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Manufacturing strategy and enterprise dynamic capability

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ABSTRACT

From a system thinking perspective, competition/cooperation boundaries govern the evolution of a firm's adaptive strategic behaviour and drive it towards its desired objectives. By analyzing different scenarios using a system dynamic simulation approach and considering market competitive dynamics, this study explores the volume flexibility measure considering both the operating environment and the simultaneous strategic behaviour of the competing firm(s). The objective is to develop new macro measures for the enterprise manufacturing strategy and link the operations management theory on volume flexibility to the dynamic capability theory. The strategic effect of enterprise volume flexibility under three market scenarios is studied and reported.

1. Introduction

The ultimate goal for industrial enterprises is to secure a long-term sustainable advantage over its rivals that contribute to wealth creation and growth over time. Manufacturing systems cannot be operated or managed if they are isolated from the rest of the organization. Skinner [1] introduced manufacturing strategy to exploit certain properties of the manufacturing function to achieve competitive advantages. Manufacturing strategy is defined as a pattern of decisions, both structural and infrastructural, which determine the capability of a manufacturing system in order to meet a set of manufacturing objectives that fit with the overall business objectives.

The typical strategic planning process for industrial enterprises starts by defining the business strategy that the firm will utilize. According to the selected type of strategy, firms have to generate a portfolio of capabilities that will determine the contribution of the manufacturing function to overall business performance. The resources that any firm acquires are the raw material for developing these capabilities and also for the firm's available future strategic choices. The process between acquiring resources and making strategic choices involves transferring these resources into capabilities that adapt to the external environment with its challenging and shifting requirements. Also a firm's capabilities should adapt in a responsive manner, with respect to its industry benchmark, i.e. competition performance.

To develop manufacturing capabilities, managers will have decisions in two categories: structural and infrastructural [2]. Structural decisions regarding capacity expansion are strategic and irreversible as they may or may not increase manufacturing flexibility as competitive capability to the enterprise. Thus exploring the effectiveness of volume flexibility gained from capacity adjustments considering the simultaneous strategic behaviour of competition and the operating environment is interesting to the decision makers.

2. Enterprise dynamic capabilities

In the continuous competition for wealth creation and market share, all firms compete to develop sustainable competitive advantages to occupy favourable market position by creating valuable, rare, and non substitutable resources that are idiosyncratic to the firm. The Resource-Based View (RBV) [3] argues that resources that are simultaneously valuable, rare, and imperfectly imitable are a source of competitive advantage. The RBV is considered a static approach and does not address how future resources could be refreshed in changing environments. Also the Strategic Conflict Approach [4], using tools of game theory, which models conflicts of interest firms may have against each other is criticized because it failed to capture the simultaneous choices over many variables that characterize competition in most industries. It incorporated only a small number of "fixed" variables in order to remain analytically tractable, which in reality would be changing over the relevant time horizons [5]. The dynamic capability perspective proposed a solution for the static view of both theories.

The original definition for the dynamic capability is, "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" [6]. In return this will help the organization to maintain their favourable position in the market landscape and allow them to evolve and adapt with the changeable external environment. The paradox is that the competitive advantage of firms lies in their managerial and organizational processes, their specific asset position, and the available paths for future expansion. At a certain point, firms will have to irreversibly "trade off" [7] some of their available options and choose between them. Also, the trade off between responsiveness and overreaction remains one of the biggest challenges managers face every day in their decisions. In hypercompetitive environments competitive advantage is transient rather than

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sustainable. The created advantage will cope with the external environment at any point of time [6] and create value with reference to a competitor's performance. If the dynamic capabilities are irrelevant to the market, they may not necessarily be valuable and will not necessarily lead to competitive advantages as the effect of the new set of resources may be negative [8].

From a manufacturing perspective the dynamic capability for enterprise organizations is known as manufacturing flexibility. Flexibility in manufacturing systems is defined as the ability of a system or facility to adjust to the changes in its internal or external environment with little penalty in time, effort, cost, or performance. Review of the literature identifies 10 types of manufacturing systems' flexibilities [9]: machine, material handling, operation, process, product, routing, volume, expansion, control program, and production flexibility. Volume flexibility was defined as the ability to operate efficiently, effectively, and profitability over a range of volumes. The importance of the volume flexibility measure lies in the need to evaluate the strategic decisions involving the acquisition of greater production capacity. Flexibility measure attempts represented a basic property of the system components and its structure *without* reference to the operating environment. Various performance measures to examine the best scaling policy under different demand scenarios demonstrated that the best scalability policy would be based on both the marketing strategy as well as the operational production objectives [10].

