System Dynamics Modeling of High Technology Industry Development in China

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Abstract

High technology industry is a complicated, multiple information feedback and non-linear system. Its developing process includes the interaction of many factors from the interior and exterior of the system. The dynamics of high technology industry development (HTID) in the field is influenced by a series of factors. The motivation that drove the effort to study the dynamics of HTID is to analyze two issues: (1) How corporate R&D intensity, and the proportion between corporate internal R&D fee and technology import fee have effect on HTID; (2) How the behavior patterns of government have influence on HTID. To analyze these issues, a formal model ---- HTID SD model was built. The main conclusions are as follow: (1) At the different stage, Chinese government should choose appropriate behavior pattern. (2) During the transitional economy, the main work of Chinese government should create favorable entrepreneurial environment; offer policy and regulation to minimize institutional obstacles of firms' innovation.

Keywords: System Dynamics, High Technology, Industry, Policy Analysis

Introduction

In the system dynamics (SD) field, the single most powerful way of understanding the behavior of a system is the creation of simulation model. The power lays in the capability of taking into account the interactions of all variables in the model at the same time. Therefore, practitioners in the SD field must determine the underlying structure of the system, grasp it and build a model that conveys the behavior of the real system. In order to construct a model to analyze high technology industry development (HTID) in the SD field, this paper follows the SD modeling process (Saeed, 1992).

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non-linear system. Its developing process includes the interaction of many factors from the interior and exterior of the system. The dynamics of HTID in the field is influenced by a series of factors. An investigation according to 20 experts and professors in America (see Fig.1) indicates that the most correlative factors in turn are: entrepreneurs; innovation culture; research-oriented university; favorable habitation and environment of working; venture capital; visionary venture capitalist; mobile labor; and well-done service agencies, etc.

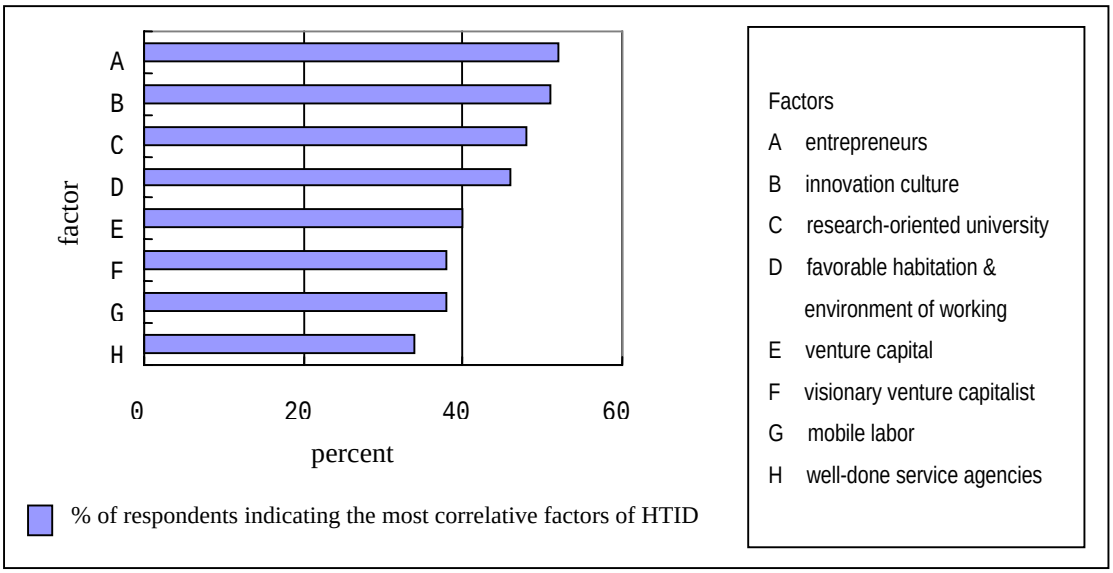

Fig.1 The key successful factors of HTID

Generally speaking, 8 factors in the Fig.1 are also the key successful factors of China's HTID. In China, however, these 8 factors are influenced by the behavior patterns of government that have a strong impact on institutional environment of HTID. Meanwhile, intensity of corporate R&D makes a great impact on HTID because of low technological innovation capabilities of Chinese firms. It's necessary to think fully of the complicacy, non-linearity and dynamic of this system during the research on the policies of HTID. The motivation that drove the effort to study the dynamics of HTID is to analyze two issues: (1) How intension of corporate R&D, and the proportion between corporate internal R&D fee and technique import one have effect on HTID; (2) How the behavior patterns of government have influence on HTID. To analyze these issues, a formal model–HTID SD model was built.

