THE BEHAVIOR OF INDUSTRIAL AND INVESTMENT STRUCTURES IN THE CHANGE OF DEMAND AND SUPPLY

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ABSTRACT

This paper presents a system dynamics model of China's industrial and investment structures. The dynamic behavior of the two structures has been analyzed in the change of demand and supply structure. The model has given special concern to China's limited resources and their allocation to different industries. A resource allocation mechanism is developed and the external robustness of the model is examined to test the control of the resources allocation system.

INTRODUCTION

Because of the unrealistic economic development policies from late 50's to 70's, which led up to the inappropriate investment allocation(referred to as investment structure below) in that period, the industrial structure of China had become quite unfavorable to economic development. Light industry, which mainly produces consumer products, had been neglected for a long time. Investment in this industry had been quite small, and in fact, there was a downward trend in the percentage of light industry investment in the total investment of the economy by 1978. Therefore, the consumer goods were often in serious short supply. In contrast, heavy industry, which mainly produces capital goods, expanded so quickly that the material and financial resources could not satisfy its overinvestment. Some of its output was oversupplied. At the same time, agriculture, the energy industry, the transportation industry and the commerce sector were growing slowly. The investment in these industries was not enough. Their growth could not meet the needs of national economic development and since the production in these industries affects energy, materials and service supplies, inefficiency resulted in the related industries (Hong 1981). Such a distorted industrial structure is still influencing the economic efficiency of the economy.

As we know from the history of economic development, a coordinated and well organized industrial structure is very important to economic development. From such an industrial structure, we can achieve the efficiency in production, with supply meeting demand and no shortage in materials or goods supply. To get such a structure with limited resources, appropriate resources allocation is required to allocate capital investment and other resources according to the demands and the strength of these demands for the production capacity of each industry (Liben 1984 and Kornai 1979). In history, the Chinese economy failed to allocate its resources to match with the demand and supply. However, in recent years some effort has been made to adjust the structures. And as the demand and supply situations change, further efforts are expected to be made. This requires adaptive change of the investment and industrial structures. Therefore, to prevent us from recommitting the same mistake, and also according to the system dynamics point of view, the investment and industrial structures need to be adjusted to fit with the changes in demand and supply. Hence, it is necessary to analyze and understand the dynamics of different industries over time and the interactive dynamics among the demand, investment and industrial structures keeping in mind the concern of limited resources allocation, especially in capital investment. Such analysis is important for future policy making. This paper is our preliminary effort toward that purpose.

THE MODEL

To approach the problem, we build a system dynamics model of the economic sector. The model is characterized by limited resources allocation, in which we mainly consider capital investment and labor allocation among different industries. There are nine main sub-sectors in the model, which are agriculture, light industry, heavy industry, the building industry, the transportation industry, the energy industry, commerce, the demand sub-sector and the accumulation sub-sector. The classification of production sectors is consistent with that of the Chinese Economic Almanac for the data availability reason (National Statistical Bureau of China 1983). Figure 1 shows us the simplified system.

From the seven production industries, we get the total output and national income, which along with other factors generates the consumption demand and the investment demand for the final products of each industry. With these two demands, we get the desired production for each industry and then the investment demand in each industry and the total investment demand. The last two demands determine the percentage investment in each

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                          ________              ______________
 _____________           I        I            I              I
I             I          I Output I            I Accumulation I
I Industries  I-------->I   and   I---------->I      and      I
I_____________I          I Income I            I  Investment  I
     /|\                 I________I            I______________I
      |                      |                        |
      |                      |                        |
 _____|_______          _____V_______            _____V_______
I             I        I             I          I             I
I Investment  I        I Consumption I-------->I   Desired   I
I  Structure  I        I  Structure  I          I Production  I
I_____________I        I_____________I          I_____________I
     /|\                                               |
      |________________________________________________|
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Figure 1 Simplified System

industry. The allocation of capital investment and labor is the key decision making in the model. How much to invest in a certain industry is determined by

KOZ.KL=KO.K*DKOZ.K/TDKO.K (1)

where

KOZ -- Capital order in Z industry
DKOZ -- Desired capital order in Z industry
TDKO -- Total desired capital order
KO -- Total capital order available

Total desired capital order is equal to the sum of the desired capital investment in all industries. Desired capital order in a certain industry is a function of the desired correction of capital from production(DCKPZ) and desired correction of capital from capital backlog(DCKBZ). The allocation of the labor force is determined by

LAZ.KL=NLIKZ.K*KAZ.K*FLAAV.K (2)

where

LAZ -- Labor allocated to Z industry
NLIKZ -- Labor intensity of capital in Z industry
KAZ -- Capital arrived in Z industry
FLAAV -- Labor availability value

The allocation of resources is one dynamic interaction among industries; the availabilities of energy supply and transportation services is another one. They will affect the production utilization of other industries if the availabilities value are less than one.

