

Empirical research on existing quantity of small and medium-sized enterprises in China, based on system dynamics

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Abstract

A system model for the existing quantity of small and medium-sized enterprises is built in this document, by establishing relationship equations with study on relationships among more than 30 variables such as total enterprise quantity, establishment rate of new enterprises, level of human resources, level of technical innovations, index of resource dependence, etc. Moderate breakthroughs are made on the mathematical methodology, such as the method of education years to calculate the level of human resources, the method of resource dependency evaluation for the resource dependency index. However, certain corrections are made for adaptation to the study. The innovative concept of establishment rate of new small and medium-sized enterprises is created in modelling and correlated with level of technical innovations, level of human resources and resource dependency index through relationship functions. The purpose thereof is to explore mechanisms where and extents to which influence factors make impact on the existing quantity of small and medium-sized enterprises. Finally, emulation prediction for the system model is made with the emulator Vensim and the error analysis on comparison between emulation and historical data is performed. It is found that the agreement with historical data is good and the error is acceptable.

Keywords: existing quantity of small and medium-sized enterprises, establishment rate of new small and medium-sized enterprises, system dynamics

1 Introduction

The system model for existing quantity of small and medium-sized enterprises is used for predictive investigation on changing quantity of enterprises as well as for analysis of how and what the impact of influence factors on existing quantity of enterprises would be during a period of time. To make convenient and reasonable system modelling, the influence factors are divided into five subsystems correlated via certain relationships.

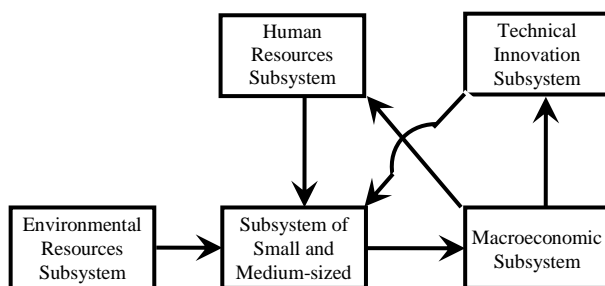


FIGURE 1 Structure of the System Model for Existing Quantity of Small and Medium-sized Enterprises.

2 Foundational Model Analysis

2.1 MODELLING PRINCIPLE

2.1.1 Analysis of System Architecture:

The establishment of small and medium-sized enterprises is influenced by multiple factors such as economy, man power, technology, policy and environment. The knowledge flows in the form of technology from the technical innovation subsystem to the subsystem of small and medium-sized enterprises. The effect of such outflow is also presented in education. The quantity of well-educated labors determines the level of human capital required by entrepreneurs and small and medium-sized enterprises, particularly small high-tech enterprises. Such labors correlate the human resources subsystem with the subsystem of small and medium-sized enterprises and flow from the former to the latter. The abundance of environmental resources influences economic structure and economic development centering within a region. The resource deterioration results in poor innovation ability and low entrepreneurial efficiency. Thus, the environmental resources subsystem provides control effect on the subsystem of small and medium-sized enterprises. Normally, more the quantity of small and

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medium-sized enterprises is, larger the contribution they make to gross domestic products will be. The corresponding taxes will be invested into education and R&D through the government's financial inclination. The funds will then flow from subsystem of small and medium-sized enterprises to macroeconomic subsystem, human resources subsystem and technical innovation subsystem, and finally make a fed impact on the subsystem of small and medium-sized enterprises.

2.1.2 Description of Variables

The human resources subsystem will explain variation of the human capital level with a focus on the level of human resources. The technical innovation subsystem will explain the extent of knowledge outflow with a focus on the level of technical innovations. The environmental resources subsystem will explain dependency of economic development modes on resources in a region with a focus on resource dependency index. The macroeconomic subsystem will explain economic development trends with a focus on gross domestic products. The subsystem of small and medium-sized enterprises will explain variation mechanism of the existing quantity of small and medium-sized enterprises with a focus on total enterprise quantity.

2.2 STRUCTURAL FLOW CHART

2.2.1 Key Feedback Loops

- Total enterprise quantity →+ Gross domestic products →+ Taxes →+ Financial revenue →+ Financial expenditure →+ Investment on R&D →+ Existing R&D quantity →+ Level of technical innovations →+ Establishment rate of new enterprises →+ Quantity of newly established enterprises →+ Total enterprise quantity
- Total enterprises quantity →+ Gross domestic products →+ Taxes →+ Financial revenue →+ Financial expenditure →+ Educational investment →+ Educational investment coefficient →+ Educational coefficient →+ Level of human resources →+ Establishment rate of new enterprises →+ Quantity of newly established enterprises →+ Total enterprise quantity

2.2.2 Flow Positions and Flow Rates

- Flow position: total enterprise quantity, flow rate: quantity of newly established enterprises, quantity of bankrupt enterprises
- Flow position: existing R&D quantity, flow rate: R&D investment, R&D decrease
- Flow position: total population quantity, flow rate: new population, death population.

