STRATEGIC MODULARIZATION AND PERFORMANCE IMPLICATIONS IN THE GLOBAL AUTOMOBILIE INDUSTRY

In an era of globalization characterized by accelerated technological change and complexity many technology-based firms (e.g., Microsoft, General Motors, Swatch, Motorola, and Sun Microsystems) operating in dynamic environments have embraced modularization as a competitive strategy that helps them respond to customers' heterogeneous demands and gain competitive advantage. The concept of modularity refers to the degree to which the system is in fact decomposable into modules [Alexander 1964] and later recombined. Thus, modularity can be seen as a general set of principles for managing complexity that is now being applied not only to technological design but also to organizational design. The erosion of global boundaries and the rapid transformation of markets due to technological change are causing the 'deconstruction' of organizational systems [Hitt, Keats & DeMarie 1998; Schilling & Vasco 2000]. For instance, 'modular structures' have been suggested to facilitate advance-manufacturing technologies [Lei, Hitt & Goldhar 1996]. According to Langlois (2000), modularity is a general set of principles for managing complexity. Sako (2003) defined modules in the context of the auto industry as a physically proximate 'chunk' of components, which can be assembled into the vehicle as one unit where common interfaces and standardization of specifications are not mandatory, and components are the building blocks of modules. Therefore, modules are subassemblies that reduce complexity and time taken in the plant for assembly. In the context of the global automobile industry, the concept of modularization has gained increased attention, since it has been linked more specifically to the design and/or assembly strategies of large auto assemblers (OEMs) and as an approach that facilitates the introduction of successful new products and have a positive impact on performance.

We argue that modularization can create dynamic capabilities through modular product and process architectures that integrates resources and competences in way that managers of different projects, departments, or external partners mix and match their varied skills, functional backgrounds and expertise in order to deliver revenue producing products and services [Eisenhardt & Martin, 2000] and satisfy individual customer requirements. New innovation dynamics are resulting from more firms using modularity not just to create product variety, but also as a new framework for aggressive strategic learning and more effective knowledge management. It seems clear that there is an urgent need for research in the field of modularity that will help managers to understand the advantages and disadvantages of a modularization strategy.

This study examines modularization as a competitive strategy in the manufacturing industry with the emergence of modularization being accompanied by new knowledge management strategies (Grant, 1996), which allow firms to develop products more effectively through flexible, "modular" organization structures (Sanchez and Mahoney, 1996). Our concept of strategic modularization goes beyond the idea lean production and is characterized by high-level flexibility to coordinate component and subassembly development between an automaker and its suppliers and allows for minimum design adjustment among components and subassemblies in order to achieve the product functions that customers want. Thus, success comes from the ability to cautiously select pre-designed components (Fujimoto and Nobeoka, 2004).

Although much research has been conducted on modularization in the personal computer and automobile industry, most of this research has focused on examining specific modules. Fixson, Ro, and Liker (2005) examine the vehicle cockpit to explore the interactions between modularity and outsourcing. Others examine modular technological upgrading in the supply of interior systems (Lara, Trujano, and Garcia-Garnica, 2005). However, to our knowledge, research has yet to explore the implications of modularization in the context of global supply chain strategy and its implication to firm performance. Building from previous research that developed a strategic modularization framework using grounded theory building approach from case studies (Kotabe, Parente, Murray, 2007), we collected empirical data and tested a model of the strategic modulartization and its implications to firm performance at the firm-level in the global automotive industry of Brazil. Thus, we intend to contribute to the extant literature on modularization by filling this gap while empirically testing a model that uncovers those factors that contribute to successful strategic modularization in the manufacturing industry, and understand how the implementation of strategic modularization leads to the firm strategic positional advantage.

In this study, we define strategic modularization (SM) as a strategic option that goes beyond the physical and functional dimensions of the module that includes an organizational and managerial system linking module integrators and module suppliers to reduce the cost of managing tacit knowledge in the

assembly process. Modularization has been recognized as a key strategic approach for increasing the firm's ability to respond quickly to sudden changes in dynamic product markets [Worren 2001]. Thus, strategic modularization helps assemblers of final products remain competitive by enabling firms to satisfy increasing customer demands while learning and adapting quickly, transferring knowledge across firm boundaries effectively, and reducing the cost of managing tacit knowledge significantly (Desmond, 2003; Lara, Trujano, and Garcia-Garnica, 2005). Thus, firms that adopt strategic modularization should realize a higher firm performance.

