Organizational structure, dynamic capability development and the strategic flexibility of operations: a behavioral approach

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Abstract

In this paper, we examine how the degree of modularity of the operations function influences operations managers' learning processes and the way they make choices in capabilities development. We ran a set of experiments for different organizational architectures with respect to modularity using a system dynamics model to represent the dynamics of the competitive environment and the dynamics of the operations function, with respect to resource and capability accumulation. Our research indicated that an integrated operations function structure is more likely to contribute to the achievement of strategic operations flexibility through stronger dynamic capabilities.

Keywords: operations strategy, behavioral operations, dynamic capabilities

Introduction

Over the last 20 years, it has become apparent that the operations strategy process should deviate from its planning orientation and move towards a process of developing resources and capabilities that augment the operations functions' strategic flexibility (Hayes et al., 2005). Strategic flexibility is a strategic asset in situations in which anticipation is impossible and strategic surprises likely (Volberda, 1998). As operations strategy is influenced by, and contributes to, higher level strategic processes, the requirement for operations strategic flexibility stems from the dynamics of the external competitive environment with respect to changes at the industry and market levels to which firms are exposed to (Nadkarni and Narayanan, 2007). In addition, the strategic flexibility of operations is highly contingent to organizational variables, i.e. to the internal organization structure of the operations function and to its decision-making architecture, and their micro foundations (Adamides and Pomonis, 2009).

In this direction, lately, many scholars linked strategic flexibility with dynamic capabilities, claiming that the development of dynamic capabilities is the prerequisite basis to strategic flexibility (Anand et al, 2009). The concept of dynamic capabilities (Teece, Peteraf and Leih, 2016) is linked to the ability of an organization to select and/or change, and/or reconfigure ordinary capabilities, and switch strategies in breadth (diversity) and depth (intensity) (Laursen and Salter, 2006). Strategic flexibility requires adaptive processes and structures that enable companies and organizational functions, such as operations, to change their baseline capabilities, anticipate shifts in market demand, develop and integrate new technologies, learn from market events, and foresee and capture new market opportunities (Felin and Powell, 2016). So, for achieving operations strategic flexibility, the priority is to design organizations for dynamic capabilities.

In this line, in this paper we examine whether the modularity of the operations function is an organizational design variable that contributes to the development of dynamic capabilities, and hence to operations strategic flexibility and performance, and if yes, under which conditions. In our perspective, the modularity of the broader operations function is determined by the degree of structural interdependence of the product development, production, and supply chain sub-functions. In modular structures these sub-functions are relatively independent, communicating through standardized interfaces, whereas in non-modular, they are integrated, and their specialization is weak. So far, research in the relationship between organizational structure, dynamic capabilities and strategic flexibility in the corporate strategy domain produced conflicting conclusions (Albert et al., 2015; Felin and Powell, 2016). Hence, the investigation of this relationship for a functional strategy (operations) is of particular importance.

In this paper, the focus of analysis is the micro-level processes that support dynamic capabilities. More specifically, we examine how the degree of modularity of the broader operations function influences operations managers' learning processes as they are engaged in operations change/improvement initiatives and resource development, and hence the way they make choices in subsequent capabilities development. That is, how they improve their understanding of their operations and the environmental challenges that they face, and how they develop the appropriate operations strategic resources, and manage trade-offs between performance objectives and their associated capabilities. Adopting a behavioral perspective (Sibony et al., 2017), in an experimental setting, we consider strategic operations capabilities development as result of organizational learning associated with individual and collective cognitive processes. Over a period of twelve months we ran a set of experiments for different organizational architectures with respect to modularity using a system dynamics model to represent the dynamics of the competitive environment and the dynamics of the operations function, with respect to resource and capability accumulation.

The paper is structured as follows: The following section discusses the relation between organizational structure and operations paying particular attention on the modularity variable. Then, dynamic capabilities are introduced emphasizing their role in operations strategic flexibility. Following, after introducing the behavioral perspective and the related issues of research methodology, we describe the experimental setup and procedures used in our research, giving emphasis on the simulation model used. We then present and discuss our findings before drawing the conclusions.