2.2.3 Emulation Model

Model emulation is made with the emulator Vensim. The structural flow chart is as shown in the Figure2.

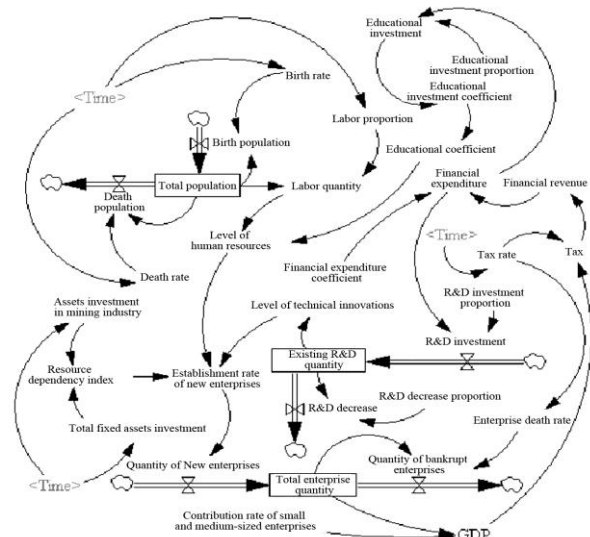


FIGURE 2 Emulation model made with Vensim

3 Establishment of Modelling Equations*

3.1 POPULATION-RELATED VARIABLES

The index linear regression† with the birth rate and natural growth rate of Chinese population during 1999 and 2008 and the time is made according to Malthus' theory of population index growth. PBR_t (birth rate of the population in year t) and PDR_t (death rate of the population in year t) are obtained as below.

$$PBR_t = 23.128 \cdot e^{-0.0326(t-1986)} / 1000,$$

$$PDR_t = 23.128 \cdot e^{-0.0326(t-1986)} / 1000 - 17.622 \cdot e^{-0.0326(t-1986)} / 1000$$

It is known from definitions of birth and death rates that:

$$PBR_t = \frac{PB_t}{(POP_{t-1} + POP_t) / 2} \quad PB_t = \frac{2POP_{t-1}}{2 - PBR_t} \quad PDR_t = \frac{2POP_{t-1}}{2 + PDR_t}$$

$$POP_t = \int_{2000}^t [PB(i) - PD(i)] \cdot di + POP_{2000}$$

$$= \int_{2000}^t [PB(i) - PD(i)] \cdot di + 127627,$$

where POP_t is the total population in year t

3.2 LABOR-RELATED VARIABLES

LR_t (the labor proportion):

$$LR_t = -0.0001 \cdot (t-1999)^2 + 0.003 \cdot (t-1999) + 0.5739,$$

* All the data used to establish the equation are totally from annual China Statistical Yearbook of National Bureau of Statistics.

† All the linear regressions mentioned in this article are analysed through IBM SPSS Statistics 19.0.0, specifically not repeat.

$$L_t = POP_t \cdot LR_t,$$

HRL_t (level of human resources in year t):
 $HRL_t = HR_t / HR_{2000} = EC_t \cdot L_t / 73991.98.$

3.3 EDUCATION-RELATED VARIABLES

EIR (educational investment proportion):

$$EIR = \frac{\sum_{i=2000}^{2009} EIR_i}{2009-2000+1} = 12.5168794\%$$

EI_t (educational investment): EI_t = FE_t · EIR, where FE_t is the financial expenditure in year t.

