From Business Model to Business Modeling: Modularity and Manipulation

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Abstract

The concept of modularity has gained considerable traction in technology studies as a way to conceive, describe and innovate complex systems, such as product design or organizational structures. In the recent literature, technological modularity has often been intertwined with business model innovation, and scholarship has started investigating how modularity in technology affects changes in business models, both at the cognitive and activity system levels. Yet we still lack a theoretical definition of what modularity is in the business model domain. Business model innovation also encompasses different possibilities of modeling businesses, which are not clearly understood nor classified. We ask when, how and if modularity theory can be extended to business models in order to enable effective and efficient modeling. We distinguish theoretically between modularity for technology and for business models, and investigate the key processes of modularization and manipulation. We introduce the basic operations of business modeling via modular operators adapted from the technological modularity domain, using iconic examples to develop an analogical reasoning between modularity in technology and in business models. Finally, we discuss opportunities for using modularity theory to foster the understanding of business models and modeling, and develop a challenging research agenda for future investigations.

Keywords*: business model, modeling, cognition, modularity, manipulation, decomposability*

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Introduction

A business model represents a business enterprise's essential value creation and capture activities in reduced and abstract form (Teece, 2010). Such models are, first of all, cognitive devices that mediate between managerial thinking and engagement in economic activities (Baden-Fuller & Morgan, 2010; Chesbrough & Rosenbloom, 2002; Martins, Rindova & Greenbaum, 2015), and so represent complex economic environments in simplified forms, facilitating reasoning and communication to third parties. While economists work with sophisticated mathematical representations, simpler tools - such as lists or maps - are often employed as models in the management field (for a taxonomy see French, Maule & Papamichail, 2009; or see Osterwalder & Pigneur, 2010 for a business model 'canvas'). The business model, specifically, has recently gained widespread interest and application among scholars and managers as a helpful tool for both thinking about and creating systems of value creation, delivery and capture (for a review see Zott, Amit & Massa, 2011).

Business models can be represented in many forms, and employing a particular style of representation can affect the associated thinking processes and thus the model's functionality (Martins et al., 2015). However, several recent scholarly representations of business models - despite being grounded in different theoretical premises - have in common the fact that they are conceived as combinations of sub-categories populated by consistent elements (see among others the classifications by Baden-Fuller & Mangematin, 2013; Demil & Lecocq, 2010; Massa & Tucci, 2013; Osterwalder & Pigneur, 2010; Zott & Amit, 2010). Also, the popularity of tools such as the 'business model canvas' (Osterwalder & Pigneur, 2010) among practitioners seems to suggest that even managers are at ease with representing business models as simplified systems of interconnected elements. Thus we start from the situation where a model for business is considered relevant and useful (Morgan, 2012), and cognitive efforts to represent "business models as models" (Baden-Fuller & Morgan, 2010) are important in order for the role of business models as "manipulable instruments" (i.e., instruments that can be voluntarily shaped and changed to gather insight) to be enacted. These in turn can be helpful in assisting scholarly and managerial reflection both on what a firm does (or could do) to create and capture value, and on how it can be modeled and innovated to fit changing technological or market conditions (Baden-Fuller & Haefliger, 2013).

In this paper, we refer to *business modeling* as the set of cognitive actions aimed at representing (complex) business activities in a parsimonious, simplified form (i.e., a business model), as well as to the set of activities that cognitively manipulate the business model to evaluate alternative ways in which it could be designed. These activities are the antecedents of business model innovation, which - however radical or incremental - often constitute a change in a business model that is commonly perceived as useful in its representation, and which scholars often connect to an opportunity for performance enhancement (Zott & Amit, 2007, 2008). Once implemented, business model innovation may lead on to sustainable business operations, or it may fail: but we leave it to past and future research as well as management practice to engage with the perils of execution. Beyond this, what is noteworthy here is that scholars seem to share a growing interest in the underlying idea of *modeling* a business model, which is tightly connected to other popular concepts such as business model *innovation* (Baden-Fuller & Haefliger, 2013; Chesbrough, 2010; Gambardella & McGahan, 2010), *renewal* (Chesbrough, 2010), *evolution* (Doz & Kosonen, 2010), and *design* (Demil & Lecocq, 2010; Zott & Amit, 2010). This growing stream of research reflects the importance of understanding the underlying dynamics related to business model experimentation and manipulation, which often represent the most common option for firms needing to respond to changing environments or fierce competition.

Despite the fact that scholars have provided multiple suggestions as to how to represent business models, surprisingly little is known about the different ways in which such models can be manipulated and how such actions can help change *existing* business models, even though there has been much interest in manipulation as a tool to support experimentation, innovation, and performance (Zott & Amit, 2007, 2010), and in manipulability as a fundamental property of any model (Baden-Fuller & Haefliger, 2013; Baden-Fuller & Morgan, 2010). As an instrument for reasoning, the business model supports fundamental management decisions for both early-stage and mature businesses; but while the idea of the application of business models as a way to design new startup ventures has taken hold easily (Gambardella & McGahan, 2010; Zott & Amit, 2007), such inquiry appears to have been more difficult (and thus less investigated) in the realms of mature firms, where issues of endogeneity, inertia, and complexity can pose additional problems. Hence, it is even more valuable to consider the business model as a cognitive and analytical tool to play with alternative scenarios for existing businesses, and to model various possible outcomes of strategic decisions. Also, despite the increasing interest in phenomena related to business model innovation, as well as their paramount importance, we still lack a clear understanding of the basic options for change in existing business models. In this study we tackle this important aspect by investigating the following research question: *How can we systematically understand and classify the manipulations of a business model?*

To respond to this question, we borrow from the theory of complex systems, and in particular from Simon (1962), who viewed modular systems as the result of deliberate human activity: i.e., that artifacts and social systems are conceived of as being composed of other subsystems. Attempts at modeling a new instantiation of an existing business model necessarily encounter the difficulties of *modularization* and *manipulation* as well as the opportunities and limitations of *decomposability* and *information hiding*. To follow this theoretical perspective, we consider the business model as a system of interconnected parts, which stand for sub-categories populated by constituent elements, such as a business' monetization mechanisms. Our approach resonates with previous themes in the business model literature. As Massa and Tucci (2013) highlight, the level of abstraction of business model representations among scholars and practitioners varies between being more or less granular (i.e., including more or less elements, depending on the level of analysis), but the different classifications still tend to remain consistently represented in terms of the inter-relatedness of their elements. We suggest that this system approach offers a basis to understand how business models might change and, particularly, how firms might conceive such innovations as, for instance, the move from 'product' to 'multi-sided platform' business models, or from vertically integrated towards networked arrangements.

Other contributions in the strategic management literature on the economies of substitution (Garud & Kumaraswamy, 1993, 1995) follow a similar logic: economies of substitution "exist when the cost of designing a higher-performance system through the partial retention of existing components is lower than the cost of designing the system afresh" (Garud & Kumaraswamy, 1993: 362). Modularization reduces costly transactions that prevent the benefits of modular systems from materializing (Garud & Kumaraswamy, 1995: 96). Modular designs - when possible and effectively implemented - allow for the achievement of greater system flexibility, along with the benefits coming from increased division of labor and specialization (Garud & Kumaraswamy, 1995). Moreover, components of modular systems can be mixed and matched in specific system designs, both to allow for larger product variety via element recombination (Devetag & Zaninotto, 2001), or to increase the overall value of existing solutions (Langlois & Robertson, 1992). In other words, elements in modular designs show high degrees of manipulability, which enable efficient and effective experimentation in terms of novel, innovative configurations. If we can conceive of business models in terms of the principles of modularity, the notion of manipulability can facilitate changes in their design, which may lead to significant innovation for firms.