A prominent mismatch in demand and supply in any industry will cause poor coordination among the production industries, and thus, a low production efficiency. Through allocation and interaction, we can see that more resources will be allocated where they are needed more. For a industry which has a larger difference between demand and supply and a stronger demand for investment, more resources and investment can be obtained and vice versa. Using this fact, the growth among industries can be coordinated and the growth of a certain industry can be kept at a rate that is required by its demand.

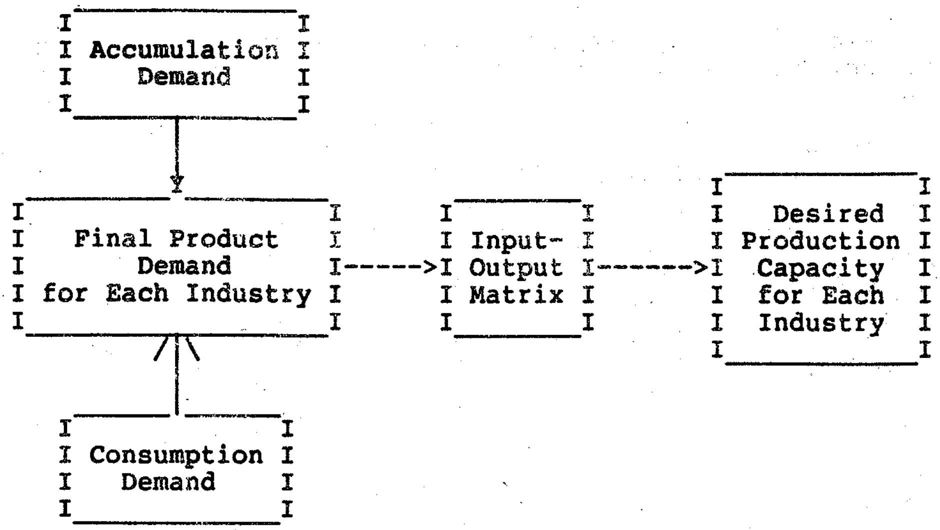

Figure 2 Derivation of Desired Production Capacity

The desired production capacity is the major factor in influencing the desired capital order of an industry. Figure 2 shows how the model derives the desired production capacity for each industry.

The consumption demand for each kind of product or service is a function of the average income per capita and the total population. The fraction of the average income spent on each kind of product or service per person constitutes the consumption structure at an average level. This structure changes over time as the average income per capita changes. We get these data from existing literature on consumption demand forecast (Shaolian 1985). From the consumption structure we derive the consumption demand for the product of each industry. The consumption demand and the accumulation demand for the products of each industry constitutes the total final product demand for each industry. Using this fact together with the input/output matrix, we get the desired production capacity for each industry.

In each production sector, there is a cobb-douglas production function with labor, capital and technology as the main inputs. We take technology here as an exogenous variable. Total population and labor available are also exogenous variables. These input data are based on the result of our previous work (The Technical and Economic Research Center of the State Council 1985).

MODEL BEHAVIOR

Figure 3 shows the capacity growth trend of each industry in the base run. Table 1 gives us the capacity growth rate of each industry.

Industries and National Income	1986-1990	1991-1995	1996-2000	2001-2005
		Average Growth Rates		
Agriculture	6.0%	6.0%	6.1%	7.0%
Light	8.0%	7.0%	8.4%	8.1%
Heavy	6.8%	7.7%	10.2%	7.0%
Building	5.0%	8.1%	10.4%	7.2%
Transportation	6.6%	7.2%	9.7%	7.2%
Commerce	7.7%	7.3%	8.9%	9.0%
Energy	8.0%	6.8%	8.6%	8.5%

Industries and National Income	2006-2015	2016-2025	1986-2000	1986-2025
		Average Growth Rates		
Agriculture	5.6%	5.1%	6.0%	5.8%
Light	6.6%	6.1%	7.8%	7.1%
Heavy	6.2%	6.3%	8.2%	7.1%
Building	6.2%	6.6%	7.8%	7.0%
Transportation	6.2%	6.2%	7.8%	6.9%
Commerce	7.8%	6.8%	7.9%	7.7%
Energy	6.7%	6.2%	7.8%	7.2%
National Income			7.0%	6.7%

Table 1 Average Growth Rates from Base Run

The capacity change pattern is determined by the investment pattern. Figure 4 shows the percentage of investment in each industry. Because the decisions of investment and development policies were not always based on the demand and supply in the history, therefore, the investment behavior of our model can not always fit the historical data very well. However, by

