Application of System Dynamics on Policy Analysis of Resource Allocation of Scientific Research

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ABSTRACT

By the thought of coordinative development between Science & Technology, economy, education and finance, this paper first concerns the problems facing China on the resource allocation of Scientific Research. A comparative study on both developed and developing countries is made. In the meantime, the mechanism of the coordinative development between Science & Technology, economy, education and finance, the coordinative development between Scientific Research (Basic Research), Applied Research & Development as well as the priority of Scientific Research in different stages of social & economic development, a system dynamic model is constructed, focusing the analysis of scale & speed of resource allocation for Scientific Research in China.

INTRODUCTION

Over the past several decades many countries have come increasingly to the realization of Basic Research may hold the underpinning to their competitive advantages and sustainable development. Advanced countries spend 12 - 30% of their Research & Development (R&D) expenditure on Basic Research by different patterns. Though China has made marverous achievements in the field of Basic Research, China's spend only around 6.3 - 7.7% of R&D expenditure on Basic Research do affect the stamina of science & technology progress of China. Increasing the input on Basic Research is emphasized by Chinese Government and many scholars.

As China is still one of the less developed economics, large scale investment on Basic Research as developed countries is impossible, but the low increasing rate of Basic Research input also affects the catch up with the scientific & technological more advantaged. As the prospects for entering into modern industrialisation are not so obvious nor can be taken for granted that late-comers have the advantages, less development countries including China must pay attention to the coordinative development so that the development can take place through synchronization of buildup science & technology capacity and elimination of buildup science & technology capacity and elimination of obstacles to development. A distinguishing pattern on Basic Research input may be used for China.

In order to deal with above-mentioned problems, a more careful and systematical analysis aided by System Dynamics is needed. During the model-building & simulation, the thought of coordinative development is stressed with the following contents:

- Coordinative development between science & technology, economy, education and finance system;
- Coordinative development between Basic Research, Applied Research and Experimental Development;
- Coordinative with the Development Stage of one country.

Previously, the system analysis as well as the experience diagnosis were taken as the main means to deal with the resource allocation on Basic Research, in this paper the policy analysis (including policy design and policy test) will be based on the comparative study and the mechanism analysis (See Figure 1).

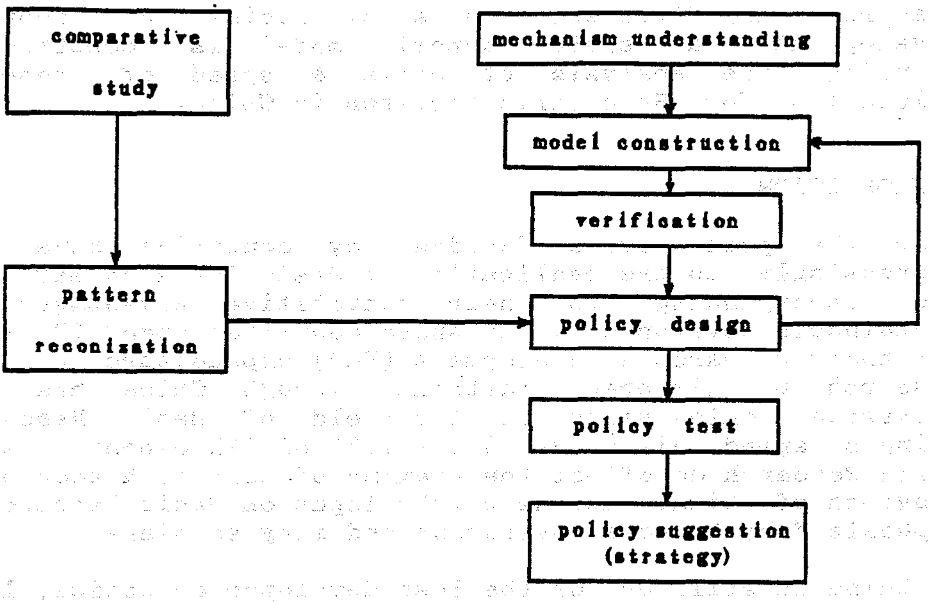

Figure 1. Research Guideline & Methodology

SEEKING PATTERNS ON RESOURCE ALLOCATION ON SCIENTIFIC RESEARCH BY COMPARATIVE STUDY

The objectives of the comparative study are following issues:

- Finding out the patterns of Basic Research input;
- Analysing the relationship between resource allocation

patterns and performance of a country;
Selecting the resource allocation strategies for Basic Research input, which is necessary by policy analysis.