Since its very early days, the business model debate has been tightly intertwined with technology and innovation (Amit & Zott, 2001; Baden-Fuller & Haefliger, 2013; Chesbrough, 2010; Gambardella & McGahan, 2010), particularly, the discussion of how the diffusion of the Internet allowed firms to introduce new business models or innovate their existing ones (Amit & Zott, 2001; Baden-Fuller & Haefliger, 2013). For instance, the degree of modularity embedded in many information-intensive artifacts - such as ICT-based products and services (Yoo, Boland Jr, Lyytinen & Majchrzak, 2012) - has promoted the emergence of platform business models, also referred to as multi-sided business models (Rochet & Tirole, 2003; 2006). These allow different sides of a market to be connected via multiple technological platforms and technological domains (consider for example how Amazon, Google, or Airbnb platforms engage with different categories of users in exchanging goods, services, or other scarce resources, e.g., customer attention). Thus technological modularity has remained at the very core of the business model debate, and scholars have paid increasing attention to the benefits of modular technologies for business model innovation, to the point of starting to question whether business models themselves can actually be modular, and how their modularity might be related to the modularity of their enabling technologies (Bonina & Liebenau, 2015; Kodama, 2004; Parmatier, 2015).

Modularity in technologies may or may not foster modularity at the business model level: but it is not our goal here to investigate whether modularity in a technology triggers modularity in a business model, but rather to investigate how we can conceive and change business models using ideas of modularity and manipulation (i.e., voluntary change), whether or not technological change is involved. This is particularly important because, despite the principles of manipulation and modularity in modeling being a common theme in the literature of business models, we still lack a clear theoretical distinction between modularity theory as applied to technologies *vs*. as applied to business models. In these regards, we argue that scholarship needs to address three aspects promptly: (1) defining what modularity means in business model terms (and, by implication, how it might or might not differ from modularity in technology); (2) understanding what are the cognitive processes supporting business modeling in modular terms, and how the cognitive reasoning involved relates to real world activities; (3) identifying the boundary conditions that determine whether modularity theory can be applied to business models and modeling. Finally, we suggest that modularity is a viable theory to inquire into business models due to its own constituting logics that have also allowed its previous application to organizational contexts (see for example Brusoni, Marengo, Prencipe & Valente, 2007; Brusoni & Prencipe, 2001a).

We characterize our approach to business models as one that focuses on cognitive modeling, rather than real world execution. Business modeling can be divided into three phases (see Table 1). *Thinking* is the cognitive effort to *inquire* into the business, and usually corresponds to the individual effort of cognitively understanding a business. *Articulating* is the individual cognitive effort to *represent* the business in a parsimonious and simplified model, so that it may be conveniently shared with other stakeholders, whose interactions may affect the model representation itself. The articulation phase may involve considering possible modifications to the original business model, achieved via cognitive manipulation - a phase in which individuals and groups cognitively 'tinker' with possible alternatives to optimize their business model. Finally, the *doing* phase implies a series of decisions and routines to *translate* the cognitive model into a set of activities in the real world of business, which involves grappling with the messy details of technology. Table 1 refers to the complex challenges managers face when designing a business model.

Table 1: Business model *thinking*, *articulating*, *doing*: challenges for a modularity perspective

	Thinking	**Articulating**	**Doing**
Focus of process	Perspective	Representation and change	Execution in action
Actors involved	Individual	Collective within the firm (stakeholders, managers, board)	Collective within and outside the firm
Relevant input	Data on organization and environment	Simplification and representation; options/alternatives	Decisions, actions and routines
Translation	Identification, reflection, analysis and deconstruction	Calibration, extrapolation, simplification, sharing, evaluation of the alternative options, simulation	Sense making and sense giving
Challenges for modularity theory	Identification of what composes a business (cognitive exercise)	Modularization and manipulation of the business model elements representing the processes to create and capture value (cognitive and theoretical exercise)	Implementation of activity systems that lead to business results (real world exercise)

Our paper proceeds by considering the concept of elements (i.e., components of a system/mode) as well as the constituting principles of modularity theory. Specifically, we consider two key notions of the business model construct: first, the *modularization* of the business model - which includes the possibility of representing a model via a set of interconnected elements. And second, we consider the *manipulation* of those interconnected elements – and so 'inquiring into' the challenges of modeling a business model. We also consider the benefits and risks of two basic properties of modular models, namely *decomposability* (Simon, 1962), and *information hiding* (Parnas, 1972).

Once the necessary principles are identified, we then tackle the thorny problem of understanding and classifying business model changes (i.e., *manipulations*) through modularity operators. To substantiate this abstract reasoning more fully, we first define these operators according to modularity theory (Baldwin & Clark, 2000; Parnas, 1972), and show how they have been originally applied to examples within the technology domain. Second, following analogical reasoning (Gavetti, Levinthal & Rivkin, 2005; Martins et al., 2015), we identify iconic examples of innovation in the business model domain and, by appreciating the salient changes, identify the types of changes that are analogous to change cases in technology. In particular, we follow three general constituting elements of the business model (i.e., value *creation*, *delivery*, and *capture*) and the changes they undergo that are comparable to our technology architecture examples, and make reference to current practical issues. We generalize our arguments with a series of propositions that extract cognitive operators explaining business model change. By applying modularity operators to business model change, we are thus able to advance a precise classification of business model changes, which can help both scholars and practitioners inquiring into different types of manipulations. Finally, we ask how modularity may further help scholars respond to questions from the contemporary business model research domain. We conclude with a set of suggestions for future contributions, which represent a challenging research agenda whose trajectory points to the intersection of business models, modeling, and modularity.

Modularity Theory and the Business Model

Essentially, modularity can be viewed both as an organizing strategy for understanding and representing complex systems - such as artifact architectures or organization structures - in terms of a series of self-contained and interlinked subsystems, variously labeled as "parts" "components", "elements" or "modules" (Baldwin & Clark, 2000; Baldwin & Clark, 2003; Brusoni et al., 2007; Brusoni & Prencipe, 2001a). A system is more or less modular depending on the possibility that it could be decomposed into loosely coupled components, and modularization can be seen as the process by which a system is structured according to a modular design, or could be redesigned to achieve a higher degree of modularity (see Table 2 for a summary of the relevant definitions).

Table 2: Modularity in technology

Term	Category	Definition	Example
Module	Object	A (conditionally) self-contained subsystem	A PC is composed of several modules such as CPU, hard disk, RAM, DVD reader, video card, etc.
Modular	Attribute	The character of a system	The PC architecture is modular in that its subsystems can be recombined according to various configurations
Modularity	Pattern	The degree to which a complex system can be conceived in terms of subsystems	The PC modularity allows to extend products life span by upgrading individual components
Modularization	Process	The act of structuring (or restructuring) a system in modular terms	The history of computing is characterized by the increasing modularization of product designs (e.g., the shift from mini-computers to PCs)

It is important to acknowledge that our understanding of systems and modularity borrows heavily from the original work of Simon (e.g., Simon, 1962) on modeling complex systems and their decomposability. Simon's contribution suggested that modeling is most fruitful if the model of the system can be simplified and decomposed into parts. This allows components that are less crucial to be put into 'black boxes' to focus more clearly on core elements and thus facilitate their manipulation (for an appreciation of how and why Simon influenced our thinking, see Boumans, 2009; Morgan, 1991). Following this line of reasoning, we stress the cognitive nature of modeling activities, which implies that the actual possibility of manipulating a model lies, above all, in the actors' *understanding* of its components and their interdependencies, rather than in the *actual* properties of the elements and the model.