The methodology for calculation of the human capital level can be divided into future proceeds method, accumulative cost method, education years method and income differentiation method. The education years method is used for human capital calculation in this model because of limited data acquisition and method unsuitability. Angus Maddison’s weighting criteria are used for the effect of academic qualifications on human capital. The weight of tertiary education is 2, and the weight of secondary education is 1.4, and the primary education is 1. The calculation method is as below:

HR_t (total human resources in year t):

$$HR_t = \int_0^{\infty} \alpha \cdot \eta(t, \alpha) \cdot L_t \cdot d\alpha = [2 \cdot \eta(t, 2) + 1.4 \cdot \eta(t, 1.4) + 1 \cdot \eta(t, 1)] \cdot L_t$$

(Where α is the education extent that is the weight given and $\eta(t, \alpha)$ is the proportion of the population with education extent in the total population in year t)

EL_t (education level in year t):

$$EL_t = 2 \cdot \eta(t, 2) + 1.4 \cdot \eta(t, 1.4) + 1 \cdot \eta(t, 1)$$

EIR_t (educational investment coefficient in year t):

$$EIR_t = EI_t / EI_{2000} = EI_t / 1624.1438$$

EC_t (educational coefficient in year t):

$$EC_t = 0.021 \cdot EIC_t + 0.997 \quad R^2 = 0.8260$$

3.4 VARIABLES RELATED TO R&D INVESTMENT

The proportion of Chinese R&D investment in the financial expenditure is 34.0% - 44.4% during 2000 and 2009, and its variable properties and data characteristics are similar to those of the educational investment. Thus, the same method is used for calculation.

RNDIR (R&D investment proportion) and RNDI_t (R&D investment in year t):

$$RNDIR = \frac{\sum_{i=2000}^{2009} RNDIR_i}{2009-2000+1} = 3.775725\%$$

$$RNDI_t = FE_t \cdot RNDIR$$

3.5 VARIABLES RELATED TO R&D DECREASE

The R&D will be decreased along with the time. The R&D decrease proportion is the proportion between R&D

decrease in a period and R&D quantity in beginning of the period. RNDDR (R&D decrease proportion) and RNDD_t (R&D decrease in year t) are obtained with testing of historical experience data, as specified in this document.

$$RNDDR = 0.2 \quad RNDD_t = RND_t \cdot RNDIR$$

3.6 VARIABLES RELATED TO R&D QUANTITY

The R&D quantity in a period is the sum of R&D quantity in the last period and R&D increase in this period (that is the difference between R&D investment and R&D decrease). Thus, RND_i (R&D investment in period i) is:

$$RND_i = RND_{i-1} + RNDI_i - RNDDR \cdot (RND_{i-1} + RNDI_i)$$

$$= 0.8 \cdot (RND_{i-1} + RNDI_i)$$

$$= 0.8 \cdot [0.8 \cdot (RND_{i-2} + RNDI_{i-1}) + RNDI_i]$$

$$= 0.8^i RNDI_1 + 0.8^{i-1} RNDI_2 + \dots + 0.8 RNDI_i$$

The R&D quantity in the first period is equal to the decreased R&D investment quantity.

$$RND_1 = 0.8 \cdot RNDI_1$$

$$RND_i = \sum_{p=1}^i 0.8^{i-p+1} \cdot RNDI_p$$

RND_t (R&D quantity in year t) and IL_t (the level of technical innovations in year t) are:

$$RND_t = \int_{2000}^t [RNDI(i) - RNDD(i)] \cdot di + RND_{2000}$$

$$= \int_{2000}^t [RNDI(i) - RNDD(i)] \cdot di + 1542.807$$

$$IL_t = RND_t / 1542.807$$

3.7 RESOURCE DEPENDENCY INDEX

The resource dependency index is defined as the ratio of fixed assets investment in the mining industry to total fixed assets investment, with Auty’s method for dividing of regions with abundant and lean resources as well as reference to the resource dependency measurement method used in China:

$$MDI_t = MFAI_t / FAI_t,$$

FAI_t (total fixed assets investment in year t) and MFAI_t (fixed assets investment in the mining industry in year t) are obtained:

$$FAI_t = 2086(t-1999)^2 - 3019(t-1999) + 11929 \quad R^2 = 0.9910$$

$$MFAI_t = 95(t-1999)^2 - 161(t-1999) + 497.84 \quad R^2 = 0.9934$$

3.8 VARIABLES RELATED TO FINANCIAL

FEC (financial expenditure coefficient) and FE_t (financial expenditure in year t) are:

$$FEC = 1.018, FE_t = FEC \cdot FR_t + 1821.299, R^2 = 0.9870.$$

There are many particular stipulations about taxation imposed on small and medium-sized enterprises in China. For example, several preferential stipulations involving small and medium-sized enterprises are mentioned in Section 4 “Tax Preferences” in Law of Corporate Income

