A SIMULATION SUPPORT SYSTEM FOR PUBLIC EDUCATION

INVESTMENT STRATEGY ANALYSIS

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ABSTRACT

A simulation model of education and economy is used to analyze the education investment strategy in a region of China. The simulation results show the proportion of educational fees and investments must be suited to the economic developing level. Thus, it is necessary to continuously increase the proportions with economic growth. In order to be convenient for decision makers, a functional simulation support system is proposed.

INTRODUCTION

In recent years, owing to the inflation which follows economic development, a serious shortage of public education funds became a very notable problem in China. Research on reasonable public education investment strategy has become an absorbing area to many economists, educators and officials. Unfortunately, it is very difficult to quantify the interaction between education and economic growth, so most research is either non-quantitative analysis or based solely on the comparison of the education investment ratio of China with that of other countries. The former can't tell the decision makers how much money is necessary, the later is not believable to the decision makers who always emphasize that there are differences in the economic systems of China and other countries. Thus, to find a quantitative and believable analysis for public education investment strategies is one of the most pressing tasks for the development of education and the economy of China.

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As we know, the development of education depends on the economic development, and education is an important factor to economic growth (Denison 1974). So we must consider the education, economy, population and the whole society as a system. The uncertainty of social-economic systems make the problem extremely complicated.

There is much literature that focuses on the interaction of education and economic growth (Schuitz 1961, Hybison 1964, Ritzen 1977). However, owing to the fact that educational and economic systems of China are really different from the Western Countries, these approaches can't be applied directly to China.

System Dynamics is a very efficient strategy simulation tool (Forrester 1969). The Club of Rome's world model (Meadow et al 1972) and Forrester's national model (1976) give us some good ideas for modeling the whole social-economic system.

In order to make the development plan of education in a region of China, we built a System Dynamics model to find a reasonable education investment strategy. A new method similar to Schultz's human capital theory is adopted to quantify the contribution of education to the economic growth. In order to give a convenient man-machine interface for the decision-makers, some techniques of decision support systems and human-computer interaction approaches are adopted (Wang et al 1986, Wang 1988). The simulation results prove that this Simulation Support Systems are a very useful tool for the education investment strategy analysis of China.

CONFIGURATION OF SIMULATION SUPPORT SYSTEM

The Simulation Support System for the education investment strategy analysis consists of 10 main modules, as shown in Fig.1.

The human-computer interface module is composed of several menus which can prompt the user to select different modules to do the work desired.

The development goal setting module is used to acquire the development goal of education and economy. It is composed of a group of questions which can elicit the decision makers to tell the system what his thinking is about the future. This information is necessary to the strategy evaluation.

The statistical data input module is a data input interface. It prompts the user to key into computer the main statistical data about education and the economy over a history period. These data are stored in the data base, they are useful for model checking and the estimation of model parameters.

The parameter estimation module is a common least-square algorithm. It uses the statistical data in the data base to estimate the parameters which are necessary to the key module of the simulation.