Similarly, current management theory draws heavily on Simon's work, but also borrows from more recent modularity theory (Baldwin & Clark, 2000) using an intellectual process of analogical reasoning that also allows us to transfer approaches and toolkits based on the theory of modularity (e.g., modular operators) from the technological to the business model domain. In fact, modularity has risen to the level of being seen as a dominant paradigm for managing complexity in a variety of different fields, such as industrial manufacturing, neuroscience, problem solving, software engineering, architectural design, and product development (to name a few). Within the management research domain, modularity principles have been widely applied to strategic management (see among others Brusoni & Prencipe, 2001a; Garud, Kumaraswamy & Langlois, 2009; Schilling, 2000), organizational design (Baldwin, Hienerth & Von Hippel, 2006; Baldwin, 2008; Garud & Kumaraswamy, 1995), and other fields. Thus we are confident that, given evidence of similar exercises in nearby theoretical domains, by extending modularity principles to business models scholars will be able to apply a large set of modularity tools and operators that have been successfully developed to inquire into technological and organizational issues, some of which we consider in this paper.

If we have to take on board the notion of 'model' in full in considering business models, we need to ask how such models work, how they can be changed by their users, and how analogical reasoning may support both their modularization and manipulation. However, it is first necessary to recognize a set of compelling challenges and boundary conditions that relate to this objective. We acknowledge that it is not obvious that modularity theory can always be applied to organization and management science (Brusoni & Prencipe, 2001a), because modular technologies may not lend themselves easily to analogies beyond technology, such as organizational design efforts (Baldwin & Clark, 2000), and that activities that appear modular may require integrated thinking and knowledge sharing (Sosa, Eppinger & Rowles, 2007). Modularity represents models and systems in arbitrary, abstract, and simplified forms, but the models and the actual activity systems they represent may ultimately not match. Still, if we allow for the possibility that modularity describes models that can usefully represent systems such as businesses, then two key processes - and thus two major challenges - stand out: the (1) *modularization* and (2) *manipulation* of the business model.

Modularization and manipulation

In our argument, *modularization* is the cognitive activity aimed at conceiving of a complex system such as a business as a simplified model of interconnected elements (Brusoni & Prencipe, 2006; Simon, 1962), while *manipulation* refers to the processes of changing a business model's elements, their linkages, and their order at the cognitive level. The manipulation phase also allows for 'tinkering' with the model and evaluating different alternatives, thus cognitively exploring which possible alternative design options might lead to the optimization of the model. These processes are part of the modeling phase in preparation for a new business model's actual implementation in the real world. Still, it is pivotal to keep in mind that what applies at the cognitive level might not be easy to enact in the real world due to constraints at both levels. At a cognitive level (Baden-Fuller & Haefliger, 2013; Baden-Fuller & Mangematin, 2013; Baden-Fuller & Morgan, 2010; Martins et al., 2015), the possibility of modularizing and manipulating a business model depends on the individual's ability to think and represent a business as a system of interconnected elements, sharing it with other stakeholders, and to be able to interact to manipulate a shared representation jointly. In contrast, the translation of a cognitive model into the real world - and thus within an activity system perspective (Zott & Amit, 2007, 2008, 2010) - depends heavily on the actual decomposability of the resources and functions in that activity system, as well as on more general organizational constraints (e.g., governance, routines, inertia, etc.). This distinction of perspectives is critical, and requires a closer inspection of the connection between a modular cognitive representation of reality and a modular set of processes or activities, as what seems feasible in cognitive terms might not be as possible in the real world.

The activity system perspective (Amit & Zott, 2001; Casadesus-Masanell & Ricart, 2010; Zott & Amit, 2010) argues that a business model can be thought of as a set of interdependent organizational activities structured by a focal firm (directly or through its partners) in order to create and capture value. According to Zott and Amit (2010), an activity system has three major design parameters: *content*, which activities are involved, *structure*, how they are linked, and *governance*, who is in charge of them. If one considers the first two elements, the overlap between the concepts of elements and their interdependencies is straightforward, especially in the case where activities can be reified in an artifact design by embedding them as functionalities assigned to specific components. As far as the third design parameter is concerned, the arguments on governance are closely related to those contributions in the literature on modularity that highlight how modularity at the artifact level fosters the emergence of modular industries (see for example Brusoni, Prencipe & Pavitt, 2001).

But an adjacent stream in the academic debate (Baden-Fuller & Haefliger, 2013; Baden-Fuller & Mangematin, 2013; Baden-Fuller & Morgan, 2010) holds that business models are not to be confounded or conflated with actual, real-world, sequences of organizational activities. Instead these contributions build on the assumption that business models are cognitive tools that allow managers to use simplified and general representations - and are thus (to some extent) separable from the firm's actual environmental context - to reflect on the essence of their business, and to make meaningful inferences in terms of cause-effect relationships between their various constituent parts. Following this line of reasoning, we need to distinguish between the organizational domain and its modularity and the business model representations in the managers' minds - that is, the distinction between real world and cognitive representations.

Our argument heeds the complexity involved in understanding the nature of the relations between the elements that allows for their manipulation. In order to be seen and understood as a modular design, and thus be manipulated, considering a business as a system of interconnected components also needs a higher level of abstraction that entails a series of cognitive steps, such as: (1) understanding which functionalities are involved in the business model as a whole; (2) assigning these functionalities to the various business model elements; (3) discerning which of those elements are the focus of attention, and appreciating the interactions between them; and (4) decoupling their interdependencies, as much as possible. None of this can be taken for granted: the cognitive part of this process - which is bounded by the individual's rationality - might not be aligned with the actual configuration of resources and activities in the real world. Modularization is a useful practice that prepares the ground for, but does not necessarily guarantee, manipulation. The actor might not be able to manipulate the system in its current state, either because of cognitive limitations on their logical skills or because of actual real world constraints.

Undertaking modeling is not trivial. We know that many managers find manipulating models difficult. Although they recognize the importance of the value creation, value capture, and value delivery elements as a narrative of their businesses, they typically try to model everything at once, and are not able to fully articulate how those individual parts interact and how they contribute to their firm's performance. Not being able to focus on what is core to their business, and then to conceptualize a business model in terms of a limited number of sub-elements (and embrace the principles of modularity) appears to inhibit understanding, and thus manipulation. As in the case of the design of complex artifacts, it is therefore important to note that embracing modularity is the result of a deliberate problem-solving approach, where a complex phenomenon is tackled by decomposing it into quasi-independent sub-components or sub-problems.

Choosing the locus of attention

All in all, while comprehensible and relatively straightforward as an idea, actually creating and adopting representations is not a trivial task. Choosing the focus of attention and the level of granularity are two very important dimensions in specifying the appropriate elements, which can be regarded as exercises in business model conceptualization that must necessarily precede its manipulation. Making the business model explicit, modularizing its elements, and then manipulating them are knowledge-intense processes, and are often carried out within social interactions. Modularization, in particular, can be addressed as a multi-level process whose granularity is contingent on individuals' perceptions of optimum effectiveness and efficiency for their final objectives. To undertake this exercise in cognitive terms, theory-driven business model classifications offer valuable templates to modularize the often rich and complex narrative of a business model into a parsimonious system of constituting elements.

