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Constructing the index system of Innovation-oriented country in China

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ABSTRACT

Considering the outstanding competitiveness of science and technology, almost every country wants to be predominant. The major interest of this paper is to deal with Chinese case. From a great deal of figures, we know that our country hasn't got the advantage to take this lead, but there are many contradictions to be solved immediately. Therefore, building up the Innovation-oriented country with Chinese own characteristic, must become the urgent political choose. In this paper, we establish a simple system of indicators of Innovation-oriented country according to its signification and feature. We use the principal component analysis of the multivariate statistics to measure the model, and use the GM(1,1) to forecast the index of the following years, which is used to measure the process of building Innovation-oriented country in China . At last, we point out some problems and counterpart suggestions.

Key words: Innovation-oriented country； the system of indicators; principal component analysis; GM(1,1)

1. Introduction

At the beginning of 21 centuries, nations all over the world release development strategies which regard science and technology as the center point, for example: The United States hasten scientific knowledge area to lead completely; Japan is to be a state based on science and technology and intelligent property right; Another developing country similar with China, India, its new technique policy also starts to draw up in 2003.

Nowadays, the period of industrialization of the science and technology results is shortening continuously, therefore in some newly arisen science areas, almost all the countries are placed in a much the same start point, developing countries are possible to get breakthrough and bring up development in the related industries, then carry out the whole leap of national competitiveness. That is why China should take the Innovation-oriented country as urgent political choose. President Hu Jintao urged that, *"The science and technology development target of the coming 15 years(2006-2020) is: build up an Innovation-oriented country by 2020, make science and technology development become the strong support of the economic society"*, at the Fourth National Conference on Science and Technology held in Beijing, capital of China, on Jan. 9, 2006.

As to the research of Innovation-oriented country, the characteristics about it have been confirmed, but not yet the way to measure the process. The purpose of this paper is twofold. First is try to find out a simple way to construct an index system according to its characteristics. Second is to deal with the Chinese case, try to figure out a suitable model to measure the steps of building up the Innovation-oriented country in China.

This paper is organized as follows: the identification and the characteristics of Innovation-oriented country are described in section 2.This section also gives comparison among three related terms: Innovation-oriented country, self-innovation and national innovation system. In section 3, map out the index system and explain the variables. Section 4 contains the model figured out by principal component analysis, and the forecast value of following years which can be used to measure the steps for China to construct the Innovation-oriented country, while conclusions are drawn follow. In the last section, we point out some real problems in the process and counterpart suggestions.

2. The identification of Innovation-oriented country

For more than 50 years, many countries have different starting points to seek to achieve industrialization and modernization. The Ministry of Science and Technology experts of China clearly pointed out only three roads: national resource, dependent and innovative to choose.

Resource countries are mainly relying on its own abundant natural resources, to increase national wealth. Middle-east countries relying on the oil are served as examples, like Iraq. China, as seen abundant with labor forces, is a resource country at present.

Dependent countries are mostly dependent on the developed economies, in the areas like capital markets and technologies. Typical examples are Latin American counties such as Mexico and Argentina.

Innovation-oriented countries are countries focus on the science and technology advantage. Currently there are 20 countries around the world who are an internationally recognized innovative countries, including the United States, Japan, Finland and South Korea.

The common features of Innovation-oriented countries are stated as four main characteristics:

First, the contribution rate of scientific and technological progress is more than 70%;

Second, the research and development investment as a proportion of GDP is 2% or more;

Third, the dependence on foreign technology rate below 30%;

Fourth, the three patents (the United States, Europe and Japan granted the patent) in these countries account for 97% of the total amount of the world.

2.1 Innovation-oriented country; self-innovation; national innovation system

"what leads to develop is the scientific development view, concrete implement path is called self-innovation, and the target is innovation-oriented country" said by Guanhua Xu, the minister of the Ministry of Science and Technology of China. Therefore we need to make clear three important and related terms: Innovation-oriented country, self-innovation and national innovation system.

Innovation-oriented countries are increasingly relying on technological innovation to get competitive advantage.