High Technology Industry Development System Dynamics Model Overview

The objective of HTID is to transform intellectual resource into science and technology one, and furthermore transform the later into high technology industry that can cultivate a large number of high technology - centered corporation. HTID system can be treat as an "input – process – output" system. It includes many elements or factors as follow: entrepreneurs, venture capital, research – oriented university and science – technology organizations (technology and person with ability), corporations, institution and environment such as government (government institution), market (market mechanism), entrepreneurial environment, innovation culture, habitation and

environment of working and so on. These elements or factors interact each other, and make a more or less impact on the high technology industry performance by innovation integration and industrialization. To gain the most satisfactory HTID performance, these elements or factors must be effectively and efficiently combined and matched by means of technological innovation, organizational innovation, institution innovation and culture innovation. So the basic logical structure of HTID SD model is built (see Fig.2). Based on this, the cause and effect diagram of HTID SD model is constructed (see Fig.3).

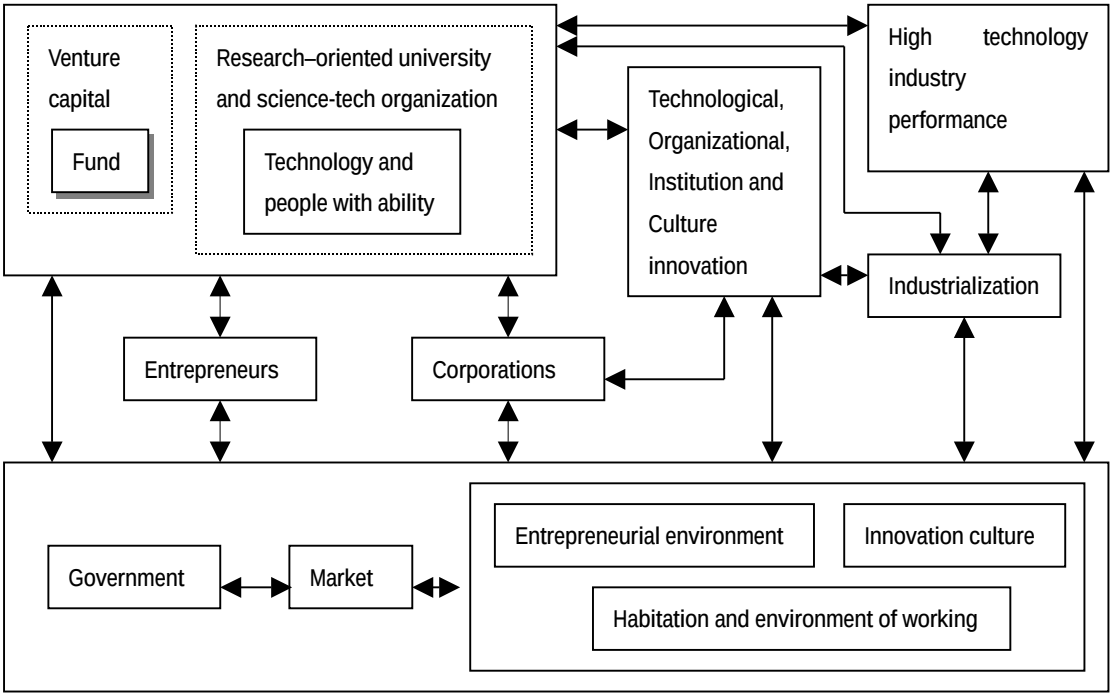

Fig.2 The basic logical structure of HTID SD

Fig.3 The cause and effect diagram of HTID SD model

The Behavior of the HTID SD Model

How the Intensity and Structure of Corporate R&D have Effect on HTID

Technological innovation is a bridge to link S&T and economy. It's the key of HTID. The two paths to build high technology industry competence are independent innovation based on internal R&D, and "3I", namely innovation process of "introduction—imitation—improvement". To effectively impel HTID, it's necessary to balance technological innovation capital between internal R&D and technology import. Therefore, based on the HTID SD model, how the intensity and structure of corporate R&D have effect on HTID of *City A* is observed.

First, it is to analyze how corporate R&D intensity has effect on HTID of *City A*. There are 5 schemes by changing technological innovation input capital proportion in total high technology industry revenues (THTIR): scheme 1 (p=2.5%), scheme 2 (p=3.0%), scheme 3 (p=3.5%), scheme 4 (p=5.0%), scheme 5 (p=6.0%). While THTIR is independent variable and the other variables hold static, the simulation result is Fig. 4.

