CSCanada
Management Science and Engineering
Vol. 7, No. 2, 2013, pp. 16-23
DOI:10.3968/j.mse.1913035X20130702.1824
ISSN 1913-0341 [Print]
ISSN 1913-035X [Online]
www.cscanada.net
www.cscanada.org

The Variation Tendency Analysis on Contribution Rate to Economic Growth by Production Factor Input in China

LI Xuanyu[a],*

[a] Tianjin Binhai Comprehensive Development Institute, Tianjin 300456, China.
* Corresponding author.

Received 11 March 2013; accepted 24 April 2013

Abstract

The economic growth is influenced by two factors, input of production factors and social production efficiency. The input of production factors is the premise and foundation of economic growth. The previous academic studies generally use the production functions to derive quantitative description of contributions and all kinds of production factors input have contributed to economic growth. Based on translog production function, measuring the contribution rate of capital, labour and energy to economic growth in China, will absolutely be able to reveal their variation trendencies, as well as the changing path of the growth model in China.

Key words: Production factors; Production Functions; Contribution rate; Variation Tendency

LI Xuanyu (2013). The Variation Tendency Analysis on Contribution Rate to Economic Growth by Production Factor Input in China. *Management Science and Engineering, 7*(2), 16-23. Available from: http://www.cscanada.net/index.php/mse/article/view/j.mse.1913035X20130702.1824 DOI: http://dx.doi.org/10.3968/j.mse.1913035X20130702.1824

INTRODUCTION

With the successive deepening of reform and opening up, China has achieved economic bloom and high increasing rates of development. In this process, all kinds of production factors input structure, organization and allocation efficiency are adjusted and changed profoundly. The contributions to economic growth exhibit shifting tendencies. A scientific analysis on these tendencies may help us understand the driving force of "China style" economic growth and comprehend its inherent characteristics. In this circumstance, the present study analyzes the contribution rate of the variation tendency on economic growth.

1. ANALYSIS ON ECONOMIC GROWTH INFLUENTIAL FACTORS

The economic growth is a macro and long-term development concept, usually referring to increasing amount of total output for a specific country or region in a certain period. The economic growth is related to many aspects, such as social production, consumption and distribution. It is also influenced by many factors, like economy, politics, culture and environment. These factors that mutually cross and permeate have comprehensive impact on the entire social and economic development process. It will affect not only the quantity but also the quality of economic growth. Therefore, the research on the influencing factors of economic growth has always been a hot topic in the field of economics.

Having been referring the economic growth experiences and features of developed capitalism countries, the receiver of 1971 Nobel Prize in Economics Simon Kuznets pointed out that the economic growth influential factors for one nation include 3 aspects, which are the increment of knowledge stock, improvement of production efficiency and industry structure modification (Barro & Martin, 2012).

The receiver of 1987 Nobel Prize in Economics Robert Solo summarized the factors of influencing economic growth to three aspects: capital, labor force and technological progress, having a particular emphasis on the key role of technological progress on economic growth.

The American famous economist Denison is called the father of growth accounting and growth factors analysis.

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His outstanding contribution is the theoretical analysis and calculation to the factors of economic growth, as well as his studies of economic growth factors in developed countries or regions such as the United States, Western Europe and Japan. Denison asserts that the economic growth influential factors briefly include two aspects, one is the factor input mainly capital and labor force, the other is the total factors productivity mainly influenced by three elements: technological progress, the allocation of resources, economies scale (Barro & Martin, 2012).

Upon the above researches, many subsequent scholars have also done a lot of researches on this issue, their conclusions can be summarized as the following three aspects (Gu Mei, 2010): Firstly, production factors input is the foundation of economic growth; Secondly, the technological progress is the fundamental driving force of economic growth; Thirdly, the function of technology progress to economic growth is reflected on social productivity improvement.

For quantitative description of each factor influence to economic growth, the academies have also conducted many researches, among which the establishment of production function model via input-output method is one of the most commonly used methods. The production function model can describe the relationship between the various input production factors and social total output in a certain period of social production. Further, the economic growth influential factors and its development laws are revealed via this input-output analysis.

2. THE NORMAL PRODUCTION FUNCTION MODEL COMPARISON

The normal production function models mainly include the Cobb - Douglas production function, constant elasticity of substitution production function, variable elasticity of substitution production function and the translog production function (Li & Li, 2012).

2.1 The Cobb - Douglas Function (C-D function)

The Cobb - Douglas function is also called C - D function, it is a kind of production function widely used in contemporary western economics, is referred in the book *The Theory of Wages* by the American mathematician Charles Cobb and economist Paul Douglas in 1928. The general form of C - D function is:

$$Y=f(L,K)=AL^{\alpha}K^{\beta}$$

In this formula, Y represents the output value, K and L respectively mean capital and labor input, A is the production conversion factor, α, β represent the elastic coefficient of capital and labor inputs respectively, this equation reflects the relationship between the various factors and economic growth.