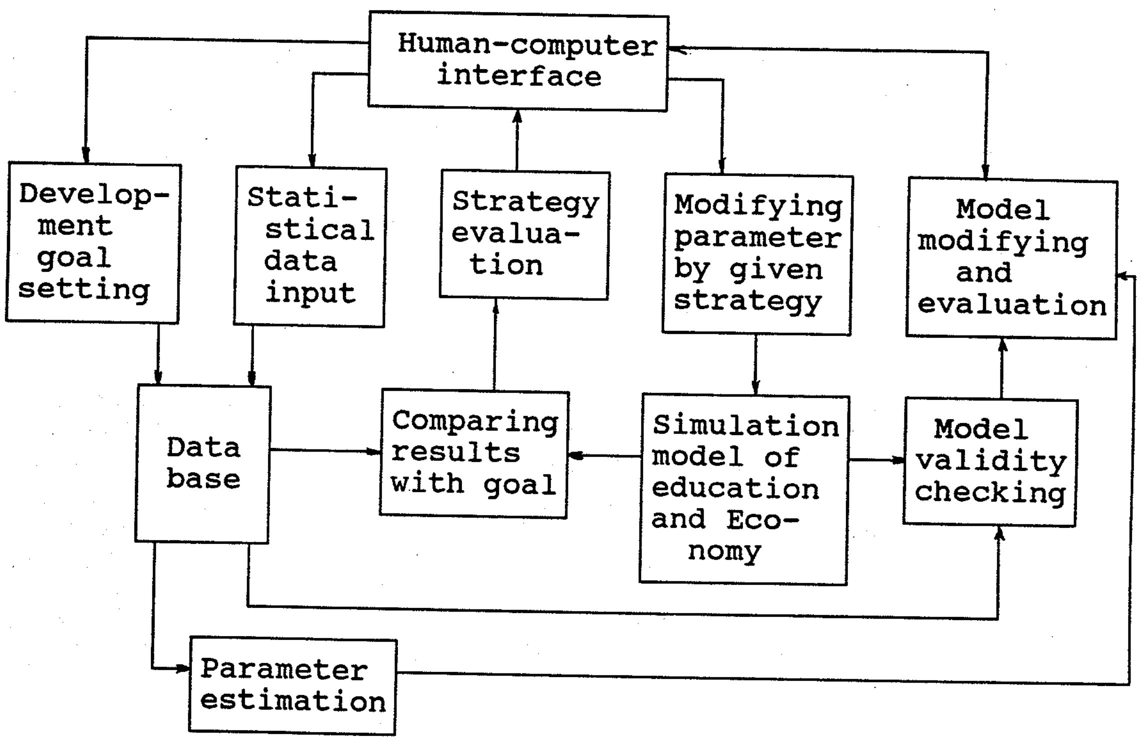

Figure 1: Configuration of the Simulation Support System

The nuclear part of this system is the simulation model of education and economy. It was written in the Dynamo language according Forrester's System Dynamics. Other modules are all around it. We will discuss it in detail in the next section.

The model validity checking module is used to check the validity of the simulation model. It compares the results of the simulation with the statistical data. If there are not any large differences between the results and the statistical data in the main indexes of education and economy, the model can pass the validity checking.

The model modifying and evaluation module is used to output the the results of model validity checking by a group of formatted tables, so they are easy to understand by the user.

The modifying parameter by given strategy module is used to translate the education investment strategy given by the decision makers to the simulation parameters in the model. Then the simulation begins to run and store the simulation results in the data file.

The comparing results with goal module is a result review module. It opens the result data file and compares the simulation results with the development goals given by the decision makers.

The strategy evaluation module is used to output the comparison results of a given strategy and the goals. The strategies which can not reach the development goals for education and the economy will be considered as unsuccessful strategies. The decision-makers can select the best strategy from the successful strategies which can reach the stated goals.

We have not finished developing all modules, because there are many functions required by the decision-makers that are not easy to be realized. The development and improvement of the simulation support system is still in progress.

SIMULATION MODEL OF EDUCATION AND ECONOMY

The simulation model of education and economy is the key module in this system and the central work of this research. The reduced cause-and-effect diagram of this model is shown in Fig.2.

From Fig.2, we see there are four main cause-and-effect loops which are all positive feedback loops.

The first one is: National income increase makes the investment in educational capital increase and educational capital cost increase. This means that a capacity increase in schools makes the students increase. After a delay, the labor force will increase, and the national income will increase again.

The second one is: National income increase makes public education fees increase, then the shortage gets decrease. The increased education fees can guarantee education quality, so the quality of graduates will increase. Then the quality of social labor will improve which can also increase the national income.

The third one is: National income increase increases the investment in capital of production. Then the total capital cost increases, and makes the national income increase also.

The forth one is: National income increase makes the investment in science and technology increase. This increasing investment can quicken the technology process, and the national income will increase again.

The former two investments can be considered as investment in human capital (Schulze 1961). The later two investments are investments in capital. These cause-and-effect relations are easy to understand philosophically. The difficulty is how to quantify these relationships.