Seven countries were chosen including (1) U.S.A.; (2) Japan; (3) West Germany; (4) France; (5) U.K.; (6) Brazil; (7) India. And four index are used to evaluate the performance in these countries, these index are GNP (or GDP), balance of high-technology trade, patents and R&D personnel. The social & economic development stage is classified mainly according to the GNP (or GDP) per capita, here stage I is featured as 300-2000 US$ while Stage II and III are 2000-4750 US$ and more than 4750 US$ respectively.

Figure 2 illustrated the ratio of Basic Research input over total R&D expenditure. The characteristics between Basic Research over R&D in different development stages in these seven countries is summarized as Table 1, which tells that the proportion of Basic Research over R&D is increased steadily in stage I and stage II, and declined a little bit in stage III.

Country	Basic Research Input / Total Research & Development Input (%)		
	Stage I	Stage II	Stage III
U.S.A.	8.5	8.6 - 12.9	12.2 - 13.6
U.K.	10.9	11.9 - 16.0	6.3
France	12 ~ 18.5	18.5 ~ 21	21.0
Japan	24.3 ~ 30	14.5 ~ 18.8	12.9~14.5
West Germany	19.5	21 ~ 27	20.5~21.5
Brazil	10.5	-----	-----
India	10.2 ~ 19.5	-----	-----
In Average	10 ~ 20	15 ~ 20	13 ~ 15

Table 1. Characteristics of Basic Research over R&D in 7 countries

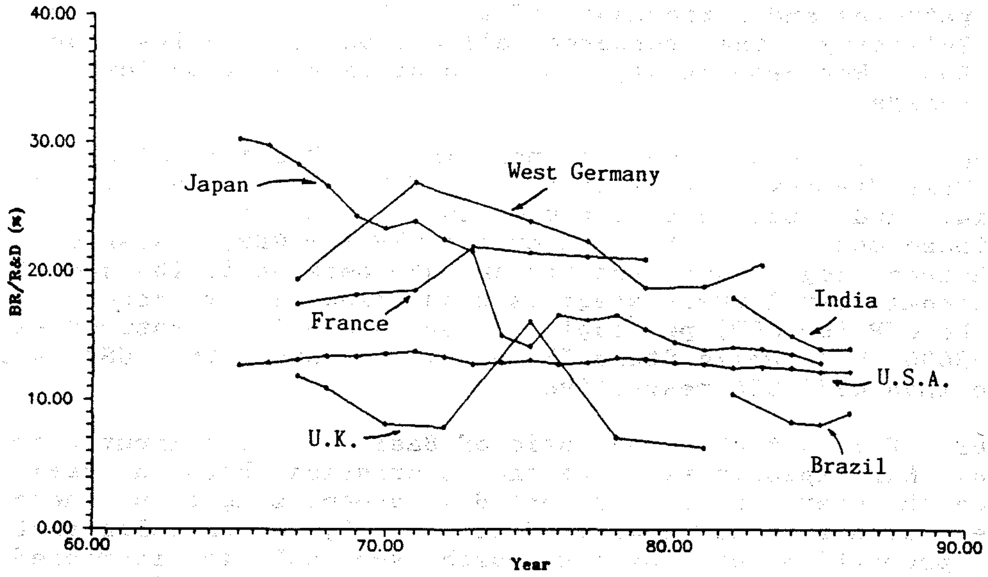

Figure 2 Input Behavior of Basic Research in 7 Countries

According to Figure 2, there exist four patterns of Basic Research over R&D (S-Curve Pattern, S'-Curve Pattern (S-Curve with saddle-form), Constant Growth Pattern and Low Growth Pattern). The relationship between investment patterns on Basic Research and the perfromances expressed by above-mentioned index is summarized as Table 2.

	S-Curve Pattern	S'-Curve Pattern	Constant Growth Pattern	Low Growth Pattern
R&D personnel	+	++	++	-
gnp	+	+	++	-
high-tech.	-	++	+	-
patents	++	+	+	+

Table 2 The Relationship Between Basic Research Input and Performance
(Notes: ++:excellence; +:good; -:ordanary)

Table 2 shows that S'-Curve Pattern (which is mainly adopted by Japan) and the Constant Growth Pattern (which is mainly adopted by France and U.S.A.) have made better performance.

