Application Study on Regional Optimization Model of Nonlinear Dynamic Input Covering Output of Hebei Province

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Abstract—Regional optimization model of nonlinear dynamic input covering output is the new development in the field. The article uses input-output theory offered by W. Leontief. To the false problem of the existence of Leontief dynamic model investment coefficient matrix B referred by Professor Jiamo Wang as the example of Hebei Province the article combines relative yearly statistics data and constructs optimization model of nonlinear dynamic input covering output .According to this the article analyzes the best growth rate of value added, industrial structure, final requirements contribution in fixed asset investment and labor force investment in every industry in the end of "The Eleventh Five-year Plan" and puts forward to the goal of economic structure optimization development in the period of "The Twelfth Five-year Plan ".

Index Terms—nonlinear; Input covering output; dynamic optimization model; Hebei Province formatting

I. INTRODUCTION

Wassily Leontief put forward input-output analysis theory to analyze industrial development and industrial relevancy. In order to analyze the characteristics of regional industrial development and its function in national economic development constructing optimization regional model of nonlinear dynamic input covering output plays the active part not only in the theory but also in the application. Some scholars have made achievements to the problem.

A. Xikang Chen put forward and built technique of main coefficient nonlinear input covering output

When studying on nonlinear input-output model in the world the problem is more number of direct consumption coefficients, which is difficult to nonlinearization. After Xikang Chen had put forward to input covering output technique Xiuli Yu presented the ideal of main coefficient nonlinearization, the method of selecting main coefficient and building new-type nonlinear input-output model regarding direct consumption coefficient as technical progress function.

B. Professor Jinshui Zhang put forward to calculable nonlinear dynamic input-output model

Professor Zhang unified Leontief linear dynamic input-output model and calculable nonlinear dynamic general balance model and got calculable nonlinear dynamic input-output model and obtained rapid calculation method of solving balanced growth track and optimal growth track and constructed calculable nonlinear dynamic input-output model in six departments in China and calculable nonlinear dynamic input-output model of human resources in seven departments in China.

C. Professor Jiamo Wang put forward practical nonlinear dynamic input-output model

Professor Jiamo Wang thought that when using Leontief dynamic input-output equation to build economic planning model or forecast model its coefficient matrix is an upper triangular matrix, which is not indecomposable matrix. So it can not meet the need of Perron-Frobinuis theorem. On this base even if optimization model and fast

traffic lane model were built its calculation result must be anamorphic and so Professor Wang put forward practical nonlinear dynamic input-output equation from length wise input-output table.

D. Foreign scholars put forward the goal of industrial structure transform and model theory

Pieplow, R. from Germany put forward the goal of industrial structure transform and model theory; Thornton, B.S. from Australia put forward data model of industrial observational material; Hernandez, C. from France put forward industrial model design; Hodgin, R. F from U.S. studied on space market model and space industry input-output model. Matsuse Takehiro from Japan put forward new demanding department bounce model of industrial development by introducing demanding bounce inverse matrix.

II. CONSTRUCTION OF MODEL

Input-output tables in 2000,2002,2005 and 2007 in Hebei Province divides national economic industry into 42 product departments and considering possibility of data offer and calculation convenient we reduce 42 product departments to 18 product departments: The first industry（1）：agriculture；the second（4）：mining, manufacturing, product and supply industry of power, gas and water; the third industry（13）：transportation storage and post, information transmission, computer service and software, wholesale and retail trade, hotel and restaurant, finance and insurance, real- estate, rent and business service, scientific research, technical service and geology exploration and entertainment and public management and social organization. Input covering output model is as Table I.

