

A Study of Business Competition from a System Dynamics Perspective

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ABSTRACT

Literature on competitiveness is numerous. In the field of business administration, strategic management and marketing management focus on how to compete in the markets. This paper begins with a review on the development of key concepts in strategic management. Next, an interpretation from the view of systems thinking on the concept of the experience curve and resource-based view of the company will be provided and made into causal-loops diagrams. Then, with system dynamics simulation methods, there will be quantified studies on the pattern of behavior occur in those causal-loops structures. Finally, based upon these findings and observations, suggestions for strategy will be discussed.

INTRODUCTION

All disciplines in the social science value the importance of studies on competitiveness. Literature on competitiveness is numerous. In the field of business administration, strategic management and marketing management focus on how to compete in the markets. In particular, strategic management discusses from all aspects how firms gain competitive advantages, and how they manage it. This paper attempts to analyze business competitive behaviors from the viewpoint of system dynamics and reinterprets a few concepts that strategic managers hold. It is hoped that this different viewpoint can arouse various insight.

This paper begins with a review on the development of key concepts in strategic management. Next, an interpretation from the view of systems thinking on the concept of the experience curve and resource-based view of the company will be provided and made into causal-loops diagrams. Then, with system dynamics simulation methods, there will be quantified studies on the pattern of behavior occur in those causal-loops structures.

DEVELOPMENT OF CRITICAL CONCEPTS IN STRATEGIC MANAGEMENT

Speaking of development of strategic management, its forerunner was the courses of "business policy" in business schools before the 1960s. At that time, so-called "business policy" means the integration and coordination of different functional departments, such as production, marketing, and so on. As to how the external environment of the business affects its performance, is not taken into consideration. In the 1960s, strategy studies not only paid attention to the integration of particular functions of different departments but the choice of the products-market arenas of the company, and the competitiveness among them. At that point, SWOT - often seen in the strategic analysis frame- was gradually forming. SWOT, a structure that covered both the internal capability and external environments, set the company strategy not only upon the analysis of the company's internal strength and weakness but the opportunities and threats in the external environment so as to avoid the weakness, dissolve facing threats, and catch opportunities in the environment.

In the 1970s, due to the unstable environment, competitiveness among businesses mounted, the growing and enlarging firms of management consultants that specialized in drawing up strategies, in addition to the diversified firm, made strategic management prospering (Rumelt et al, 1991). At this time, strategic management emphasized pragmatic tools and methods. Few researched into empirical studies or constituted theories. Among these tools and methods, the most famous model has been the experience curve and the growth-share matrix model developed by the BCG. It is still in the dispensable section of many management textbooks. The growth-share matrix model, according to the growth rate of an industry and the size of the relative competitive position, can be divided into four quadrants, upon which every unit's position of strategic business is based, in order to determine the future strategic direction of every unit. The growth-share matrix model was founded on the concept of the experience curve, the following section of this article will include an introduction to the experience curve.

From the 1980s, the theories of economics were introduced into strategic management. The most notable was Porter (1980), who used the theories relating to industry economics to construct a structure of strategic analysis.

His prominent strategic analysis structure of "five forces" focuses on the industrial environment of the business, and examines competitors, upstream suppliers, downstream customers, coming entrants and firms of substitutes, which hinder the monopolies advantages of a business. With a strategy exercised to control the five forces, a better monopolies structure is formed and maintained. The best position is then found in this structure in order to gain monopolies profits.

Undoubtedly, Porter's concept to combine strategies and external environment deeply affected strategic managers. It brought about a couple of setbacks as well. The rise of the resource-based view of the firm in the 1990s is possibly an adjustment to the overemphasis of the external environment. The earliest literature on the resource-based view of the firm was published by Wernerfelt (1984) in the *Strategic Management Journal*, a specialized periodical on strategic management. Nevertheless, this viewpoint was not taken seriously at that time since Porter's theory of building a monopolies position of competitive advantages on the industrial structure was overwhelmingly prominent. It was until the early 1990s that the entire field of strategic management and the business world began to review their past strategy which overemphasized the external environment, and adjust their focus to find the importance of internal resources of a company. This viewpoint holds that company resources do not come easily from the market so they are not mobile. In the long run, internal resources of different companies would varied, which forms the competitive advantage of a company. As to the profit sources of a factory, there are two sources in general: one is the industry attractiveness and the other the relative competitive advantage. The empirical studies show, however, that there is no relation between the industrial structure and the profit rate. Most scholars consider that the difference of the inter-industrial profit rate is much wider than that of the intra-industrial profit rate (Grant, 1991). Therefore, the competitive advantage is the key to profit making of a company while the base of forming competitive advantages relies on the internal resources of that company, which further distinguishes the significance of the company's internal resources.

