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System Dynamic Modeling

of Technological Capabilities Accumulation

Xu Qingrui , **Chen Jin,** **Zhao Xiaoqing**
Sbaxuqr@sina.com.cn **cjhd@cma.zju.edu.cn** **lsh69@163.com**
School of Management, Zhejiang University, Hangzhou, P.R.C., 310027

Abstract: This paper focuses on the system dynamic model of accumulation and path selection of firm's technological capabilities (FTC). Based on the ten years' data of West Lake Electronic Co., the accumulation process of FTC is simulated. It analyzes the impact of switching between technological introduction, in-house R&D and cooperative R&D impact on the accumulation of FTC. And it also analyzes the impact of investment of difference path on the accumulation of FTC.

Key Words: Technological capabilities, system dynamic model

1. Introduction

The rate of technological change, together with increasingly complex nature of many technologies, means that few organizations can now afford to maintain in-house expertise in every potentially relevant technical area. Therefore most R&D and project managers now recognize that no company, even the large ones, can continue to survive as a technological island. In addition, there is a great appreciation of the important role that external technology source can play in providing a window on emerging or rapidly advancing area of science and technology. This is particularly true when developments arise from outside a company's traditional area of business, or from overseas (Tidd, et., 1997). The competence-based approach emphasizes the process of competence accumulation or learning.

The relationship between core competence and portfolio innovation is the mutual interactions as followings:

1) The choice of innovation portfolio is based on the firm's core competence;
2) Portfolio innovation is the pathway for core competence to be cultivated and enhanced, because the core competence is the complex interacted result of firm's technological, organizational, cultural elements.

In order to gain some inside looks into the firm's core competence building and enhancing process, we will examine the basic patterns and its rules in competence building. From the experiences of Chinese firms, there are three patterns as followings (Xu Qingrui, Guo Bing and Chen Jin, 1996):

- Pattern 1: Building core competence via Secondary Innovation, that is, through technology importing, absorption and self-reliance innovation. The preconditions of this pattern are that the firm should have strong absorptive capacity, while there exists a large gap in core technologies.
- Pattern 2: Building core competence through collaboration with other organizations. This includes equity-based associations, such as joint ventures and direct investments, and nonequity associations, such as technology licensing, technology exchange, testing agreements, technology sharing agreements, and research contracts.. The preconditions of this pattern are that the firm should have a good relationship or cooperation experience with

partners.

- Pattern 3: Building core competence through in-house development. This offers the potential to protect existing competencies and to develop new competencies within an organization (Cohen and Levinthal, 1990).The preconditions are that the firm should have grasped a certain mix of core technology, and also, the technological change should not be too frequent and severe.

We expect that different types of technological change will tend to have different relationships with firms' existing capabilities and, therefore, influence the choice between internal development and external acquisition of new knowledge.

According to our research on some Chinese firms, the methods of acquiring new knowledge not only relate to the types of technological change, they also relate to the firms' technological capability and investment ability. From strategic view, an analysis framework on the path selection of firm's technological competence accumulation is showed as Figure 1.

A firm's external environment includes the dynamically fast development of industrial technological, capital markets, law, etc; internal environment includes technological capability, competence, financial ability, etc.. In this paper, we mainly analyze the three factors: industrial technological change, technological capability, and financial ability .

There are three types of change within a technological system: encompassing, complementary, and incremental changes (A.Nagarajan and Wmitchell, 1998). Encompassing change involves radical alteration of core competence. Complementary change involves radical alteration of complementary assets that do not also involve radical alteration of core activities. Incremental change involves incremental adjustments to core or complementary activities.

Encompassing, complementary, and incremental changes often have substantially different effects on a firm's existing knowledge and, in turn, on the methods that firms use to acquire new knowledge.

The accumulation of a firm's technological capability is a long-term, path-dependent process in which knowledge learning and knowledge creating interact. The path selection of firm's technological capability accumulation has some requirements to the firm's current technological capabilities.

The accumulation of technological capability is also a process of capital investment. So, we must consider the firm's financial ability in selecting the paths of accumulation.

Table 1 shows the methods and paths that firm should use to accumulate technological capability.

