A System Thinking Approach to Select Avenue of Science & Technology Development

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ABSTRACT

It is a very important issue for China's sustainable development of economy and society aided by Science & Technology (S&T) Development. The Avenue of Science & Technology Development(ASTD) occupies a special place in the development process of Science & Technology. In Western views, innovation goes through from basic research, technological development to the commercialization. But for most developing countries, as we understood, innovation often started from the process of technology acquisition, and innovation occurs when the indigenous technological innovation capability is good. So the S&T development of China may take avenue as NICs did, and improving indigenous technological innovation capabilities is extremely important, but China's strong S&T potentiality should not be ignored, there do exists a special strategy of S&T development for China. Concerning the vague understand on the choice of avenue of science and technology development in China as well as the avenue of science and technology development did not match with national situation of China, this paper provides a system thinking tool, a system dynamics model, to analyze the choice of avenue of science and technology development in coming 50 years in China.

FOUR AVENUES OF SCIENCE & TECHNOLOGY DEVELOPMENT

The avenue science and technology, is the strategic issue for one country. The research of Hyung Sup Choi (1984), UNIDO(1980) and others show there exist four avenues of science & technology development (See Table 1)

Table 1 The Avenue of Science & Technology: A Review

Author	Avenue of Science & Technology Development
UNIDO	Selection, Acquisition--Assimilation--Development
IDRC	Acquisition--Assimilation--Development
H.S. Choi	Tech. Acquisition--Assimilation--Basic Research
Tetel	Assimilation--Incremental Improvement--Research
Freeman	Incremental Innovation--Radical Innovation

From above viewpoints, four avenue for science & technology development exists:

1. Technology Acquisition (TA): it contains turn-key project, licence production, equipment importation. This avenue was often adopted by countries with technology backward. Japan emphasized this avenue during Meiji time, and then was very successful in raising production level.

2. Assimilation Upon Imported Technology (AUIT): it means technology acquisition accompanied by self-reliant innovation. Japan was a model to use this avenue after World War II. During year 1954 to 1964, 42 million yen was spent on one imported technology, while the assimilation expenditure was 58 million yen correspondingly. By using AUIT, Japan was transferred from technology follower to technology leader in the world.

3. Incremental Self-Reliant Innovation (ISRI): here, innovation was made by self effort but still technology paradigm was still from abroad.

4. Radical Self-Reliant Innovation (RSRI): here, innovation was generated by fundamental research, and from fundamental research to applied research and experimental development. The US is the typical country to use the avenue of RSRI, and US is still the leader in world science and technology. This avenue is also called linear avenue (Pavitt, 1993).

For one country, it is hard to separate this four avenues all the avenues are interrelated. So the selection of avenue of science and technology development focuses on the dominant avenue.

CHINA'S EXPERIENCES OF SELECTING AVENUE OF S&T

China has made great achievement in science and technology since 1949. The key research & development (R&D) results increased dramatically (See Fig.1)

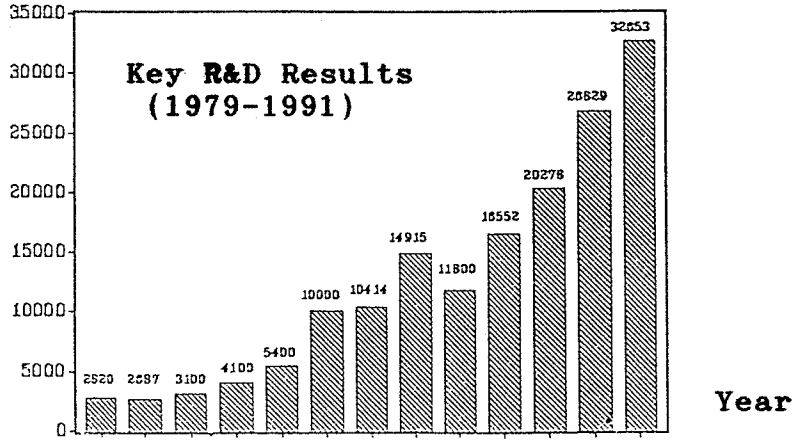

Fig. 1 Key R&D Results in China From 1979-1991

But China has great difficulty in catching up the country with scientific and technological more advanced. One of the reasons is the poor selection of avenue of science and technology development.