Organizational structure and operations strategy

In general, operations strategy may be viewed as the emergent outcome of decision-making in three interrelated organizational functions (production, procurement and distribution, and new product development (Adamides and Pomonis, 2009). Decisions concern the development of capabilities as ensembles of strategic resources and related processes/routines to deploy them. The broader decision areas that extend across all three sub-functions are: capacity, the supply chain of the firm, technology, and organization and human resources (Slack and Lewis, 2008). These four areas can be refined into more specific decisions of the structure (capacity, sourcing, technology) and ("softer") infrastructure (work planning, measurement, organization, etc.) of the operations function (Hayes et al., 2005).

In a resource-based perspective, these decisions concern the development of appropriate levels of tangible and intangible asset stocks (resources, capabilities), which are necessary for achieving a sustainable fit of operations (and the firm) with its environment (Dierickx and Cool, 1989), along the dimensions of cost, flexibility, speed, quality and dependability. More specifically, strategic decisions concern the selection of the appropriate organizational activities/routines whose execution will eventually close the gap between the required and the available resource and capability stock levels. The levels of capabilities are accumulated through the execution of organizational activities and influence the rates of resource accumulations (e.g. complex scheduling capability facilitates the deployment of flexible machinery). Both capability and resource accumulations may be self-reinforcing, e.g., an existing capability in complex scheduling may be easily extended horizontally by training internally new schedulers, or vertically by learning more complex and more efficient methods.

The combination/architecture of operations strategic assets and the associated decision processes, and their stock levels (i.e. how they are interrelated), define not only the range and the economies of the activities in which the firm can engage at any point in time, but also plays a decisive role on the choices of the future competitive objectives by determining the difficulty involved in developing the newly required assets (Ghemawat et al., 2001). Specific assets, at specific stock levels may augment or limit the decision space of future operations and corporate strategies (path-dependent objectives' trade-offs). This is an important issue in operations strategy and many improvement initiatives are towards mitigating these trade-offs (Anand et al, 2009). In addition, for every operations sub-function (e.g. New Product Development), the choice of the appropriate routines depends on the quality of perception and understanding of the incoming signals from the other sub-functions, other linked firm functions (e.g. marketing), the corporate strategy, as well as the external environment. The difficulty in deciding and implementing routines/actions depends on the connectivity of, and the shared commitments that the sub-function has made with other organizational units. In actual fact, the nature and magnitude of this connectivity, and the way that is managed, determines the effectiveness of dynamic capabilities and the degree of the strategic flexibility of the operations function.

Organizational design is closely associated to operations strategic flexibility. Slack and Lewis (2008), point out that organizational design is both output and input of the operations strategy process: "As a 'pattern of decisions' which shape the internal organization of resources, 'organizational structure' is clearly a fundamental 'output' of operations strategy. Yet the organization's structure also provides the mechanics by which strategy is formed and, as such, is an 'input' to operations strategy". In other words, an organization's designed and emerged environment provides the context in which operations strategy is being formulated or formed. Hence, understanding its dynamics is a prerequisite for understanding the operations strategy process and its outcomes. Linked to the above discussion, this implies that the organizational design and the related to decision architecture determine the effort required for, and the outcome of, the selection and/or development of the required operations resources and the management of the complementarities and trade-offs between them. The management of complementarities and trade-offs provides a proactive mechanism that enables change and strategic flexibility.

Decision process architecture and dynamic capabilities

In the resource-based view of strategy, competitive advantage is a function of the availability of certain resources and capabilities (Grant, 1997). Capabilities are constituted by assets/resources, such as scheduling software, and routines/processes for deploying these assets (Amit and Schoemaker, 1993). As it was already mentioned, dynamic capabilities are related to the ability to modify (operational) capabilities effectively. In other words, dynamic capabilities are linked to an organization's ability to innovate its strategy through the appropriation of the right knowledge by sensing the environment, seizing opportunities and transforming its strategic process(es) and outcomes. Sensing is associated with exploration, whereas seizing with both exploitation of the internalized environmental signals, ideas, concepts, technologies etc., as well as with the exploration of the external environment for gaining economic value from the innovative products and/or services developed through transforming activities and novel resources and capabilities.