Tax of People’s Republic of China, such that “the corporate income tax will be levied at the tax rate of 20% on small and micro-profitable enterprises that meet conditions, and the corporate income tax will be levied at the tax rate of 15% on high-tech enterprises that should get significant national supports”. Therefore, there are different tax rates associated with different industries and small and medium-sized enterprises with different sizes. This study is to investigate the effect of external circumstances on creation, development and death of small and medium-sized enterprises. Thus, it is feasible to find the impact of adjustment to tax rates by considering average tax rates as per the ratio of taxes to GDP.

$$\begin{aligned} \text{TAX}_t &= \text{GDP}_t \cdot \text{TR}_t \\ \text{TR}_t &= 0.0051 \cdot (t-1999) + 0.1269 \quad R^2 = 0.9616 \\ \text{FR}_t &= 1.167 \cdot \text{TAX}_t - 1661.441 \quad R^2 = 1.0000 \end{aligned}$$

3.9 VARIABLES RELATED TO BANKRUPT ENTERPRISES

In recent years, there are annually 8% - 10% of small and medium-sized enterprises going bankrupt in China. Most of small and medium-sized enterprises are not in existence for more than 5 years. For such enterprises, the tax level will influence directly their profit rates and dominate the quantity of those going bankrupt. Therefore, the enterprise death rate is introduced between the tax and the quantity of bankrupt enterprises, and is defined as the ratio of bankrupt enterprise quantity to total enterprise quantity. It means that bankrupt enterprise quantity is equal to the product of total enterprise quantity and enterprise death rate. A strong linear relationship between enterprise death rate and tax rate is found from data adjustment to the enterprise death rate, and its value is always kept as about half of the tax rate value. SMEDR t (the death rate of small and medium-sized enterprises in year t) and SMEDt (the quantity of small and medium-sized enterprises going bankrupt) are obtained:

$$\text{SMED}_t = \text{SME}_t \cdot \text{SMEDR}_t, \text{SMEDR}_t = \text{TR}_t / 2.$$

3.10 VARIABLES RELATED TO TOTAL ENTERPRISE QUANTITY

The total quantity of small and medium-sized enterprises during 2000 and 2004 is estimated with linear regression of statistics (after 2005) about the quantity of small and medium-sized enterprises that are provided by National Bureau of Statistics and iResearch. A medium-sized variable called the contribution rate of small and medium-sized enterprises is introduced to explain the effect of small and medium-sized enterprises on GDP.

SMEC (contribution rate of small and medium-sized enterprises), GDPt (gross domestic products in year t) and SMEt (total quantity of small and medium-sized enterprises in year t) are obtained:

$$\begin{aligned} \text{SMEC} &= 99.120, \\ \text{GDP}_t &= 99.120 \cdot \text{SME}_t - 73824.273, R^2 = 0.9840. \end{aligned}$$

$$\begin{aligned} \text{SME}_t &= \int_{2000}^t [\text{SMEB}(i) - \text{SMED}(i)] \cdot di + \text{SME}_{2000} \\ &= \int_{2000}^t [\text{SMEB}(i) - \text{SMED}(i)] \cdot di + 1693.313 \end{aligned}$$

3.11 POPULATION-RELATED VARIABLES

A medium-sized variable called the establishment rate of new enterprises is introduced to explain the effects of these three factors on new enterprise quantity. The establishment rate of new enterprises is defined as the equivalent value of new enterprise quantity in the present period to new enterprise quantity in the first period (the first period in this model is the year of 2000) as a standard. SMEBt (quantity of small and medium-sized enterprises newly established) is obtained:

$$\text{SMEB}_t = \text{SMEBR}_t / 280.211,$$

where SME_{ts} and SME_{te} are total quantity in beginning of the period and total quantity at end of the period)

$$\begin{aligned} \text{SME}_{te} &= \text{SME}_t, \text{SMEDR}_t = \text{TR}_t / 2, \\ \text{SME}_{ts} &= \text{SME}_{te} / (1 - \text{SMEDR}_t), \\ \text{SMEB}_t &= \text{SME}_{ts} - \text{SME}_{te}, \text{SMEBR}_t = \text{SMEB}_t / \text{SMEB}_{2000}. \end{aligned}$$

4 Inspection of Model Reliability

4.1 STRUCTURAL INSPECTION

The reasonability of model structure determines whether emulation can be made in the expected direction and whether variation relationships among variables conform to basic principles and practical experiences. Key parts of this model are obtained with the analysis of numerous historical literatures and actual situation about establishment and development of small and medium-sized enterprises in China. The extent to which influence factors make impact on the system has been fit from actual situation in years. Therefore, the structure of this model is basically reasonable and effective in terms of basic principles or practical experiences.