- In 1950s, China learned from Former Soviet Union, and China emphasized the imitation to self-design, but basic research was also stressed. Thus, attentions had paid to TA, AUIT, and innovation;

- From 1960s to 1970s, China made great efforts to "Catch up UK and US" and self-reliant innovation was the dominant avenue for science and technology. Due the great lag between R&D to manufacturing and marketing, many R&D results failed to be used for economic development;

- 1980s is the time for economic reform in China, the avenue of science and technology development included three levels: a. key R&D program or Spark Program (in fact the program is applied research); high-technology program (863 Program); and, c. basic research program.

The above introduction showed China has vague selection of avenue of science and technology development, and tried to do anything in R&D and attention was paid to all the four avenues. As a result, the R&D investment is in a random state. (See Fig. 2). We think the situation will affect modernization course in China, especially science and technology is isolated from economic development.

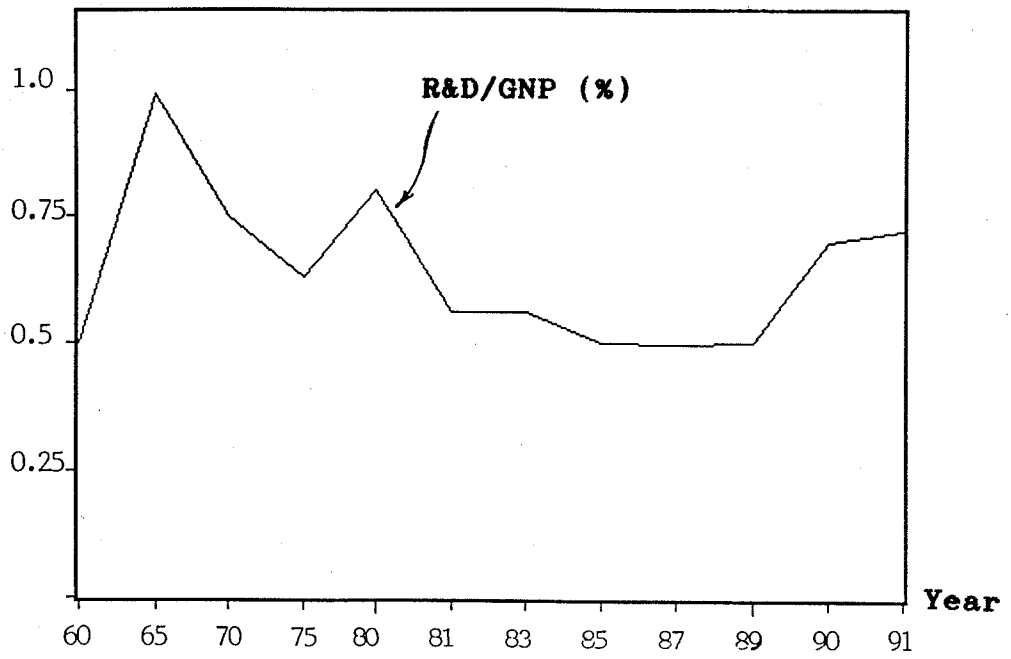

Fig. 2 R&D Expenditure in China (1965-1991)

SYSTEM THINKING OF AVENUE OF SCIENCE & TECHNOLOGY IN CHINA

To select the avenue of science and technology development for one country, a comparative study was made (Chen Jin, 1994). And it is found that the avenue of science and technology development must coordinated with science and technology environment, science and technology condition and national innovation systems. It formulates the "Diamond Model" of science and technology development for one country (See Fig. 3).