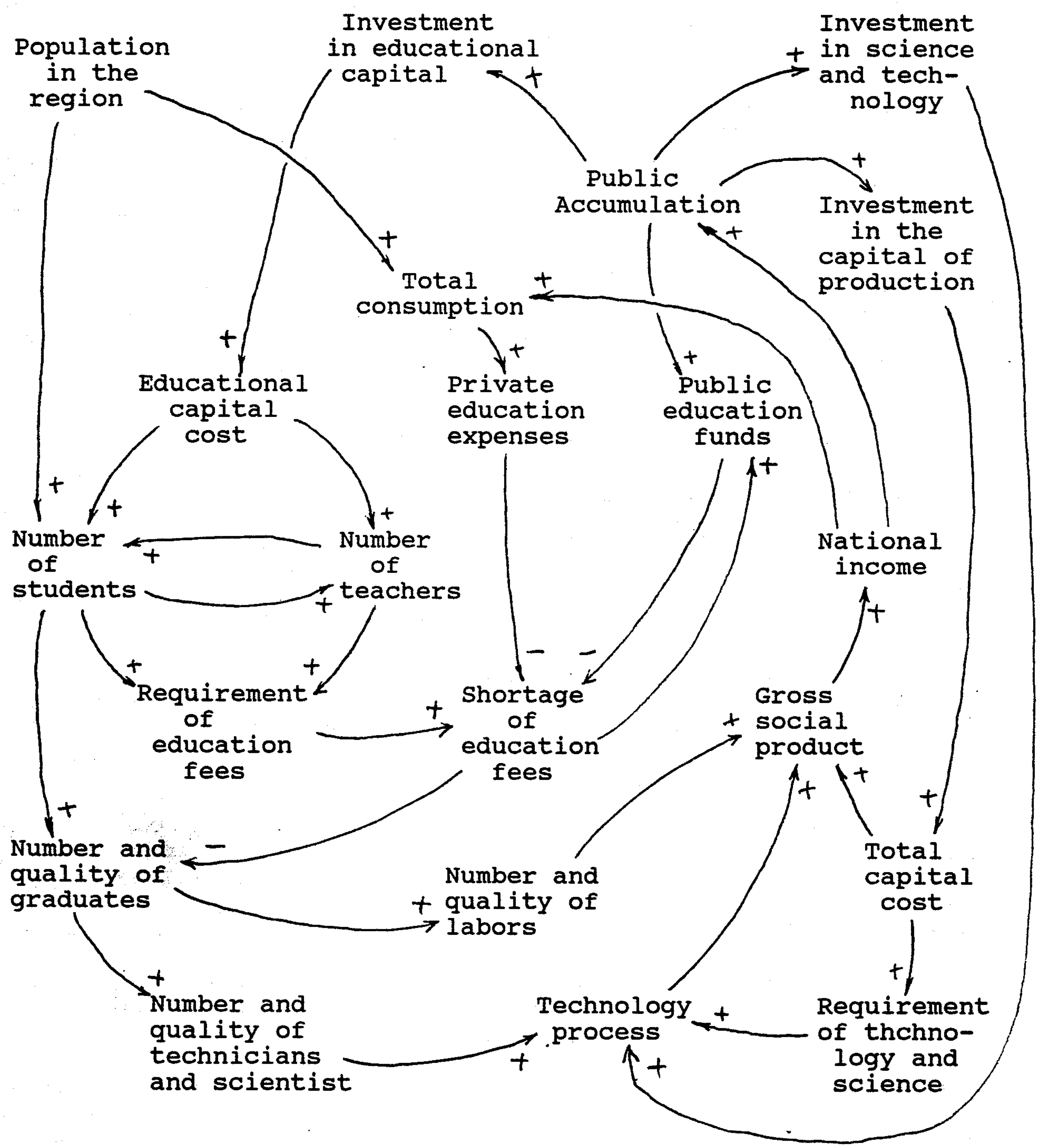

Figure 2: Cause-and-Effect Diagram of Simulation Model of Education and Economy

The effects of labor, capital and technology progress on gross social production can be described by the Cobb-Douglas production function (Solow 1957). Although the C-D function is a classical production function, it is widely used in China now after some improvements were developed (Wang et al 1988a). This is because the parameter estimation of a C-D function is easier than other production functions. The reason that we use the gross social product instead of gross national product is that there are not enough statistical data of GNP in China. The main difference between GNP and GSP is that the later is not a net product value.