REINTERPRETATION OF STRATEGIC MANAGEMENT FROM THE SYSTEMS PERSPECTIVE

After a brief review of the development of concepts in strategic management, a couple of key concepts in strategic management will be reinterpreted in this section. They are the mainstream of strategic management in the 1970s, the experience curve, and that in the early 1990s, the resource-based view of the firm. With regard to the latter, we would interpret Prahalad and Hamel's article published in *Harvard Business Review*, (Prahalad & Hamel, 1990).

Experience Curve:

Early in the 1930s, when Wright (1936) studied the aerospace industry, he had observed that the accumulated number of manufacturing airplanes was relative to the unit cost. He found that as the number increased by one time, the relative reduction of labor cost was 20 percent off, which is called "learning curve." Since the mid 1960s, Boston Consulting Group and a few other centers of management conducted a number of studies and got the same result. They found that the particular phenomenon occurred not only in labour cost but any other cost except the cost of purchasing material from outside. Consequently, this phenomenon that all costs decrease as the accumulated production does is called "experience curve", in order to distinguish from "learning curve," which only refers to labour cost.

Aaker (1984) concluded that there were four reasons for the formation of the experience curve: the effect of worker's learning, improvement of production technique, redesign of the product and scale effect. The application of the experience curve in strategy lies in how faster the company can accumulate experiences than its competitor so as to reduce cost and get the advantage of costs. However, to accumulate experiences faster, the company has to first raise its rate of market occupation. With sufficient occupation of market can the company defeat its competitor in accumulating experiences. Therefore, the strategist of the experience curve often resorts to lower prices in order to expand the market.

As to the above strategy based on the experience curve, if reinterpreted with the viewpoint of systems thinking, a causal-loops diagram can be shown (Figure 1). Suppose at the beginning, the company uses the strategy of low prices to increase its product attraction and raise the rate of market occupation. The sale volume thus increases, which makes the company to accumulate production faster than its competitor. With the effect of the experience curve, accumulation of experiences will reduce unit cost of every product so that lower prices can be utilized to gain a bigger share of the market, which accumulates more production experiences, lowers the cost and thus the price can be further reduced. A cycle is therefore formed. Our observation is that there are even number of negative signs in these causal links of the cycle. The cycle is the so-called positive feedback loop in systems thinking. Therefore, with systems thinking's interpretation of the experience curve strategy, we may conclude that the strategy is one of positive feedback loop or can be called a "growth engine."

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Regarding positive feedback loop, if we conduct further studies, it can be divided into controllable and non-controllable. The so-called controllable positive feedback loop means some causal links of the positive feedback loop result from man-made policy or can be changed by human, which makes the causal link disappear and thus the entire positive feedback loop disappears. The non-controllable positive feedback loop means all causal links that form the loop cannot be changed by human. The non-controllable positive feedback loop can form exponential growth or decay. But, for a controllable loop, it is not necessarily to form exponential growth or decay behavior. Maybe, before the possibility of rapid increase or sudden decline, a change of man-made policy occurs and the whole loop comes to a halt.

Here, the positive feedback loop of the experience curve strategy is controllable. Thus, if the pricing policy is not based on the cost, the loop is no longer a positive feedback loop. The possibility of exponential growth behavior would come to a halt.

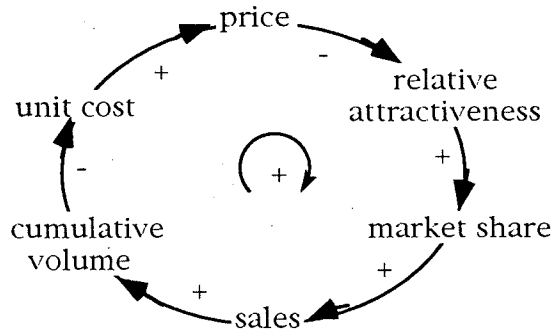


Figure 1: The causal-loop diagram of the positive feedback loop formed by the experience curve competition strategy

Resource-Based View of the Firm – the Example of Prahalad and Hamel's Article (1990)

The article begins with comparing the differences between GTE and NEC. Ten years ago, GTE's annual profit were three times larger than the NEC's. Ten years after, NEC's annual profit were twice as large as GTE's. What is the reason? Prahalad and Hamel explained that is because the NEC was filled with strategic intent, focuses on core competence and invest to raise its competence. GTE, on the other hand, was a traditional diversified firm. It regarded the firm itself as a group of numerous unrelated businesses. On the basis of power division, it is expected that all businesses can do their best to make the maximum profit for the firm. Despite having the high degree capacity of technology, all managers of all business units mind their own business. Due to the over division of power, however, it is difficult to achieve core competence, which in turn weakens the forces and makes the core competence difficult to accumulate.