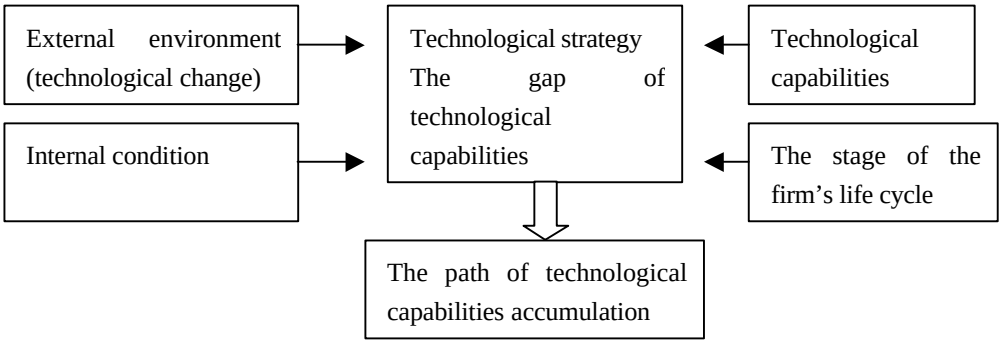

Figure 1: A framework on the firm's technological competence accumulation

Table1 the path selection of firm's technological capability accumulation

FTC / FA / Tech.. change	Strong		Weak	
	Strong	Weak	Strong	Weak
Encompassing	Acquire	Collaboration R&D	Acquire	Technology importing
Complementary	Internal R&D or acquire	Collaboration R&D	Acquire	Technology importing
Incremental	Internal R&D	Internal R&D	Collaboration R&D	Technology importing

In table 2, FTC = Firm's Technological Capability, FA= Financial Ability

2. System Dynamic Model Building

Firm's technological capabilities system (FTC) includes four sub-systems (Figure 2):

TIC: Technology Importing Capabilities
TMC: Technology Monitoring Capabilities
TAC: Technology Absorbing Capabilities
TCC: Technology Creative Capabilities

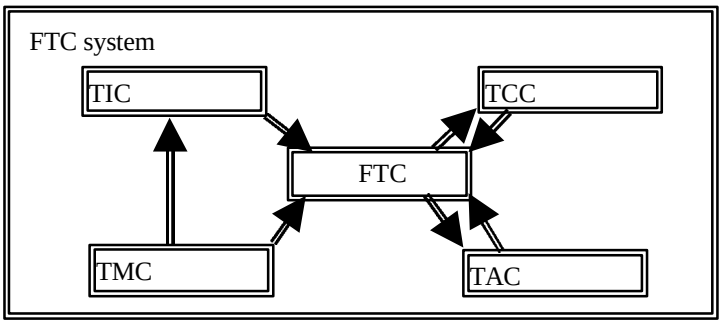

Figure 2 The Structure of Technology capabilities system

Technological capabilities accumulation is a interactive process between knowledge learning and knowledge creating. The selection of different paths has a multi-feedback effects to the process of technological accumulation.

So, we propose a system dynamic model of accumulation and path selection of FTC. Based on the ten years' data of West Lake Co., the accumulation process of FTC is simulated. It analyzes impact of switching between technological introduction, in-house R&D and cooperative R&D on the accumulation of FTC.

The accumulation paths of FTC have an effect on system of FTC through knowledge learning and knowledge creating. At the same time, the system of FTC has effect on the selection of accumulation paths of FTC through multi-feedback. Figure 3 shows the basic structure of our model .

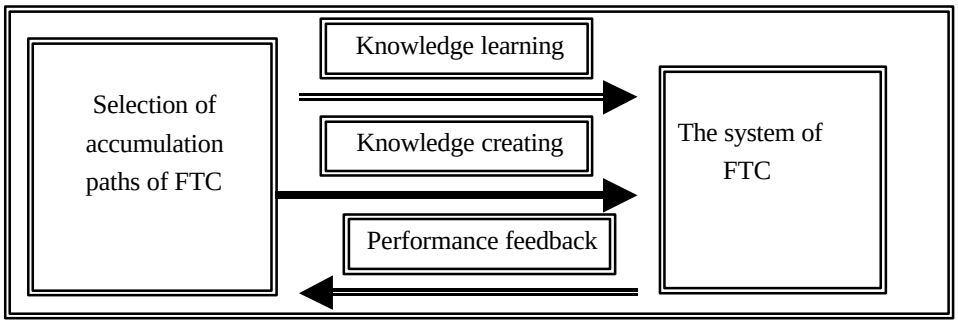

Figure 3 the basic structure of SD model .