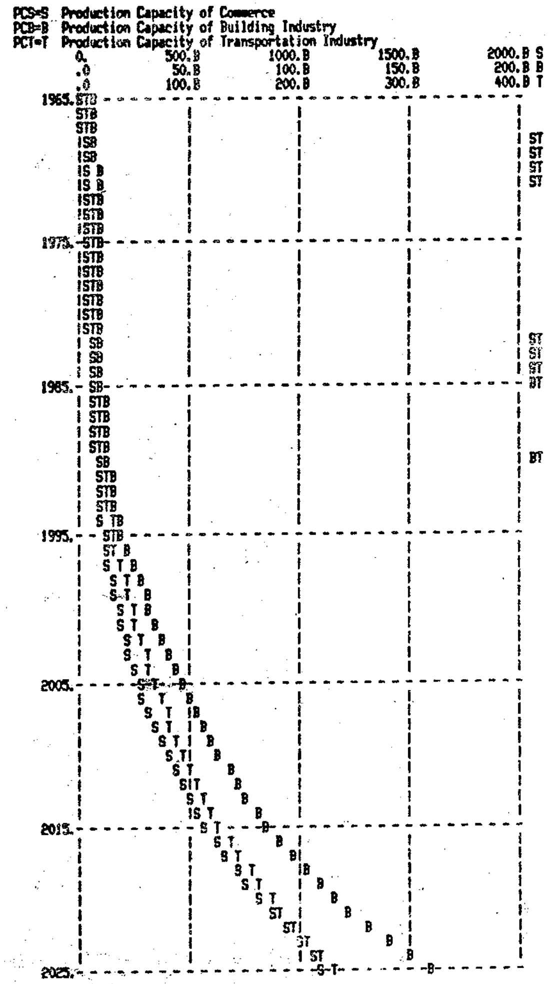

Figure 3 (cont.) Production Growth Trend

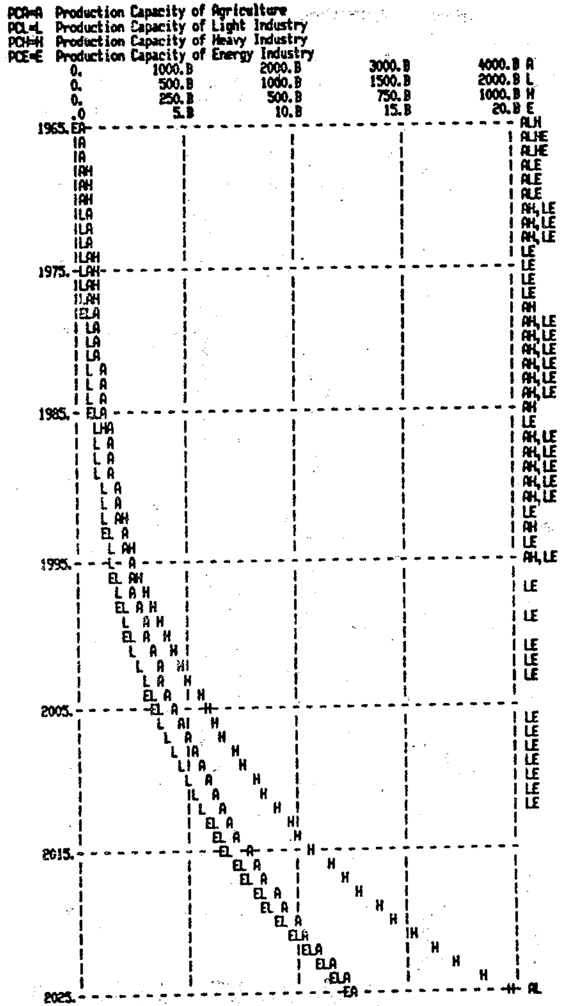

Figure 3 Production Growth Trend

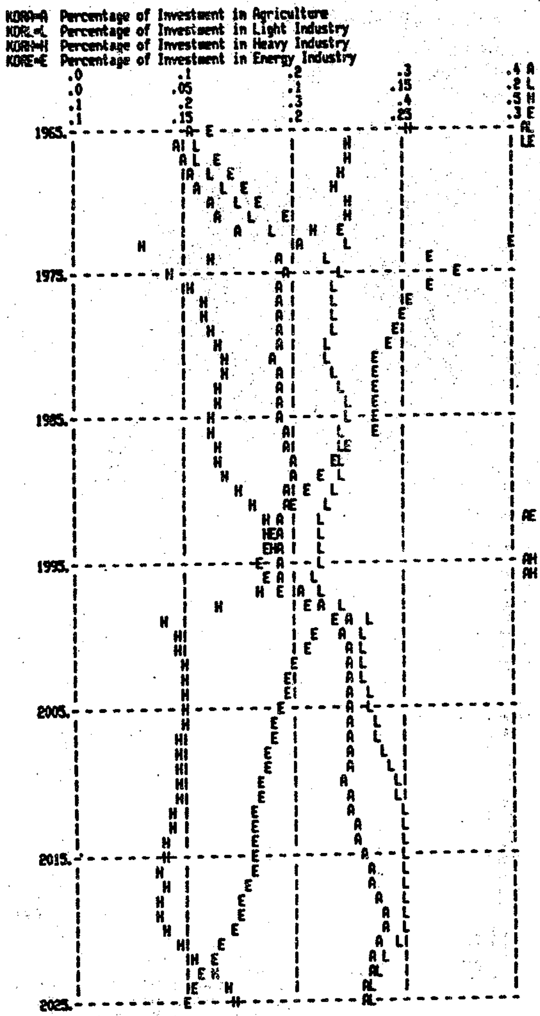

Figure 4 Percentage of Investment in Each Industry

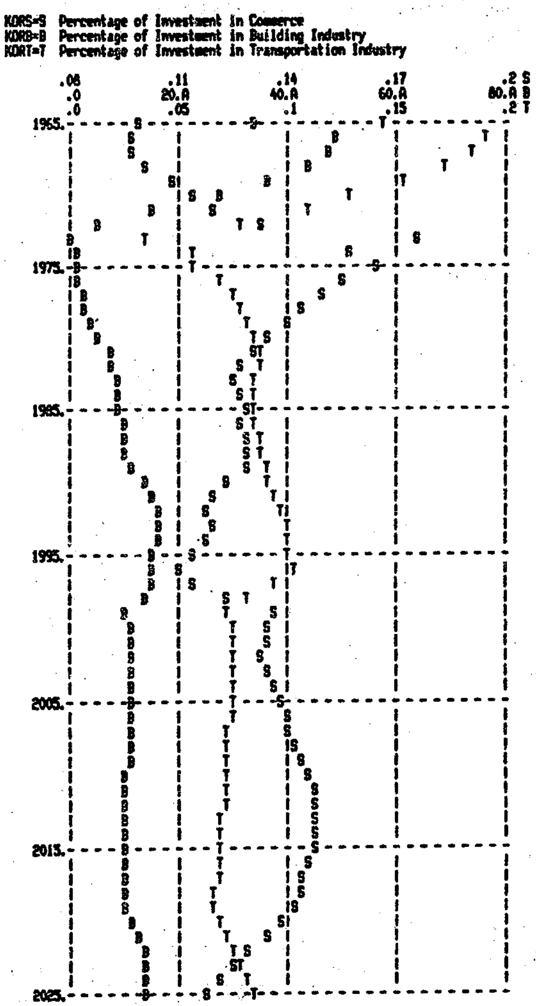

Figure 4 (cont.) Percentage of Investment in Each Industry adding the historical policy factor into the model, the model's historical behavior can fit the data quite well.

The investment pattern is dominated by the mechanism of demand and supply. On the demand side, the demand structure and its change pattern are important factors in influencing the investment structure. There are many factors which can have an effect on the demand structure. One is the fraction of average income spent on Z item(FRMSZ). Figure 5 shows the trend of FRMSZ. Another is the capital accumulation demand; and the population volume might be still another. On the supply side, labor, capital and technology are the three factors.

In the period 1985-1995, the accumulation rate(i.e. the percentage of national income to be used in investment and in the inventory) will increase(see Figure 6). There is a strong demand for capital goods; therefore, the percentage of capital investment in the heavy, building and transportation industries(KORH,KORB,KORT respectively), which are the main sectors producing capital goods, will show increasing trends.

With the interaction among industries and because of the limited capital investment, the percentage of capital investment in agriculture, light industry, the energy industry and commerce(KORA, KORL, KORE, KORS) in the same period will have decreasing trends. Over the next 15 years (1996-2010), the fractions of the average income spent on clothes, commodities and service(FRMSW, FRMSC, and FRMSS), which generate the demand for the products of agriculture, light industry and commerce, will increase more quickly, and the capital goods supply will satisfy the investment demand, the value of the delivery delay of capital order(KDDK) will become low; therefore, the demand for consumer products will grow more quickly, the KORA, KORL and KORS will increase; and at the same time the demand for capital goods will become comparatively less, the KORH, KORB and KORT will decrease. After the year 2010, FRMSW, FRMSC and FRMSS will be almost constant, and the fractions of the average income spent on housing and transportation(FRMSB and FRMST) will increase. The increases of KDDK and the accumulation rate reflect the increasing demand for capital goods, therefore, KORH, KORB and KORT will increase again, while KORL and KORS will be brought down after the year 2010.