The literature offers different schemas to categorize business models, which means this exercise can be performed at different levels of granularity and selectivity or - in Massa and Tucci's (2013) words - at "different levels of abstraction". For example, Demil and Lecocq (2010) provide a three-element framing based on (1) resources and competences, (2) organization, and (3) value proposition, while Baden-Fuller and Mangematin (2013) and Baden-Fuller and Haefliger (2013) offer a four-element classification based on (1) customer sensing, (2) customer engagement, (3) monetization, (4) value chain and linkages, which has a special focus on the customer-firm interface that resonates with Rochet and Tirole's (2003, 2006) theory work on multi-sided platforms. In contrast, Osterwalder and Pigneur's (2010) business model 'canvas' offers a nine-element classification including (1) key partners, (2) key activities, (3) key resources, (4) value proposition, (5) customer relationships, (6) channels, (7) customer segments, (8) cost structure, and (9) revenue streams, but with no particular focus. We value the contribution of each of these (and other) classifications in identifying key business model aspects, and leave it to the readers to engage with the one that best suits their needs. As our analogical arguments aim to be equally applicable to any of these classifications, so as to maximize their generalizability and applicability to future classifications, this paper uses a very parsimonious model of three elements that modularize the business model in processes of value (1) creation, (2) delivery and (3) capture – and we compare and contrast two particular approaches.

There are currently two very different foci of scholarly attention. Traditional strategy scholars holding the 'resource based view of the firm' focus on the firm's internal operations, and its supply chain of partners, including its knowledge partners - treating customers and customer interactions largely as a 'black box' (e.g. Barney, 1991; Zott & Amit, 2010). This perspective typically assumes a fixed form of customer engagement (typically a product or service system, or sometimes a project based system) – and considers that business model manipulation involves value chain considerations, such as outsourcing, partnering, knowledge management, etc. An alternative perspective is represented by contributions (such as by Baden-Fuller & Mangematin, 2013; Eisenmann, Parker & Van Alstyne, 2011; Füller, Jawecki & Mühlbacher, 2007; Hienerth, Keinz & Lettl, 2011; Rochet & Tirole, 2003; 2006) which - building on evidence gathered by observing the evolution of information intensive industries - focus on the boundary space between the firm and its customers and users, and treat the firm's internal structures and organizations as fixed, at least in the first place. From this perspective, manipulations typically consider different kinds of customer arrangements (product/service vs. multi-sided platform) as key. In both cases, while there is still modularization and manipulation, what is modularized and what is manipulated differ, even though both designs can be grouped under the broad 'business model' label. In both cases, the system is decomposed, and is made modular, as we explain below - but what is decomposed and what is made modular are a matter of choice that depends on the scholar's or manager's perspective.

Information hiding

To guarantee greater degrees of manipulability, and efficient and effective experimentation with the model, another key principle of modularity needs to be introduced. According to another fundamental principle of modularity - known as *information hiding* (Baldwin & Clark, 2000; Parnas, 1972; Schilling, 2000) - one only needs to understand what an individual element does, and how it interacts with the other elements, to be able to adjust the overall system performance via that element. This means that information on the inner workings of all the other elements can be safely and efficiently ignored or hidden when a given element is being manipulated. Information hiding allows business model designers to postpone many decisions about the actual design of the overall system - which may just involve single elements - and can be made at later stages in the model's development. In short, modular designs create options, in the sense that elements can incorporate option values because they allow design decisions to be postponed into the future, so allowing the system to evolve over time, by introducing local changes at the single component level, without the need to revise the whole modular architecture (Parnas, 1972). To the extent that the system is actually modular, information hiding can be a tremendous advantage.

Still, the flip side of the coin - the risk of information hiding - is of simplifying complexity and so disregarding residual interdependencies between elements, and misrepresenting how specific elements will perform in the future. This means not being able to grasp a holistic view of the model, and thus not being able to inquire into it in its entirety. For this reason, we argue that inquiring into a business model in a modular fashion should involve a back-and-forth reasoning at the system and subsystems levels. In fact, by applying a modular representation, should involve combining the benefits of retaining an overall view of the system with the efficiencies of fostering local changes. In practical terms this translates into assessing - via an iterative process - how a change in or of a single element might influence the system as a whole, and eventually going back to modify that element in order to change the entire business model in a way that retains its ability to fulfil its ultimate purpose.

The interplay between elements and the system as a whole provides for efficient experimentation because it operates at the cognitive level, but holds the potential for influencing collective decisions and implementations at the activity level. Business models draw boundaries between their elements, so that the model itself appears to be compartmentalized. These boundaries are not always obvious organizational structures - such as functional or divisional sub-organizations - and hence require new thinking about the links that connect them. It is paramount, then, to identify the appropriate level of granularity different business model classifications can offer, as well as the level of modularity by which they represent business processes (Massa & Tucci, 2013). This is a complex task, because the model designer needs to avoid over-simplifications that come at the cost of lack of precision, but also avoid over-specification that could lead to information overload. In this fashion, information hiding allows for inquiring into single elements efficiently, but then also needs to be combined with a holistic overview at the system level to understand how the part(s) influence the whole. Assessing the appropriate level at which modularity should be applied takes into account the current business processes as well as potential new processes that could be innovated or acquired. Doz and Kosonen (2010) speak of “resource fluidity” that allows managers to consider business model renewal, and use modularity as one approach by which business models can take into account more malleable resources that can be decoupled and modularized. However, once this and the aforementioned conditions (i.e., granularity of the representation; modularization, information hiding etc.) have been assessed, one can move to the actual manipulation of the model. Thus, our next step turns to specific modularity operators that can be utilized for experimenting with and changing business models.

The Six Operators:

From Technology Design to Business Model Change

As described earlier, a key property and benefit of modular systems is the opportunity to introduce innovation into the system via element-based change. In the modularity perspective, a consolidated view is that of modular operators - a taxonomy of generic design actions inherited from the field of complex adaptive systems (Simon, 1962) - that allows for the manipulation of the architecture at the level of its elements. Baldwin and Clark (2000) identified six modular operators: *splitting, substituting, augmenting, inverting, excluding* and *porting*. Table 3 defines these operators and offers relevant examples of technological artifact designs.

Table 3: Definitions of modular operators and examples from technology

	Technological domain	
Operator	**Definition**	**Example**
Splitting	Separating a module into two or more new modules	Moving from integrated to swappable batteries in electronic devices
Substituting	Replacing a module with another module performing the same task	Swapping processors in PC, upgrading a software application
Augmenting	Adding a module to increase the functions of the artifact	Adding the option of saving data on a cloud service
Inverting	Promoting and embedded function to stand alone module	From DEC's embedded system to UNIX as a stand along operating system
Excluding	Removing a module to reduce the functions of the artifact	Stripped down products/services, portable computers without DVD reader
Porting	Moving a module from one architecture to another	Using an Apple printer in a PC network

Source: adapted and revised from Baldwin & Clark (2000).