The U.S. citizen Austria economist Joseph Schumpeter, is often thought of as the first economist to draw attention to the importance of innovation. He defines five types of innovation, (i)introduction of a new product or a qualitative change in an existing product; (ii)process innovation new to an industry; (iii)the opening of a new market; (iv)development of new sources of supply for raw materials or other input; (v)changes in industrial organization. That is to build up a new production function, lead the new thought and the new method into the economic activities to carry out a new combination of production factors. Promote it to the national level, self-innovation is the central part of adjusting an industrial structure and changing the growth mode.

National Innovation System (NIS) is defined *as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies"*. (Freeman, 1987) It can be viewed as the last type of innovation—changes in industrial organization, which emphasizes the system arrangement and the interactions of each individual in the system. Depending on their own politics, history and economic system, all nations have different levels of innovation results and the combination degree of the science and technology activity and the economy activity, which constitute the special features of NIS of each country. As a result, our country needs to set up the Chinese characteristic National Innovation System.

In a word, there exists a very strong inner relation among these three terms: To build an Innovation-oriented country is the goal; Self-innovation is the concrete path which attains the goal; National Innovation System then, is the organization system in order to build up Innovation-oriented country, the activity principle of that system would be carry on self-innovation.

3. Constructing the index system of Innovation-oriented country

To go deep into the process of building Innovation-oriented country, we need to know which steps we are now or sometimes do comparison with other nations, then need to figure out some methods to measure this process. This paper is trying to constructing the index system of Innovation-oriented country to solve this problem.

According to the identification and the features of innovation-oriented country, also consider for the availability of the data, this index system contains 4 first-class indexes, 8 second-class indexes, and finally 9 third-class variables.

— *Potential resources in technology and economic:* this stands for the resource we have at present, which will contribute to the innovation activities later. It contains 2 second-class indexes:

  — Human capital storage: considering the amount of people who work on innovation activities, in possession of knowledge, skill and experience,

  X1: Aggregate Personnel employees in research and development in china

  — Economic resource storage: considering the overall accumulated level of domestic economic resource, can be easily evaluated by GDP per capita, it contains variable:

  X2: GDP per capita (yuan)

— *Activities of technological innovation:* this can be simply measured by the input of science innovation of both national and company's individual activities. It contains 2 second-class indexes:

  — National activities: considering the innovation activities centralized on the issues of the whole nation and funded by the government, it contains variable:

  X3: The percentage R&D investment account for GDP(%)

  — Company's individual activities: considering the innovation activities centralized on the issues of the companies, from which gain more profit, it contains variable:

  X4: The ratio between technology import and assimilation (%)

  X5: The ratio between R&D expenditure funded by private industry and funded by nation

— *Output capacity of technological innovation:* this reflects the real results produced by various combinations of factors, which is the most direct and most important index to evaluate the innovation ability of techniques. It contains 2 second-class indexes:

— Science and technology results: considering the amount of creative results in science and technology field, it contains variable:

X6: Registered number of scientific and technological achievements (piece)

— The patents applied: considering the inventions which applied for the patents, it contains variable:

X7: Number of patent application (piece)

— *Environment of innovation:* in a give condition of the policy system and the science and technology devotion, the exterior environment will has deep and complicated influence on the innovation capacity. It also contains 2 second-class indexes:

— Protection for the Intellectual Property: considering the patents which authorized officially, measures the protection power over the intellectual property, it contains variable:

X8: Number of authorized patent (piece)

— Financial support: considering the financial expenditure used for science research and technology development, measures the support power over the field of science and technology, it contains variable:

X9: The state financial expenditure for scientific research (a hundred million)

4. Empirical analysis

Now the index system has been constructed, the following work would be achieve the other purpose, deal with the Chinese case, try to estimate a suitable model to measure the steps of building up the Innovation-oriented country in China.

This paper we employ the principal component analysis to measure the model in the statistical software SPSS, with the 5-year datum from 1999 to 2003. As the model been figured out, we can get the scores of each year, which can be applied to the GM(1,1) model to predict the following years' Innovation-oriented country index scores. Then those predicted scores are to measure the steps of constructing Innovation-oriented country for China.

So this empirical analysis is divided into three parts, the first is applying the principle component analysis to measure the model, the second is applying GM(1,1) to forecast the following years' scores for Innovation-oriented country index, and the last part of this section is some conclusion drawn from the analysis, that is to measure the steps based on the predicting values.

