A System Dynamics Modeling for Sustainable Growth in China

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Abstract: Most of the developing countries including China are faced with the problem that how to allocate its limited resource properly to make its economy grows continuously. In this paper, the system dynamics methodology is induced to solve the problem facing China. Based on the deep discussion of the interactive mechanism and interrelations among S&T, education and economy systems, and by SD modeling and simulation, this study gave out the policy advice. For example, It would be a more harmonious strategy in which both input of S&T and education increase at logarithm and education input ahead about 10 years of S&T input.

Keyword: System Dynamics; Sustainable Growth; Coordinate development of S&T-Education-Economy systems

I. Introduction

For developing countries such as China, one of the most difficult problems in the development of economy is how to allocate its limited resource properly to make its economy grows continuously. From our study, there are two key factors that are critical to the sustainable growth: the development of education and S&T systems. Practices of developed countries in the past several decades have proved that education and S&T made great contribution to the growth of economy. What's more, their experiences have also shown that the contributions to the growth of economy in the different development levels of education and S&T are different. Therefore, it's necessary to explore the interrelation and mechanism among education, S&T and economy, and the proper scale and structure of education and S&T based on the demand of economy.

As we all know, great changes have taken place in China in the past 2 decades, with a high rate of economic growth. But, how to keep a sustainable growth in 21 century is still a critical problem in China. Under the background of knowledge-based economy era and globalization, it's a great challenge for China to grasp promptly the opportunities, shorten the gap with developed countries, and increase international competitiveness of firms, industries and nation.

II. Theory of Harmonious Growth among S&T - Education-Economy Systems

According to our study, the general education level of a country always has a positive relationship with its S&T and economy power. The development of almost all the developed countries was contributed by the well education system. Accordingly, the economic growth offered more investment to education and S&T. Under the context of knowledge-based economy and globalization, the principal resource for the sustainable growth of economy will be knowledge, especially advanced S&T knowledge, and the most important mechanism is the production, distribution and application of knowledge. Obviously, knowledge is produced by a

lot of qualified human resource, and all these are derived from education in the final analysis. So, how to keep a harmonious interaction will be the key problem in the new era for China.

Harmonious development among S&T-Education-Economy systems (STEE) is the key internal factor for China to keep the sustainable growth of economy, and is also fundamental to shorten the gap with developed countries. Not only the traditional agriculture and industry, but also the rising knowledge industry has to be driven and enhanced by education and S&T systems. What's more, it is also the basis to optimize national resource allocation. In fact, in most time of the past 50 years in China, the interactions among STEE systems didn't run so well, and the economy growth wasn't mainly depending on advanced S&T level and well-educated workforce, but on excessively consuming of natural resource. Due to the large population and the relatively limited resource, as well as the increasing environmental pollution, it is especially important for China to survey the interactive status among STEE, and probe into the solution to reform.

The past practices both home and abroad had proved that, the power or potential of S&T and education is the necessary condition for no matter nations or enterprises to win competition advantages. But, in the other hand, it's not the sufficient condition. For example, though owning the strong advanced S&T and good education system, the economic and political system of former-U.S.S.R. didn't run so well, which lead to its breakdown in 1991. What's more, Ethiopia who had believed in that 'investment on human capital is the source of economic growth' had really invest much on HC, but it now facing with a lot of heavy challenges such as laggard pace of social-economy development with sharpened conflicts, poor international competence, etc. In our opinion, in spite of influences of other situations, one of the radical causes of these problems is the disharmony in the development among education, S&T and economy.

In fact, China also has often had the trouble of disharmony among education-S&T-economy since 1949. The rate of S&T and education input growth extremely lagged behind the rate of economy growth during a long period in China before middle of 1990s. From table 1 we can see that both the R&D (the core of S&T) and education input in China are much lower than those developed countries, even lower than many developing countries such as India. Only in recent years, with the strategy of 'flourish nation by developing S&T and education' been put in practice, the input of S&T has begun to have a rapid growth.

Table 1 Percentage of R&D and education expenditure in GDP

Content / Country	R&D expenditure/GDP(%) (96)	Education expenditure/GDP(%) (95)
China	0.60	2.5
USA	2.64	5.4
Japan	2.80	3.6
Britain	1.95	5.3
India	0.73	3.3

Source: Chinese statistic yearbook 2000.

In terms of the structure and interaction, in our opinion, the harmonious development among S&T-Education-Economy systems has three implications:

1) To realize the holistic harmony among S&T-Education-Economy systems, it must get the internal harmony within all the three systems——that means a well internal structure.
2) Based on well internal structure of all the subsystems, the mutual interactions among subsystems are beneficial to the realization of their goals.
3) The ideal condition of harmonious development among S&T-Education-Economy systems is the general harmony among the three systems, which concretely means the

optimized holistic effect and well structure.