The firm based on the core competence is like a huge tree, its root being the core competitiveness and several competitiveness forming several concrete core products; core products bloom into end-products that all business units own. For instance, 3M uses limited core competence – substrates and gluing; various arrangements form numerous profit-making end-products. Core competence is not like any other resources. The more you use it, the more you can share and the more intensified it becomes; the more it is used to develop end-products, the stronger it is. The firm that applies the core competence strategy is competitive in end-products. Many firms try to maximize their share of the global market in order to maintain their core competence.

According to the above brief summary, with the viewpoint of systems thinking, the strategy concept of core competence can be reinterpreted, as shown in the causal loops diagram (Figure 2). The core competence will affect core products while the strength of core products will in turn affect the functions and volume of end-products. In comparison with the competitor's end-products in the market, the relative competitive position will be determined and the sale volume of the firm will be affected. The more it is sold, the more profit it will make. A certain percentage of income is then higher than the budget invested in core competence, which further raise the core competence, have a better relative competitive position and form a better and better positive feedback loop. On the other hand, the more end-products are developed, the more application of core competence can be. This is a positive feedback loop. As to those firms that adopt the core competence strategy, they normally have extremely high ambition towards their core competence, and thus often expect their core products to be more competitive than their competitors. When there is a gap, these firms will continuously invest in core competence, which forms a negative feedback loop towards the goal:

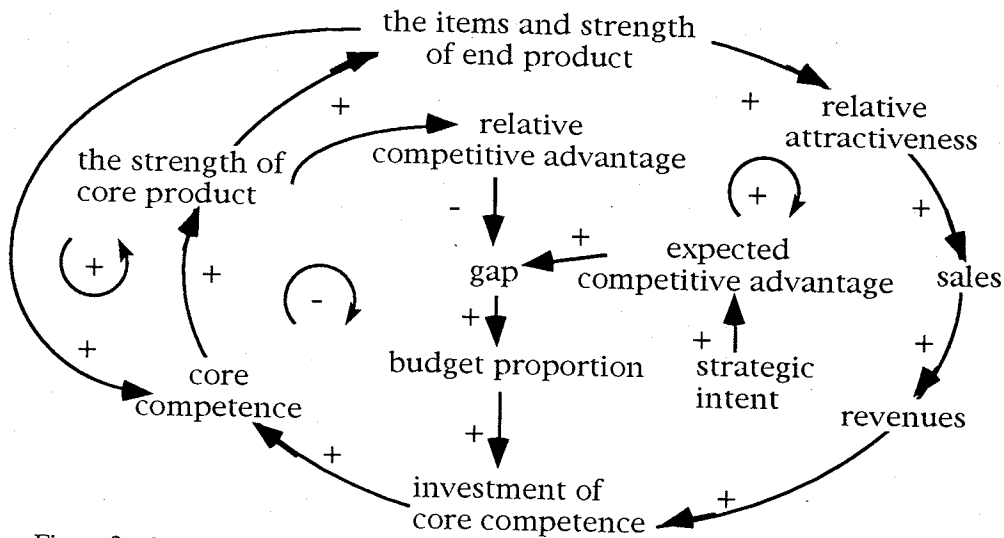


Figure 2: the causal loops diagram formed by the core competence competition strategy

FURTHER INQUIRY WITH SYSTEM DYNAMICS

Both concepts in the above section stress the internal experience and capacity of a firm. They do not consider the competitor's reaction in the market. This section will expand the thinking border of original concepts and take the competitor's strategy into account. To consider the competitor's reaction will complicate the issue, which makes it difficult to handle by systems thinking and thus must rely on systems dynamics methodology with the calculation of simulation by computer.

Experience Curve:

The situation we consider here is that there are only two competitors in the market, and both have the effect of the experience curve. The causal-loops diagram is shown in Figure 3. Suppose the cost affects prices of A and B in the diagram, i.e., they adopt cost plus pricing. As the cost is reduced, prices are lowered. On the contrary, prices get higher when the cost increases. Here, the product price is the only competitive weapon. So, in the model, the relative price of A and B which A price divided B price is also the only cause that affects the relative competitive position of both sides in the market. The higher A's price is relative to B's, the smaller A's market attractiveness is; the smaller A's market share becomes, the bigger B's market share will be, provided that A's market share plus B's equals one, and the market scale doesn't be affected by both prices, remains constant.