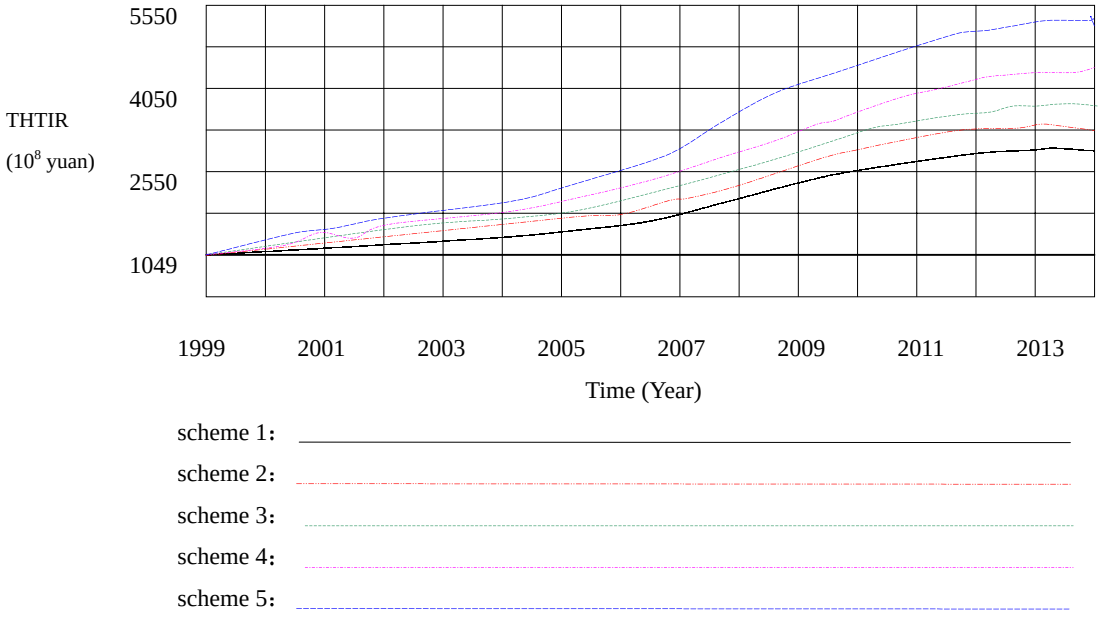

Fig.4 Technological innovation capital input proportion effecting THTIR

According to Fig.4, THTIR will increase faster with the increase of technological innovation capital input proportion, as is consistent with the practice of Chinese HTID. For example, the lower R&D intension in Hangzhou contributes to the lower HTID speed, while the higher R&D intension in Beijing and Shenzhen leads to the relative higher HTID speed. Therefore, it is of great significance for Chinese corporations to improve the R&D intensity.

Second, how the proportion between corporate internal R&D fee and technology import one has effect on HTID of *City A* is observed. In 1997, the technology import capital of *City A* is about 0.84 billion yuan, accounted for 2.1% of THTIR; the internal R&D capital is about 1.54 billion yuan, accounted for 3.8% of THTIR. While the total technological innovation capital input proportion of HTID is 5.9% and the proportion between corporate internal R&D fee and technology import one is modified, the simulation result is Tab.1.

Tab.1 The proportion between corporate internal R&D fee and technology import effecting HTID

Internal R&D (%) I	Technology import (%) O	I/O	THTIR (10^8 yuan)		
			1997	1998	1999
5.9	0	---	343	501	756
5.0	0.9	5.5: 1	391	617	943
4.5	1.4	3.2: 1	715	1038	1624
4.0	1.9	2.1: 1	529	826	1347
3.8	**2.1**	**1.8: 1**	**406**	**687**	**1049**
3.3	2.6	1.3: 1	384	642	901
2.5	3.4	1: 1.4	328	519	865
2.0	3.9	1: 1.8	293	486	697
1.0	4.9	1: 4.9	205	361	509
0	5.9	---	184	278	367

According to Tab.1, THTIR can reach tiptop when the proportion of technological innovation input capital between internal R&D and technology import is 3.2:1. When internal R&D input proportion range from 3.8% to 5.0% and technology import from 0.9% to 2.1%, THTIR is relative higher. If I/O=5.5:1, THTIR descend and its growth gets slow. It indicates that completely depending on internal R&D without timely and effectively absorbing advanced technologies cannot promote HTID.