The behaviors of the percentage of investment in agriculture and the energy industry(KORA and KORE) need careful consideration. People expect that KORA will experience a diminishing trend, whereas KORE will experience an increasing trend. However, our preliminary results indicate just the opposite. We think the increasing trend of KORA is caused by the demand from the large population and the high value of the capital/output ratio. We also think that after the year 2000,

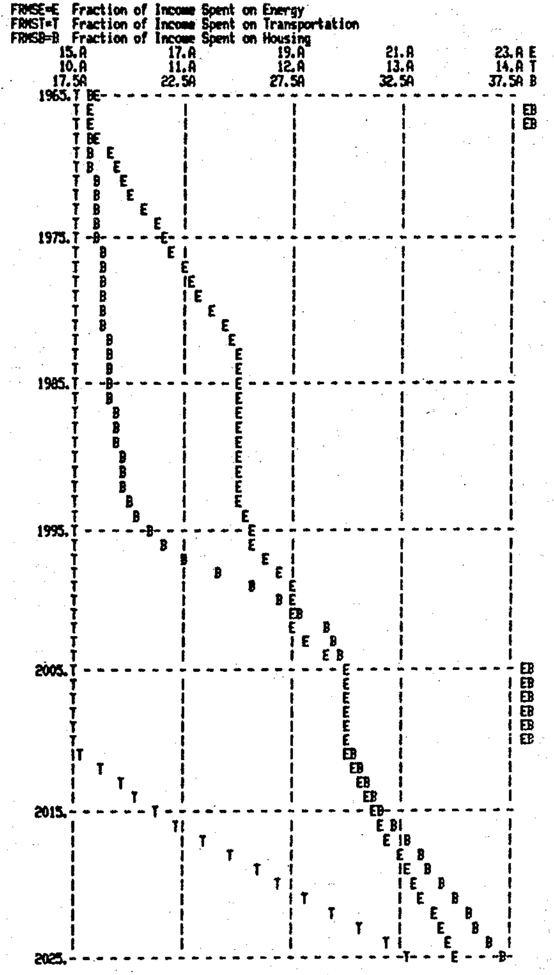

Figure 5 (cont.) Fraction of Income Spent on Each Item

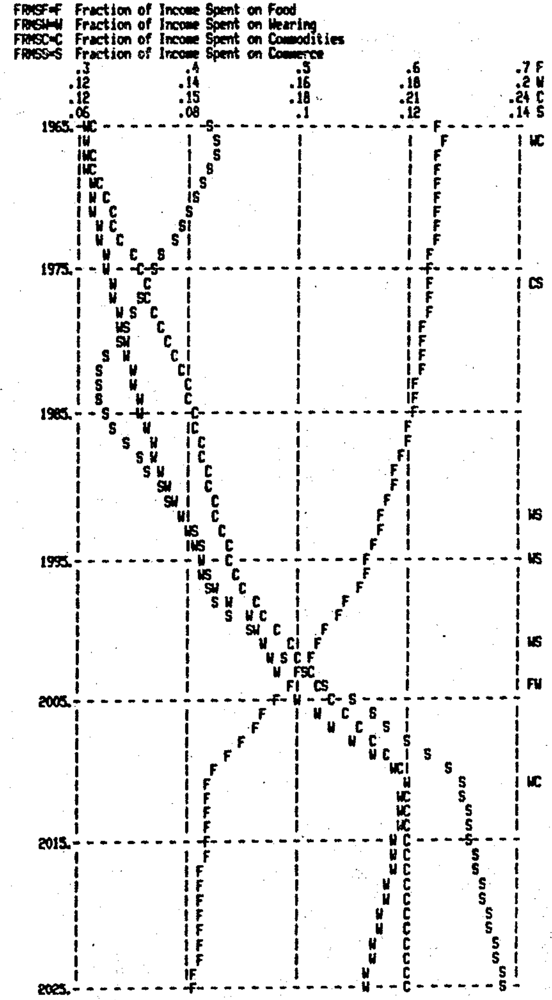

Figure 5 Fraction of Income Spent on Each Item

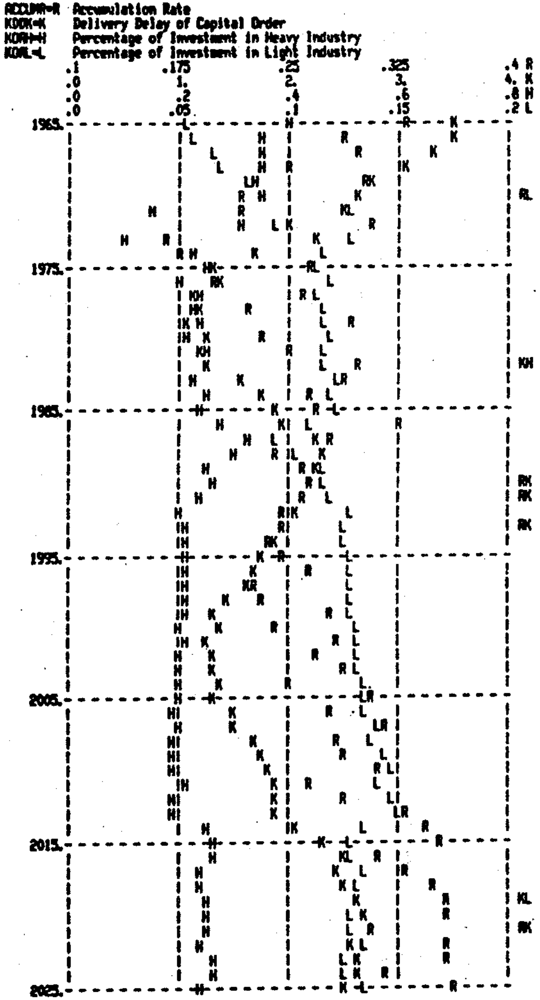

Figure 8 Results of Noise Test

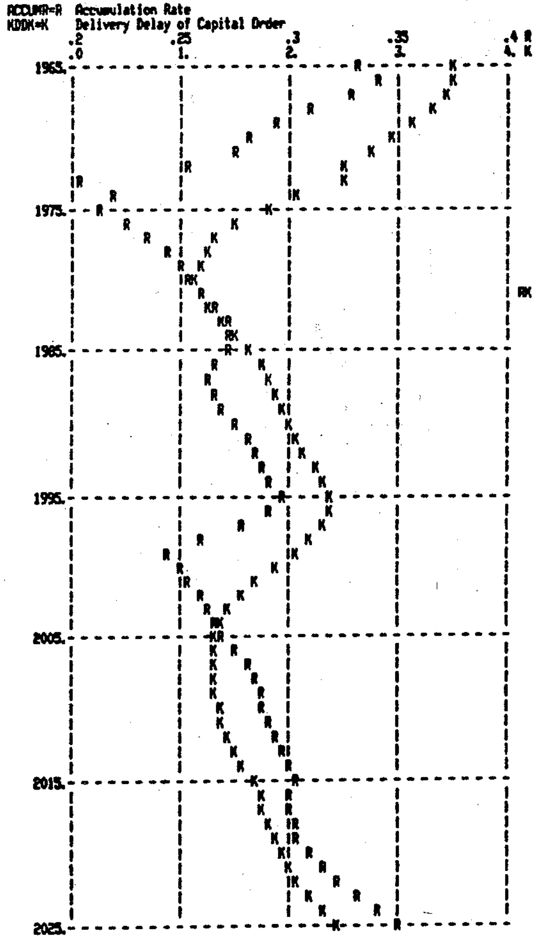

Figure 6 Accumulation Rate and Delivery Delay of Capital Order

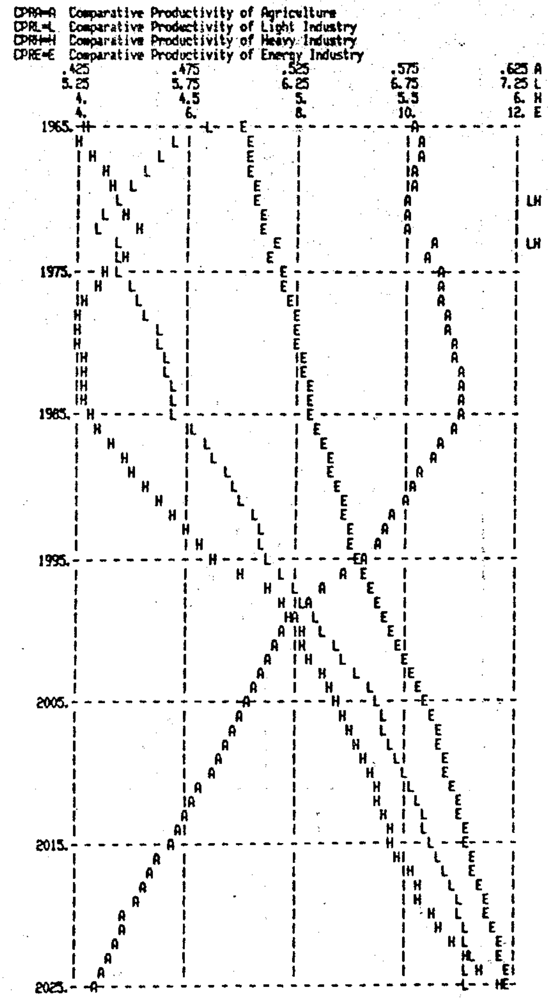

Figure 7 Comparative Productivity in Each Industry

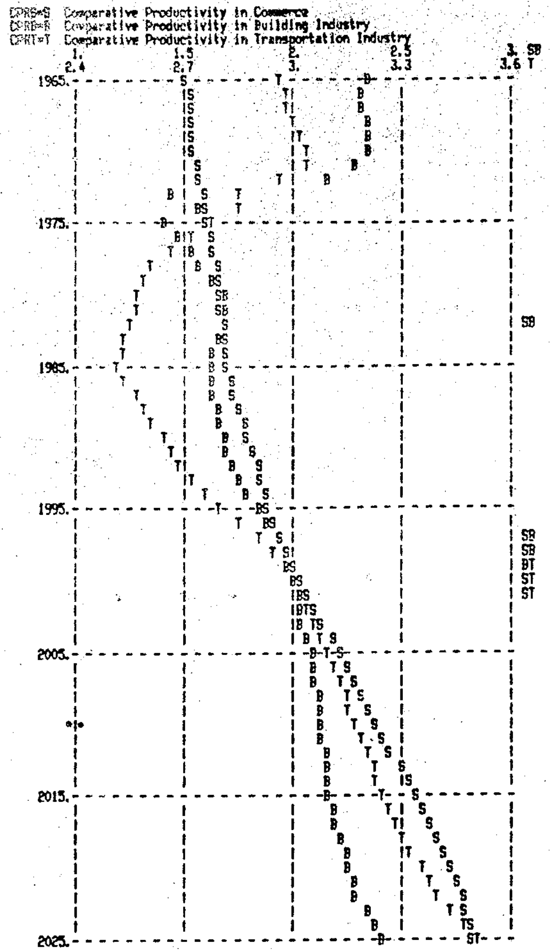

Figure 7 (cont.) Comparative Productivity in Each Industry the energy supply will not be a problem; therefore, KORE will not experience an increasing trend.

In Figure 6, we see that KDDK reaches its peak and then decreases along with the accumulation rate. This phase relation reflects the real situation of the economy. When the accumulation rate reaches its lowest point, the KDDK does not. This is because the capital investment in heavy industry decreases as the accumulation rate goes down, and the production capacity of capital goods also decreases; then the backlog volume and the KDDK can not be reduced quickly.