4.1 Apply the principal component analysis to measure the model

Factor analysis, including both principal component analysis and common factor analysis, is a statistical approach that can be used to analyze interrelationships among a large number of variables and to explain these variables in terms of their common underlying dimensions (factors).

The objective of factor analysis is to find a way of condensing the information contained in a number of original variables into a smaller set of variables with a minimum loss of information.

Factor analysis differs from the dependence techniques (i.e, multiple regression discriminant analysis, multivariate analysis of variance, or canonical correlation) in which one or more variables are explicitly considered the criterion or dependent variables and all others are the predictor or independent variables. Factor analysis is an interdependence technique in which all variables are simultaneously considered, each related to all others, and still employing the concept of the variates, the linear composite of variables. [1]

The common factor and component analysis models are both widely used. The selection of one model over the other is based on two criteria: (1) the objective of the factor analysis; (2) the amount of prior knowledge about the variance in the variables.[2]

In this paper, we apply the principal component analysis because the primary concern is about prediction and we want the minimum number of factors to account for the maximum portion of the variance represented in the original set of variables.

We will use statistical software SPSS to do analysis and draw the 5-year (1999-2003) datum from the Year Book as Tabel 1 in the Appendix shows. To eliminate the dimension factor, first we need to standardize the original datum. The variables $X_1, X_2, \cdots, X_9$ are transferred to $ZX_1, ZX_2, \cdots, ZX_9$.

[1] P91, Hair, Joseph F. Jr. (1998),*Multivariate Data Analysis*, Englewood Cliffs, N.J. ; London : Prentice Hall
[2] P102, Hair, Joseph F. Jr. (1998),*Multivariate Data Analysis*, Englewood Cliffs, N.J. ; London : Prentice Hall

Stage 1

Factor analysis procedures are based on the initial computation of a complete table of intercorrelations among the variables (correlation matrix). Therefore the first step is a visual examination of the correlations, identifying those that are statistically significant. Table 4.1.1 shows the correlation matrix for the nine indicators of Innovation-oriented country. We can conclude from it, these 9 variables are highly correlated as the correlations are mostly bigger than 0.8. It provides an adequate basis for proceeding to the next stages, because factor analysis is an interdependence technique in which each variable related to all others.

Table 4.1.1 Correlation Coefficient Matrix

	Zx1	Zx2	Zx3	Zx4	Zx5	Zx6	Zx7	Zx8	Zx9
Zx1	1.000	.983	.998	.909	.982	-.428	.984	.888	.956
Zx2	.983	1.000	.978	.860	.996	-.413	.999	.947	.991
Zx3	.998	.978	1.000	.905	.980	-.473	.982	.874	.954
Zx4	.909	.860	.905	1.000	.884	-.469	.847	.676	.802
Zx5	.982	.996	.980	.884	1.000	-.479	.993	.921	.988
Zx6	-.428	-.413	-.473	-.469	-.479	1.000	-.419	-.194	-.450
Zx7	.984	.999	.982	.847	.993	-.419	1.000	.947	.991
Zx8	.888	.947	.874	.676	.921	-.194	.947	1.000	.958
Zx9	.956	.991	.954	.802	.988	-.450	.991	.958	1.000

Stage 2

The second step is to select the number of components to be retained for further analysis. This step is according to the adequacy examination on both overall basis and for each variable.

In deciding when to stop factoring, the researcher generally begins with some predetermined criterion, such as the percentage of variance or latent root criterion, to arrive at a specific number of factors to extract. …The factoring procedure usually should not be stopped until the extracted factors account for at least 95 percent of the variance or until the last factor accounts for only a small portion.[3]

As to the overall basis examination, we use the percentage of variance criteria. Table 4.1.2 contains information of the two component extracted by the constraint which eigenvalue is bigger than 0.6. It also illustrate the components' relative explanatory power expressed by their eigenvalue: the variance achieves 96.070%, that is, the two principal components can carry 96.070% of the original information, thereby we can believe these two components give an adequate description of the whole datum.

Table 4.1.2 Extraction of Component Factors

Component	Extraction Sums of Squared Loadings		
	eigenvalue	% of Variance	Cumulative %
1	7.761	86.233	86.233
2	.885	9.836	96.070

Extraction Method: Principal Component Analysis.