How the Behavior Patterns of Government have Influence on HTID

The practice of HTID all over the country shows that only market mechanism is insufficiently effective to develop high technology industry. Appropriable behavior patterns of government, which is integration of government's policies and actions for accelerating HTID, also are important forces of HTID. As a whole, the behavior patterns of government developing high technology industry can be sorted into highly concentrating mode (directly government controlling mode, named "pattern a"), multiply dispersing mode (indirectly government controlling mode, named "pattern b"), and concentrative harmonizing mode (combining collective management with disperse management, or combining government with market, named "pattern c"). At the different stage of HTID, the specific content of the behavior patterns of government is different.

Firstly, how at the preliminary stage of HTID the different government behavior patterns have effect on HTID is observed. While THTIR is independent variable and the other variables hold static, the simulation result is Fig. 5.

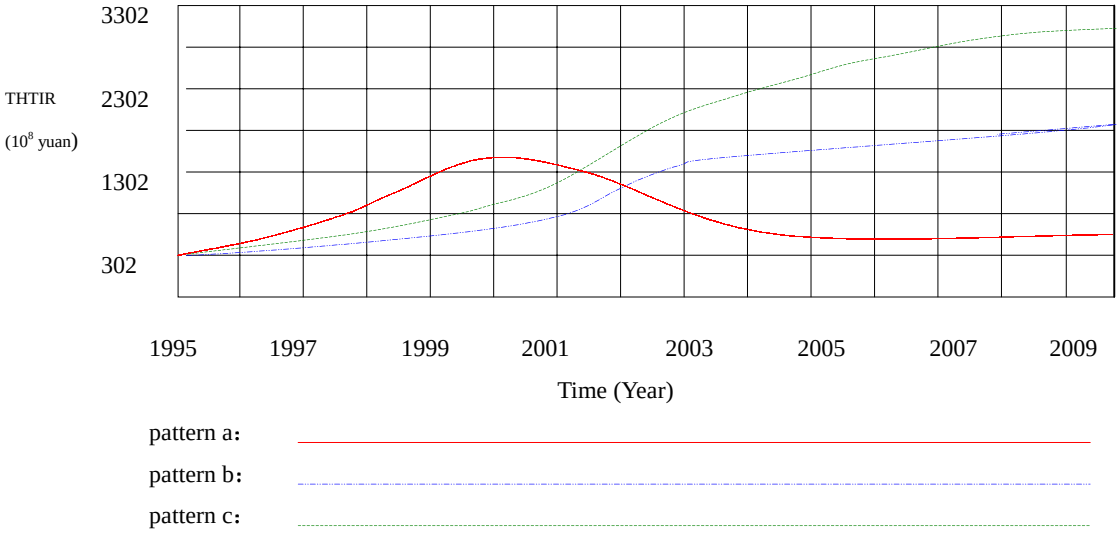

Fig.5 The different government behavior patterns at the same stage (preliminary stage) effecting HTID

Fig.5 indicates that the different government behavior patterns at the same stage (preliminary stage) have distinct effect on HTID.THTIR can grow rapidly by pattern a in the short term, but it will falls speedily when it arrives at the top. THTIR grows slowly by pattern b. Although THTIR grows by pattern c more slowly than it by pattern a, but THTIR can grow rapidly by pattern c in the long term. According to

situation of Chinese HTID, the pattern c is the best choice.

Second, how at the different stage of HTID pattern c has effect on HTID of *City B* is analyzed. Pattern c can be further subdivided into two sub-patterns, namely pattern c1 (give priority to governmental adjustability) and pattern c2 (give priority to marketing adjustability). The process of HTID is divided into four stages, namely preliminary stage, prophase of growth stage, metaphase and anaphase of growth, mature stage. So 16 portfolio strategies can be gotten (see Tab. 2). The process of HTID of *City B* can be divided into the above 4 stages (see Fig.6). While THTIR is independent variable, and the other variables hold static, and 16 portfolio strategies are simulated respectively, the simulation result is Tab.2.

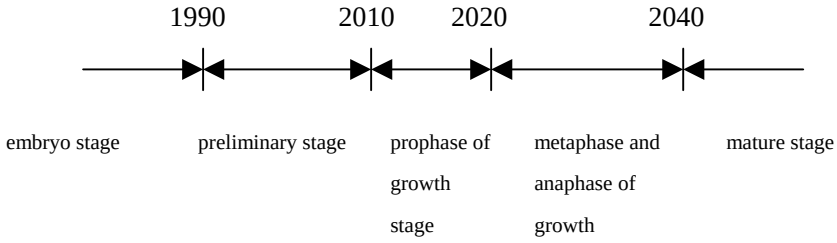

Fig.6 The process of HTID of City B

Tab.2 shows that the fourth portfolio strategy (D4) is the most feasible. So at the preliminary stage and prophase of growth stage, it should give priority to concentrating management of government that can impel the industrialization process. At the metaphase and anaphase of growth stage and at the mature stage, it should give priority to market adjustability and the government behavior pattern should harmonizing management-oriented.