TABLE I INPUT COVERING OUTPUT TABLE OF 18 PRODUCT DEPARTMENTS IN HEBEI PROVINCE

Output / Input / Occupation		**Middle product**				**Final product**	**Total output**
		1	***2*** …	***17***	***18***		
Middle consumption	***1***	X_{11}	X_{12} …	X_{117}	X_{118}	Y_1	X_1
	2	X_{21}	X_{22} …	X_{217}	X_{218}	Y_2	X_2
	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	17	X_{171}	X_{172} …	X_{1717}	X_{1718}	Y_{17}	X_{17}
	18	X_{181}	X_{182} …	X_{1817}	X_{1818}	Y_{18}	X_{18}
Original input		Z_1	Z_2 …	Z_{17}	Z_{18}		
Total input		X_1	X_2 …	X_{17}	X_{18}		
Covering parts	***Capital assets***	K_1	K_2 …	K_{17}	K_{18}		
	Labor force	L_1	L_2 …	L_{17}	L_{18}		

The data in model is mainly from input-output table in 2000, 2002, 2005 and 2007 in Hebei Province and refers to The Economic Yearbook of Hebei Province from 2000 to 2008 and relative data in statistics abstract of Hebei Province.

A. Parameter calculation

（1）*To calculate direct consumption coefficient matrix* $\hat{A}_t$

Coefficient calculation is $a_{ij} = X_{ij} / X_j$, a_{ij} is the number of products or service consumed directly to unit total output in i department in the middle course of consumption in j department. That is to say total input (X_j) in j department removes X_{ij} of products or service consumed directly to unit total output in i department in the middle course of consumption in this department. This matrix is diagonal matrix, in which the factors on the diagonal line are the sum of factors of Leontief direct consumption matrix corresponding line.

（2）To calculate investment coefficient matrix $\hat{B}_t$ and depreciation of fixed assets coefficient α_t

In order to calculate investment coefficient matrix $\hat{B}_t$ firstly we have non-seasonal exponential smoothing to the data of every department accumulative investment and output from 2000 to 2007 in Hebei Province and then have curve-fitting to two groups. From formula $\tilde{b}_{ti} = \Delta TZ_{it} / \Delta X_{it}$ （$\tilde{b}_{ti}$ is newly increased fixed assets investment volume needed by total output in every unit, ΔX_{it} shows newly increased total output in i department in t year, ΔTZ_{it} shows fixed assets investment in i department in t year）we can calculate capital coefficient in 2007; calculation of depreciation of fixed assets coefficient α_t is to use the ratio of depreciation of fixed assets in total output in the input-output table in the year of 2000,2002,2005 and 2007 in Hebei Province and is got by interpolation and weighted average.

（3）To calculate labor force investment coefficient matrix $\hat{C}_t$ and labor force capital occupying coefficient β_t

The method of calculating labor force investment coefficient is the same with getting capital coefficient. When we calculate newly increased labor force investment every year according to staff's average salary and the number of staff in every department every year we can calculate labor force capital in every department every year and then subtract the value of two linking years to get labor force capital input used
to extend reproduction. Using $\tilde{c}_{ti} = \Delta TC_{it} / \Delta X_{it}$ （$\tilde{c}_{ti}$ shows the amount of labor force investment needed by newly increased total output in every unit, ΔX_{it} shows newly increased total output in i department in t year, ΔTC_{it} shows labor force newly increased investment in i department in t year）we can calculate labor force investment coefficient; , is to use labour force salary in input-output table in four years to subtract labor force capital input used to extend reproduction in the relative year and we use difference to compare with total output and ratio is to have interpolation and weighted average to get the value.

III. APPLICATION OF MODEL

A. Economic structure optimization model of average and non-average growth nonlinear characteristics vendor model

From crosswise Table I the sum of middle demand and final demand is total output and there is the input-output model:

1) Basic crosswise model:

$$AX_t + Y_t = X_t \quad t = 1, 2, \cdots \qquad \text{——（3-1）}$$

From length wise Table I there is input-output model

2) Length wise nonlinear dynamic occupying output model:

$$X_t = \tilde{A}_t X_t + \tilde{B}_t \Delta X_t + \tilde{C}_t \Delta X_t + ZC_t + \alpha_t X_t + \beta_t X_t \qquad \text{——（3-2）}$$

In it from length wise Table I the sum of middle input and initial input is total input and the left of equation is total input and the right of equation is the sum of middle input and initial input.

We divide initial input into five parts: newly increased fixed assets input（$\tilde{B}_t \Delta X_t$）, newly increased labor force input（$\tilde{C}_t \Delta X$）, other initial input（ZC_t）,compensation current period fixed assets consumption input（$\alpha_t X_t$） and labor force capital occupation($\beta_t X_t$).