As to the examination for each variable, we can check the communality matrix. Table 4.1.3 provides summary statistics detailing how well each variable is "explained" by the two components. Take the first number in the matrix for example, this number 0.981 means that the first standard variable can be explained 98.1%by the extracted two components. We can see from the table that these two components can explained each variable very well, because all the communalities are excess 0.8 and even most of them can achieve 0.95.

[3] P104, Hair, Joseph F. Jr. (1998),*Multivariate Data Analysis*, Englewood Cliffs, N.J. ; London : Prentice Hall

Table 4.1.3 Communality

Standardized variable	Extraction
Zx1: aggregate personnel employees	.981
Zx2: GDP per capita	.998
Zx3: R&D/GDP	.978
Zx4: ratio between technology import and assimilation	.808
Zx5: ratio between R&D expenditure funded by private industry and by nation	.997
Zx6: registered number of scientific and technological achievements	.971
Zx7: number of patent application	.996
Zx8: number of authorized patent	.945
Zx9: state financial expenditure for scientific research	.972

Extraction Method: Principal Component Analysis.

Stage 3

As far as the components are extracted, the correlation matrix is then transformed through estimation of a factor model to obtain a component matrix (Table 4.1.4). The first and second component columns stand for the correlation coefficients between the extracted components and the variables. We can see from the table, the first component get the larger number, that is to say the first component is highly related with the original variables, indicating that the first component reflects almost all the information. This conclusion is equivalent to Table 4.1.2, where we can conclude that the first component carries 86.233% of original information.

Because the goodness of the first component performed, we will only concern this component in the following sections.

Table 4.1.4 Component matrix

Standardized variable	Component	
	1	2
Zx1: aggregate personnel employees	.990	.032
Zx2: GDP per capita	.996	.082
Zx3: R&D/GDP	.989	-.017
Zx4: ratio between technology import and assimilation	.889	-.135
Zx5: ratio between R&D expenditure funded by private industry and by nation	.999	.002
Zx6: registered number of scientific and technological achievements	-.479	.861
Zx7: number of patent application	.995	.078
Zx8: number of authorized patent	.915	.329
Zx9: state financial expenditure for scientific research	.984	.056

Extraction Method: Principal Component Analysis.

a 2 components extracted.

Stage 4

Now that we have got the component matrix, we can calculate factor scores for the first component. Draw the component function from Table 4.1.4,

PCR1=0.990zx1+0.996zx2+0.989zx3+0.889zx4+0.999zx5-0.479zx6+0.995zx7
+0.915zx8+0.984zx9,

And put in the standardized original datum, then we can get the factor score of the first component, which could be substituted for the original 9 variables in other analysis. It is showed in the Table 4.1.5.and the time-series plot 4.1.5.

Table 4.1.5 Scores

	1999	2000	2001	2002	2003
PCR1	-9.68	-5.05	-0.02	4.76	9.98

4.2 Apply GM(1,1) to forecast the following years' scores

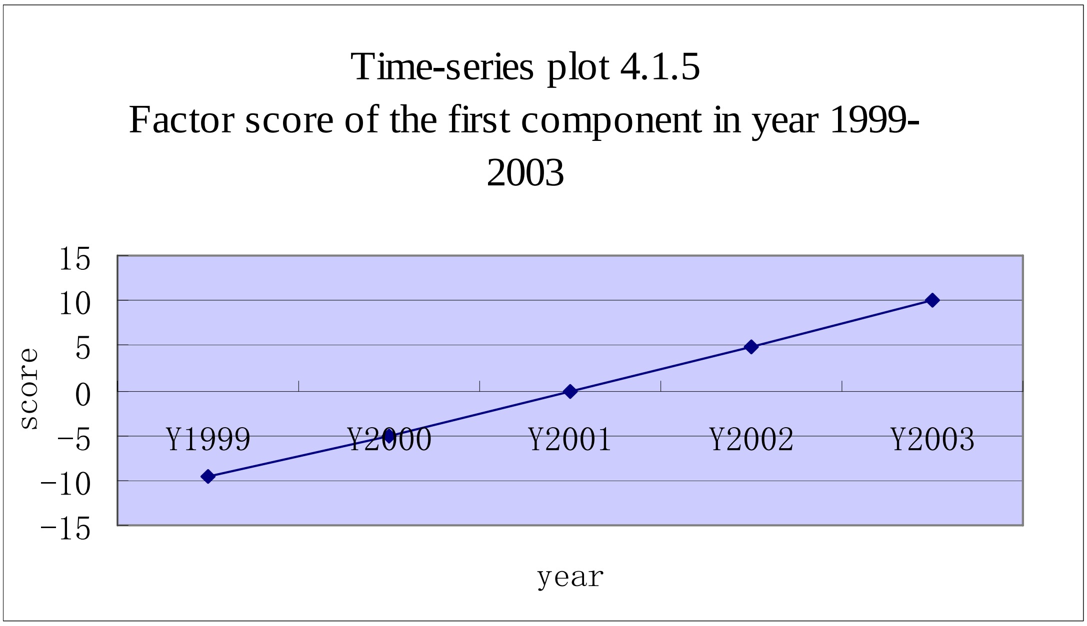
GM(1, 1), the series predicting method in Gray Model concerning one variable and one order differentiation, is applied here to estimate the Innovation-oriented country index of the following years. This model is based on the random original time series, which the newly time series is accumulated from. The orderliness presented in the newly accumulated series can be approached by the solutions of the one-ordered linear differential equations. Its feature is data number unlimited, as well as need not to get rid of factors uncomparable. The GM(1,1) model always act as good satisfaction in the accuracy request, and the estimate result is higher credibility. But the shortage is the accuracy will lower gradually, along with the propulsion of the predicting time.