Understanding dynamic capabilities requires understanding their micro foundations (Dong et al, 2016; Helfat and Martin, 2015) that are associated to individual and organizational learning efficiency. Learning efficiency, in turn, is a function of absorptive capacity that depends on the amount and diversity of prior knowledge (Cohen and Levithal, 1990). This can be better understood by considering two key attributes of mental models that are directly related to absorptive capacity: complexity and centrality (Nadkarni and Narayanan, 2005). Complexity is the result of the degree of differentiation (the range/diversity of internal and external organizational concepts included in the mental model) and integration (degree of connectedness among concepts) of the model. Complex change- and innovation-related mental models allow firms to notice and respond to a larger number of different stimuli, thus increasing their strategy innovation capacity. They allow managers to scan the environment and respond to incoming stimuli more effectively by associating environmental events with elements of the existing organizational knowledge base. Centrality, on the other hand, refers to the focus and hierarchy of mental models. A centralized model is focused around a limited number of core concepts. As a result, complex mental models are the basis for dynamic capabilities that are responsible for increased absorptive capacity, making the organization more responsive to external signals, and proactively better positioned as far strategy innovation is concerned.

Complex models are developed by exposition to complex and diverse issues and their social resolution processes (discussions, debates, delegations, etc.) in multidisciplinary settings, whereas centralized ones by dealing with a limited number of issues in depth. The degree of exposition to complex and diverse issues that form mental/cognitive models is contingent to the organizational architecture (division of labor and task assignment), but most importantly to knowledge and learning processes. As cognition, learning and cooperation are behavioral issues, it seems appropriate to investigate the relationship between organizational modularity and strategic flexibility through a behavioral perspective.

Behavioral operations and experimentation

Behavioral operations can be defined as an emergent approach to the study of operations that explicitly incorporates social and cognitive psychology theory. In particular, behavioral operations contain the study of attributes of human behavior and cognition that impact the design, management, and improvement of operating systems, and the study of the interaction between such attributes and operating systems and processes (Gino and Pisano, 2008). Despite increased interest in behavioral operations, not much research has been produced on behavioral operations strategy. So, one of the aims and contributions of this study is to make more explicit what behavioral operations strategy is, and what are its main concerns.

Human cognition, emotions and social behavior can bring obstacles to strategic decision making as biases. Sibony et al. (2017) provided an understanding of how individual and group biases operate on investment, resource allocation and “blue sky” (innovation) decision processes and how organizational design can amplify, neutralize or dampen these biases. By using the levers of decision architecture to calibrate decision outcomes to organizational goals, the authors claim that behavioral strategy can contribute to management practice by helping managers design decision processes that achieve desired levels of risk, agility, and innovation.

Regarding research methodology, behavioral strategy relies on the active involvement of decision makers in controlled experiments (Bendoly and Eckerd, 2013). In particular, laboratory experiments are used for investigating theory, examining anomalies and evaluating new theories (Croson and Gachter, 2010). A stream of research in behavioral decision making involves the use of simulation models to represent the dynamics of the environment in which decision-makers are embedded and interact with (Delgado-Alvarez et al., 2017). Simulation models though appropriate interfaces provide stimuli and response options to the subjects in the experiments. Although such models provide a limited number of options and the general environment is rather stylized, for certain issues, and in connection with more realistic approaches (natural experiments), they provide a valid and useful experimental setup.

Experimentation set up and process

To investigate the relation between modularity and strategic flexibility, we used an experimental setup based on a system dynamics model of resource-based operations strategy. The model was constructed and validated after thoroughly reviewing OM/OS metrics and their interdependencies (Roth et al., 2008), and has been implemented as a stand-alone software artifact with a user-friendly interface. Subjects were allocated to two alternative organizational structure configurations (modular and non-modular) and interacted with this model. Before depicting the experimentation procedure, we describe the model that formed the core of the process.

A system dynamics model of operations capabilities

System dynamics is an approach developed for studying the behavior of systems exhibiting high dynamic complexity as a result of complex dynamic interactions among their elements. System dynamics focuses on feedback loops, which contain stocks (levels) and flows (rates). Stocks represent the state of the system whereas flows the rate of change of the state of the system. The discussion in the previous section suggests that this approach is very suitable for developing a model for operations strategy in the resource-based context. The accumulation of different assets as a result of the execution of specific activities over time can be modelled by stocks, whereas the rates of accumulation (routines) and “natural” or forced erosion/depletion as flows (Warren 2002; Mollona 2002).