To follow the analogical reasoning noted above, we will first connect the technology design operators to iconic technology design examples, and then identify corresponding iconic business model change examples. Thus we will be able to advance theoretical propositions for the transfer of these operators from the technology domain and their cognitive adoption to the business model domain. Given the conceptual nature of our work, our goal is not to offer precise accounts of actual businesses within particular firms or industries - as an empirical case study research would - but rather to identify vignettes that are clear enough to reduce the complexity and relate to the theoretical operators, so favoring understanding and analogical reasoning. To maximize the generalizability of our analogy, and avoid suggesting that our exercise might be more suitable to only one of the classifications in the literature, we decided not to perform this exercise on existing business model frameworks (see for example Baden-Fuller & Haefliger, 2013; Baden-Fuller &

Mangematin, 2013; Demil & Lecocq, 2010; Osterwalder & Pigneur, 2010) but rather to identify a set of activities which represents a general system of value (1) creation, (2) delivery, and (3) capture that could be relevant to all businesses. In doing so, we note in Table 4 two possible types of examples following our discussion of the locus of attention in strategic management – one that focuses on manipulating elements that are internal to the firm and one that focuses on manipulations of the customer interface. We use this parsimonious representation to identify the basic modular system of the business model, and use it in our vignettes to provide examples of business model modeling. The links connecting the three inter-connected elements (as represented by the square boxes in Figure 1) indicate that these activities are not fully independent, but rather there is some degree of residual dependence (i.e., quasi-decomposability) between them, and, from a cognitive perspective, they can be perceived as part of an overall system - the overarching business model. In Table 4, business model elements (and related arrows) are represented differently according to how the application of the modular operator affects them: single solid lines correspond to pre-existing elements which are not influenced by the modular operator; double lined, grey filled, elements are new elements that are introduced in the business model by the operator; and elements which are eliminated from the business model appear in dotted lines (note also that squares and circles are used to distinguish between elements belonging to different business models, or different sides of a multi-sided business model).

Figure 1: A simplified representation of a business model as a modular design composed of three basic elements: value creation, delivery and capture.

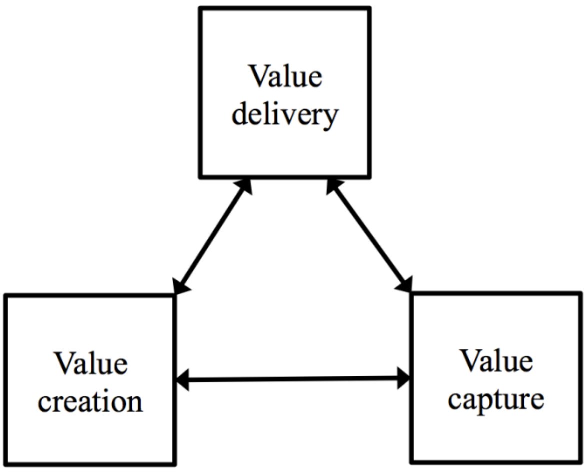
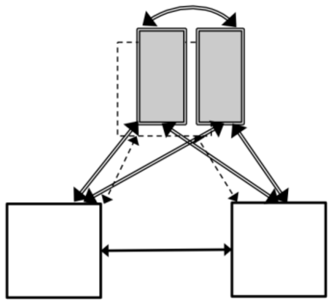
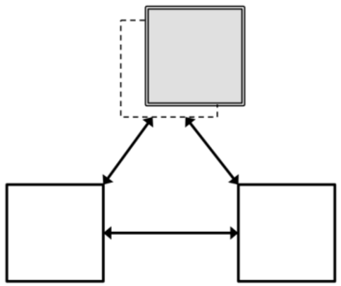
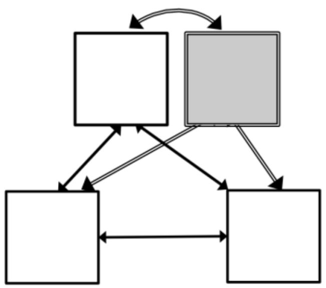
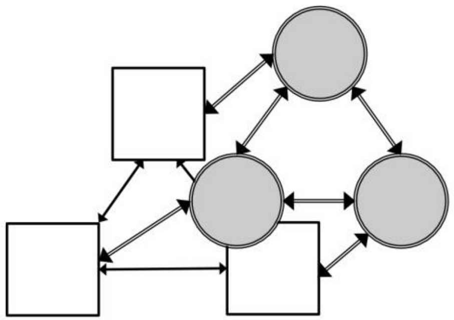
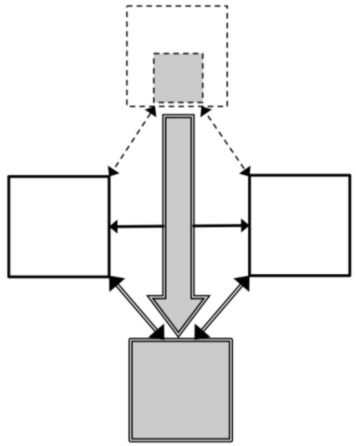
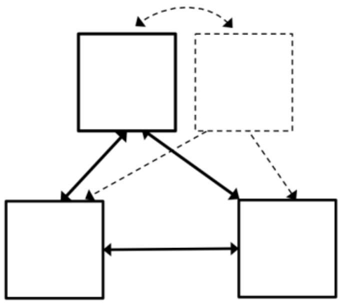
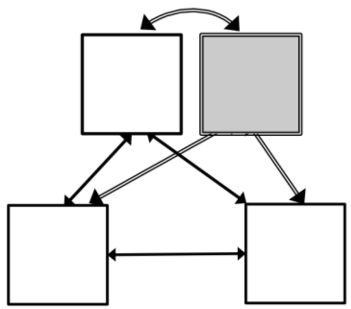
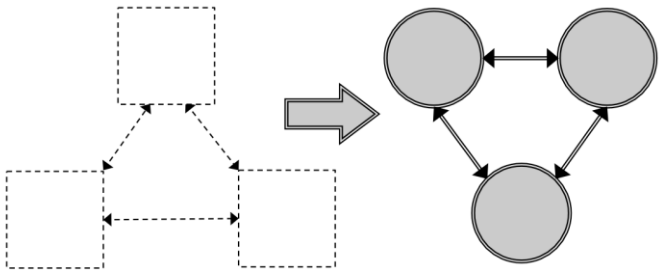


Table 4: Definitions of modular operators and examples for business modeling

Business Model Domain				
Operator	**Graphic representation**	**Definition**	**Traditional strategy example**	**Customer interface example**
Splitting		Separating a business model element into two or more new model elements	Identifying a new product to satisfy existing customer needs (e.g., HBO)	Introducing subscription billing policies to shift from one time to recurring customers (e.g. Microsoft Office for tablets)
Substituting		Replacing a business model element with another element performing the same task	Vertically integrating the supply chain instead of relying on external suppliers (e.g., Starbucks)	Moving from a simple product offering to a community-based marketplace (e.g., Ely Lilli)
Augmenting	 	Establishing a new business model element (or more elements in order to account for a new layer in a multi-sided business model) to increase the value of the business model and/or its elements	Adding total quality management function to control the supply chain more effectively (e.g., Toyota)	Leveraging synergies between product and service sides to increase the value of the total offering (e.g., Oracle) or moving from single-sided business model to multi-sided platform (e.g., Google)

Inverting		Leveraging a specific part of a business model, to stand alone element or stand-alone business model	Creating new stand-alone departments from a firm's existing departments (e.g., Xerox Centralized Print Services)	Elevating a part of the business model from peripheral to core status (e.g., Gillette razor-blade)
Excluding	 	Removing a component to narrow down the business model's function	No frills offering at lower cost (e.g., Ryanair)	Stripping down additional services and sides of a business model (e.g., US National Public Radio)
Porting		Moving a business model component (or an entire model) from one domain to another	Adapting the razor-blade model from shaving to printers (e.g., Epson Printers)	Importing social-network interaction into video gaming (e.g., Sony Playstation)

Legend:
Continuous lines: elements and linkages that remain stable in the model. Dotted lines: elements and linkages that are eliminated from the model.
Double lines and grey figures: new elements and new linkages that are introduced in the model

Splitting

The first fundamental operator in modularity is *splitting,* which consists in separating a module by dividing it into two or more (independent) sub-elements. This is consistent with the idea that conceptualizing the design of an artifact at a finer grain gives the opportunity to experiment with many more design specifications, thus speeding up the quest for performance-enhancing solutions. In the technological domain, a typical example of this operator is represented by reworking activities within a product architecture aimed at isolating some features or tasks belonging to a relatively large component, as, for instance, in the case of the transition from integrated to swappable batteries in electronic devices.