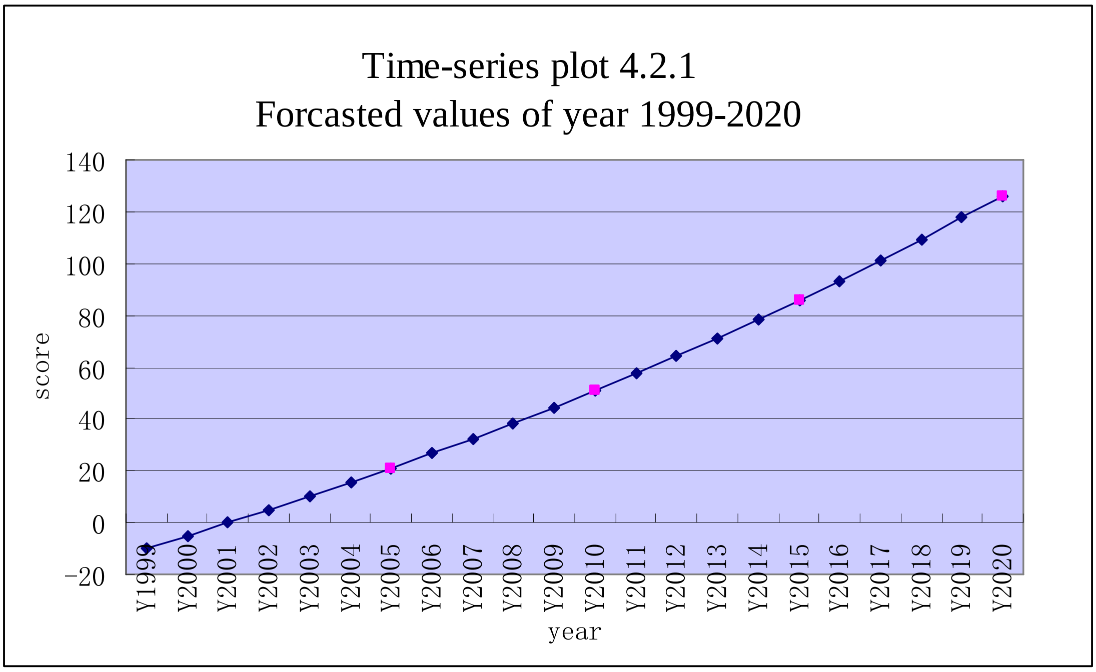
We pick up the increase amount of the first principal component score PCR1 to apply the GM(1,1), the steps are stated in the Appendix II, according to the book *The foundation of Gray Model*, written by Julong Deng.