This causal-loops diagram is mainly consisted of two positive feedback loops. On the left hand side, A's strategy forms a positive feedback loop, and on the right hand side, B's the other. Similar to the systems archetype of the "success to the successful" (Senge, 1990), however, does it show the pattern of behavior of "success to the successful"? According to the causal-loops diagram in Figure 3, we shall further examine it with a model of system dynamics built by STELLA software. For the equations, please refer to the appendix.

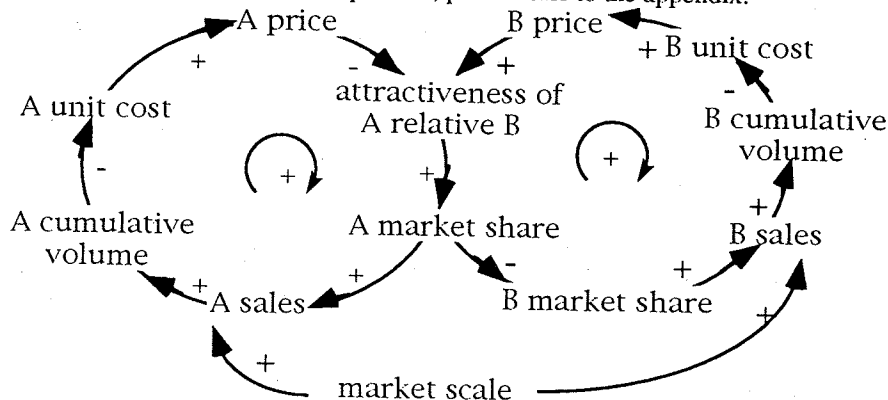


Figure 3: The causal-loops diagram of the experience curve after considering the competitor

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With this model, we can compare A's and B's performances in the difference situation. These situations are arranged according to various levels of market's responsive sensibility, market's responsive speed and the experience curve, among which the market's responsive sensibility curve and the experience curve can be shown with graphic function, as presented in Figure 4.

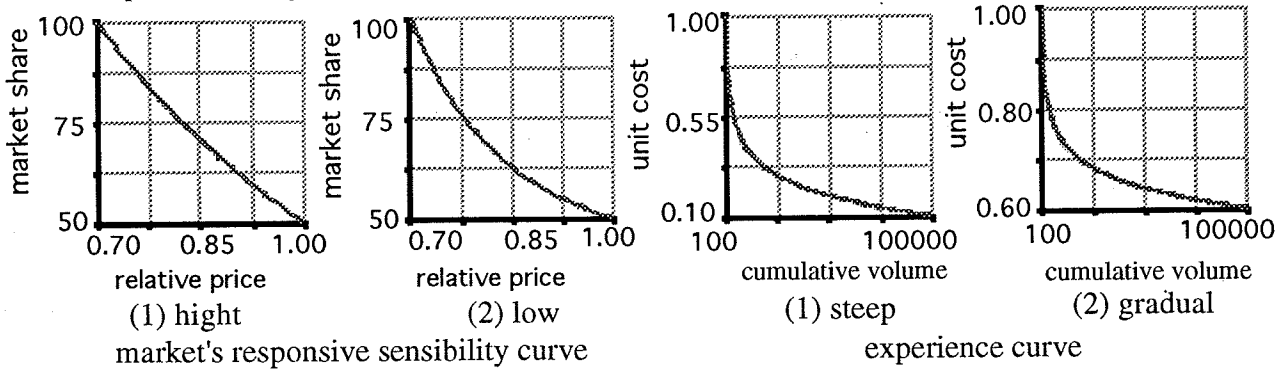


Figure 4: The graphic function of the market's responsive sensibility and the experience curve

Table 1 is the factor- situation matrix designed by this study:

Table 1: Factor- situation matrix

market's responsive sensibility		low	high	low	high	
market's responsive speed		fast	fast	slow	slow	
experience curve						
experience curve	same	gradual	situation1	situation2	situation3	situation4
		steep	situation5	situation6	situation7	situation8
	not same		situation9	situation10	situation11	situation12

In this simulation experiment, we use cumulative profits as the index to measure performance. Firm A begins to adopt the strategy of low prices from the second period and resume its normal profit rate in the eighth period. Firm B, however, always maintain its normal profit rate with the cost plus pricing and ignores A's strategy. The model ran for fifty periods.

***With the same experience curve**

In the circumstance that A's and B's experience curves are the same, there are eight situations, situation 1 to 8. The simulation results in figure5 show that, except the result of situation 6, all the other situations have the similar results after fifty periods: though A's sale volume in every period is bigger than B's, its accumulated profit always lags behind B's.

***With the different experience curve**

In the circumstance that A's experience curve is steeper than B's, there are four situations. After fifty periods of simulation, the results show that A's accumulated profit is better than B's, as presented in Figure 5.