In industrial structure theory, we have the concept of comparative productivity of an industry which is equal to the percentage of one industry's net product in the total national income over the percentage of its labor force in total labor force of the economy. It is a common phenomenon in most developed countries that the comparative productivity of agriculture will decrease over time, and the comparative productivity of heavy, light, energy and transportation industries will experience increasing trends over time (Zhi 1985). The behavior of our model is quite consistent with this phenomenon, (see Figure 7). The comparative productivity of commerce usually demonstrates a downward trend in many countries. In contrast, the results of our model show an upward trend. These results indicate that the contribution to national income from agriculture will decrease, while the contributions from other industries will increase.

Figure 8 shows the results of a noise test at the accumulation rate. This rate is subjective to noise in a real system and often caused overinvestment in heavy industry in the past. The noise range is from -10% to +10% of the accumulation rate. The results show that the percentage of heavy industry investment keeps almost the same level as in the base run and no overinvestment or underinvestment in heavy industry will be triggered off by the noise after 1990. The control mechanism of the model works as well as in the case of no external noise. These results convince us that the model has a degree of external robustness (Coyle 1977).

SENSITIVITY ANALYSIS

Sensitivity analyses have been made from two points of view: demand and supply. On the demand side, the fraction of average income spent on food, on housing and on commodities(FRMSF, FRMSB and FRMSC) are the three factors influencing the future demand on the products of agriculture, light, heavy and the building industries. The factors are the table functions of average income per capita(AIPC). They change as the AIPC increases. It is difficult to predict their exact values for the future, but by the following analyses on these parameters, we can find out what effect they will have on the growth speed of these industries and on that of the whole economy (Camara 1985).