Average growth nonlinear characteristics vendor model

Average growth nonlinear characteristics vendor model（on the basis of model of combining dynamic and static state）

If $\tilde{D}_t = \tilde{B}_t + \tilde{C}_t$； then format（3-2）can be written:

$$X_t = (\tilde{A}_t + \alpha_t + \beta_t)X_t + \tilde{D}_t \Delta X_t + ZC_t \quad \text{——（3-3）}$$

The above format（3-3）is built vertically from input-output table and coefficient matrix $(\tilde{A}_t + \alpha_t + \beta_t)$ and $\tilde{D}_t$ of equation is formed diagonal matrix by diagonal factors. According to Professor Jiamo Wang's discussion in reference [7] we can get the following nonlinear dynamic input covering output model:

$$(\tilde{A}_t + \alpha_t + \beta_t)X_t + \tilde{D}_t \Delta X_t + ZC_t = AX_t + YC_t + YI_t + EX_t \quad \text{（3-4 ）}$$

In it ：（net output=output-input）

YC_t is inhabitants' consumption； YI_t is capital formation. The above format（3-4）can be written:

$$X_{t+1} = \tilde{D}_t^{-1}[A + \tilde{D}_t - (\tilde{A}_t + \alpha_t + \beta_t)]X_t + \tilde{D}_t^{-1}[(YC_t + YI_t + EX_t) - ZC_t] \quad \text{——（3-5）}$$

Coefficient matrix $\tilde{D}_t^{-1}[A + \tilde{D}_t - (\tilde{A}_t + \alpha_t + \beta_t)]$ of format is not strange matrix and because of satisfying non disintegration condition of P-F theorem variable ZC_t, YC_t, YI_t and EX_t of format（3-5）can be biochemistry and after it the model is as the following :

$$\begin{aligned}\tilde{D}_t \Delta X_t &= AX_t + YC_t + YI_t + EX_{tt} - (\tilde{A}_t + \alpha_t + \beta_t)X_t - ZC_t \\ &= AX_t + \delta_{ct}X_t + \delta_{it}X_t + \delta_{et}X_t - (\tilde{A}_t + \alpha_t + \beta_t)X_t - \delta_{zt}X_t \\ &= [A - (\tilde{A}_t + \alpha_t + \beta_t) + (\delta_{ct} + \delta_{it} + \delta_{et} - \delta_{zt})]X_t\end{aligned}$$

$$\Rightarrow \Delta X_t = \tilde{D}_t^{-1}[A - (\tilde{A}_t + \alpha_t + \beta_t) + (\delta_{ct} + \delta_{it} + \delta_{et} - \delta_{zt})]X_t \quad \text{——（3-6）}$$

$$D X_t = \lambda X_t \quad \text{——（3-7）}$$

In it: $YC_t = \delta_{ct}X_t \quad YI_t = \delta_{it}X_t \quad EX_t = \delta_{et}X_t \quad ZC_t = \delta_{zt}X_t$

$$\mathrm{D} = \tilde{D}_t^{-1}[A - (\tilde{A}_t + \alpha_t + \beta_t) + (\delta_{ct} + \delta_{it} + \delta_{et} - \delta_{zt})]$$

3) Non-average growth nonlinear characteristics vector model

Format（3-6） and format（3-7）are growth characteristics vector model at the same speed in every industry. But in the actual economic operation development speed in every industry is different. If pre-evaluated growth speed of 18 departments in Hebei Province respectively is as Table 2, we can select 18 departments to form speed matrix Λ and its inverse matrix is Λ^{-1} and if it is connected with format （3-6） and（3-7） we can get nonlinear dynamic characteristics vector model at the different developing speed in every industry, i.e. non-average development nonlinear characteristics vector model, which is as the format（3-8）.