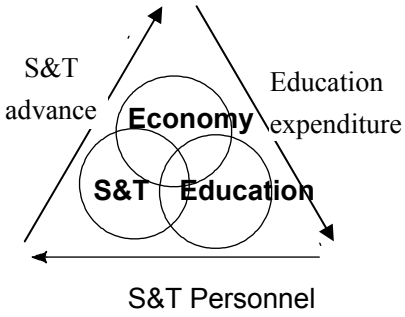


Figure 1 Interaction among STEE systems

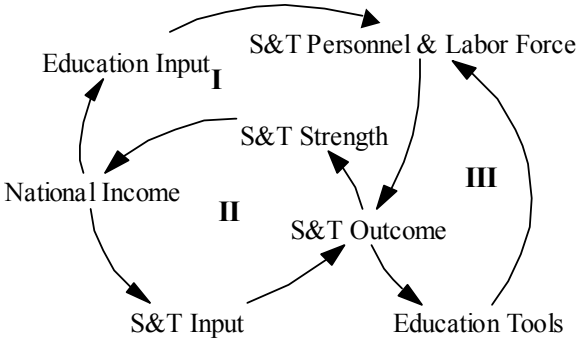


Figure 2 A brief Interactive pattern among STEE systems

III. Modeling the Major Relationships Among the 3 Main Systems

3.1 The mechanism of interaction among STEE systems

It's necessary to understand the mechanism before modeling, by means of system thinking and analysis, qualitative analysis is the basis for quantitative analysis. Combined analysis and simulation on investment patterns of R&D expenditure and education expenditure. Two level considerations for harmonious development were shown in fig 3.

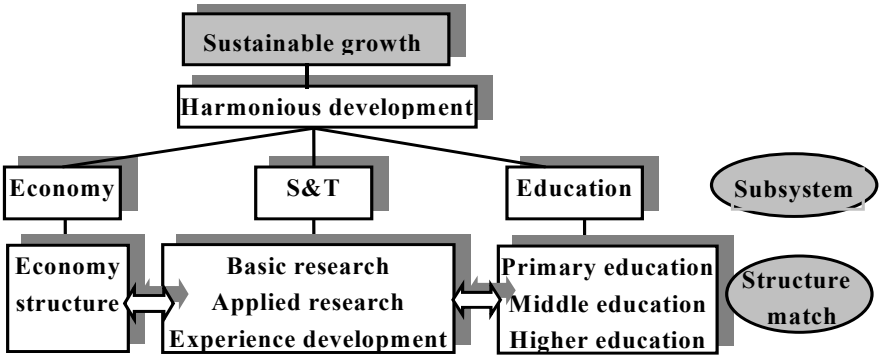


Fig.3 Two level considerations for harmonious development

3.2 Modeling by system dynamics approach

As we discussed above, S&T and education systems are crucial to the sustainable growth of economy. So, it's necessary for the government to make corresponding policies and strategies about investment in S&T and education. But, due to the limited social-economy resource and financial budget in China, it's unpractical to allocate resource evenly in S&T and education systems. So we face the choice of education system leading or S&T system leading.

We analyzed the choice of Chinese S&T and educational investment strategy by inducing the system dynamics methodology. Because that R&D is the core of S&T activities, and the data is easier to access, we use R&D expenditure instead of S&T expenditure. The model focused on several problems as follow:

1) the dynamic change of R&D expenditure and its proportion in GDP;

2) the dynamic change of education expenditure and its proportion in GDP;

Then, by SD simulating and policy analyzing, and based on the research on the interaction among S&T-Education-Economy systems, we gave the policy advice on the choice of investment strategy for education and S&T.

IV. System Dynamics Simulation and Optimization of Resource Allocation

The goal of our modeling and policy analysis is to find out a policy by which to realize optimized allocation and maximized effect of limited resource.

According to the experiments abroad in the past century, there are two basic patterns on R&D funding: (A) High starting point with constant low increasing rate; (B) Low starting point with high increasing rate at certain stage (E.g. 1940's in Us, 1960's in Japan).

There are several patterns on education funding:

(A) Constant increasing rate; (B) S-shape curve, Equipment-investment-first then education-investment (e.g. Mexico, Spanish); (C) Exponential increasing rate; (D) Logarithmic increasing rate, Education-investment-first in developed country (as the U.S., Japan, FRG).

In view of actual situation of China, four basic growth pattern for R&D and education input are considered:

Pattern 1: the proportion of input to GDP or NI is fixed and the total input increases with economic development;

Pattern 2: the proportion increases at a fixed speed;

Pattern 3: increases at a lower speed first, then higher speed, finally keeps steady (exponential);

Pattern 4: the proportion increases at a higher speed first, then keeps steady for some time, then slow down until get to a steady value (logarithmic).