***A change of pricing policy**

Now we shall focus on situation 6 for further experiment. We change the pricing policy of both A and B. It is still A that adopts low prices while B recognizing A's strategy of low prices does the same and have even lower prices. A responds by lowering his price furthermore, which leads to a price war. Figure 6 shows one of the situations.

As the simulation result shows, no matter how violent the war is (the percentage of lowering prices shown in the model) or regardless of the responsive speed (the time shown in the model that both sides acknowledge the opponent's lowering prices), firm A apparently cannot defeat firm B, but makes either two loss in the war or alternate loss.

***Summary**

From the above result, we found that when there is no difference between the experience curve of both competitors, one side would succeed by employing the strategy of the experience curve only on the condition that the market

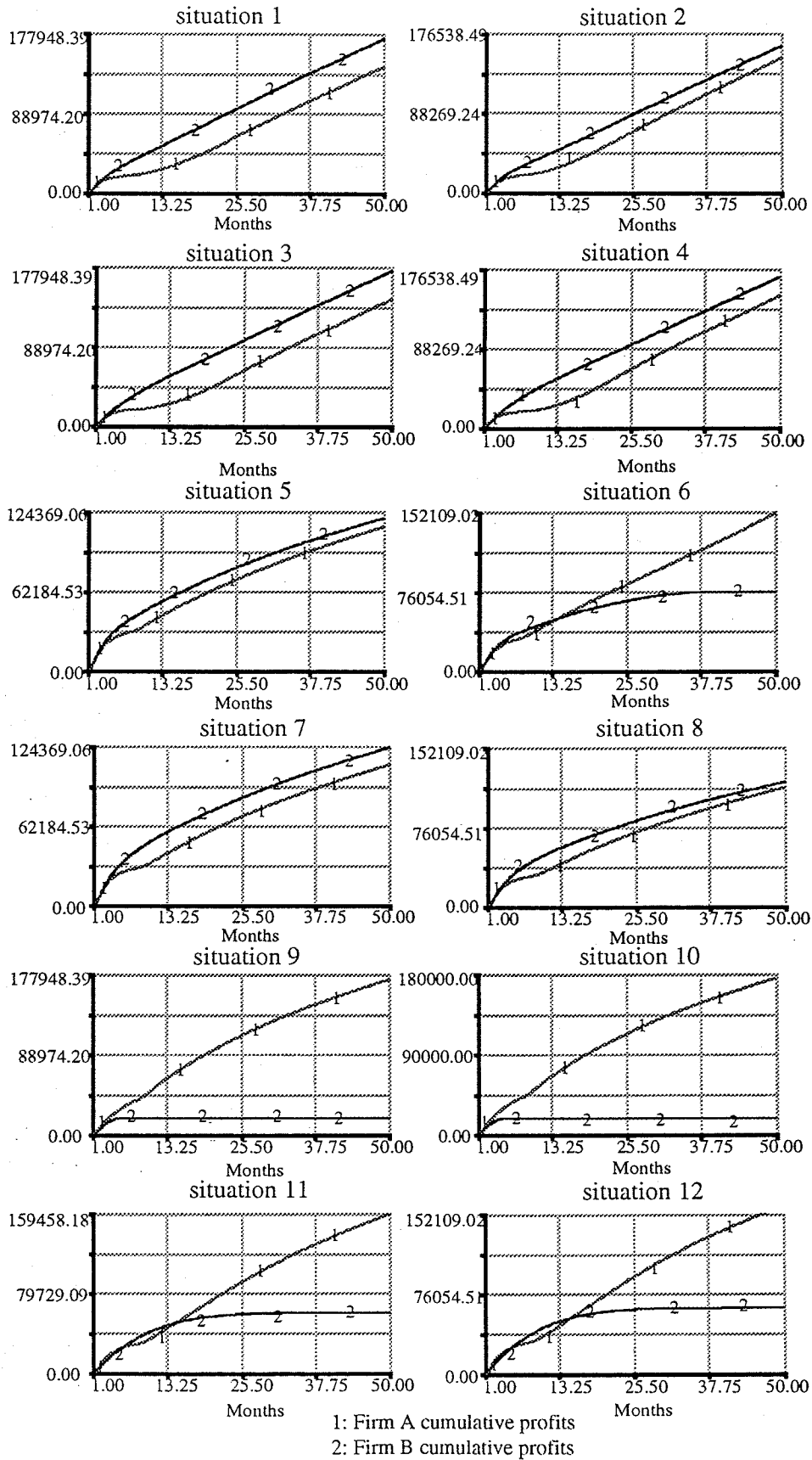


Figure 5: The simulation results of a experience curve model

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responds fast and sensitive to the price, and the experience curve of the firm is very steep. More importantly, the competitor would not take any action to fight back. But if the market responds sensitive and fast, B can spot the change in the market soon and responds to it. Moreover, in the early stage when A reduces its price, B accumulates more profits than A, which enables B to fight back. As a result, a price war easily breaks out and both lose. However, if there is a difference between the experience curve of both competitors, the side that has a steeper experience curve can succeed using the strategy of experience curve, regardless of the external market situation.