LITERATURE REVIEW AND THEORETICAL DEVELOPMENT

Some scholars have looked at the advantages of modular product designs, such as its impact on the production configuration options available to firms and to customers [Baldwin & Clark, 1997; Garud & Kumaraswamy, 1995; Sanchez & Mahoney, 1996]. Modularity is argued to help organizations to achieve mass customization, shorten product development cycles, speed technological change, and lower costs [O'Grady 1999]. In addition, product modularity might enable firms to reap some of the network externality[1] advantages of a standards-based architecture while still producing unique, proprietary components [Garud and Kumaraswamy 1995].

Baldwin & Clark [1997] suggested that "by delegating the manufacturing process to many separate suppliers, each one of which adds value, the assembler gains flexibility and cuts costs". Modularity has enabled companies to handle increasingly complex technology. "By breaking up a product into subsystems (or modules), designers, producers, and users have gained enormous flexibilities. Different companies can take responsibility for separate modules and be confident that a reliable product will arise from their collective efforts." [pp. 85].

Developments in technology, the World Wide Web, and trends such as globalization, deregulation, and 'mass customization' [Pine 1993, Kotha 1995] are pressuring organizations to become more flexible. For instance, the dynamic business environment of today requires that firm be able to quickly adapt to constantly changing market context, offer a high variety of product options to satisfy individual customer requirements, and have the ability to apply different resources and capabilities according to specific situations. Finally, product modularization goes beyond the traditional modes of operation such as contract manufacturing (i.e. outsourcing) and strategic alliance (i.e. joint ventures and licensing). For instance, General Motors sees it as a way of simplifying production (not simply outsourcing), which "means giving the supplier the responsibility to engineer, validate, build and warranty a large chunk of the vehicle" [Automotive News, June 5th 2000]. Consequently, suppliers in the automaker industry are currently providing more and more integrated modules, and also taking more of the engineering design and development work [Modern Material Handling 2000].

More recently, we have observed that organizations increasingly adopt modular production in such a way that a strategic organizational arrangement for simultaneously utilizing modular product platforms and modular process architectures[2] as the key enablers of strategic flexibility is put in place (Sanchez, 1995).[3] According to Worren, Moore, and Cardona (2002), modular product and process architecture are important sources of strategic flexibility for firms facing a dynamic market environment, because both are prerequisites for efficient mass customization and cycle time reduction. In our conceptualization, strategic

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[1] According to Katz & Shapiro [1986] and Schilling [2000], network externality occurs when a consumer's benefit from using a good is related directly to the number of other users of the same good.

[2] A *modular product platform* is created by designing the product in ways that it can be decomposed into independent components and/or modules in a way that they can be reassembled together without any loss of functionality. In addition, standard interfaces must be specified in order to manage the flow of inputs and outputs between interacting components, and/or modules. *Modular process architecture* describes the decomposition of a firm's activities (or modules) into specific routines, tasks, and interactions that allow frequent reconfiguration of processes through mixing and matching. For a more detailed explanation and definitions, see Sanchez and Mahoney (1996) and Worren, Moore, and Cardona (2002).

[3] Strategic flexibility has two basic dimensions: adaptability and versatility. *Adaptability* is defined as the ability to change the course of action quickly to take advantage of an opportunity or to avoid a threat. *Versatility* is the ability to apply different resources and capabilities according to specific situations. This involves the ability to mix and match components to deliver product variety to customers.

modularization includes product and process innovations and shares all the benefits associated with lean principles and outsourcing by eliminating waste and inventory through the value chain.

There is evidence that firms that adopted modularity as an strategic approach have increased product variety and strategic flexibility, achieved economies of scale, reduced order lead-time, lower capital costs, lower overall costs, simplified control mechanisms, increased feasibility of product/component change, and are finding easy to perform product upgrade, maintenance, repair and disposal [O'Grady 1999]. Therefore, drawing from the literature presented earlier and the importance of strategic modularization for technology-based manufacturing organizations operating in dynamic markets, we propose the following normative framework to be empirically tested. Next, we will develop our normative theoretical framework and present the model's relevant constructs and testable propositions

Frequency of Face-to-Face Communication

Baldwin and Clark [1997] argued that there are limitations to the benefits of modularity due to the existence of tacit know-how. Thus, a successful modularization strategy must account for innovative ways to effectively manage knowledge transfer. In the context of high technological and dynamic industries, modular product components are conforming to standardize interfaces and firms are more and more engaging in network alliances with their suppliers, customers, distributors and competitors. In those network alliances and other modular organizational structures knowledge sharing becomes a central issue and it is associated with organizational flexibility and learning.