Cognitively applying this operator to business modeling generally entails focusing on aspects of a business model at a finer level of detail, again by dividing one or more elements into smaller sub-elements. While business model changes might derive directly from splitting at the technological level (e.g., the advent of the centralized computing paradigm in favor of client-server solutions, which resulted in novel business models for the software industry), in other instances such splitting might occur at a more abstract - business model - level. In this case, splitting can be interpreted as the action of dividing one business model element into two or more subcomponents which perform more specialized tasks. For instance, one could distinguish, within the general 'value capture' module, between revenue model and cost model components. Such splitting allowed Microsoft to focus on their revenue model and come up with a subscription offering for Office in the tablet market, allowing the recurring billing of customers who had formerly been one-time purchasers, leaving the cost model untouched. Likewise, in value creation, one could focus separately on customer engagement and customer sensing. In other words, generally speaking, splitting a module might require the reworking of some activities in the remaining model elements to preserve the business model's overall consistency. Thus, we can argue that:

> *Proposition 1: In the business model domain, 'splitting' is the operator that enables cognitive inquiries into the separation of an individual element into two or more sub-elements.*

Substituting

The second operator is *substituting* - replacing a module with another one performing the same task. This is a fundamental operation in modularity, as it allows for the exploration of new areas of the solution space via module upgrading. Many examples can be observed, both in terms of producers experimenting with their technology product architectures, such as swapping a type of processor or software in a personal computer as a way of introducing variety and higher performance in a product line, or improving a mobile phone's wi-fi connectivity by substituting a GPRS-based data service with a component that can support faster connectivity (e.g., 2G, 3G, 4G, etc.).

In general terms, a business model undergoes an element substitution process every time one or more value creation, delivery or capture elements are replaced by another which, despite being internally arranged with a different set of activities, performs the same task in the business model architecture. Scholars or managers may use such archetypal 'swapping' operations to evaluate the effectiveness of incremental business model innovation (e.g., 'Leaving everything else untouched, what if we change this?'). This can take the form of high-level abstraction - e.g., at the value creation level: ('Could we engage the customer through a taxi, rather than a bus, mode?') - or a more practical evaluation of alternative ways to implement activities pertaining to a specific business model element (e.g., substituting the standard 'paid' mode by introducing 'free-to-play' or 'freemium' modes in an app's value capture mechanism). However, this type of change might force managers to reconsider their product types, as free-to play games (e.g., Angry Birds) might need to be designed to fit with the requirements of in-game advertisers. To be effective, substitution needs to also consider the overall business model and re-design some of its elements within the interplay between the system and its elements. Consider crowdsourcing as the poster child of *substituting*, e.g., Amazon's Mechanical Turk micro-task platform or Eli Lilly's InnoCentive marketplace for innovative ideas. In both these cases, the business model innovation lies in conceptualizing alternative ways to organize and execute production or design/ideation tasks by engaging large external crowds of contributors in the firm's business operations. So we can posit that:

> *Proposition 2: In the business model domain, 'substituting' is an operator that allows cognitive inquiries into replacing one original business model element with a different one that performs the same task but in a different way.*

Augmenting

The third modular operator is *augmenting*, which can be defined as the action of adding a module to the existing architecture in order to increase the number of tasks or functions the artifact can perform. A classic example of augmenting in the technology design domain is represented by adding a cloud-storing data service to a digital device, or including a camera or a GPS system into a mobile phone's architecture.

Augmenting in business modeling can mean developing additional value creation mechanisms to satisfy existing customer needs, as in the case of HBO exploiting value creation via reselling third-party content and producing its own original series. Or one could enhance and exploit synergies by augmenting existing elements with additional benefits. For example, SAP or Oracle might benefit from connecting their software sales (which respond to a typical product business model) to an after-sale business model such as customization and consulting for product implementation. This might provide an efficient product-service bundle, which extends their monetization options thanks to effective servitization. However, when this happens, SAP or Oracle might not only need to reshape their products (to make sure they favor customization), but also their pricing schemes and organizational structures in order to move value creation resources from their pre-sale to post-sale activities

In cognitive terms, scholars or practitioners might apply *augmenting* to their business model whenever they introduce a new element to exploit synergies with different value creation, delivery, or capture mechanisms. Another, even more radical way, to apply augmenting would be by introducing many elements in parallel in order to account for a new layer in a multi-sided business model. For example, Google's initial business model was single-mindedly focused on creating value for its search engine's final users, with a clear emphasis on reaching a critical mass of such users. But it was later developed into a fully-fledged multi-sided platform where monetization was via channeling users' attention towards clicks paid for by advertisers, a different side of the market that was augmented into the original business model. However, in order to maximize the value of this operation, Google had to undergo a major redefinition of its platform design, to allow (for example) sponsored links, and reference systems for various products. In general terms, augmenting starts by introducing a different category of user/customer who will both contribute to value creation for the original user/customer and can be the subject of a new value creation module. The shift from a single to a multi-sided business model also very often requires thinking about different value delivery and capture mechanisms for the new side. Thus:

> *Proposition 3: In the business model domain, 'augmenting' is the operator that allows cognitive inquiries into establishing or leveraging complementarities across different sides of a business model, to increase the value of the business model and/or of its constituent elements.*

Inverting

The fourth modularity operator is *inverting*, which involves picking an embedded function within a module and promoting it as a stand-alone module or architecture. An example of such an action in the technology design domain is the case of the development of UNIX as a stand-alone operating system, starting from its predecessor's (DEC's) embedded operating system.

In terms of conceptualizing business models, *inverting* can be achieved by selecting an element which is merely instrumental to value creation, delivery, or capture in a given business model and elevating it to the status of the focal point in a new business model configuration. Take, as an example, the iconic razor and blades business model popularized by Gillette: innovating the traditional business model, where value capture is the direct consequence of selling a product as a whole, towards a loss leadership/freebie business model which leverages complementary assets, is a straightforward interpretation of the notion of 'inverting' in business modeling. Another example is represented by the recent rise of TV formats (e.g., game, quiz and reality shows) within the television industry: once internally developed as part of a particular TV network's overall offer, today they have increasingly become autonomous products produced and marketed by external production companies (such as the entertainment production company Endemol) across different media and targeting audiences in various worldwide markets. Similar to the other operators, inverting can only be maximized by considering the possibility that other business model elements might need to undergo adjustments in order to guarantee the new business model's effectiveness. Thus, in moving from a traditional business model to its 'razor-blade' one, Gillette had to undergo a redefinition of both its product architecture and its pricing mechanisms, which led to significant increases in the prices of the blades and the razor itself being sold at a discount. Thus, we advance the following:

Proposition 4: In the business model domain, 'inverting' is the operator that enables cognitive inquiries into the promotion of a distinct, peripheral business model element into a core, stand-alone status.