We analyze and evaluate the results of SD simulation mainly by criterions as follows:

1) GDP (unit: 100 billion yuan); 2) Total Factor Productivity (TFP, unit: %); 3) R&D personnel.

Accordingly, there are 16 kinds of possible patterns combined by Education and S&T input. According to the criteria mentioned above and the result of simulation, and in view of the actual situation of China, pattern 14, 24, 22, 32, 34 and 44 are more appropriate than other ones.

Based on above six better performance patterns, further analysis is shown in fig.5.

Based upon the actual situation in China and evaluation criterions, P44, that is to say, input of both S&T and education increase at logarithm (policy 4), is the most befitting strategy for China. Further, from policy 4 of fig.4 we can find out the bigger slope of education than that of R&D before the end of 1st decade in 21 century, which indicates that ratio of education growth is higher than that of R&D before that period. It proved that, in order to keep a sustainable development, China should carry on the educational-priority strategy first before about 2010, and then followed by S&T-priority strategy.

In fact, a study by Xu Qingrui et al.(1989) had pointed out that, in order to keep a harmonious economic growth, China should implement the education development-first strategy before the end of 1st decade in 21 century, and then the growth rate of R&D(S&T) should exceed that of education gradually. They put the simulation results of national income, education budget and R&D budget into one axis system to find out interrelations among them. From fig.6 we can see that education and R&D systems have a faster growth rate than that of national income. What's more, education budget has a faster growth rate than that of R&D (S&T) before about 2010, and then R&D begins to grow faster than education system. Their study proved that in view of the actual situation of China, where growth rate of education and S&T systems lagged behind that of economy, education should have a faster growth first in a period. Only based on the developed education system can we get enough S&T and other qualified human resource to keep a sustainable economy growth.