Media Richness Theory argues that a richer medium of communication such as face-to-face interaction is better for knowledge sharing and learning [Daft and Lengel, 1986]. In other words, personal and more open communication increases the richness of communication channels. Greater interpersonal familiarity and personal affinity can be expected to increase the openness of communication between interacting parties [Gupta & Govindarajan 2000].

Researchers have emphasized the importance of both internal and external communication for the performance of product development organizations [Brown & Eisenhardt 1995; Ancona & Caldwell 1992]. Therefore, in the case of strategic modularization where the module provider is involved in product development, effective coordination through frequent communication between module integrator and module provider is critical [Takeishi 2001]. Dyer [1996a] concluded that Toyota and Nissan had more frequent face-to-face interaction with their suppliers then the American competitors, in turn contributing to their 'short model cycle'. The author also found that Toyota and Nissan had more guest engineers at their sites than U.S automakers, which indicates the importance of extensive communication between co-located engineers. Toyota's network is able to transfer efficiently transfer knowledge because there are a variety of processes available to transfer both explicit and tacit knowledge in a multilateral setting [Dyer & Nobeoka 2000].

Finally, the frequency in which members from module integrator and module providers involved in the design and production processes interact in face-to-face communication should be associated with more efficient outcomes from the adoption of strategic modularization. Based on the argument above we suggest the following proposition:

> **Proposition 1:** When adopting modularization, firms communicating face-to-face more frequently are more likely to achieve higher levels of performance.

Technology Transfer Capabilities

The resource-based view (RBV) of the firm presents a perspective of competition that portrays the value of a firm's resources and capabilities as derived from a dynamic interplay of market forces (Wernerfelt, 1984; Barney 1991). A firm's response to environmental constraints through resource allocation, along with strategic formulation and implementation, leads to the development of capabilities that can give firm competitive advantages (Kotabe and Swan, 1995; Allred, 2001). The technology acquisition decision is defined as the choice that firms face between internal technology development and external technology reliance (Noori, 1990). When a firm makes technology-related decisions, it must focus its attention on those capabilities that would give the firm distinct competitive advantage (Dierickx and Cool, 1989), by either developing and/or acquiring those capabilities. Consequently, the firm's ability to

safely and securely transfer technology between its development team and suppliers should enhance its ability to innovate.

We argue that in the context of modularization, suppliers have more flexibility to innovate in the event of major demand shifts. Suppliers have a large customer base allowing them to learn from their other customers. In turn OEM also learn from the suppliers facilitating its overall ability to compete. In the modularization relationship, OEM and suppliers develop a type of alliance with each other based on the prospects of a long-term relationship that will last at least for the life of the product model. There is a high level of trust involved in these relationships with competitive advantage deriving from the core process, which in this case is the design and development of the new models.

In the automotive industry it is important not to transfer your competitive advantage to your suppliers. But, some automakers adopting strategic modularization have gone a step further by encouraging suppliers to set production near its assembly lines by designing the plant and the car in conjunction with its suppliers. In its modular type plants, suppliers must take on more of the engineering and development responsibilities and get involved earlier in the design process. In turn, the automaker can leverage its capabilities with its suppliers' capabilities. In this industry, there is a lot of pressure from competition and from constantly evolving technologies, which requires OEMs to build strong relationships with their suppliers. They leverage their capabilities through the codesign of components and systems, and must be effective in managing and coordinating this flow and the transfer of information and technology back and forward in this relationship. Therefore, the capability to transfer technology with module suppliers implies a high level of integration that allows for an efficient definition of the module boundaries and facilitates the achievement of higher levels of performance. Based on the above arguments, we suggest the following proposition:

> **Proposition 2:** When adopting modularization, firms developing technology transfer capabilities are more likely to achieve higher levels of performance.

Entrepreneurial Strategic Intent.

Researchers have conceptualized entrepreneurship in broad terms such as the process of pursuing opportunities (Worren, Moore, and Cardona, 2002). We adopted the narrower definition suggested by Lumpkin and Dess (1996) who define entrepreneurship as new entry, which can be accomplished by entering new or established markets with new or existing products. We asked respondents to indicate whether they had formally developed business plans to use new technologies and product models to enter new markets before they decided to adopt strategic modularization. As mentioned earlier, a firm adopting extensive outsourcing strategies will need to deal with high levels of tacit knowledge that can be better managed by adopting a modular approach to production, which allows for a more effective management of tacit knowledge. These can be a valuable decision when developing new products or entering new markets.