Let $Y(t)$ be the GSP in t^{th} year,
$K(t)$ be the total capital cost in t^{th} year, and
$L(t)$ be the total labors in t^{th} year.

$$Y(t)=A(t)\cdot K(t)^{u}\cdot L(t)^{v} \qquad (1)$$

where, $A(t)$ is the technology progress in t^{th} year, u and v are the parameters to be estimated, and $u+v=1$.

In order to quantify the quality of labor, we can use the labor simplifying ratio which was proposed by educational-economists in the Soviet Union.

Assuming the value of a laborer without any education is 1 unit, then the value of a laborer with a k^{th} level education is more than 1 unit. The ratio of value of a laborer with a k^{th} level education to the value of a laborer without any education is defined as the labor simplifying ratio of the k^{th} education, remarked as h_k.

The labor simplifying ratios used in the simulation model are determined by the results of a study of productivity of workers with different levels of education, and a study of average incomes of peasants with different levels of education. The former was done by the authors in a machine-tool plant. The later was reported by the People Daily in China. The labor simplifying ratios are shown in Table 1.

Table 1: The Labor Simplifying Ratios

Education level	Labor simplifying ratio
Illiterate person	1.00
Primary school	1.20
Junior middle school	1.40
Senior middle school	1.60
Skilled worker school	1.65
Polytechnic school	1.70
Polytechnic college	1.90
University	2.00
Graduate school	2.20

Then the total labors in t^{th} year can be calculated by the following formula,

$$L(t) = L(t-1)+h_1(t)\cdot R_1(t)+h_2(t)\cdot R_2(t)+\cdots+h_n(t)\cdot R_n(t) - r\cdot L(t-1), \qquad (2)$$

where $R_k(t)$ is the number of graduates of k^{th} level schools in the t^{th} year, r is the retired rate of labors, and n is the number of levels of schools.

We assume that the labor simplifying ratios are variable with time. They can vary from their standard values with the change of shortage in education fees. The relation between the two variables is described by a table function based on the experiences of educators and the managers of schools.