To reduce the complexity of the activity-resource network, and in order to provide measures of strategic “fit” as a result of the execution of specific activities, resources are aggregated around the generic operations macro-competences (synonymous to macro-capabilities) capabilities of (low) cost, flexibility, quality, speed and dependability which coincide with the principal manufacturing strategic objectives and their associated performance metrics. These competences are the result of the combination of tangible and intangible assets, and their associated routines gathered and combined towards a specific operations strategic objective. Each competence stock level aggregates the levels of assets/resources that participate in the development and conservation of the specific competence. The level of a competence-oriented resource stock over a particular time interval depends not only on the rate of its accumulation (as a result of the execution of specific routines), but also on the rate of its erosion (Dierickx and Cool, 1989). In addition to "physical" erosion of assets due to time and use, competence-specific asset erosion takes place as a result of decisions and investments which contribute to conflicting competence development (e.g. investments in a large-scale dedicated production line erodes the flexibility competence). Furthermore, the rate of competence stock erosion is influenced by factors of the external environment of the firm, such as competitor moves, as well as political, social, economic and technological forces. The stock of a competence which is aligned with the current competitive environment setting erodes slowly or stays intact. Oppositely, the stock of a competence which is in discrepancy with the environment is devaluated fast and additional effort may be required to build the competence when the attribute comes back to fashion.

In system dynamics terms, the level of each of the N competence stocks (for the model implemented, N = 5), $S_{n,t}$, at time t, is given by

$$S_{n,t} = S_{n,t} + (E_{n,dt} - R_{n,dt}) \qquad (1)$$

where $S_{n,t}$ is the stock level of the competence at time t, and $E_{n,dt}$ is the rate of the total net effect of the effort put in accumulating assets by executing a predefined set of activities (resource accumulation routines (Mollona, 2002)) of structural and infrastructural nature towards the specific competence in the time period ($t,t+1$),

$$E_{n,dt} = e_{n,dt} \bullet \sum_{1}^{N} C_{n,t} S_{n,t} \qquad (2)$$

where $C_{n,t}$ is a time-dependent coupling coefficient that quantifies every individual relationship (contribution, trade-off or neutral, as defined by $\bullet$) between a competence-oriented asset stock level, $S_{n,t}$, and $e_{n,dt}$. is the rate of gross effort put in accumulating assets for the specific strategic attribute/capability stock,

$$e_{n,dt} = (1 + S_{n,t}\mu)(\sum_{1}^{U} a_{sk,dt} + \sum_{1}^{V} a_{il,dt})\delta \qquad (3)$$

where $a_{sk,dt}$ is the intensity of the net effort put in executing the structural activity a_{sk} at time interval dt, and $a_{il,dt}$ is the intensity of the net effort put in executing the infrastructural activity a_{il} at the same time interval (assuming they result in constant competence accumulation rate), $a_{sk,dt} = f_{ask,n} * a_{sk,dt}$ if $f_{ask,n} \neq 0$ and $a_{sk,dt} = 0$ otherwise.
$a_{sk,dt}$ is the rate of gross effort put in executing the structural activity k, and $f_{ask,n}$ is an element taken from the UxN activity-competence matrix that denotes the impact of the structural activity a_{sk} (and its corresponding resource(s)) on the development of competence n. Negative values of $f_{ask,n}$ denote negative impact.

Examples of structural activities considered in the experiments were the building of capacity, the implementation of a particular level of vertical integration and the adoption and commitment towards a specific process type (jobbing, batch, line). Similarly, for infrastructural activities $a_{il,dt} = f_{ail,n} * a_{il,dt}$ if $f_{ail,n} \neq 0$, and $a_{il,dt} = 0$ otherwise. Both $a_{il,dt}$ and $f_{ail,n}$ are defined as their corresponding counterparts for structural activities.