First let's look at the effect of change in FRMSF. The table function of FRMSF in the base run is given below

```
FRMSF=TABXT(TFRMSF,SAIPC,100,1700,200)                  (3)
TFRMSF=.63/.61/.57/.54/.51/.48/.45/.42/.4185            (4)
```

SAIPC is the smoothed value of AIPC. FRMSF decreases when SAIPC increases. It is possible for FRMSF to decrease faster than in the base run case as SAIPC increases. When we change the table function to the following,

```
TFRMSF=.63/.61/.51/.44/.41/.4086/.4073/.4059/.4045      (5)
```

the growth rate of each industry will look like what is shown in Table 2. Compared with the base run results, we find that a quicker decrease in FRMSF will cause the average growth rate of agriculture to decrease further in the future, and the average growth rates of heavy and transportation industries as well as commerce will have larger values. However, in the long run, the average growth rate of national income will not be influenced significantly.

Industries and National Income	Years 1986-2000	Ranges 1986-2025
	Average Growth Rates	
Agriculture	5.6%	5.7%
Light	7.7%	7.1%
Heavy	8.5%	7.1%
Building	8.1%	7.0%
Transportation	8.2%	7.0%
Commerce	8.9%	8.1%
Energy	7.8%	7.3%
National Income	7.0%	6.7%

Table 2 Results to the Change of FRMSF

If FRMSF takes an even sharper diminishing trend, like the following,

```
TFRMSF=.63/.61/.51/.41/.33/.3288/.3276/.3264/.3252      (6)
```

then the average growth rate of agriculture in 1986 - 2025 will be 5.4%. Again, the average growth rate of national income will not be significantly altered in the long run.