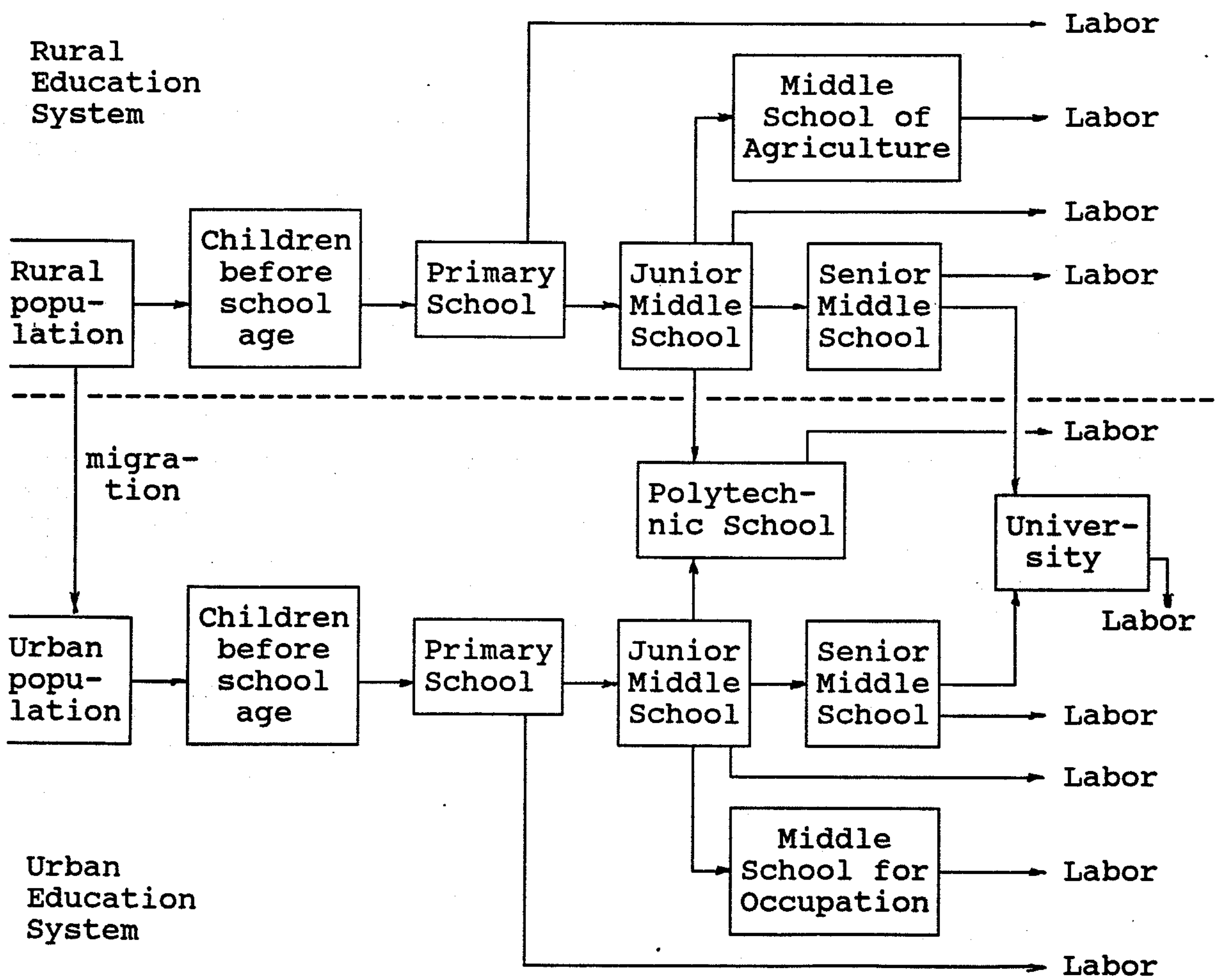

Figure 3: Student Flow Diagram of Chinese Education System

The technology progress in the t^{th} year can be determined by the following recurrence formula:

$$A(t) = a \cdot A(t-1)^{b} \cdot [S(t)/L(t)]^{c}, \quad (3)$$

where, S(t) is the level of manpower in the science and technology section. It can be calculated by a formula similar to (2). The parameters a, b and c are to be estimated.

This formula was developed by Wang et al (1988b) in the research on forecasting of science, technology and education in this region. It fits the statistical data very well. Its economic meaning is that technology progress depends on the technology level in last year and the proportion of scientists and technicians in the common laborer pool.

This model is composed of more than 350 equations. This number does not include the equation numbers of parameters and tables. The schools are divided into rural schools and urban schools because the two kinds of educational fund systems run in different ways. The student flow diagram of the Chinese education system is shown in Fig.3.

Based on the population forecasting data, we can determine the number of children who will enroll in primary schools in future years. Then according to the student flow rules and the capacities of all kinds of schools, we can calculate the numbers of students in all kinds of schools. These data are basic data to determine the requirement of education fees. As space is limited, we do not discuss the calculation approach in detail.

SIMULATION RESULTS AND STRATEGY ANALYSIS

The key module, Simulation Model of Education and Economy, was programmed in Professional Dynamo Plus (PD-Plus). It was run on an IBM PC/AT. After repeated simulations, reasonable educational investment and fund strategies have been achieved.

The current proportion of educational fees in the national income of this region is about 1.90%. The changes in GSP in 2000 and 2020, with this proportion are shown in Table 2.

From Table 2, we see that when the educational fee proportion increases from 1.9% to 2.8% and 3.0%, the GSP in 2000 and 2020 will reach a maximum of 285.95 and 850.96 billion yuans respectively. However, if the proportion is increased to more than 3.0%, the values in 2000 and 2020 will go down.