Excluding

The fifth modularity operator is *excluding*, which involves removing one or more modules from an existing architecture to reduce the range of functions or tasks performed by the artifact as a whole. This is typically the case of many stripped down, 'no-frills' technology products or offerings, e.g., low-end market notebooks lacking DVD players, or sports cars (e.g., Lotus) which lack any of the technological devices (e.g., air conditioning, audio wi-fi, traction controls) that would increase weight and thus decrease performance.

The excluding operator is applied by scholars or managers inquiring into eliminating parts of a business model, for example by removing a specific customer segment or even a whole side of a multi-sided business model. Excluding can be a powerful cognitive pattern to evaluate more parsimonious business model configurations by leveraging on a firm's core competences. On a more practical level, excluding can be observed every time a business refocuses its value creation and capture efforts for particular customers. Public radio broadcasting (e.g., US National Public Radio) represents an alternative to commercial radio broadcasting, where advertising is excluded and radio stations seek voluntary contributions from listeners as a simpler value capture device. Another iconic example is low-cost airlines such as Easyjet or Ryanair, which strip the flying experience of its complementary service elements (e.g., free food, pre-assigned seats, included checked-in baggage, etc.) down to the minimum to achieve more competitive pricing. Thus our fifth proposition is:

Proposition 5: In the business model domain, 'excluding' is the operator that enables cognitive inquiries into eliminating parts of a business model, for example, turning a double-sided business model into a single-sided one.

Porting

Finally *porting* involves moving a module from one architecture to another, as in the case of using a Linux server within a Windows or an Apple based PC network, by exploiting increased compatibility in the interfaces that allow the various modules to communicate with each other.

In terms of business modeling, porting is implemented by moving whole business models (or some of their elements) from one domain to another. Firms tend to engage with a specific set of business models, but porting elements or entire models in from another industry might create the opportunity for a 'new-to-the-industry' business model, which could improve value creation and capture. Take, as an example, the case of Zynga, the largest developer of social games, which has increased its users' experience by allowing them to play with peers via mobile apps enhanced with several social networking features. This type of value delivery has also been implemented by Sony's Playstation and Microsoft's X-Box, which now offer web-based multiplayer functionalities with social networking features. These video-games examples seem to focus on porting a specific element (the social-network or the peer-to-peer customer engagement) from the social networking (e.g., Facebook) domain to that of video gaming.

However *porting* can also involve entire business models. For instance, take the increasing introduction of sharing economy models, such as collaborative consumption, into traditional business models such as car rental (e.g., the Zipcar business model). Generally speaking, every time scholars or practitioners speculate on ‘how to become the Airbnb of industry X’ or ‘the Ikea of industry Y’, they are making a thought exercise based on the idea of porting. Still, porting a whole business model is an operation that needs not only consideration of the new business model in its entirety, but also its complementarities with other existing business models in the portfolio (when relevant). For example, major airlines wanting to embrace a complementary low-cost service based on a ‘Ryanair-like business model’ may need to adjust the pricing and services of their prime operation to avoid cannibalization between their own business models. A holistic view of these factors must also consider business model configurations at the portfolio level. Thus we propose:

> *Proposition 6: In the business model domain, ‘porting’ is the operator that enables cognitive inquiries by adopting a business model (or some business model elements) from different domains and industries, and which are which ‘new to the field’.*

So far, we have sketched a first overview of the possible opportunities derived by extending some key principles of modularity into business model thinking and manipulation. We have generalized the modularity operators in terms of cognitive patterns that scholars or practitioners might find useful to think about when renewing their business models. We have also considered how those who want to manipulate model elements need to consider the parallel effects on the business model as a whole, or in some cases even at the business model portfolio level. The examples above suggest practical ways in which applying modular operators might help them delve more systematically into thinking and classifying business model change. Moreover, we have considered how scholars and managers might gather deeper insights by looking at existing iconic patterns of business model innovation from their direct competitors, or from other industries.

As an illustration of how applying different operators can result in meaningful business model variations, consider this stylized example of Amazon’s business model innovation. Amazon initially challenged its ‘bricks and mortar’ business model, which was typical of the traditional retailing industry, by substituting a new online distribution platform for its conventional delivery and customer engagement channels (physical stores). A few years later, Amazon introduced another major innovation into its business model, again by substituting the typical e-commerce value chain and linkages (based on proprietary warehousing), to allow other physical sellers to use Amazon’s customer base. Similarly, allowing final users to buy from both their and their complementors' catalogues can be seen as an example of augmentation, which led to Amazon refashioning its e-commerce platform into a fully double-sided market. Finally, the more recent introduction of Amazon Simple Storage Service (S3) can be seen as the result of inversion, where Amazon's internal assets, traditionally used instrumentally to connect with traditional customers, become the subject of its new Internet-based services and infrastructures offering. All these changes need to fit within an overall portfolio strategy where Amazon adjusts multiple business model elements to make sure that the individual business models first work holistically in themselves, and ultimately within the configurations of its whole business model portfolio.

Business Models and Modularity:

Contributions and Research Agenda

Our paper provides insights into the debate on business modeling and innovation by looking at the business model through a modularity perspective. We speculate about a grammar for describing business model changes in terms of a series of basic operations that can be performed at the cognitive level, and eventually at the activity system level, on a given business model. The (challenging) processes of modularizing and manipulating a model depend strongly on a specific property called *decomposability* - namely the extent to which a system can be subdivided into loosely coupled sub-elements - which is a key characteristic of all complex systems. This conceptualization has been strongly influenced by Simon's (Simon, 1962) idea of *nearly decomposable hierarchic systems*, architectures where interactions within the various subsystems occur at a higher scale and frequency than those that take place across different subsystems. In such instances, even if the decomposability is only imperfect, and some residual interdependencies between subsystems might eventually remain to be dealt with, modularity can act as a first useful approximation to orient cognitive problem-solving activities: effectively breaking down the complexity of the whole system to make problems manageable (Baldwin & Clark, 2000). Thus, higher levels of performance of the whole system could be reached by optimizing its component subsystems. Our classifications provide a basic set of operators to understand such modular-based optimization patterns. However, our contribution can only scratch the surface of such a complex and profound issue, and leaves several possibilities for future investigation.

Table 5 spells out our research agenda on business modeling based on the two trajectories of modularization and manipulation.

Table 5: Research topics and questions for business model research

Business model agenda	Research topics	Research questions
Modularization	Model complexity	What is an effective and comprehensive level of complexity for a business model? What does the right level of complexity depend on?
	Explicitness and reflectivity	How can the business model be made explicit? When and how do managers reflect upon their business model?
	Level of analysis	What is the relation between the technological, organizational and knowledge levels in business model modularization?
Manipulation	Operators	Which operators are appropriate and practical for use in a business model context?
	Element complementarity	What are useful ways to map interactions between business model elements? How can workable business model configurations be identified?
	Context	What is a productive context for change? When do / can management teams engage in business model change?