Secondly, let's look at the effect of change in FRMSB. The following is the table function of FRMSB in the base run.

```
FRMSB=TABXT(TFRMSB,SAIPC,100,1700,200)
TFRMSB=.018/.019/.02/.025/.029/.03/.03/.03/.0309        (7)
```

FRMSB might have higher values in the future. Table 3 shows the results of average growth rate for agriculture and the building industry, when we choose

```
TFRMSB=.018/.021/.025/.028/.03/.032/.033/.0345/.036   (8)
TFRMSF=.63/.61/.51/.41/.33/.3288/.3276/.3264/.3252    (9)
```

Industries and National Income	Years 1986-2000	Ranges 1986-2025
	Average Growth Rates	
Agriculture	5.6%	5.5%
Building	8.2%	7.2%
National Income	7.0%	6.7%

Table 3 Results to the Change of FRMSB and FRMSF

In Table 3, we see that the average growth rate of the building industry will increase and that of agriculture will decrease.

Thirdly, let's look at the effect of change in FRMSC. The table function of FRMSC in base run is given as follows:

```
FRMSC=TABXT(TFRMSC,SAIPC,100,1700,200)               (10)
TFRMSC=.12/.15/.16/.17/.18/.19/.20/.21/.21           (11)
```

Table 4 shows the results the of model simulation when we change the table function to the following:

```
FRMSC=.12/.14/.17/.24/.28/.29/.29/.29/.29            (12)
```

and with the same change to FRMSF as explained above.

Industries and National Income	Years 1986-2000	Ranges 1986-2025
	Average Growth Rates	
Agriculture	5.6%	5.7%
Light	7.8%	7.5%
Heavy	8.7%	7.5%
National Income	7.0%	6.8%

Table 4 Results to the Change of FRMSC and FRMSF

The results show that the average growth rate of light and heavy industries will go up by 0.4% and that of the national income will go up by 0.1% in the long run.

On the supply side, the policy constant for labor intensity of capital and the technology in each industry(PNLIKZ and TEZ) are the main parameters we are going to consider. By changing PNLIKZ, we can adjust the value of labor intensity of an industry between labor intensive and capital intensive. Their normal values in the base run are 1. In our analysis, we let the constant of agriculture, light industry and commerce equal 0.8, 1.2, 1.2 respectively from the year 1990; this has the effect of making agriculture less labor intensive, while light industry and commerce become more labor intensive. The result is shown in Table 5.

Industries and National Income	Years Ranges 1986-2000	1986-2025
	Average Growth Rates	
Agriculture	6.1%	6.0%
Light	8.3%	7.5%
Commerce	8.4%	8.1%
National Income	7.2%	6.9%

Table 5 Results to the Change of PNLIKA, PNLIKL and PNLIKS

With this policy, not only light industry and commerce can grow at a higher average rate, but also the average growth rate of agriculture and the national income will improve.

The level of technology is usually different in different industries. The technology progress in light industry is slower than in other industries. Table 6 shows the result when the technology progress in light industry is 5 years behind that of the average level for other industries.

Industries and National Income	Years Ranges 1986-2000	1986-2025
	Average Growth Rates	
Light	7.3%	7.1%
National Income	6.8%	6.6%

Table 6 Results with a time lag in the progress of TEL

The result shows that this lag will bring down the average growth rate of light industry and also that of national income.

CONCLUSION

This paper represents our first effort in working on such a relatively large resources constrained allocation model of system dynamics(about 600 equations). The main difficulty involved with such a model is to gain control and stability of the model. Nevertheless, it can be acquired. We hold that such kinds of models can help the modelers in system dynamics to deal with the more real problems of the social economic system, especially in developing countries, where the resources allocation is usually constrained.

Based on these results and analyses, we conclude that the percentages of investment in each industry will influence one another. In addition, determined by the mechanisms of demand and supply, there will be an increasing trend in the percentage of investment for the capital goods producing industries, and a decreasing trend in the percentage of investment for the consumer goods and services industries in the next 10 years. Later the situations of these two will change over time.

Any change in the fraction of average income spent on each consumer item will change the average growth rate of the corresponding industries which produce the item, but it will not significantly affect the average growth rate of national income in the long run. However, the change in the supply of one industry will not only have an effect on the average growth rate of that industry but it will also affect the average growth rate of the whole economy in the long run.

Extended work on the model could be made in the decision part of resources allocation. In a real system, there might be other criteria besides the demand criterion to be considered when determining how much to invest in each industry. In our model, the input/output parameters matrix is constant. To be realistic, it should be adjusted over time.

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