Models that study the dynamic behaviour of two competing firms over market share to examine the assumptions of conventional neoclassical models, for example [11], test the assumptions of perfect foresight and instantaneous capacity adjustment against the bounded rational models that assume some limitation in the forecasting abilities and the responsiveness of capacity adjustment capabilities of the firm proved the big risk of ignoring the role of disequilibrium dynamics. Following this stream of research, this study is focused on exploring the volume flexibility measure considering both the operating environment and the simultaneous strategic behaviour of the competing firm(s) based on the firm's intended strategic targets and its available capability. Results were obtained considering the disequilibrium dynamics of competitive markets.

3. Model formulation

3.1. Mathematical model

In exploring the dynamics of volume flexibility in different market scenarios, the presented model ignores the neoclassical assumption of perfect foresight and instantaneous capacity adjustments. We consider only the case of disequilibrium due to lags in production capacity adjustment and bounded rationality in decision making to study the dynamics of volume flexibility for manufacturing enterprises. The model is formulated as a set of nonlinear differential equations in continuous time.

3.1.1. Market dynamics and industry orders sub-model

Following a logit choice model [12], the market is represented by two segments of customers, one attracted to price and the other attracted to availability. The attraction to price and cost affect the total attractiveness of a product to the customer and is calculated as:

$$A_T(i) = A_P(i) \times A_V(i) \tag{1}$$

where A_T is the product's total attractiveness, A_P is the attractiveness of price and A_V is the attractiveness of availability. Availability and price attractiveness are represented exponentially to capture the accumulated customer experience over time as follows:

$$A_V(i) = \exp(S_V \times D_P(i)) \tag{2}$$

$$A_P(i) = \exp\left(S_P \times \left(\frac{P(i)}{\mathrm{LP}(i)}\right)\right) \tag{3}$$

S_V and S_P capture the customer's preference for availability and price, respectively. The firm's delivery performance, D_P, is the delivery delay D_d compared to the reference delivery delay, RD_d benchmark known by the customer in the market. Delivery delay is the ratio of backlog, $B(i)$, to shipments $S(i)$ given by Little's Law [13]. To normalize prices, the customer is assumed to compare the price, P, in reference to the lowest available price at any time $\mathrm{LP}(i)$, due to advancement in advertising and information technology. The firm's score in product attractiveness may limit its total industry order share; the order rate is calculated according to Bass diffusion model [14] that capture the product life cycle behaviour as:

$$\frac{dO(i)}{dt} = A_T(i) \times \left(\frac{dO_r(i)}{dt}\right) \tag{4}$$

$$\frac{dA}{dt} = P_A\left(\mathrm{ADV} + \frac{\mathrm{WOM} \times A_P}{\mathrm{POP}}\right) \tag{5}$$

$$\frac{dO_r}{dt} = \sigma\left(\frac{dA}{dt}\right) + \sum\left(I_B(i)\left(\frac{dD(i)}{dt}\right)\right) \tag{6}$$

where $O(i)$ is the orders received by the firm. The total industry order rate dO_r/dt depends on the initial industry orders for the product and the reorder rate for product replacement. The adoption rate dA/dt is a function of word of mouth (WOM), number of potential adopters P_A, number of customers who adopt the product, A_P, and other external factors, such as advertising strength (ADV) in reference to the market population, POP. Number of products per customer is captured by σ, while I_B is the installed base of the product and dD/dx is the discard rate that captures the life time of the product life cycle.

3.1.2. Capacity adjustment sub-model

Capacity planning can be described as an interactive process between identifying the required manufacturing technologies and expanding capacity levels through tactical moves such as direct acquisition, outsourcing and/or strategic alliances. The overall objective is to meet the desired market share and maximize the return on investment based on the firm's strategic intent in a responsive manner relative to competition performance. To avoid the "bullwhip effect" [15], the firm is assumed to maintain no inventory policy. As a result, production is equal to shipments. Although it is desirable to satisfy all market demands from in-house production, for a certain type of capacity shortfall, outsourcing could be more effective as a tactical option in preserving the firm's market position by enhancing its responsiveness to unexpected short-term demand variations.