We argue that there is a linkage between the adoption of strategic modularization and the firm's articulated strategic intent for developing new products or entering new markets with customized products that better satisfy individual customer's needs and in turn lead to superior performance. Competition in the automobile industry is about the best product design. It is important to efficiently address customers' needs as well as to build a responsive manufacturing process when planning the introduction of new products in the automobile industry. We argue that strategic modularization facilitates firms' innovation and entrepreneurial intent leading to superior performance. Based on the above arguments, we suggest the following proposition:

> **Proposition 3:** When adopting modularization, firms developing higher levels of entrepreneurial strategic intent are more likely to achieve higher levels of performance.

METHODS AND ANALYSIS

The data for this research were collected in three stages. First in 2003, then again in 2005 and 2008, through a questionnaire mail survey of Brazilian automobile manufacturers and suppliers. The development of the items was informed by the field studies and the semi-structured interviews with

managers and executives working in the automobile industry in Brazil. The questionnaire was sent to the of 493 business units in the phase one, A total of 136 valid questionnaires were returned. Follow-ups in 2005 and 2008 resulted in 124 business units responding for all 3 years of the study, 2003, 2005, and 2008. Firms of a variety of ages, sizes, and geographical scope were represented in the final sample group. Preliminary analysis of the data was done with multiple OLS regression and correlations.

In general our preliminary results seem to support our three theoretical propositions that strategic modularization impact firm performance through higher levels of face-to-face communication, development of technology transfer capabilities, and increasing entrepreneurial strategic intent.

DISCUSSION AND IMPLICATIONS

Our literature review indicated that strategic modularization is expected to help organizations achieve shorter product development cycles, speed technological change, improve product quality, and reduce costs. More importantly, we argue that strategic modularization is also expected to integrate tacit knowledge at the module supplier-level, which in turn lead to higher levels of face-to-face communication, development of technology transfer capabilities, and increasing entrepreneurial strategic intent, subsequently leading to superior performance.

Our preliminary findings indicate that the key to efficiency in strategic modularization is to develop operational and collaborative arrangements where major suppliers (module providers) invest in their own plants to build customized modules and deliver them in just-in-time sequence to the final assembly line, thereby eliminating needless inventory and costly delivery infrastructure. Therefore, modular production can significantly reduce investment and operational costs. Moreover, results indicated that strategic modularization allowed firms to focus on the manufacturing of components that match their resources and capabilities. Through specialization, firms benefit from learning by their own experimentation of new technologies and designs over a larger customer base, without having to incur excessive costs when trying alternative configurations. Modular assembly can be seen as a way to cut manufacturing costs and accelerate new-vehicle development where workers bolt together large, pre-assembled modules, such as the entire cockpit, reducing the number of parts in each car by 50 percent, allowing OEM to operate with fewer line workers.

Modularity has enabled companies to handle increasingly complex technology (Baldwin and Clark, 1997, 2000). Our research seems to support our argument that by disassembling the product into independent modules, different organizations can take responsibilities for separate modules. Consequently, design teams, manufacturers, and final users gain more flexibility. In this process, automakers can be confident that a reliable product will arise from their collective efforts with their module suppliers. In general, findings indicated that this process facilitates the production of high-quality products because it leverages suppliers' capabilities.

Strategic modularization allow automakers to transfer part of the assembly responsibility to the supplier-level while retaining the final quality inspection, which proved to be a more efficient method to control quality and costs while delivering product to the market faster by aligning everyone's interest in achieving higher strategic positional advantage.

One important contribution of this study is the development of an integrative framework and lending support to some of the hypothesized causal links in the strategic flexibility approach (Sanchez, 1995; Worren, Moore, and Cardona, 2002). Our study also contributes to extant research (Fisher, Jain, and MacDuffie, 1995, Worren, Moore, and Cardona, 2002) by emphasizing modularization as a key competitive strategy in attaining high levels of flexibility and product variety. Product variety capability as the ability to produce different models in the same assembly line sequentially allows the firm to target to diverse customer needs, while at the same time benefiting from low incremental cost of producing new model variations and reducing design and development cost by allowing the reuse of existing components. Moreover, our study should cultivate researchers' interest in the importance of modularization and its role as a strategic approach for competitive advantage.

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