might as yet be non-existent as they emerge from interactions between knowledge sets (Simon 1960). Therefore, the higher the complexity of a problem, the more extensive the interactions between knowledge sets required in its solution search. This typology of low, moderate, and high-interaction complex problems (Nickerson and Zenger 2004) informs our BMD taxonomy.

Low-interaction or decomposable problems are ones in which the value of solutions depends very little on the interaction among knowledge sets and design choices. Problems can be decomposed into sub-problems where firms possessing distinct knowledge can independently address a sub-problem, thereby leading to global solutions. The BMD choices that firms make connecting to an existing ecosystem involves simple low-interaction problems. For example, a firm creating an innovative online game can concentrate on just its technological capabilities in game design and not concentrate on distribution, delivery, and payment systems or IT maintenance. Instead, it can connect to an existing platform like iTunes or Google Play store, however with low power within the ecology of

Table 1. BMD with increasing complexity.

	Connect	Create	Self-organize
Problem dependence	Low-interaction problem	Moderate-interaction decomposable problem	High-interaction non-decomposable problem
Complexity level	Low	Moderate	High
Nature of innovations	Closed-innovation	Open-innovation	Complex-innovations
Focal firm's role	Joining existing platform	Platform owner, ecosystem/network orchestrator	Ecology-wide orchestrator
Power of the focal firm	Low power within network/ ecosystem	High power within network/ ecosystem	Emergent power within ecology
Locus of innovation	Within or among multiple firms	In communities	Dispersed non-linear interactions outside the firm
Boundary	Low boundary spanning	Moderate boundary spanning	High boundary spanning
Example	Making a game for PlayStation, Making products for a new market standard.	Creation of Apple iTunes, Charging on the Go by Tesla, Creating standards like 5G.	New energy systems like airline biofuels, New transportation systems like Hyperloop.

actors since, for the platform owners, the permeability of firm boundaries required for enabling such connections is slight and can be selectively controlled. The BM of the app developer, who possesses distinct knowledge in game design, acts as a component of a broader system that enables it to *connect* with its customers. In doing so, they create value for themselves, the customers, and the platform to which they are connecting. The only requirement is to follow common design protocols and standards that enable seamless connectivity to the platform.

Moderate-interaction problems are nearly decomposable ones. The level of interaction among design choices is intermediate in that sub-problems associated with unique knowledge sets can be defined and, therefore, modularised (Campagnolo and Camuffo 2010). However, the value of a design choice within one sub-problem is not entirely independent of the design choices made in another sub-problem. For example, the BM can be based on *creating* a platform that enables user engagement, co-creation with customers, and connecting with other firms. Such a BMD involves a much higher permeability of firm boundaries for the flow of knowledge with outside actors than merely connecting with them. The BMD choices will be influenced, for example, by what knowledge the firm can gain from its users, how well to engage with them, and how to integrate that knowledge for capturing value out of them. As such, the design choices the firms make cannot be independent of the choices made by other actors.

The boundaries of a moderate-interaction problem, although being an open system, are well defined, explicit and self-contained, and any transformations in the system can be traced to internal or well-defined input functions (Chu, Strand, and Fjelland 2003). 'Charging on the Go,' a concept similar to filling gasoline from the extensive supply networks while driving, is crucial for the mass adoption of electric cars. An electric car company like Tesla succeeded only after simultaneous developments in charging station networks and superior battery technologies. Though these problems are interdependent, they can be modularised. Modularity in such nearly decomposable problems shapes the permeability and extent of firm boundaries, thereby determining the organisational structures that the underlying innovations create. An underlying innovation or technology's degree of modularity varies from highly modular to highly integral (Campagnolo and Camuffo 2010), but it still allows for collaborative development as sub-problems, with a higher blueprint in mind and the eventual outcome, predictable to a great extent.

Sometimes, the innovations are highly complex that the problem cannot be decomposed into subproblems that firms can solve in an existing innovation network or ecosystem. The reason is that innovation networks and ecosystems are created for a specific purpose, even though their goals could change. Complex-innovations are the solutions to such high-interaction or non-decomposable problems and have solutions in which the value of solutions depends on interactions among design choices. Interactions among distinct knowledge sets are so extensive that defining sub-problems do not lead to finding effective solutions and will not enable the creation and capture of fair value. Problems such as the diffusion of new energy systems or new transportation systems require distinct knowledge sets from different actors to be brought together, and the value so created will be impossible to create separately as subproblems. These innovations require the active orchestrated knowledge of the broader ecology and high circulation of knowledge within it, depending on the nature of the problem.