Since capacity cannot be changed instantly, and to express the delay in capacity adjustment, the firm's production capacity, C, is expressed as a third order exponential smooth with a capacity acquisition delay C_{AD} normalized by the normal capacity utilization of the industry, NCU, as follows:

$$C(i) = \mathrm{SMOOTH}\,3I\left(C_T(i), C_{\mathrm{AD}}(i), 0.5 \times \frac{O_r(i)}{\mathrm{NCU}(i)}\right) \tag{7}$$

$$C_T(i) = \mathrm{MAX}\left(\mathrm{MES}(i), \mathrm{MS}_T(i) \times \frac{\mathrm{EID}(i)}{\mathrm{NCU}(i)}\right) \tag{8}$$

Firms seek minimum target capacity, C_T, based minimum efficient scale MES, or according to the firm's target market share, MS_T, applied to its forecast of expected industry demand, EID, adjusted by normal capacity utilization NCU.

3.1.3. Volume flexibility sub-model

Volume flexibility, VF, is considered to be the ability to operate efficiently, effectively and profitably over a range of volumes and is expressed by [16] as:

$$\mathrm{VF}(i) = 1 - \frac{aF_c(i)}{b(i) \times C(i)} \tag{9}$$

$$F_c(i) = C(i) \times \mathrm{UF}_c(i) \tag{10}$$

$$b(i) = P(i) - \mathrm{UV}_c(i) \times \mathrm{LS}(i) \tag{11}$$

where F_c is the total fixed cost, UF_c and UV_c are the unit fixed and variable cost, respectively, a is the number of capacity units required per part, b is the contribution margin for the product, P is the product price and LS captures the learning effect strength. The firm's learning effectiveness on market share may differ from one organization to another due to different managerial practices and/or cultural considerations, such as working environment and workforce background.

3.2. Simulation results

In this section, results from various simulation experiments conducted to investigate the impact of volume flexibility on the firm's performance are reported. The market share % coupled with the volume flexibility measure is used in this analysis as the main performance measure that can offer insight into decisions concerning infrastructural and irreversible actions such as capacity expansion. To explore the behaviour of volume flexibility as a capability at the strategic level, three scenarios were developed, analyzed and compared. The learning effect, the order fulfilment capability, and the outsourcing performance are the three major themes of competition between firm F1 and F2 in the following three scenarios. The key parameters for the two firms used in the base case of comparison are shown in Table 1.

The first scenario shows the effect of volume flexibility due to differences in order fulfilment responsiveness and its impact on market share. The differences in achieving the industry order fulfilment benchmark are captured by the normal delivery delay (NDD). The second firm F2 outperformed F1 in the order fulfilment responsiveness by 25%, which is one month earlier than the assumed average normal delivery delay benchmark in the base case (4 month) as shown in Fig. 1. Results show that the capability of 25% faster in order responsiveness resulted in more than 25% higher market share for firm F2.

The second analysis explores the case where firm F2 responds to the backlog accumulation by outsourcing 3 months earlier than firm F1, which represents 25% better performance than in the base case. Outsourcing delay (OD), causes differences in volume flexibility and market share that favour firm F2 as shown in Fig. 2.

Finally, the third analysis explores the case where firm F2 focuses on labour training that affects both variable and fixed production costs more than firm F1 and therefore allows more tolerance for prise competition. The learning effect caused a decrease in the unit cost by 30% and 15% for firm F2 and F1, respectively, after each production cycle (20,000 U). The learning effect was captured by changing the learning strength weights for firm F2 to outperform F1 by 25%. The market share performance for both firms is reported in Fig. 3.

By comparing all three scenarios representing the order fulfilment performance, the outsourcing and strategic alliances performance, and the learning curve performance together, as shown in Fig. 4, the following observations are revealed. Supply

Table 1
Selected parameters for the base case.