In this system, a firm first figure out the gap of FTC according to its existing technological capabilities and its anticipant technological capabilities, then select the accumulation path of FTC according to its financial ability and industrial dynamics.

The devotion to accumulation of FTC breeds knowledge learning and knowledge creating, then knowledge learning and knowledge creating enforces technological innovation capabilities and strategic capabilities. Moreover, this improves the effectiveness of accumulation path selection of FTC. The accumulation of FTC brings two feedback, it affects the accumulation path selection of FTC through reducing the gap of FTC on the one hand; on the other hand it affects the accumulation path selection of FTC through improving the firm's performance and enhancing financial ability. The main causal- effect of accumulation of FTC is shown as figure 4.

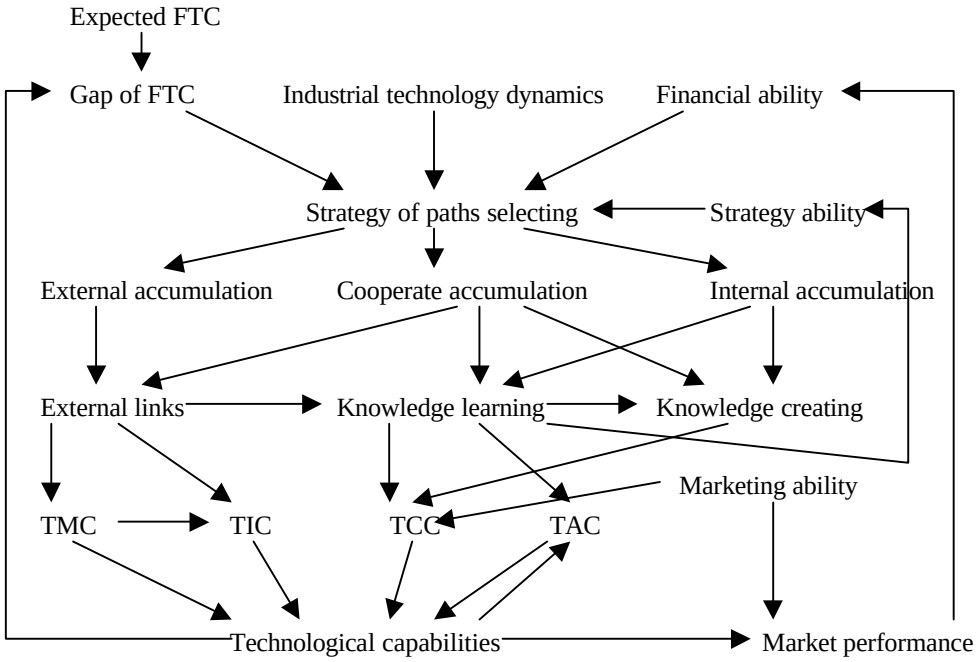

Figure 4 Simple illustration of causal-effect relation on accumulation of FTC

3. Validity test and Policy analysis of the SD model

With policy analysis, we analyze the impact of accumulation paths of FTC to increase of FTC. We take West Lake Electronic Co (WEC). as a simulating object.

The core product of WEC is TV. set. During the process of technological development, WEC accumulates its key competence through technology importing, assimilating, indigenous development and collaborate innovation, see Table 2. This process is quite typical in Chinese firms .

Table 2 The process of technological competence accumulation in WEC

Core Tech. Platform	Time	Path of accumulation	Technologies
Color TV. set production Tech.	1985-1986	Tech. Importing, Internal R&D	21" TV. set
Large screen TV. set product Tech.	1987-1990	Internal R&D	25", 29" large screen TV. set
Color monitor production Tech.	1993	Tech. Importing	
NICAM digital Tech.	1996	Internal R&D	NICAM TV.
Digital TV. set production Tech.	1995-1997	Internal R&D	Product 3000 digital TV. set
Informational TV. set	1998-	Collaboration R&D	Build digital industrial collaboration

3.1 Validity test of SD model

We take the capabilities data in 1990 which were figured using technological capabilities valuation model as initial value of level variable of dynamic model, the results of simulating are shown as figure 5. The results of simulation are similar to the real increase process of FTC (see Table 3) .