TABLE II PRE- EVALUATED GROWTH SPEED OF 18 DEPARTMENTS PROVINCE

Department	1	2	3	…	15	16	17	18
Growth speed	ν_1	ν_2	ν_3		ν_{15}	ν_{16}	ν_{17}	ν_{18}

$$\Lambda = \begin{bmatrix} \nu_1 & & & \\ & \nu_2 & & \\ & & \cdots & \\ & & & \nu_n \end{bmatrix}; \quad \Lambda^{-1} = \begin{bmatrix} \frac{1}{\nu_1} & & & \\ & \frac{1}{\nu_2} & & \\ & & \cdots & \\ & & & \frac{1}{\nu_n} \end{bmatrix}$$

Then we can get non-average development nonlinear characteristics vector model;

$$\Lambda^{-1}\Delta X_t = \Lambda^{-1}DX_t = \lambda X_t \qquad \text{——} \quad (3\text{-}8)$$

B. Calculation result of model

1) Value added and industrial structure in the end of "The Eleventh Five-year Plan"and" The Twelfth Five-year Plan"

By nonlinear model and economic structure optimization model we can measure the growth speed of every department and the result of economic structure model is near to reality. According to the result in 2010 gross domestic product in Hebei Province is Yuan 1935.161 billion and the proportion of three times industrial structure is 12.51：53.16：34.33 and if it can operate according to optimal economic structure the gross domestic product is Yuan 2313.921 billion and three times industrial structure is 11.53：52.68：35.79. According to economic structure optimization model and current economic structure up to 2015 estimated gross domestic product is Yuan 3303.756 billion and proportion of industrial structure is 10.85：51.05：38.10.

2) Pulling situation of final demand to provincial gross domestic product

According to economic structure optimization model it is calculated to get contribution and pulling situation of final demand to provincial gross domestic product in Table III. We can know that the form of consumption and capital pulls economic situation obviously in Hebei Province and pull function of net output is not enough.

TABLE III CONTRIBUTION AND PULLING SITUATION OF FINAL DEMAND TO PROVINCIAL GROSS DOMESTIC PRODUCT IN 2010

	Consumption in 2010	**Capital form in 2010**	**Net output in 2010**
Contribution rate（%）	44.84	43.54	11.69
Pull（%）	5.43	5.27	1.41

3) Contribution of fixed assets investment and labor force investment inevery industry and department

From Table IV obtaining output value of inputting one unit labor capital is quite bigger than it of inputting one unit fixed assets and every industry should assort reasonably fixed capital resources and labor force resources to attain effective allocation and improve industry development.

TABLE IV CONTRIBUTION SITUATION OF FIXED ASSETS AND LABOR FORCE ASSETS TO VALUE ADDED IN 2010

	Limit contribution rate of fixed assets depreciation（%）	**Limit contribution rate of net investment（%）**	**Contribution rate of labor force occupation（%）**	**Limit contribution rate of labor force capital（%）**
The first industry	1.54	2.54	0.87	12.59
The second industry	0.69	0.58	0.30	16.35
The third industry	0.69	1.95	0.40	68.14

IV. CONCLUSION

A. Evaluation of model

Model realizes nonlinear. The model can imitate economic development phenomenon in every department and has ideal forecast to economic development in every department in future.

Not only model can contribute to study on investment in every department but also it contains occupation in every department and it also can study on contribution of occupation to its department development to make the economic content of model more complete.

The model can imitate final requirements (consumption, capital formation and net export) and total output.

Mathematics concept is very strict and solve of model is unique and stable; calculation is simple and convenience and has strong operability.

B. The disadvantages of model

Although the model contains in the production (capital assets investment) and L (labor force capital investment), but technical progress does not consider the function of growth.

Having curve imitation to initial data needs to make initial data smooth and deleting irregular changing factors and it needs to have further discussion that the result can imitate current economic activity regulation or not.

Calculating labor force occupation of industry department is to use product of employee's average salary and the number of employees in every department as occupation of total labor force capital and when calculating contribution rate of labor force investment it can have a little gap with reality.

ACKNOWLEDGMENT

The project supported by Hebei Province Natural Science Funds; Industry Optimization System Theory and Application Based on Nonlinear dynamic Input-Output Expansion Technology; No. F2008001220.

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RÉSUMÉ

Hui Song, male, 55 years old, who is a boffin and director in Statistics Science Institute of Statistics Bureau of Hebei Province. He studies mainly on national economic accounting and analysis on input-output and his works published include "Study on Model of Industrial Structure and Department Development ", "The Influence of Science and Technology Advancement to Upgrading of Chinese Industrial Structure from input-output Model" and so on.