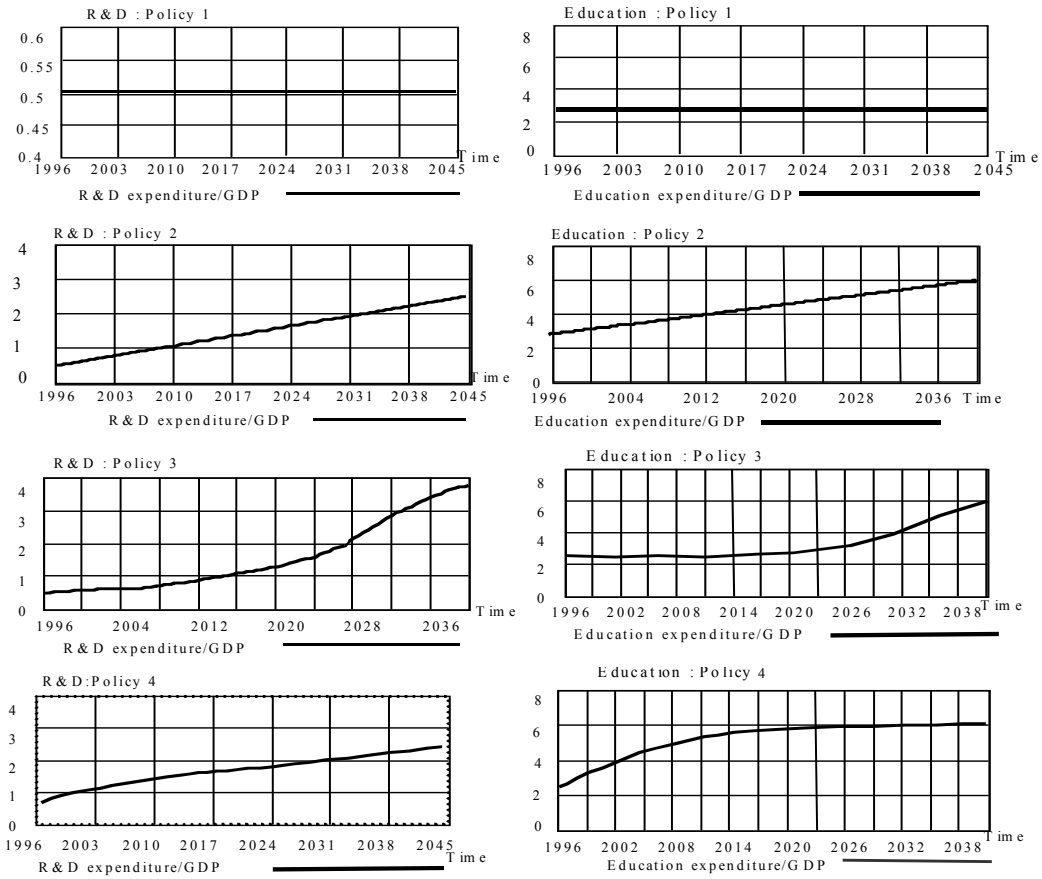


Fig.4. Simulation of different patterns

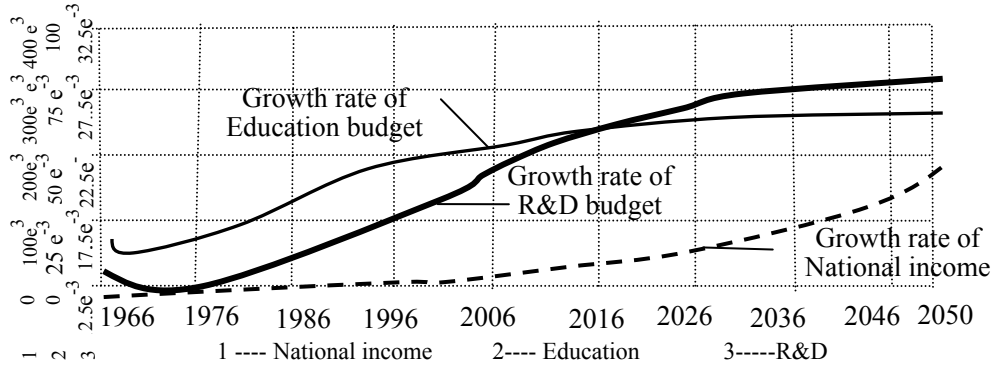


Fig.6 A draft graph of education-leading strategy for China

V. Conclusion

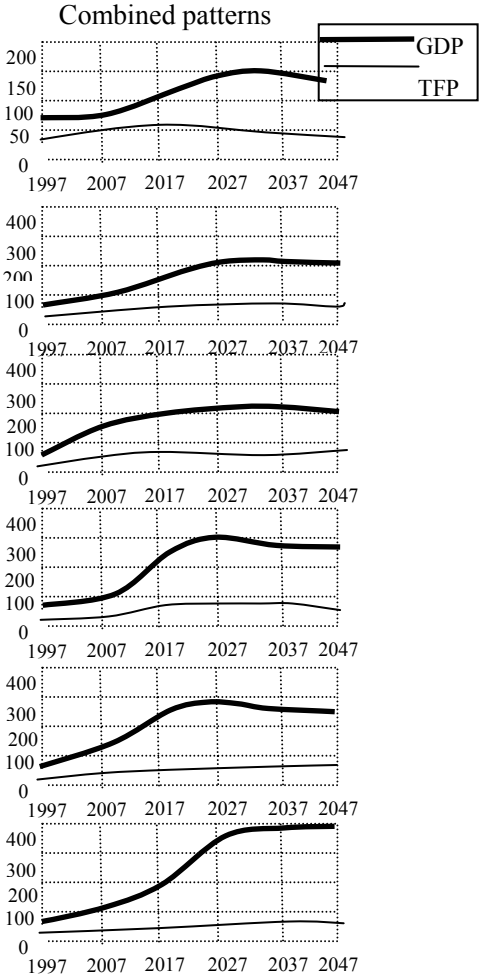
With the rapid economic and social development, China is now in great demand of qualified S&T talents. Accordingly, China should implement the education-priority strategy, by which to meet the increasing demand. In views of the relatively small proportion of financial investment to S&T and education in the past several decades, S&T and education systems should have a faster development than economy system. The growth rate of education expenditure should be greater than that of national income. Further, growth rate of education input is higher before the end of 2010 than that of S&T input (Fig.6).

From the discussion above, the problem about the resource allocation in education, S&T and economy is solved successfully with the SD methodology. Especially, the study about the problem

is based on the deep discussion of the interrelations among education, S&T and economy. So the obtained conclusions are believable, such as the proper ratio of education expenditure to GDP.

In fact, our policy advice has been accepted by some decision-makers, and education system has keeps a higher growth rate in recent years. The Prime Minister Zhu Rongji announced a few months ago that the investment in education should be higher than the other sectors in several years in China. As a sequence, in several years there is 1% increase in education budget each year.

Combined patterns



Simulation results

P14	1997	2010	2025	2050
GDP	75.3	90	150	150
TFP	29.6	52	53	48

P22	1997	2010	2025	2050
GDP	75.3	123	200	204
TFP	29.6	51	70	70

P24	1997	2010	2025	2050
GDP	75.3	146	206	194
TFP	29.6	44	80	80

P32	1997	2010	2025	2050
GDP	75.3	102	295	260
TFP	29.6	35	88	70

P34	1997	2010	2025	2050
GDP	75.3	133	273	240
TFP	29.6	40	63	80

P14	1997	2010	2025	2050
GDP	75.3	127	360	392
TFP	29.6	33	63	80

Fig. 5 simulation results of different patterns

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