In order to make further analysis, correlation analysis based on the Gray System Theory(GTS) is made, Table 3 shows the caculated results. And Table 3 also tells that there exists higher correlation between Basic Research and the economic & social performance in France, U.S.A. and Japan.

Correlation / Item / Input Pattern	GNP (GDP)	R&D Personnel	High-tech. Trade	Patent
Japan	0.383	0.509	0.572	0.826
U.S.A.	0.418	0.639	0.783	0.844
West Germany	0.429	0.562	0.641	0.728
France	0.717	0.717	0.909	0.941
U.K.	0.397	0.453	0.555	0.746
India	0.555	0.547	0.545	0.654
Brazil	0.538	0.561	0.610	0.574

Table 3 Correlation Analysis Results

MECHANISM ANALYSIS WITH SYSTEMS THINKING

In our systems thinking, the input of Basic Research must be coordinated with the development of economy, education, finance as well as modification the internal structure of science & technology per se. So there exists a large-scale system with hirarchy structure (See Figure 3). According to Figure 3, there are 5 subsystems: economy subsystem, population subsystem, education subsystem, finance subsystem as well as science--technology subsystem. A detailed causal-effect loops about science & technology with simplified loops about the other 4 subsystems is shown as Figure 4. The coming model simulation will seek the resource allocation policy on Basic Research subjected to the requirement of these two coordination.

The Basic Run of this modle is shown as Figure 5. According the Basic Run, the input on Basic Research increases to around 18% (over total R&D) at 2016 in the form of exponential form and decreases to 13% (over total R&D) in the form of inverted s-curve), as a result, GNP and total science & technology out increase with steady and sustainable pace. Though the ratio between technology