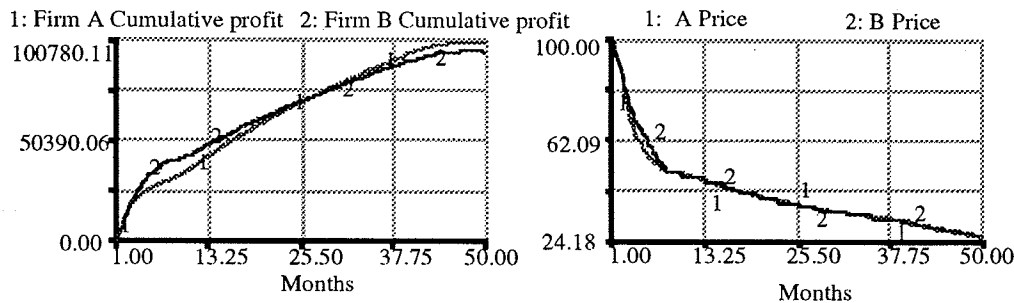


Figure 6: One of the situations of the change of pricing policy in experience curve model

*Implication in management

The experience curve may form the strategy of positive feedback loop. But it is difficult to form sustained competitive advantage. It is the improvement of the experience curve itself that makes the sustained competitive advantage. Through organizational learning, the firms learn from the past experiences of production and marketing to improve their experience curves. So we may conclude that the organizational learning capability is more fundamental than the experience curve to gain the sustained competitive advantage.

*Insight to systems thinking

The casual-loops diagram in Figure 3 match the systems archetype of "success to the successful". We expected its pattern of behavior was one success and the other failure from the "success to the successful" structure. But the simulation results do not follow our expectation. Obviously, it once again proves what Forrester (1975) held that a complicated system will result in counterintuitive behaviors. No doubt, the application of the systems archetypes has some limitation. We further inquire this causal-loops diagram, and find that the two main loops apparently are positive feedback loops but they actually contain limit factors, coming from the experience curve itself. As the experience curve is a downward curve towards a certain point, of which behavior is exactly what the structure of the negative feedback loop can have. Therefore, we can say that the experience curve itself is a negative feedback loop that adjusts towards the limit goal. So the positive feedback loop included the experience curve in its causal links can be transformed into a combination structure of the positive and negative feedback loops. That is the systems archetype of "limits to growth". No wonder the strength of the positive feedback loop formed by the experience curve is somewhat limited. The insight from this study is: when examining what systems archetypes form the multi-loop structure, we have to be cautious about those causal links of nonlinear graphic functions as they might contain some key loop structures.

Resource-Based View of the Firm

According to Figure 2 and Morone's description (Morone, 1993) on the evolution of three individual cases, i.e., the business department of GE Medical System, Motorola-Communication and Corning, we construct a system dynamics model. This model especially stresses the formation of core competence from the result of numerous mistakes of attempts, and it is eventually built by learning. Thus at the beginning, the R&D budget is allocated at random to the two different funds of core and non-core competences, in order to develop technique related end products. It is not necessarily that money can transform into successful products. Here the successful transformation fraction controls the size of the transformation. After successful transformation, only those the related to core competence experience of successfully developing products will be accumulated to core competence while the non-core competence part is left out. At a certain point of core competence accumulation, managing levels of the firm will recognize that is the core competence, of which the firm will devote itself to developing. Then, all R&D budget will be allocated to developing products of core competence. The more it is used, the stronger the core competence is; the stronger it becomes, the higher the possibilities of successfully-developed products will be, which in turn will further raise the successful transformation fraction and makes accumulating experiences of core competence faster. Figure 7 is part of this model:

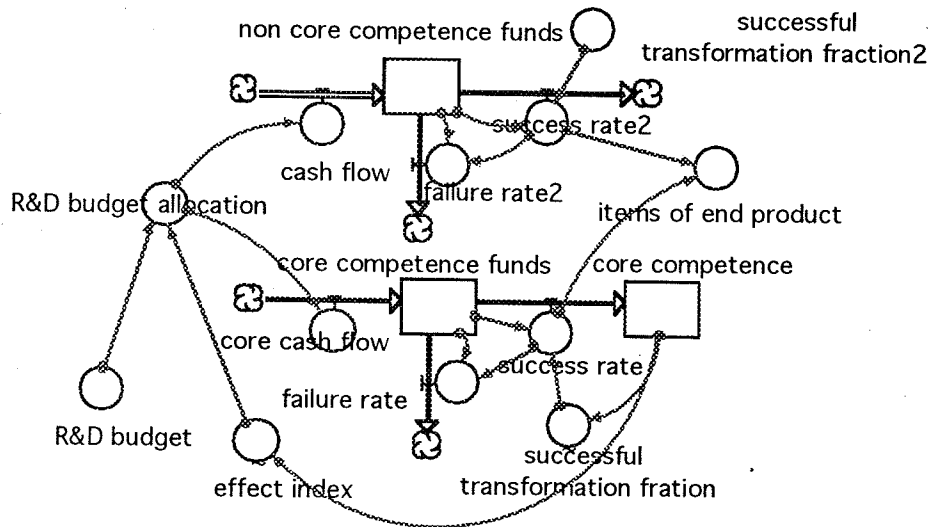


Figure 7: Part of the core competence model

The result of the simulation shows that when both competitors adopt the same model, random picks at the beginning will have a totally different situation – two extremes of the "success to the successful" structure, as presented in Figure 8, which fully matches the systems archetype of "success to the successful."

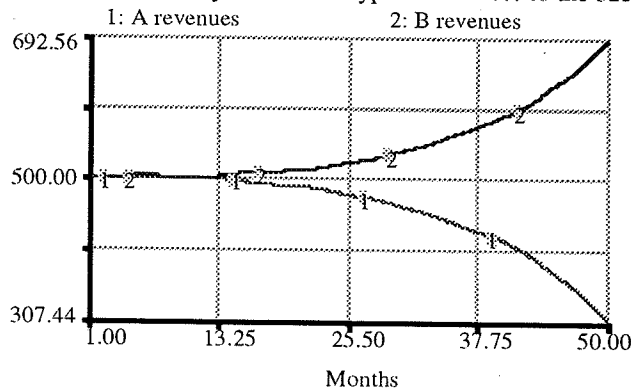


Figure 8: Result of the core competence simulation model

In this model, two variables are extremely sensitive. One variable is the successful transformation fraction, affected by the degree of core competence. It shows the learning capacity of the firm. When the successful transformation fraction gets more sensitive to the degree of core competence, it means that the firm is more capable of learning from past experiences. The other variable is the effect index of core competence level on R&D budget allocation. That index is an upward curve, it shows the recognition ability and commitment of the managing level to core competence. When the core competence is not obviously seen, the managers cannot recognize it and thus the index goes down. When the core competence gets obvious, the index goes up. When the core competence exceed a certain point, the index is 1. It means the managers are fully capable of recognizing the core competence, and willing to allocate all the R&D budget in it. The simulation result shows those possessed sensitive successful transformation fraction and a steep effect index will easily gain a sustained competitive advantage.

***Summary**

In summary of the simulation result, we find that the positive feedback loop strategy of core competence is very powerful and it will create sustained competitive advantages for the firm. Under the structure of the positive loop is the more fundamental learning ability of the organization, and the managers' foresight and commitment to core competence. When both competitors in the market adopt the same strategy, the key to success lies on the above two factors.

CONCLUSION

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We may conclude from the reinterpretation with the system dynamics perspective of the experience curve strategy and the core competence strategy as follows:

1. These strategies interacting with market all form the positive feedback loops.
2. Reviewing the evolution of strategic management, we find that the emphasis of the strategy has shifted from the earlier experience curve to current core competence, that is, from superficial and tangible to fundamental and intangible. So the corresponding positive loop strategy also become more fundamental and intangible. Through the examination with the system dynamics methodology, we further find that the strength of the more fundamental positive feedback loop gets stronger. While the positive feedback loop strategy of the experience curve cannot form a competitive advantage, that of the core competence can sustain competitive advantages.
3. The consistence of the firm's capacity and its positive feedback loop strategy was not considered. According to the systems archetype of "growth and underinvestment," a growing firm must pay attention to whether the capacity itself can sustain its rapid growth. If the consistence of the growth engine and the capacity itself is not considered, the firm will soon face a growth of limit. Besides, this concept itself is incomplete and the thinking is not thorough enough.
4. Under the structure of the two positive feedback loop strategies, both contain several highly sensitive variables, which mean the learning capacity and the commitment of the managers.

Based on these findings, we further suggest the strategy of systems thinking to be: look for a stronger positive loop than the competitor's as the foundation to sustained competitive advantages; meanwhile, consider the consistence of the capacity itself and the positive feedback loop.