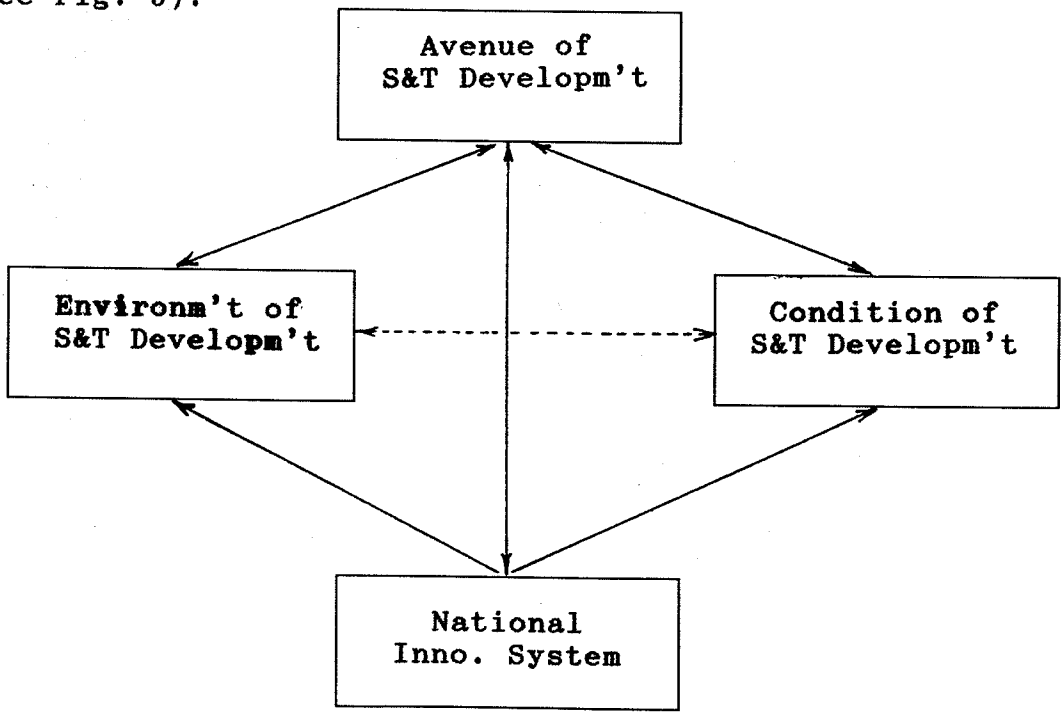

Fig. 3 Diamond Model of Science and Technology Development

Thus a system dynamics model was constructed to analysis the selection of science and technology development avenue.

In science and technology environment system, we consider three main subsystem:

1. economic system: mainly the variables of fixed assets investment, labor productivity;
2. population system: in China, the pressure of population is a very heavy, mach fiscal input paid the new population;
3. ecology environment system: the high economic growth in China induced much environmental loss, great money needed to protect environment in the future.

2. In science and technology condition system, we consider the existing interactions between basic research, applied research and experimental development in China, the interactions is both R&D personnel and R&D capital expenditure.

3. In national innovation system sector, we consider the role of education, including interaction among education input, education structure and R&D.

Three index were used judge the suitness of avenue. There are Gross National Products (GNP), ANP (Adjusted GNP, equals GNP minus environmental loss), RDS(Research & Development Results). And policy tests focus the ratio of assimilation expenditure over total R&D input.

If the the ratio of assimilation expenditure over total R&D input is around 20% (that means China still adopt radical self-reliant innovation avenue), the GNP, ANP and RDS are poor in long-run (See Fig. 4). And If the the ratio of assimilation expenditure over total R&D input increases more (from update 10% to 40-42% in year 2006, and then decreases the ratio in year 2020), the GNP, ANP and RDS are very good in long-run (See Fig. 5). So year 2020 is the turning point of avenue selection for science and technology development in China. From now to year 2020, assimilation upon imported technology is advised as the dominant avenue of S&T, and then China could adopt radical self-reliant innovation avenue.

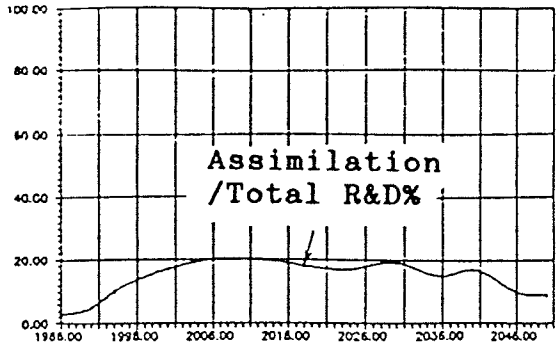

Fig.4 Policy Test Result (I)

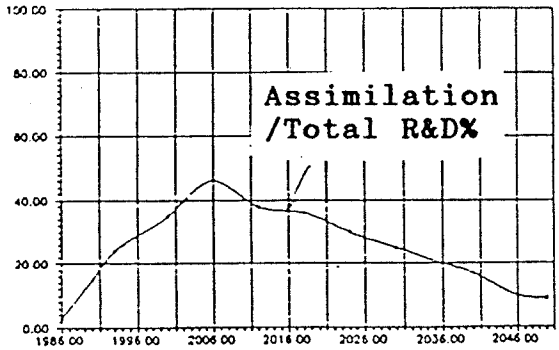

Fig.5 Policy Test Result (II)

CONCLUNG REMARKS

Policy tests shows that the choice of avenue of science and technology development must match with one nation's Science & Technology environment and condition. Under such a conclusion, the "assimilation based on imported technology" is advised the dominant mode of avenue of science and technology development in current stage in China, and "self radical technological innovation" is the target dominant mode of avenue of science and technology development for future China.

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