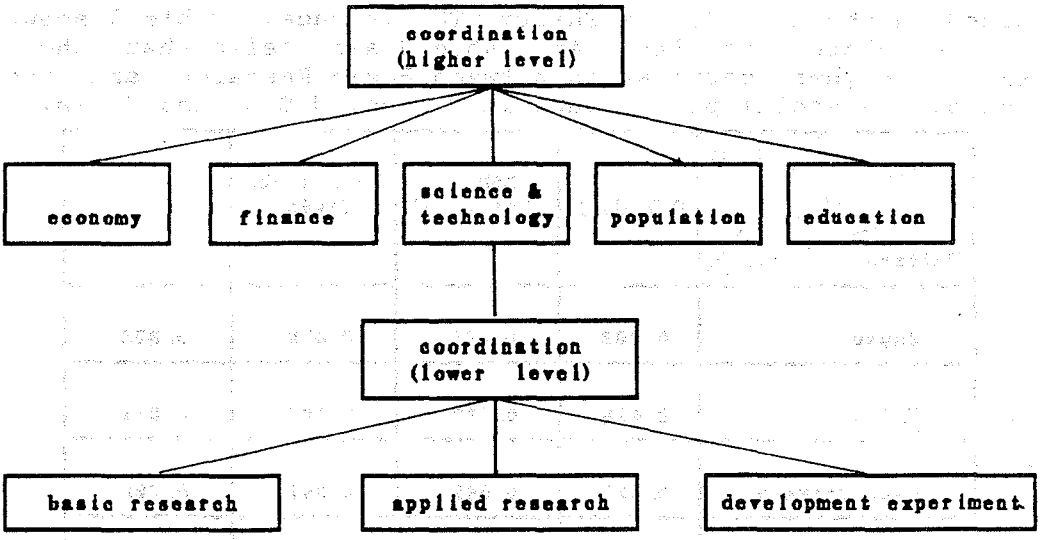

Figure 3. Model Structure

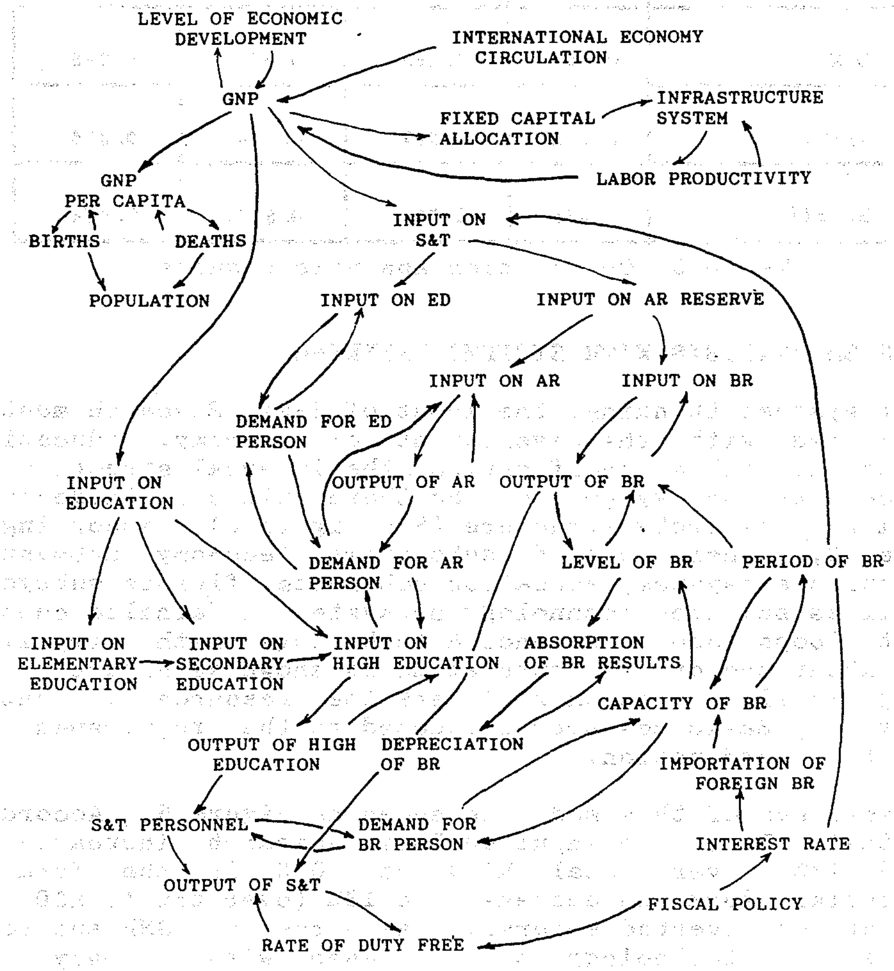

Figure 4. Causal Relationship of The Total System

acquisition expenditure over in-house R&D expenditure is high in recent 10-15 years, the rely on the foreign technology will decrease in long range operation. More and more talent personnel (above master degree) could be trained during the process of Basic Research.

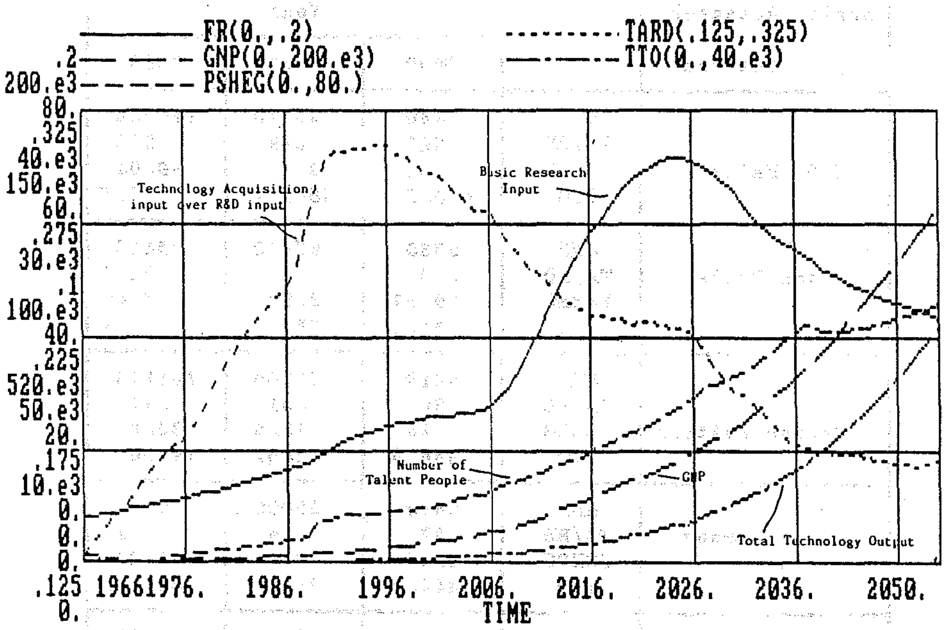

Figure 5. Basic Run of Resource Allocation Model

POLICY TEST & ANALYSIS

Started at the time of 1992 when the ratio between Basic Research over R&D was 7.2%, resource allocation patterns of 7 countries are simulated as Table 4 showed. Here four index are used to evaluate the performance of development of China which affected by the effort of Basic Research directly or indirectly. These index are GNP (Unit: million US$), ratio of technology acquisition expenditure over in-house R&D expenditure (abbreviated as TA/RD), number of talent persons (above master degree, unit: 10 thousand, abbreviated as PSHEG), and the number of total science & technology output (Unit: 10 thousand item, abbreviated as TTO). TTO is also the index of the coordination among internal science & technology system.