4.2 PARAMETER INSPECTION

4.2.1 Dimensional Inspection

The model can be inspected with the function of “units check” in Vensim. There would be error prompts if the variable dimensions could not be kept consistent. This model has been checked to be correct, and this means that the variable units are consistent.

4.2.2 Parameter Inspection

The results of model emulation vary with parameters. The properness of a parameter value (with positive or negative sign) can be indicated by means of goodness of fit between variables. Strict regression analysis has been used to establish the relationship equations between model variables. Thus, regression equations in the model

have a good fit. There are strong significance correlation and significance from a statistic view, so it is believed that model parameters are reasonable and effective.

Parameter intervals in the emulation cycle are inspected. For example, the interval inspection is made for tax rate, labour proportion, financial expenditure coefficient, etc. It is found that parameter intervals are within a reasonable range. Detailed inspection processes are not mentioned any more.

4.3 HISTORICAL INSPECTION

The error analysis is performed for part of important variables in the model, such as total enterprise quantity, GDP, financial expenditure, total population, tax, fixed assets investment, educational investment, R&D investment, financial investment, fixed assets investment in the mining industry, new enterprise quantity, bankrupt enterprise quantity, etc.

4.3.1 Relative Error

The ratio of the difference between emulation data and real data to the real data is used as the relative error of variable emulation results. In the equation, e_{it} represent

the relative error of emulation data to real data that are associated with variable i in year t , and x_{it} represents historical data associated with variable i in year t , and y_{it} represents emulation data, and $i(i=1,2,3\dots)$ represents

$$e_{it} = \frac{|x_{it} - y_{it}|}{x_{it}}$$

variable i and t represents year t . There are no absolute inspection criteria in theoretical studies with the system dynamics. However, it is described in the book called Econometrics written by Li Zinai that emulation results could be considered as having good predictability if the value of relative error e_{it} for more than 70% of variables is less than 5% and the relative error for all variables is within 10%⁴. Calculation of the relative error is performed with use of far variables in the feedback loop as good as possible in order to reflect model reliability, because most of close variables have a strong explanatory relationship with each other. It can be seen from the above table that the errors of important variables observed through emulation such as total enterprise quantity, GDP and total population are within 10%, and particularly the error of total enterprise quantity is within 2%. Thus, relative errors in the model are small (see Table 1).

TABLE 1 Emulation and Real Data and Relative Errors

Year	Total enterprise quantity			GDP			Total population		
	Emulation	Real	Error	Emulation	Real	Error	Emulation	Real	Error
2005	2793	2836	1.50%	198067	184937.4	7.10%	130477	130756	0.21%
2006	3093	3152	1.87%	227770	216314.4	5.30%	131085	131448	0.28%
2007	3435	3453	0.51%	261681	265810.3	1.55%	131651	132129	0.36%
2008	3827	3850	0.58%	300577	314045.4	4.29%	132179	132802	0.47%
2009	4279	4292	0.29%	345350	340506.9	1.42%	132669	133474	0.60%

4.3.2 Mean Square Percentage Error

The mean square index for the relative error of variables in periods is used to calculate the mean square percentage error of variables (see Table 2). In the equation, e_i represents the mean square percentage error of variable i , and e_{it} represents the relative error of emulation data to real data that are associated with variable i in year t , and i ($i = 1, 2, 3\dots$) represents variable i , and t ($t = 2000, 2001\dots2020$) represents year t :

$$e_i = \sqrt{\sum_1^n e_{it}^2 / n}$$

TABLE 2 Mean Square Percentage Error

Variable	Error
Total enterprise quantity	0.89%
GDP	2.62%
Financial expenditure	4.80%
Total population	0.29%
Tax	4.82%
Fixed assets	18.07%
Educational investment	3.72%
R&D investment	4.81%
Financial revenue	4.62%
Mining industry	3.57%
New enterprises	3.65%
Bankrupt enterprises	2.78%

Similarly, emulation results could be considered as having good predictability if the value of mean square percentage error e_i for more than 70% of variables is less than 5% and the mean square percentage error for all variables is within 10%.

It can be seen from the above table that mean square percentage errors of all variables are within 5%, and only e_i for fixed assets investment is 18.07%.