Among those research opportunities, we isolate a set of compelling questions. For example, what are the conditions under which managers can tackle the challenge of effectively specifying a business model in modular terms? If quasi-decomposability in the underlying architecture allows modular upgradability in complex systems, which principles allow similar innovation patterns in the case of business model manipulation? While the idea that highly independent business model elements allow for simpler experimentation paths towards configurations that yield higher performance seems both straightforward and intriguing, spelling out the recipe for modularization remains challenging. How to reach a quasi-decomposable model should be a key topic for future research.

Model complexity is a central question in considerations about modularization. Which are the relevant management theories that should be drawn on when creating elements' boundaries and specifying their interactions? In this respect, it might be promising to consider marketing and value theories, as well as consumer behavior research, to gain a deeper understanding of how value can been defined - beyond strategic management's rather narrow focus on firm performance - at the cost of considerations of customer surplus and value for stakeholders. An informed abstraction from the activity system underpinning the business may lead to an explicit and workable business model. In the jargon of modularity, such managerial abstractions can be regarded as *design rules* (e.g. Leonard-Barton, 1998). While in artifact design such rules enable modularization by clarifying the inner workings of the business model's entire architecture (i.e., identifying its elements and how their interfaces specify how they are supposed to interact), the design rules that are effective in business modeling are those that make the elements and their interactions explicit in terms of the fundamental value generation, delivery, and capture issues.

In addition to this cognitive perspective on business model modularization, there are two other major enabling factors which can help the modular reconfiguration of a business model. First, there is growing evidence that technological improvements in Information and Communication Technologies (ICT) are enabling the emergence of new business opportunities (Baldwin & Clark, 2000; Brusoni & Prencipe, 2006). Digitalization has allowed shifts in monetization schemes in some content industries from flat fees to pay per use modes, which would previously have been technologically impossible. Thus ICT enables business model changes via the upgrading of their elements, as well as possibly in other ways. Second - beyond purely technological enablers such as ICT - the material and architectural traits of artifacts can create opportunities for new divisions of labor and innovation which promise to have implications for business units or for whole value chains (Amit & Zott, 2001; Zott & Amit, 2008). Moving from interconnected artifact designs towards modularized architectures allows greater opportunity for outsourcing, subcontracting, functional changes, and innovation. Overall, this trend allows for the introduction of changes at the value delivery level by introducing alternative value chain schemes that leave existing value creation and capture mechanisms virtually untouched. It might be interesting to understand how these might influence the architectures of the whole ecosystems on which business models are based (Brusoni et al., 2001; Henderson & Clark, 1990; Kallinikos, 2012). Again, this might be seen as an instance of business model innovation through element upgrading.

Complicating matters further, scholars need to inquire into how modularization could be carried on at different levels. Technological modularity can apply at the level of technological and organizational interdependence (Brusoni & Prencipe, 2006; Sosa, Eppinger & Rowles, 2004), in which tasks can represent routines in a software program, or that are performed by team members speaking to each other. Modularizing a software program means locating sub-routines within one module so as to minimize interactions between modules and enable engineers to work separately on different modules, without interfering too much with each other, and allowing the program to continue to function using multiple modules. Modularizing the organization of multiple teams means dividing tasks so that teams can work in parallel and that most interactions occur within rather than across teams. Sosa et al. (2004; 2007) speak explicitly about the connections between the two levels, and how the modularity of teams should be aligned with the modularity of the technologies on which they are working. When referring to the modularity of business models, we also talk about a third level - the knowledge domain (Brusoni & Prencipe, 2006: 185) - which precedes and accompanies both the organizational and the technology domains, in that managers need to understand what they are modularizing and why - in terms of both business activities and technologies.

The second set of questions, which relate to the issue of manipulability and its boundary conditions, also deserves particular attention. First, some of the lessons learned from modularity can be applied fruitfully regardless of the extent to which a business model is truly modular. Applying modularity principles and operators can also be helpful as a first cognitive approximation in settings where the business model is not made explicit, or is best described as non-modular or as deeply intertwined. In many instances, it may seem that business models are delicate, tightly interconnected systems of parts where changing even a single element could trigger a series of adjustments that would influence the model's overall integration and performance. In this regard, different levels of integration between elements - e.g., tightly vs. loosely coupled relationships (Brusoni & Prencipe, 2001b) - might moderate the relationship between a change in an element and the system's overall performance, thus leading to different outcomes. For instance, simply introducing a *premium service* on top of a previously *free* offering will not work out effectively in a business model without also retouching the value creation domain that is being adjusted (the premium user might be not the same as the free user, and engaging such consumers might require different skills). In terms of modularity theory, such a change would trigger a sequence of testing and integration activities between the elements (given their interdependencies, and due to the model's non-decomposability), which might entail adjustments or revisions in various elements before a satisfactory outcome can be reached. This also connects to the idea of product or service bundling (Stremersch & Tellis, 2002), in the sense that bundling different elements together (e.g., different value offers, such as the *premium* and the *free*) will lead to the configuration of the business model (e.g., into a *freemium* model) whose effects might differ from those of just the sum of the two configurations in isolation.

Further, the idea of manipulation deserves attention in terms of how modular operators are applied in business model innovation. Do they highlight alternative, novel, competing, better versions of the original business model's configuration? Or do they suggest complementary, integrative business models that a firm can implement jointly and simultaneously as a way to diversify its recipes for success? Modularity may or may not be an ideal guide - but we can identify three research topics that may help shed light on the application of the operators: the complementarity of elements within business model configurations; the context of manipulation in collective thinking; and engagement among the management team.

Many large companies engage in running more than one business model simultaneously (Casadesus-Masanell & Tarzijan, 2012; Markides & Charitou, 2004), and the manipulation of a business model may lead to complementarities between those different models. Random manipulation cannot be a goal, but rather an informed play that may result in new business model configurations that promise to be viable innovations when implemented. In order to understand complementarities among business model elements (and between entire models) it may first of all be helpful to map and follow the interactions that exist in the current configuration. Value delivery involves upstream and downstream partners, whose behaviors may be beyond the control of the focal firm, and such partners may limit information flows about their critical strategic moves. Future research in strategy should consider multiple business models explicitly, and which sorts of configurations prove viable for firms. Literature on this topic is scarce, despite the insights that complementarities between business models matter both for performance and for competitive dynamics and innovation.

Finally, our analogical reasoning compares technology and business model operators, suggesting that modularity theory might inform both technologies and business models. However, a well-known trade-off applies in both fields: the modularization of a system should not be thought of as being independent of its environment, lest it suffers from being locked in to inferior designs or inefficient search patterns (Baden-Fuller & Haefliger, 2013). Thus, the modularization of a business model as a cognitive task should take into account the intensity of environmental change: this is a prerequisite for effective business model change, and so may be a limitation on the usefulness of the operators we outline above.

Innovation is not a leisurely activity, and needs to be conducted under strict deadlines. Others have compared management to theatre production, and insisted that the costs of iteration in experimentation mean that knowledge work becomes more and more like rehearsals prior to stage performances (Austin & Devin, 2003). Business models reduce reality to a set of comprehensive elements that can be rehearsed and then played out under various scenarios - and quickly, cheaply, and collectively. The rehearsal requires manipulation of the different elements so that the play (the new business model) comes together as a coherent and effective piece in performance. All the actors involved need to watch, learn, and agree on what the new production will look like: only then can implementation start and the new strategy hit the ground running. We are confident that future research leveraging modularity theory can inform scholars and practitioners about the challenging process of understanding the interplay between cognition and action in business model innovation.

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