Tab.2 Portfolio strategies of pattern c and their simulation result at the different stage of HTID

Portfolio strategies	Preliminary stage	Growth stage		Mature stage
		Prophase	Metaphase and anaphase	
D1	C1	C1	C1	C1
D2	C1	C1	C1	C2
D3	C1	C1	C2	C1
D4	C1	C1	C2	C2
D5	C1	C2	C1	C1
D6	C1	C2	C1	C2
D7	C1	C2	C2	C1
D8	C1	C2	C2	C2
D9	C2	C1	C1	C1
D10	C2	C1	C1	C2
D11	C2	C1	C2	C1
D12	C2	C1	C2	C2
D13	C2	C2	C1	C1
D14	C2	C2	C1	C2
D15	C2	C2	C2	C1
D16	C2	C2	C2	C2

Conclusion

The main conclusions are as follow: (1) In the whole process of HTID, the R&D fund should be increased step by step. Based on technology trajectory of HTID and market competition, the proportion between internal R&D fee and technology import fee should be made reasonable changes. There are two strategies for cultivating and enhancing high technology firms' technological innovation capability. As is shown by Fig.7, one is technology import/improvement; the other is endogenetic innovation. (2) At the different stage, government should choose appropriate behavior pattern. At the start-up phase and the prophase of growth stage, it should give priority to centralized management. It can impel the industrialization process by increasing governmental organization and intervention. At the metaphase and anaphase of growth stage and at the mature stage, it should give priority to market adjustability and governmental behavior should give priority to harmonizing management. (3) During the transitional economy, the main work of government in China should create favorable entrepreneurial environment; offer policy and regulation to minimize institutional obstacles of firms' innovation. Currently, it is necessary for government in China to integrate innovation resource for the purpose of impelling the great industrialization project and the important construction of industrial base.

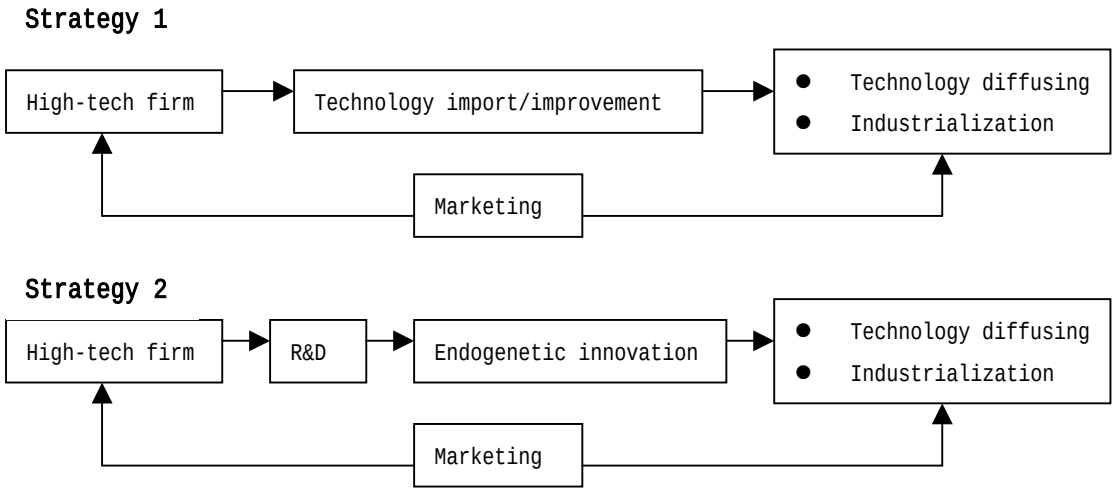

Fig.7 Two Strategies

References

Lihong Guo, et al., 1999, High Technology Industry: Development Laws and Venture Capital, Beijing.

Qifan Wang, 1990, System Dynamics, Higher Education Press, Beijing.

Qingrui Xu, 2000, Research, Development and Technological Innovation Management, Higher Education Press, Beijing.

Saeed. K. 1992, Slicing a Complex Problem for System Dynamics Modeling, System Dynamics Review 8(3): 251-261.

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