Table 3 Comparing the results of simulation and the results of valuation of FTC

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Simulating results	759.1	803	842	956.8	1021.3	1340.4	1466.3	1551.9	1634.7	1932.3
Valuation results	759.1	804.1	832.2	947.3	988.3	1386.4	1453.2	1538.6	1624.1	18941894.0
Error %	0	-0.14	1.18	1.00	3.34	-3.32	0.90	0.86	0.65	2.02

The data in table 3 shows that the errors between simulation results and valuation results belongs to the region (-3.32, 3.34). The errors are small, that validate the effectiveness of the system dynamic model.

3.2 The impact of financial investment on each accumulation path to accumulation of FTC

We analyze WEC's capital assignment in the process of switching from technological importing to internal R&D. In fact, this firm invested about 32000 thousand yuan on technology importing, its ratio with sale was 2.6%; the firm invested 46652 thousand yuan on internal R&D, its ratio with sale was 3.8%. We suppose the gross investment (6.4%) is constant, we do several simulation through changing the capital's assignment between the two paths. The results are shown as Table 4.

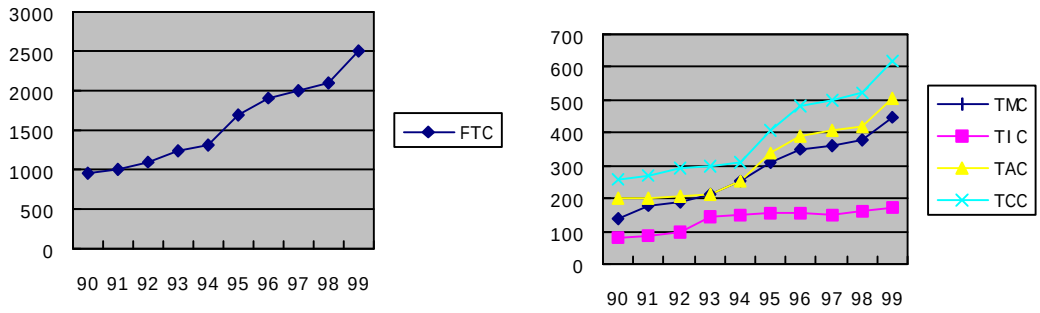

Figure 5 Simulating results of FTC accumulation

Table 4 Simulation results of increase rate of FTC

The capital ratio(%) on internal R&D	The capital ratio(%) on technological importing	Increase rate (%) of FTC (1995)	Increase rate (%) of FTC (1996)	Increase rate (%) of FTC (1997)	Increase rate (%) of FTC (1998)
6.4	0.0	4.05	4.95	3.09	7.37
5.7	0.7	5.16	6.12	5.34	9.38
5.0	1.4	7.03	7.97	6.99	11.23
4.3	2.1	6.54	7.33	6.76	10.46
3.8 (actual)	2.6	5.28	6.80	6.00	9.86
3.1	3.3	4.67	5.65	5.46	8.17
2.4	4.0	4.34	5.43	5.55	6.92
1.7	4.7	3.55	4.77	4.98	5.78
1.0	5.4	4.23	4.96	5.67	5.99
0.0	6.4	3.09	3.78	4.76	4.93

From the results of table 4, we know when the ratio between internal R&D and technological importing investment is 3.6 : 1, the increase rate of FTC is maximal. When the investment ratio on internal R&D is between 3.8% and 5.7%, the investment ratio on technology importing is between 0.7% and 2.6%, the increase rate of FTC is more. So WLE may improve its investment ratio to increase accumulation rate of FTC.

4. Conclusion

Firm's Technological capabilities (FTC) are the integration of knowledge and skills for firm to undertake technological monitoring, introducing, absorbing and creating, which are the basis of competitive advantage of firm. Acquisition of FTC is an accumulative and path-dependent process, mechanism of which isn't clarified yet.

From the two-sided view of knowledge learning and creating, the accumulation mechanism of FTC has been studied. Based on it, the analytical framework and system dynamic model of FTC accumulation was proposed, which can provide the strategic reference for firm to select the best accumulation of FTC and control the key factors in the accumulation process.

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