The question arises as to which firms could engage in enabling ecology wide, dispersed, and often non-linear interactions between different knowledge sets whose locus is outside the firm. Given our focus on emergence, our argument is that complex-innovations are emergent and uncertain. In this context, the traditional view of a 'focal firm' with the dominant power, the ability to mobilise resources to achieve individual or collective goals (Avelino and Rotmans 2009), to design and govern does not apply. It is in this context that we bring in the notion of non-predictive design and emergent power. Non-predictive design entails no prediction or judgment whatsoever and no expectation of some preferred outcome as a result of actions (Packard and Clark 2019). When it comes to complex-innovations, the new knowledge required for their emergence is partially located with the niche/new actors in an industry. The constraints in the existing technologies, such as environmental sustainability goals, are faced most acutely by incumbent firms. As a result, they have constraint related knowledge.

The power that enables firms to engage in enabling high interactions outside the firm arises in our case from the niche and constraint related knowledge of the actors, be they new or existing firms. Therefore, our focus is on such firms that engage in non-predictive design (Simon 1996; Packard and Clark 2019) in industries where they have no preexisting dominant power. As a result of their enabling actions and interactions with other actors, the firm gains emergent power and becomes focal firms in new industries that are thus created. Such an understanding of complex, non-predictive problem solving by firms informs our further theorising of BMD in complex-innovations.

4. BMD for complex-innovations

We develop a model of the emergence of BMD alternatives under complex and uncertain environments (Figure 1). The model incorporates the principles of design under complexity, a non-predictive design approach (Rai et al. 2017) aimed at connecting complex-innovations to the antecedents of BMs. We start with how the design literature was used for BMD. Specifically, the focus is on the antecedents of BMD that includes goals, environmental constraints, stakeholder activities, and templates (Amit and Zott 2015), and the strategizing and development of dynamic capabilities that constrain BM choices (DaSilva and Trkman 2014; Teece 2018). We examine how they are applicable under complex and uncertain environments, particularly on the activities entailed in organising complex-innovations such as orchestrating collaborative knowledge capabilities to support a variety of new product efforts and for external interventions such as in developing public policy (Carlile 2004; Dougherty and Dunne 2011, 2012; Garud, Tuertscher, and Van de Ven 2013). While presenting our arguments on connecting complex-innovations to the antecedents of BMs (see Figure 1), we also showcase how the BMD antecedents present challenges and deviate from current understanding (Amit and Zott 2015) when the underlying innovations as complex (Table 2).

4.1. Leveraging external environmental constraints

One of the examples used by Amit and Zott (2015) to illustrate the BMD antecedent of having a goal was 'to create transparency and control to the consumer compared to traditional lending practices.' This goal then led to the design of an Internet-based P2P lending model. These broad goals have also been construed as a strategy by scholars while delineating strategy from BMs (Massa, Tucci, and Afuah 2017). Based on design principles, goals could be broad and open-ended (Amit and Zott 2015).

However, while dealing with complex-innovations, managers might have problems defining goals given that the number of unknowns is high. Complex-innovations entail that they have to work with ambiguous and broad goals rather than clear ones (Dunne and Dougherty 2016). For example, while

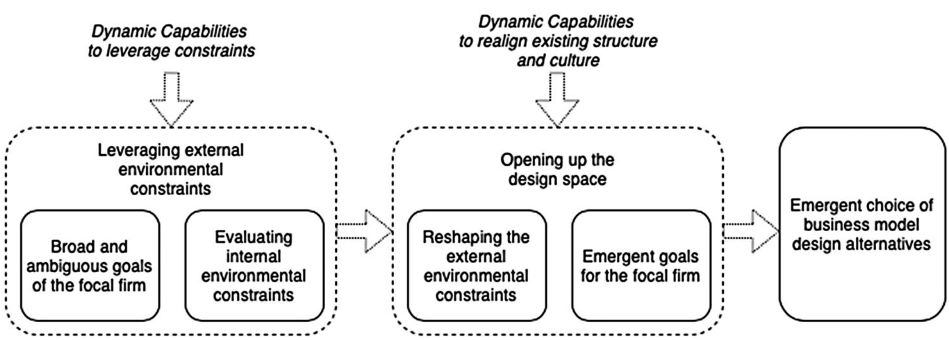

Figure 1. The emergence of BMD alternatives.