Parameters	Value	Unit
Normal delivery delay (NDD)	4	Month
Outsourcing delay (OD)	0.25	Year
Product price (P)	1000	\$/U
Normal capacity utilization (NCU)	80	%
Capacity acquisition delay (C_{AD})	1	Year
Minimum efficient scale (MES)	10,000	U
Learning curve strength (LS)	$\mathrm{Log}_2 0.7$	Dimensionless
Capacity units per part (a)	1	Dimensionless
Ratio of fixed to variable cost ($\mathrm{UF}_c/\mathrm{UV}_c$)	3	Dimensionless
Target market share (MS_T)	50	%

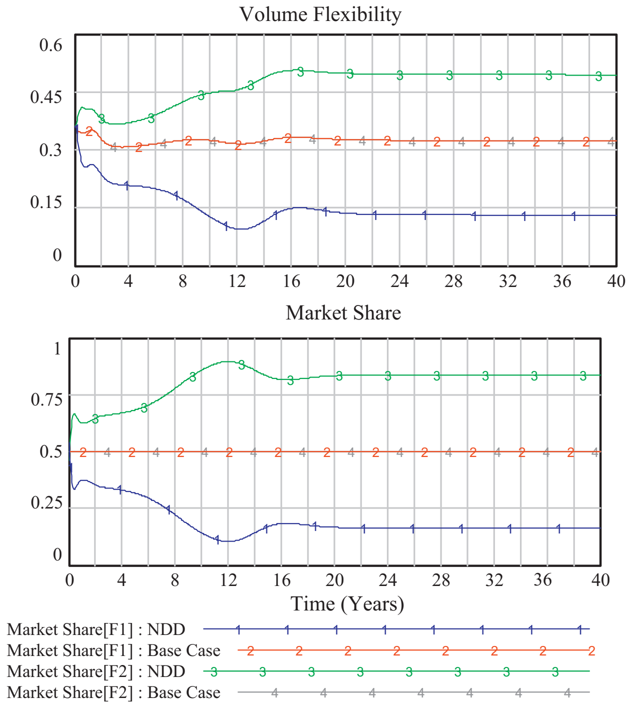

Fig. 1. Firm F2 outperforms F1 in order fulfilment.

chain management practices, such as outsourcing and strategic alliances, lead to the greatest source of volume flexibility if compared to other internal sources of flexibility, such as order fulfilment performance or the learning curve's positive effect on fixed and variable unit costs. The second best managerial practice for firms, in the presented market structure and scenarios, is to focus on achieving the normal delivery delay benchmark of the industry. Finally, due to the exponential characteristic of the learning effect and its impact on business performance, the performance difference in market share is delayed for approximately 1 year, as shown in Fig. 3, which make this choice the least responsive among other scenarios.

The 3 scenarios assume the same market speed as a key behavioural assumption. Results are sensitive to the adoption rate

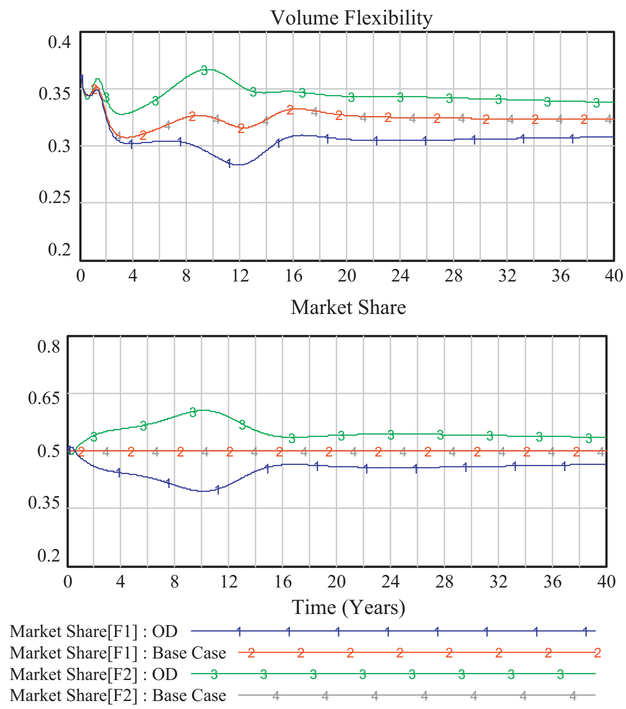

Fig. 2. Firm F2 outperforms F1 in outsourcing.