Examples of infrastructural activities that were put under consideration in the experiments were the implementation of short or lengthy schedules, the implementation of workers' training programs and the adoption of TQM practices. It should be noted that the elements of both sets are variables whose values denote the intensity of the execution of the activity, and consequently the effort put towards the accumulation of the corresponding assets/resources (the effort to change their levels). For example, in numerical terms, the *a* value corresponding to the activity of training workers may take values ranging from 0 to 5, where 0 corresponds to no training activities and 5 to intensive training programs that result in the corresponding increase in the stock level of the corresponding resource "trained workers". All values refer to time unit periods (months).

$S_{n,t}$ is the stock level of the competence *n* at time *t*, μ is the asset mass efficiency coefficient that denotes the degree of positive influence of the particular competence stock level on its rate of accumulation, and δ is the time-dependent time compression diseconomies coefficient (Dierickx and Cool, 1989) that rewards accumulation of efforts spread in successive time intervals, rather that more intense accumulation at the same time interval.

Going back to (1), $R_{n,dt}$ is the total value of the accumulated assets eroded (the rate of devaluation of the specific competence) in the same period.

$$R_{n,dt} = jS_{n,t} + g\left(\sum_{1}^{V} a^{r}_{sk,dt} + \sum_{1}^{U} a^{r}_{il,dt}\right) \quad (4)$$

$a^{r}_{sk,dt} = a_{sk,dt}$ if $f_{ask,n} \neq 0$, and $a_{sk} = 0$ otherwise, and $a^{r}_{il,dt} = a_{il,dt}$ if $f_{ail,n} \neq 0$, and $a_{il} = 0$ otherwise,

j and *g* are coefficients that calibrate the negative contribution of a competence stock level on its depletion rate, and the positive contribution of executing competence destroying activities, respectively.

If we assume that both $E_{n,dt}$ and $R_{n,dt}$ take random values from the same real number field, then $S_{n,t}$ varies randomly, and if the mean of the values of $R_{n,dt}$ over a time period *T* is greater than the mean of the corresponding values of $E_{n,dt}$, then the specific competence will exhibit an increasing trend. In other words, the stock level of a competence increases if its corresponding assets are accumulating faster than they are depreciating. Obviously, the opposite holds if assets are eroded faster than they are accumulated. From the management's point of view, an increasing accumulation pattern can be achieved by either keeping the assets or competence depreciation rate low or by increasing the effectiveness of the effort towards building manufacturing competences. Turbulent market conditions may result in fast competence depreciation rates beyond management's control. Then, the operations management's strategic task is concentrated on increasing the speed of resource accumulation and competence building through increasing the effectiveness of the corresponding activities. This can be done by understanding and managing intelligently the linkages between the elements of the activity-resource-competence system. Clearly, this requires an understanding of these linkages, which is achieved by reflecting on past actions and their observed outcomes. Overall, managers that can understand the complexity of the activity-resource architecture can manage linkages effectively.

Experimentation process

In the experiments, participants were required to manage/decide the values of a (intensity of activity execution), and to determine and quantify/set the relationship between asset stocks and intensity of activities, so that specific capability levels are achieved in specific time intervals. In effect, this means that participants must choose a set of routines that will induce a rate flow $E_{n,dt}$ into the competence-oriented asset stock, so that it reaches the desired state at the required time instance.

The effect of participants' decisions were assessed by comparing the values of the assets accumulated as result of decisions with a desired competence level G, where $G_{n,t}$ - $S_{n,t}$ defined the degree of fit of operations resources and capabilities with the environment (value of zero indicates perfect fit). In practice, this requires knowledge of the stocks levels of the other related competences as well as of their linkages with the chosen set of activities. Experiments were carried out with a total of 24 subjects (graduate students that have successfully completed two operations management/strategy courses and a semester project and have had at least four years of managerial experience in at least junior operations management positions) using the above system dynamics model. Subjects were assumed to be part of the operations function of a global bicycle manufacturer.