Table 2. Nature of BMD antecedents when innovations are complex.

BM antecedents	Managerial challenges concerning complex-innovations	Focal firm's activities in generating antecedents
Goals	Defining expectations and orientations for an uncertain future	Work with broad, ambiguous and emergent goals, although with inherent social value
Environmental constraints	Lack of preexisting knowledge to deal with constraints	Leveraging and reshaping the constraints
Stakeholder activities	Collaborating with diverse stakeholders when the potential for capturing value is uncertain	Engaging with the broader ecology by opening up the design space; Exploring alignment of core activities with emerging innovations in the design space
Templates	Lack of information regarding the evolution of the innovations to base the template on	Emergent choice of BMD templates

dealing with sustainable air transportation, Airbus has the goal 'to act as a catalyst in developing innovative alternative fuel sources in support of a sustainable air transport industry.' Even though this might be construed as a vision statement, it does not resemble an actionable strategy. It only means that they are open to collaborate for sustainable air transportation. In doing so, they are able to shape the emergence of innovations that otherwise could disrupt their existing activities. As a significant stakeholder in the air transport industry, involving itself in the activities related to alternative fuels enables Airbus to shape its emergence effectively even though they cannot be planned for (Dougherty and Dunne 2011). Otherwise the emerging innovations might become detrimental or disrupt their existing activities and BMs. The disruptions to the air transport industry that could be caused by the emerging innovations are now co-opted into Airbus's BM. The value of engaging in complex-innovations with ambiguous goals is that the value creation and capture will not be a zero-sum game. However, that new value could arise from unexpected sources. Thus, the broad and ambiguous goals are not the final goals but the precursor to a non-predictive design (Simon 1996) whereby 'in selecting today's ends we are but selecting tomorrow's constraints' (Sarasvathy 2004, 523). The goals become a design attitude that refers to the expectations and orientations (Boland and Collopy 2004) that the firm brings in to an opportunity to transform existing situations into ones whose outcome could as yet not be determined (Simon 1996).

The design concept of 'constraints 'serves to give boundaries to a problem … … and defines it' (Boland and Collopy 2004, 269). From design literature, constraints should be accepted as a design antecedent that can inspire and reflect as they set new boundaries (Vandenbosch and Gallagher 2004). Amit and Zott (2015) positions environmental constraints as a design antecedent of BMs; and distinguish between the external constraints, the ones imposed upon by the economic, legal, socio-political, regulatory, cultural and environmental factors and the internal constraints, such as the availability of resources and the capabilities of the focal firm. Managers often consider constraints as obstacles to be worked around and eliminated (Vandenbosch and Gallagher 2004). However, from design thinking, external constraints could be challenged, accepted, adopted, or explored. The external constraints are an initial condition influencing the goals when the problems are ill-defined. The existing external constraints, such as emission regulations and global warming concerns, contribute to defining the initial goal, albeit broad and ambiguous, of Airbus. These focal firm goals are an essential factor in shaping the outcome of creating and capturing value from complex-innovations. The constraints will be leveraged in the problem definition and influence the emergence of solutions as one of the initial factors: without the constraints, new value creation would not have existed in the first place. Therefore, the external constraints rather than external to the problem and a hindrance to the pursuance of a solution become an antecedent that contributes to the emergence of innovations.

External environmental constraints such as emission regulations, global warming concerns, and fluctuating petroleum prices to get translated into goals, albeit broad and ambiguous, require adequate capabilities within the firm. Such an intent to act represents higher-order dynamic capabilities (Teece 2018) in identifying possibilities of leveraging the constraints. Thereby, the focal firm's dynamic capabilities determine if the external constraints are a hindrance or an initialising constituent towards action and thereby future value. In this regard, defining broad goals enables the firm to evaluate the internal environmental constraints that prevent it from pursuing its own goals. The firm-level constraints, such as the non-availability of resources and capabilities, informs what they have and could commit to engaging with others in pursuance of those broad goals (Wiltbank et al. 2006). Thereby, the internal constraints, defined by the limitations for acting along with known knowledge sets, should enlarge the boundaries of the design problem. Moreover, 'the effective use of specialised knowledge depends on a prior restructuring of complex and uncertain situations' (Schön 1983, 19). The enlarged boundaries overlap those of other actors, whereby their resources and capabilities get to interact (Carlile 2004).