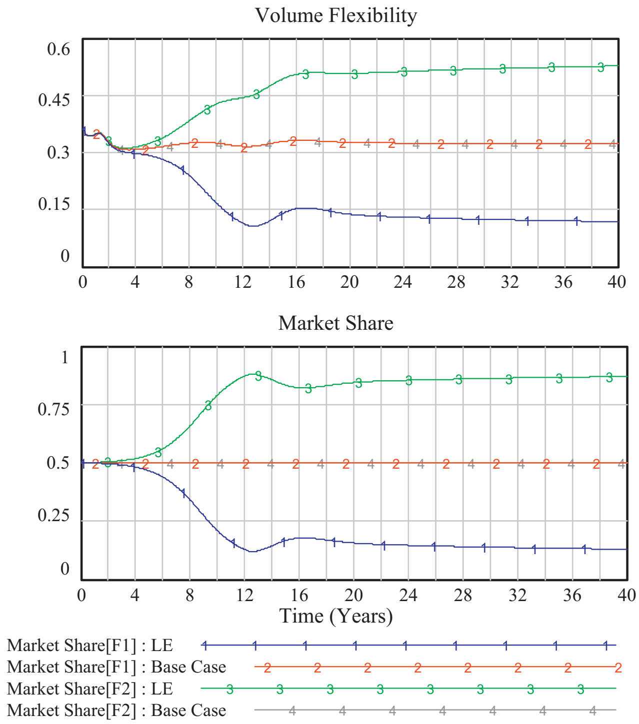

Fig. 3. Firm F2 outperforms F1 in learning effect.

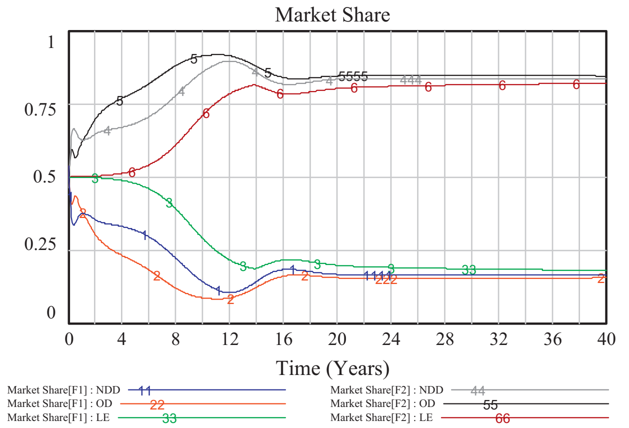

Fig. 4. The three scenarios comparison.

of the market and therefore to the product life cycle speed. Faster market scenarios, due to changes in the advertising strength or the strength of the market word of mouth (WOM) may change the sequence of effective strategic decisions. In our case, the training effect may overcome gains achieved from focusing on meeting the normal delivery delay benchmark of the industry. The analysis shows that the faster accumulation of production experience in faster market scenarios may lead to more savings in production costs and therefore lower prices and bigger market share. Outperforming by outsourcing remains a dominant strategy in the three presented scenarios even under fast market scenarios or short product life cycles.

4. Conclusion

This research has explored how operations management theory on volume flexibility can be linked to the dynamic capability theory to develop new macro measures for the enterprise manufacturing strategy. Model results show that there are differences in the resource options available to the firm, as suggested by the resource base view [3], and this may limit the implementation of volume flexibility capability as a competitive advantage. Short-term sources of flexibility such as inventory or capacity buffers may respond to small market fluctuations in demand, while large market fluctuations are more controlled by the irreversible type of strategy the firm may possess and accumulate over longer time periods regarding production capacity capability. Industrial enterprises will have to adapt their manufacturing capabilities to outperform the evolving industry benchmark. The benchmark evolution speed, either in market(s) or between industry members, is affected by the evolving customer preferences and the degree of allowed competition governed by policy makers. However, under different scenarios, given the universality of the uncertain environment, volume flexibility capability is commonly desirable by the enterprise to achieve a certain level of competitive advantage in its market(s). Finally, global manufacturing networks that coordinate outsourcing, enhance responsiveness and share information fairly are expected to dominate the next era of manufacturing practices on the strategic, tactical and operation levels.

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