For the experiments, initially, nine scenarios of urban life in 2025 were developed paying particular importance on cycling. The nine scenarios were decomposed and made more explicit with respect to operations objectives. Subjects had to manage the operations sub-functions of the company. Managerial roles were assigned according to the specialization and experience of the subjects. Two types of environmental (operations improvement) challenges (simple/decomposable and complex/non-decomposable) were randomly created in the context of scenarios and presented to the subjects. They were constituted of a collection of operations improvement decision variables taken from the operations management literature (Roth et al., 2008; Anand et al., 2009). This meant that he organization of participants ought to develop dynamic capabilities by juxtaposing the qualitative characteristics of the environment to quantitative target values of stock levels, G, and regulate/manage the rates of accumulation to reach the target value (not more, not less) is a specific (simulation) time interval.

Two groups of subjects corresponding to two different organizational structures (modular and non-modular) had to respond to improvement challenges by choosing in the model's interface the appropriate improvement initiatives (values of a and f). Each initiative contributed to the increase or not of capabilities related to cost, flexibility, speed, dependability and quality. As challenges were being created and presented to the subjects, they were associated with a specific level of required capability, which was not presented to the subjects. Simple cases were defined in three relatively independent phrases, each phrase being associated with a specific sub-function, whereas complex ones were presented as an integrated text/scenario. Six levels of breath (interdependence/ complexity) and depth (requirement for deep knowledge of the issue) were embedded in the phrases. Subjects of modular organizations were grouped in two (for each sub-function) and placed in different rooms communicating only by two written messages at every round. In the modular organization setting, each room had its own computer with a copy of the simulation model, whereas in the non-modular, a single copy of the model was used. Subjects in non-modular organizations were in the same room and communicated without any restriction. Results of choices were communicated back to the subjects. For the modular organization, three rounds of decomposed challenges/requirements were followed by one of complex one. The opposite was for the non-modular structure (three complex challenges were followed by a decomposed one).

In every experiment, the model calculated the discrepancy *G* between the required and the achieved level of capability, providing thus a measure of performance. Forty experiments of 24 rounds were executed over a period of twelve months with different mixtures of complex and simple issues. After six months, the two six-member groups were replaced, without changing the settings and the performance record of the fictitious organizations.

Results

Table 1 summarizes the results of the experiments. For the modular structures, the values represent the average values of the three sub-functions. The results indicated that non-modular organization structures are more suitable (faster learning) for operations in complex situations. Integral teams engaged in the treatment of non-decomposable issues performed better than teams with specialized tasks in modular structures. Overall, their average discrepancy between achieved and required capabilities (levels in model stocks) was 1,23 (required capability levels in all five capabilities, at any time, ranged from 3 to 5), compared to 2,38 of the teams in modular organizational structures. However, the latter performed better when strategic issues were decomposable into specific to sub-functions initiatives. This indicated that the former organization structure enhances learning and contributes to operations strategic flexibility. The behavior of the operations managerial stuff observed is in accordance with insights from cognitive psychology, which maintain that continuous exposure to complex problems increases cognitive schemas complexity and absorptive capacity, and thus the ability to make better sense of complex novel situations (Nadkarni and Narayanan, 2007).

Table 1 – Average discrepancies between required and obtained capability levels

Structure	Challenge	Cost	Flexibility	Speed	Dependability	Quality	Overall
Modular	Simple	0,73	1,72	1,06	2,20	1,21	
	Simple	0,69	1,32	1,31	1,97	1,71	
	Simple	0,96	1,97	1,08	1.71	1,63	
	Complex	2,13	2,22	2,65	2,75	2,25	2,38
Non-modular	Complex	2,14	2,05	2,88	1,99	1,72	
	Complex	2,31	2,33	2.35	2,17	1,67	
	Complex	2,12	2,71	2,37	2,31	1,91	
	Simple	1,17	1,24	1,12	1,93	1,27	1,23

Conclusions

By highlighting the role of managerial cognition and human capital in organizational learning, our research indicated that an integrated operations function structure is more likely to contribute to the achievement of strategic operations flexibility through stronger dynamic capabilities. This supports the idea that knowledge decomposition differs from work decomposition and cannot be easily modularized. On the opposite side, a modular form seems more suitable when the operations strategic issues that are faced can be decomposed to specific knowledge domains. Formal and extensive validation of the experimental setting and rigorous statistical analysis of the results are the future directions of the research.

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