4.2. Opening up the design space.

From the very nature of complex-innovations, no one firm alone or in a network has the necessary resources and capabilities to bring them to fruition. Instead, they emerge out of interactions between diverse actors in the innovation ecology. The internal environmental constraints, the evaluation of which entails enlarged and overlapping boundaries, enables the focal firm to open up the design space. We conceptualise the design space as a formal or informal organisational form that enables interaction between diverse actors and is facilitated by a focal firm's actions. The boundaries of the design space are permeable enough to allow for actors to enter and interact. Since complex-innovations are the desirable solutions to high-interaction problems, they emerge only when such interactions are facilitated. Therefore, the permeability of the design space's boundaries is required since it allows for non-linear interactions of actors from diverse settings.

Theories of knowledge boundaries in complexity suggest that the transformation of collective activities takes place in open design spaces (Carlile 2004; Dougherty and Dunne 2012). However, the ability to open up the design space by appropriate strategies depends on the dynamic capabilities of the focal firm (Rindova and Kotha 2001; Carlile 2004): herein the ability to develop and deploy a combination of competences and resources in uncertain environments (Eisenhardt and Martin 2000). In complexity, a firm's dynamic capabilities are not about choosing and honing a BM (Teece 2018), but about creating the necessary environment for generating the options. Dynamic capabilities of these kinds represent higher-order capabilities of a transformative nature that enable the firm to realign its existing structure and culture (Teece 2018). Connections, how they are created are intrinsically linked to the value creation potential the design space offers for the participants, even though enabled by the strategies employed by the focal firm to attract diverse actors. The focal firm and other firms choose to engage within the design space by considering if their core activities are aligned with or be possibly disrupted by the emerging innovations. Other firms may also engage with the design space if the emerging innovations are complementary to their existing activities and, therefore, able to appropriate value out of it (Hill and Rothaermel 2003).

Decisions regarding opening up the design space depend on the broad initial goals of the firm, that are dependent on the nature of uncertainty presented by the constraints on the design problem. A higher level or immitigable uncertainty brought about by extreme external environmental constraints places uncertainty on required resources, thereby increasing internal environmental constraints. The openness of the design space depends on the level of uncertainty whereby higher the uncertainty associated with the innovations, higher the openness. In the case of high uncertainties associated with complex-innovations, a 'radically open system' (Chu, Strand, and Fjelland 2003), which allows for a high number of external actors and their knowledge sets to interact, is preferable. This allows for rich connections between diverse, autonomous, and highly adaptive actors that interact nonlinearly. A radically open design space captures the complexity that emerges from the interactions as they deal with innovation problems of the high-interaction non-decomposable kind (Yoo et al. 2012). Non-linear interaction in the design space leads to self-organization, a dynamic process by which under its dynamics, a system spontaneously gets increasingly more organised (Kauffman 1992), and thereby not the result of individual actors seeking specific outcomes.

Design spaces based on radically open systems have to be facilitated by the focal firm based on its actions. The facilitation depends on the strategies employed to open up the system for diverse actors and the connections between them and lay the basic rules for interactions to happen. The design space could be opened up by employing strategies that are aimed at bringing in diverse actors. Complexity and the underlying uncertainty mean that it is difficult for the focal firm to know who is the right partner or stakeholder beforehand. Neither are other firms aware of the focal firm's issues. Therefore, firms cannot draw on existing ecosystems or create new ones intentionally as the knowledge for doing so does not exist.

Moreover, competitors might be wary of engaging with the focal form due to the uncertainties in value appropriation. Firms can employ strategies such as selective revealing or free revealing of knowledge under such circumstances (Alexy, George, and Salter 2013). Free revealing entails voluntarily giving exclusive information to all interested parties (Baldwin and Hippel 2011). In our case, the information could be related to the constraints faced by the firm if it is an existing firm or related to new technologies if they are niche actors.