Judging from the above review of literature on strategic management, we conclude that the development of the strategic positive loop is inclined to get more fundamental and become more intangible. Moreover, it is observed under the structure of these positive loops, all those variables affected by the learning capacity of the firm turn out highly sensitive. We believe that the positive feedback loop strategy formed by organizational learning capacity will be the source for a firm to gain sustained competitive advantages in the competitive market.

REFERENCES

- Aaker, D. A. 1984. *Strategic Market Management*. New York: John Wiley & Sons, Inc.
- Forrester, J. W. 1975. *Counterintuitive Behavior of Social Systems. Collected Papers of Jay W. Forrester*. Cambridge: Wright-Allen Press, Inc.
- Grant, R. M. 1991. The Resource-Based Theory of Competitive Advantage: Implications for Strategy Formulation. *California Management Review*. Spring: 114-135.
- Morone, J. G. 1993. *Winning in High-Tech Markets*. Cambridge: Harvard Business School Press.
- Porter, M. E. 1980. *Competitive Strategy: Techniques for Analyzing Industries and Competitors*. New York: The Free Press.
- Prahalad, C. K. and G. Hamel. 1990. The Core Competence of the Corporation. *Harvard Business Review*. May-June: 71-91.
- Rumelt, R. P., D. Schendel, and D. J. Teece. 1991. Strategic Management and Economics. *Strategic Management Journal*. 12: 5-29.
- Senge, P. M. 1990. *The Fifth Discipline- the Art & Practice of the Learning Organization*. New York: Doubleday/Currency.
- Wernerfelt, B. 1984. A Resource-Based View of the Firm. *Strategic Management Journal*. 5(2): 171-180.
- Wright, T. P. 1936. Factors Affecting the Cost of Airplanes. *Journal of the Aeronautical Science*. 3: 16-24.

APPENDIX

$A_cumulative_sales(t) = A_cumulative_sales(t - dt) + (Firm_A_sales) * dt$
INIT $A_cumulative_sales = 100$

$Firm_A_sales = A_market_share/100*market_scale$
 $B_cumulative_sales(t) = B_cumulative_sales(t - dt) + (Firm_B_sales) * dt$
INIT $B_cumulative_sales = 100$

$Firm_B_sales = (1-A_market_share/100)*market_scale$
 $Firm_A_Cumulative_profits(t) = Firm_A_Cumulative_profits(t - dt) + (A_gross_profits) * dt$
INIT $Firm_A_Cumulative_profits = 0$

A_gross_profits = Firm_A_sales*(Product_A_Price-A_cost)
 Firm_B_Cumulative_profits(t) = Firm_B_Cumulative_profits(t - dt) + (B_gross_profits) * dt
 INIT Firm_B_Cumulative_profits = 0

B_gross_profits = Firm_B_sales*(Product_B_Price-B_cost)
 Product_A_Price(t) = Product_A_Price(t - dt) + (- A_price_adjust) * dt
 INIT Product_A_Price = 100

A_price_adjust = Product_A_Price-A_objective_price
 Product_B_Price(t) = Product_B_Price(t - dt) + (- B_price_adjust) * dt
 INIT Product_B_Price = 100

B_price_adjust = Product_B_Price-B_objective_price
 market_scale = 1000
 attractiveness_of_A_relative_to_B = (Product_A_Price/Product_B_Price)^(-1)
 A_cost = A_unit_cost*90
 A_market_share = SMTH3(A_relative_attractiveness,market's_responsive_time)
 A_objective_price = A_cost*(1.1-step(0.1,2)+step(0.1,8))
 A_relative_attractiveness = price_weighting_factor*(50*attractiveness_of_A_relative_to_B-28.5)/0.43
 B_cost = B_unit_cost*90
 B_objective_price = B_cost*1.1
 market's_responsive_time = 3
 price_weighting_factor = 1
 A_unit_cost = GRAPH(LOG10(A_cumulative_sales))
 (2.00, 1.00), (2.30, 0.91), (2.60, 0.82), (2.90, 0.73), (3.20, 0.64), (3.50, 0.55), (3.80, 0.46), (4.10, 0.37), (4.40,
 0.28), (4.70, 0.19), (5.00, 0.1)
 B_unit_cost = GRAPH(LOG10(B_cumulative_sales))
 (2.00, 1.00), (2.30, 0.91), (2.60, 0.82), (2.90, 0.73), (3.20, 0.64), (3.50, 0.55), (3.80, 0.46), (4.10, 0.37), (4.40,
 0.28), (4.70, 0.19), (5.00, 0.1)