Finally we can get the forecast values of the years 2004-2020 as the following table and the time-series plot show:

Table 4．2．1.　　The forecast values of 2004-2020

Year	1999	2000	2001	2002	2003	2004	2005	2006
Increase amount	0	4.72	4.86	5.01	5.16	5.32	5.48	5.65
Forecast value	-9.68	-4.96	-0.10	4.92	10.08	15.40	20.88	26.53
Year	2007	2008	2009	2010	2011	2012	2013	2014
Increase amount	5.82	6.00	6.18	6.36	6.56	6.76	6.96	7.17
Forecast value	32.35	38.34	44.52	50.88	57.44	64.20	71.16	78.33
Year	2015	2016	2017	2018	2019	2020		
Increase amount	7.39	7.61	7.84	8.08	8.33	8.58		
Forecast value	85.72	93.33	101.18	109.26	117.59	126.17		


Time-series plot 4.1.5
Factor score of the first component in year 1999-2003
15
10
5
0
−5
−10
−15
score
Y1999
Y2000
Y2001
Y2002
Y2003
year


Time-series plot 4.2.1
Forcasted values of year 1999-2020
140
120
100
80
60
40
20
0
−20
score
Y1999
Y2000
Y2001
Y2002
Y2003
Y2004
Y2005
Y2006
Y2007
Y2008
Y2009
Y2010
Y2011
Y2012
Y2013
Y2014
Y2015
Y2016
Y2017
Y2018
Y2019
Y2020
year

4.3 Conclusion from the empirical analysis

We have got the forecast values of Innovation-oriented country index, now the major interest is if those values will be match with the task, to build up an Innovation-oriented country by 2020 as President Hu Jintao urged.

Three steps of these 15 years plan, each step ranges each 5 years, can be mapped out by the forecast value of Innovation-oriented country index:

The first step from the year 2006 to 2010 needs to assure the index increase from 20.88 to 50.88, the amplitude is 30.00, and in these 5 years the index must increase by 143.68%;

The second step from the year 2010 to 2015 needs to assure the index increase from 50.88 to 85.72, the amplitude is 34.84, and in these 5 years the index must increase by 68.47%;

The third step from the year 2015 to 2020 needs to assure the index increase from 85.72 to 126.17, the amplitude is 40.45, and in these 5 years the index must increase by 47.19%.

These results measure the target value for China to build the Innovation-oriented country. And all these empirical investigation indicates that China has a long way to achieve the goal.

5. Some problems to build the Innovation-oriented country in China and counterpart suggestions

5.1. Human resource in science and technology

Although the total amounts of science and technology human resource and persons in R&D area in our country are reside in the first and the second place in the world respectively, the sharp sub- talented person is short of, and the innovation ability of science and technology is not strong;

Concretely say, the counterparts solutions for this problem can be divided to three parts: first in the business enterprises, we can carry out plans, such as "talented person project" and "innovation team"...etc. , promote to usher in the innovation talented persons, program the steps to carry out the innovation-oriented strategy; second in the high schools and the research institutes, establish the base of the training talented persons with innovation spirit, and strengthen contact with business enterprises to transport science and technology talented persons they need; Also need to lay equal stress on science and technology universality with science and technology innovation, enhancing the self-innovation consciousness of the whole societies, extending the social foundation of science and technology innovation.

5.2. Devotion of R&D

Science and technology devotion is still not enough. The level of present percentage of R&D accounts for GDP equals to that of the mid and late 1960s in Japan and the mid 1980s in Korea.

The solution must be enlarge the devotion strength of science and technology, and diversify devotion outlets, to form the effective mechanism of the interactions between technique and the capital, then provide the strong material foundation and the financial power guarantee for the self-innovation. For example, build up the stable growth mechanism of financial devotion in science and technology, and establish diversiform and multi-layers systems of the financial capital market, lead and encourage social resources to devote in the innovation activities of science and technology.

5.3. Evaluation system of Innovation-oriented country

Lack of evaluation system makes us lost in the process of building Innovation-oriented country.

We have to establish an evaluation system of Innovation-oriented country in time, used for evaluating the process in our country and make comparison with other countries. For example, we need to discuss the reasonable proportion among the original innovation, integrate innovation and digest and absorb innovation; need to map out target value of each stage of building the Innovation-oriented country.