Through the simple rules that govern the interaction between actors, self-organization, happens within the design space. Firms use a few increasingly simple rules or guidelines for engagement in dynamic markets to address opportunities realised through interfirm collaboration (Rindova and Kotha 2001; Davis, Eisenhardt, and Bingham 2009). Simple rules of engagement are required, as there is no hierarchy of command and control in the open design space (Anderson 1999). The orchestrator, in this case, the focal firm, lays the basic rules of engagement between actors that can help manage the constraints inherent in collaboration, which can sometimes threaten to tear a creative community apart (Dougherty and Dunne 2011). The expectations and orientations that the focal firm brings to the design space are the core element behind defining these very rules. The open design enables interactions that result in transforming each other's knowledge (Carlile 2004), contributing to the emergence of innovations and the associated value propositions. The expectations and orientations about the value that the firms bring into the design space are altered. As the interactions take place between the actors and the external constraints, the rules of engagement might get modified in feedback (Dattée, Alexy, and Autio 2018).

The interplay between what happens in between the interactions in design space and the external environmental constraints lead to a renegotiation of the very meaning of constraints itself and leads to being an antecedent of the design choices that emerges (Vandenbosch and Gallagher 2004). Since non-decomposable radically open systems transform their external environment and, in turn, get transformed by it (Chu, Strand, and Fjelland 2003), feedback is established between the design space and the external environmental constraints. In such a state of balancing and embracing, actors are both constrained and enabled by the nature of the environment in which they operate (Brown and Eisenhardt 1997; Stacey 2007). The literature on complex-innovations (Dougherty and Dunne 2011) views external environmental conditions as something to be shaped rather than as a limiting constraint. The feedback established between the design space and the external environmental constraints mutually shapes each other as the actors in the external environment engage within the enlarged boundaries of the design space. While incorporating complexity, goals that are broad and ambiguous to being with, become emergent (Simon 1995). Goals emerge from the design process since knowledge not considered from the outset is used along the process: new knowledge emerges in and through interactions with the external environment (Simon 1995). Consistent with our view of non-predictive design, the altered expectations and orientations regarding the value and the emerging goals leads to decisions regarding expanding or shrinking the design space.

A recent example of this phenomenon is when Hyperloop-One, a land-based high-speed transportation system under development, opened up its design space to engage with the global community. However, the complexity of Hyperloop emerges from the fact that it is a speculative design with high levels of technological and commercial uncertainties as against the tried and tested design of a high-speed train. Hyperloop-One says that 'Our goal is to get different key stakeholders (government officials, academics, private investors, and architects, to name a few) involved to facilitate the implementation of this technology. We are asking for teams comprised of these stakeholders to make a case for how Hyperloop can drive economic growth and create new opportunities in their community.' The diversity of the actors, particularly the policymakers and key influencers, are a catalyst in shaping the economic, legal, socio-political, regulatory, cultural, and environmental factors that might otherwise constrain the emergence of Hyperloop transportation. The shaping of the external constraints influences the emerging Hyperloop innovations, setting up a feedback system.

4.3. Emergent choice of BMD alternatives

Using templates (Amit and Zott 2015), or drawing on existing ideas and approaches is commonplace in design (Boland and Collopy 2004). Since templates shape the outcome by providing design alternatives about what works and not in specific situations, they are considered to be a BMD antecedent (Amit and Zott 2015). Therefore, a designer, aware of the value appropriation potential of design templates could evaluate them based on the knowledge about their innovation compatibility (Baden-Fuller and Haefliger 2013). However, due to the uncertain nature of complex-innovations, their exploitation cannot be anticipated based on design alternatives that have worked in the past. Therefore, the design alternatives should be an emergent property that arises from the design space. This is not to say that the design concepts of borrowing, recycling, using a default, and existing vocabulary (Boland and Collopy 2004) are not relevant when designing BMs for complex-innovations. Instead, the choice of using such templates or entirely new ones is not a given. It is dependent on the coevolution of actors and their resources in the design space and the value creation opportunities that emerge out of it. Only by depending on the emerging innovations and in collaboration with the stakeholders involved can the designers in the focal firm decide how to appropriate the emerging value.