The current proportion of investment in educational capital construction over the total investment in capital construction is about 6.5% in this region. If we adjust this proportion with the educational fee proportion, the economic growth can get a larger increase. The results are shown in Table 3.

Table 2: The Effect of Educational Fee Proportion to Economic Growth

(unit: billion yuan)

Proportion (%)	GSP in 2000	GSP in 2020
1.5	280.35	824.20
1.9	283.68	838.16
2.0	284.09	840.28
2.5	285.62	848.15
2.7	285.88	849.81
2.8	285.95	850.39
2.9	285.95	850.75
3.0	285.91	850.96*
3.1	285.82	850.96
3.2	285.71	850.73
3.5	285.23	848.88
4.0	283.99	840.83

Table 3: The Effect of Educational Investment Proportion and Educational Fee Proportion to Economic Growth

(unit: billion yuan)

Edu. fee proportion (%)	Edu. investment proportion (%)	GSP in 2000	GSP in 2020
1.9	6.5	283.68	838.16
3.0	7.5	285.78	859.56
3.0	8.5	285.38	865.71
3.0	9.5	284.87	870.09
3.0	10.5	284.43	872.98
3.0	11.5	284.17	874.69
3.0	12.5	284.08	875.57
3.0	13.0	284.08	875.74*
3.0	13.5	284.08	875.74
3.0	14.0	284.08	875.60
3.0	14.5	284.08	875.30
3.1	13.0	284.01	875.80**
3.1	13.5	284.01	875.80

From Table 3, we see that the GSP in 2000 decreases as the educational investment proportion increases. This is because the educational investment is delay-effective to the economic growth. The GSP in 2020 increases with this proportion increase, but when it is over 13.0% the GSP in 2020 will go down. When the educational fee and investment proportions are 3.1% and 13.0% respectively, the GSP in 2020 can reach its maximum of 875.80 billion yuans.

In above results we consider the educational fee and investment proportions to be constants. This is not true. Owing to that the requirement of education will continuously increase with the economic growth and the technology progress, the educational fee and investment proportions must be a function of time. The simulation results show that when the fee proportion is taken as 3.0%, there will be a surplus of educational fees before 1995 but a shortage after 1995.

According to the rule which requires educational fees to increase with economic growth, it is better that the educational fee proportion take following values in future years, as shown in Table 4.

Table 4: The Required Educational Fee Proportion in the Future

Year	1989	1990	1991	1992	1993	1994	1995
Fee prp.(%)	2.09	2.26	2.37	2.52	2.70	2.86	3.02

Year	1996	1997	1998	1999	2000	2020	2030
Fee prp.(%)	3.12	3.16	3.23	3.43	3.67	4.17	4.35

If this time series of educational fee proportions will be taken the GSP in 2000 and 2020 will increase to:

GSP in 2000 = 289.56 billion yuans, and
GSP in 2020 = 929.26 billion yuans.

They are 2.07% and 10.87% more than the GSP in 2000 and 2020 when the current fee and investment proportions will still be taken. So we see that to take proper educational fee and investment proportions can distinctly promote economic growth.

CONCLUSIONS

From this research on educational investment strategy, we can get following conclusions:

1) The current proportions of educational fees in national income and educational investment in total capital construction in this region are too low, with the result that the speed of economic growth has been limited. So it is an urgent matter to greatly increase the two proportions at once.

2) However, it does not follow that a higher educational fee proportion results in faster economic growth. There is an optimal matching of the educational proportions to the economic

development level. If the unvarying proportions were adopted, the optimal values of the two proportions suitable to the economic development level of this region would be 3.1% and 13.0%, separately.

3) The requirement of educational fees and investment will continuously increase with the economic growth, so the better way is to increase the proportions continuously. The time series of educational fee proportions shown in Table 4 can be taken as a better alternative.

4) In the simulation model of education and economy, education, population, economy and human society are considered as a whole system, so we can get a good understanding of the interactions between education and economy.

5) The simulation support system proposed in this paper has a reasonable configuration and some useful functions, it will become an efficient computer-aided decision tool for the decision-makers as they select the correct education development strategy.

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