5 Model emulation results and conclusions

It is expected that the quantity of small and medium-sized enterprises in China will be 181,129,000 by the year of 2020, which is increased by 138,209,000 from 42,920,000 in 2009 and at the composite annual growth rate of 12.7485%. GDP will be RMB 171.653 trillion by the year of 2020, which is increased by RMB 137.6024 trillion from RMB 34.0506 trillion in 2009 and at the composite annual growth rate of 14.4311%.

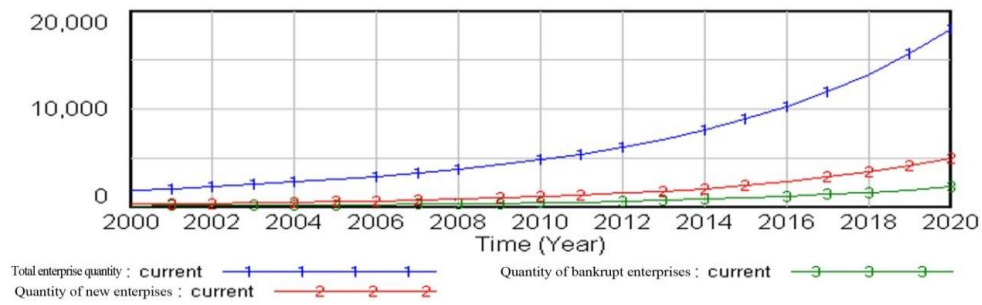


FIGURE 3 The Emulation Result for Quantity of Small and Medium-sized Enterprises

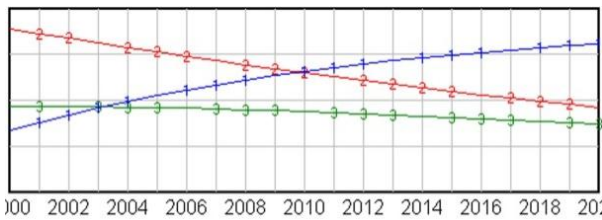


FIGURE 4 The Emulation Result for Population Quantity(1:Total, 2:Birth, 3:Death)

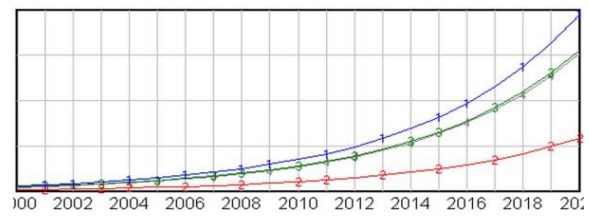


FIGURE 5 The Emulation Result for Finance(1:Educational, 2:R&D, 3:Expenditure, 4:Revenue)

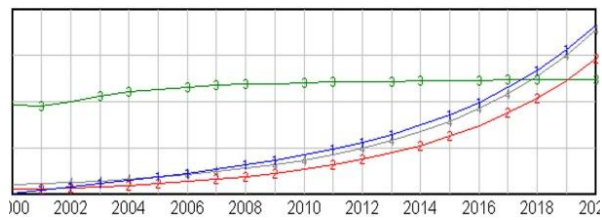


FIGURE 6 The Emulation Result for the Establishment Rate of Enterprise(1:HR, 2:R&D, 3:Dependency, 4:SMEBR)

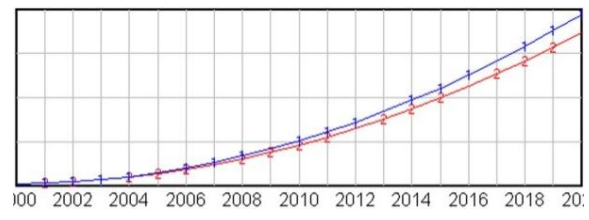


FIGURE 7 The Emulation Result for Resource Dependency(1:Assets investment in mining, 2:Total)

The quantities of birth population and death population are decreasing annually, but the decrease of birth population is obviously larger than the quantity of death population. Thus, the total population is still increasing but at a growth rate that slows down gradually.

The establishment rate of new enterprises increases with constantly improved levels of human resources and technical innovations, but the resource dependency index is basically kept unchanged. The level of human resources is influenced in its way of increasing by slowdown of the population growth, and this causes slowdown of the growth of new small and medium-sized enterprises. The quantity of R&D investment is then influenced indirectly through the feedback loop, leading to a slight prevention effect. This can be seen from distance variation of the curve representing levels of technical innovations and human resources. The growth of educational investment also slows down due to the effect of level of human resources, but not significantly.

Taxes keep growing synchronously with GDP. Tax rates are increasing but to a small extent from a statistic view, so it is believed that model parameters are reasonable and effective.

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