While working with complex-innovations, BMs could end up with a novelty, lock-in, complementarities, or efficiency centred design (Zott and Amit 2010) or a combination of these. For instance, while 'constantly acting to reduce its fuel consumption and carbon emissions,' which entails complex-innovations, the Airline KLM created a joint venture, SkyNRG, along with other actors for supplying sustainable fuel. The design theme is novel as it entails the adoption of new activities and new ways of linking them with their core activities of airline operations. It provides KLM with emergent power over competing airlines as they become locked into the supply chains. Simultaneously, the activity system design achieves higher efficiency by reducing transaction costs from the current hedging of fuel from traditional suppliers.

Developing dynamic capabilities to respond to contingencies will define the BMD of a firm (DaSilva and Trkman 2014; Teece 2018). Since dynamic capabilities, even in turbulent environments, are a planned adaptation (Eisenhardt and Martin 2000), they might only be suitable when organisations engage in innovation through rational planning and modularity (Wiltbank et al. 2006). However, as we see in the case of KLM, a visionary approach defines the broad goals and enable stakeholder engagement and resource commitments, the exploitation of which could be through a transformative strategy that emerges in and through interactions (Wiltbank et al. 2006). The design templates might be borrowed from others, a default for a setting, or recycled from earlier attempts (Amit and Zott 2015). However, the designers do not have the freedom to choose a design and work towards it. Instead, we argue that the choice of BMD in complex-innovations emerge through the dynamic interactions in the design space.

5. Discussion and conclusion

We have developed a conceptual model (Figure 1) of the antecedents of creating and capturing value from complex-innovations. The antecedents of BMD when it comes to complex-innovations is a highly complex ongoing and responsive process that, when enabled by the actions of a focal firm, leads to the emergent choice of BMD alternatives. Our theorising shows that firms, when faced with uncertain and complex-innovation problems, have the agency to be focal firms if they have the dynamic capabilities to leverage the constraints to come up with broad goals and realign existing structure and culture to open up the design space. By exploring the antecedents of BMD in the case of complex-innovations, we make significant contributions to the BM literature.

First, when it comes to complex-innovations, instead of considering BMD antecedents to be a given (Amit and Zott 2015), we bring forward the notion of non-predictive design (Simon 1996; Packard and Clark 2019). The non-predictive design represents a transformative teleology (Stacey, Griffin, and Shaw 2000) wherein the meaning of the future arises as continuous transformations in the present. An organisation engages in complex-innovations, anticipating future value from it, albeit uncertain about when and how. The antecedents of the BM, as they emerge, creates the diversity required for complex-innovations, the coevolution of which generates the emergent choice of BMD alternatives.

Second, we show how external environmental constraints, initially by leveraging and then managing and reshaping them, acts as an enabling antecedent rather than a detriment when it comes to BMD under complexity. Even though Amit and Zott (2015) consider stakeholder activities and environmental constraints distinct, there is considerable interaction between the two concepts in designing BMs for complex-innovations. Our model depicts how the interplay between the external environmental constraints and the design space emerges, whereby they mutually influence each other, resembling a complex responsive process (Stacey, Griffin, and Shaw 2000, 188). We highlight the agency of the focal firm in initiating and facilitating this emergent process, which depends on their dynamic capabilities to leverage external constraints and realign existing structure and culture.

Our theorising has practical significance for firms to engage in ecosystem building in uncertain and constrained environments to create and capture value from emerging complex-innovations. Our model shows how the problem and solution space is built simultaneously and how they coevolve to generate desirable design alternatives. The model can be used as a design artifact for managers to work with, develop the capabilities for and engage in actions to deal with the uncertainty in creating and capturing value from complex-innovations.

To conclude, BMD antecedents coevolve with their underlying innovations in a complex responsive process. It leads to an emergent choice of BMD alternatives that firms can choose from in designing their BMs. We acknowledge that design in complexity is an emerging field and attributing agency to actors in complex systems, an even recent focus in literature. Further research is needed to strengthen the concurrent emergence of BMD antecedents and innovations and the role of focal firms in facilitating emergence in desirable ways. We suggest empirical work to develop further the conceptual model upon which we base our arguments.

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