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APPENDIX I

Table 1. Datum of 9 variables

	X1	X2	X3	X4	X5	X6	X7	X8	X9
1999	82.2	6551	0.83	11.46	0.37	31060	134239	100156	543.85
2000	92.2	7086	1	13.48	0.39	32858	170682	105345	575.62
2001	95.7	7651	1.07	14.59	0.42	28448	203573	114251	703.26
2002	103.5	8214	1.23	14.49	0.44	26697	252631	132399	816.22
2003	109.48	9101	1.31	14.96	0.47	30486	308487	182226	975.54

Data from: 2004 Statistical Year Book of China.

APPENDIX II

Steps of applying GM(1,1) to forecast the 2006-2020 value

1. accumulate the series: $X_{(k)}^{(1)} = \sum_{i=1}^{k} X_{(i)}^{(0)}$

   $X^{(0)}$ is the original series,

   consists of $X_{(1)}^{(0)} = 4.63; X_{(2)}^{(0)} = 5.03; X_{(3)}^{(0)} = 4.69; X_{(4)}^{(0)} = 5.32$,

   $X^{(1)}$ is the accumulate series,

   consists of $X_{(1)}^{(1)} = 4.63; X_{(2)}^{(1)} = 9.66; X_{(3)}^{(1)} = 14.35; X_{(4)}^{(1)} = 19.67$.

2. fix the matrix by $\frac{dX^{(1)}}{dt} + aX_{(t)}^{(1)} = u$

$\hat{a} = \begin{bmatrix} a \\ u \end{bmatrix} = (B^T B)^{-1} B^T X_n$,

$$B=\begin{bmatrix}-\frac{1}{2}(X_{(1)}^{(1)}+X_{(2)}^{(1)})M1\\ -\frac{1}{2}(X_{(2)}^{(1)}+X_{(3)}^{(1)})M1\\ -\frac{1}{2}(X_{(3)}^{(1)}+X_{(4)}^{(1)})M1\end{bmatrix}=\begin{bmatrix}-7.145M1\\ -12.01M1\\ -17.01M1\end{bmatrix},$$

$$Xn=\begin{bmatrix}X_{(2)}^{(0)}\\ X_{(3)}^{(0)}\\ X_{(4)}^{(0)}\end{bmatrix}=\begin{bmatrix}5.03\\ 4.69\\ 5.32\end{bmatrix}.$$

3. calculate the parameters:

$$\hat{a}=\begin{bmatrix}a\\ u\end{bmatrix}=(B^TB)^{-1}B^TX_n=\begin{bmatrix}-0.02988\\ 4.653222\end{bmatrix}$$

a=-0.02988, u=4.653222

4. fix the model:

$$\hat{X}_{(k+1)}^{(1)}=(X_{(1)}^{(0)}-\frac{u}{a})e^{-ak}+\frac{u}{a}=(4.63-\frac{4.653222}{-0.02988})e^{-(-0.02988)k}+\frac{4.653222}{-0.02988}$$

And we can get the forecast value,

$$\hat{X}_{(5)}^{(1)}=24.98846,\hat{X}_{(4)}^{(1)}=19.66853,\hat{X}_{(3)}^{(1)}=14.5052,\hat{X}_{(2)}^{(1)}=9.493846,\hat{X}_{(1)}^{(1)}=\hat{X}_{(1)}^{(0)}=X_{(1)}^{(0)}=4.63$$

5. test the forecast value

$$\delta_i=\frac{\left[x_{(i)}^{(1)}-\hat{x}_{(i)}^{(1)}\right]}{x_{(i)}^{(1)}},$$ where $|\delta_i|$ is less than 5% can pass the test,

We can calculate out $\delta_2=1.72\%,\delta_3=-1.08\%,\delta_4=0.00\%$, therefore it can be passed.

6. reduce by $\hat{X}_{(k+1)}^{(0)}=\hat{X}_{(k+1)}^{(1)}-\hat{X}_{(k)}^{(1)}$ and get

$$\hat{X}_{(5)}^{(0)}=5.319923,\hat{X}_{(4)}^{(0)}=5.163333,\hat{X}_{(3)}^{(0)}=5.011353,\hat{X}_{(2)}^{(0)}=4.863846,\hat{X}_{(1)}^{(0)}=4.63$$

7. the final model for forecasting $\hat{X}_{(k+1)}^{(0)}=\hat{X}_{(k+1)}^{(1)}-\hat{X}_{(k)}^{(1)}=4.720681e^{0.02988k}$
8. use this model to forecast the Innovation-oriented country exponent from 2004-2020.