By the comprehensive analysis we could see that no country's pattern is so good to follow about the Basic Research input. But the synergic pattern (synergy of France & Japan Pattern, same as Basic Run) is the best pattern for its better performance (the simulated results shows that the annual growth rate of GNP could be 5.3% from 2000 to 2050, and the corresponding growth rate for talent people and total technology output are 3.7% and 7.7%, and the ratio between technology acquisition expenditure and total R&D expenditure decreased from 0.28 to 0.15).

Basic Research Input Pattern	Index	Year		
		2000	2030	2050
U.S. Pattern	GNP	9430	32570	140800*
	TA/RD	.281	.219	.200
	PSHEG	9.28	3.24	-9.04
	TTO	536.3	5581.7	18270*
Japan Pattern	GNP	9336	57440	65510
	TA/RD	.23	.19	.20
	PSHEG	9.37	9.26	6.40
	TTO	366.1	1654.1	6887.1
France Pattern	GNP	9310	51600	144170
	TA/RD	.29	.21	.13
	PSHEG	9.26	12.0	39.8
	TTO	336.0	5581	16200
West germany Pattern	GNP	9316	59000	60670
	TA/RD	.37	.14	.31
	PSHEG	9.29	36.1	7.84
	TTO	344.2	2336.5	8445.2
U.K.Pattern	GNP	9278	40520	54480
	TA/RD	.28	.43	.38
	PSHEG	9.13	19.1	2.05
	TTO	303.5	1196	3760
Indian pattern	GNP	9310	46770	65760
	TA/RD	.26	.21	.17
	PSHEG	9.26	62.12	-3.44
	TTO	334	1328	5113
Brazil Pattern	GNP	9277	34700	38240
	TA/RD	.28	.36	.36
	PSHEG	9.13	37.66	4.58
	TTO	304	633	1805
Synergy Pattern	GNP	9823	56330	128870*
	TA/RD	.28	.17	.15 *
	PSHEG	9.35	38.79	57.44*
	TTO	362	5324	14500*

Table 4. The Results of Policy Tests on The Basic Research Input

CONCLUSION & DISCUSSION

The conclusions by our research are:

1. The very first issue which arises in the course of development of China is the dynamic choice of the resource allocation pattern for Basic Research by the economy or industrialization stage. Our comparative study and model simulation shows during China's development Stage II as we defined previoursly, Resource allocation on Basic Research might as well increse with expenontial growth form and during Stage III, the iuput on Basic Research remains steadily (a little bit decreasement).

2. An essential procondition for sustainable development of China demands a coordination between science & technology, education, economy, population and finance as well as the coordination between science & technology. Priority must be given to the first coordination. Though the simulation the U.S.A. Pattern for the Basic Research input proved the best choice of China's coordination among internal science & technology system (total technology output is around 162.7 million items), the France-Japan Synergy Pattern is advised as the pattern for Basic Research input for its better comprehensive performance.

3. Basic Research, the main source of productive activity, by the very nature require a long period of time over which benefit can be gained. According to the results of our simulation, the performances resulted in different resource allocation policy on Basic Research remain the same level in recent 7-10 years (refer to Table 4). So the input on Basic Research must be taken in a strategic view.

4. Concerning the problems of social, science & technology system, system modeling and simulation must be based on clear understanding of the potentials a country processes and the contrains to which it is subjected. Some method, such as comparative study is advised to be used to draw some qualitative conclusion. The using of comparative study is proved to enhance the effectiveness of policy test and simulation.

5. During the process of system modeling on a large-scale social & economic system, each subsystem should not be taken as equal one, a hirarchy structure is advised to set up to catch up the main subsystem, and coordinations at different level required by the users. More mathemtical anslysis is needed, and this is the very work of System Dynamics in 21th century.

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