Based on C - D function, Hicks, Tinbergen and Solow et al raised production function model respectively, among which the Solow growth function model is most frequently applied. This model assumes that the technological progress is not embodied in capital or labor, its general form is $Y=A_t f(K,L)$, in which A_t is the technology level in t period. Solo derives the following equation by linearized the model through data dispersion.

$$y=a+\alpha k+\beta l$$

"y" is the output growth rate; k is growth rate of capital investment amount; l is the growth rate of labor input, α is the growth rate of technology progress.

2.2 The Constant Elasticity of Substitution Production Function (Ces Function)

The constant elasticity of substitution production function is proposed by the 4 scientists: Arrow, Chenery, Mihas and Solow in 1961, its basic form is as followed:

$$Y = A(\delta K^{-\rho} + \mu L^{-\rho})^{\frac{-1}{\rho}}$$

Where, A is the efficiency coefficient, δ is capital allocation ratio that represents the capital concentration in same technology level, μ is the labor distribution rate that represents the labor concentration in same technology level, and $\delta+\mu=1$; $\rho = \frac{1-\sigma}{\sigma}$, $-1 \le \rho \le +\infty$, σ is named elasticity of substitution that represents the difficulties of production factors internal replacement, the formula is as followed:

$$\sigma = \frac{d(K/L)}{K/L} \div \frac{d(\frac{\partial Y}{\partial L} / \frac{\partial Y}{\partial K})}{\frac{\partial Y}{\partial L} / \frac{\partial Y}{\partial K}}$$

2.3 The Variable Elasticity of Substitution Production Function (Ves Function)

The Variable Elasticity of Substitution Production Function is proposed by Sato and Hoffman in 1968. This production function is established by considering the elasticity of substitution changes with time going over on the basis of CES function. The basic model is:

It is assumed that the input factors' elasticity of substitution σ is a linear function of time t, that is

$$\sigma = f(t) = a + bt$$

The above equation is merged in the CES function, it is derived:

$$Y = A(\delta K^{\frac{f(t)-1}{f(t)}} + \mu L^{\frac{f(t)-1}{f(t)}})^{\frac{f(t)}{f(t)-1}}$$

2.4. The Translog Production Function (TPF function)

Due to that the above production function are established under certain assumptions of input factors substitution elasticity, so it has significant limitations in practical application. Regarding this problem, in 1973 Christensen, Jorgenson and Laura proposed a more general production function that has variable elasticity of substitution: Translog Production Function, the basic form is:

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$$InY = a_0 + a_K InK + a_L InL + \frac{1}{2}a_{KK}(InK)^2 + \frac{1}{2}a_{LL}(InL)^2 + a_{KL} InK \cdot InL$$

Compared with other production function, the translog production function has the following advantages:

(1) The translog production function model has characteristics of easy estimation and strong inclusion (Li, 2000), which belongs to the Quadratic Response Surface model in term of structure. It can effectively research the mutual influence among different inputs in production function, the difference of input technology progress and the changes of technology progress with time (Zheng & Liu, 2004).

(2) The translog production function model has a more flexible function form. It can provide the approximate expression of second Taylor's series for any second differentiable real functions. In addition, the model does not apply any additional restrictions on technological progress(Zhang, 2002), so it enhances the model's reliability in a certain extent.

(3) Regarding the form of translog production function, it has more rich content than the C-D and CES production function. It not only can reflect the relationship between the output and the input factors, but also reflects the substitution relationship among the input factors, which more accurately facilitates to reveal the contribution rate of input to output.

3. THE TRANSLOG PRODUCTION FUNCTION MODEL COVERING ENERGY CONSUMPTION

3.1 Model Establishment

Regarding the above advantages of translog production function, this paper will use the translog production function model to research the variation tendencies of capital, labor force, energy consumption's contribution rate to China's economic growth. The translog production function model covering energy consumption is:

$$InY = a_0 + a_K InK + a_L InL + a_E InE + \frac{1}{2}a_{EE}(InE)^2 + \frac{1}{2}a_{KK}(InK)^2 + \frac{1}{2}a_{LL}(InL)^2 + a_{KL} InK \cdot InL + a_{KE} InK \cdot InE + a_{LE} InL \cdot InE \quad (1)$$

Where,

Y, is the economic output, normally represented by GDP (Gross Domestic Products)

K, is the capital input in economy, normally represented by capital stock.

L, is the labor force input in economy.

E, is the energy input in economy, normally presented by the total energy consumption

a_i and a_{ij} are the model parameters to be determined.

Known from formula (1), the output elasticity of capital, labor force and energy are followed:

$$\sigma_K = \frac{dY/Y}{dK/K} = \frac{dInY}{dInK} = a_K + a_{KK} InK + a_{KL} InL + a_{KE} InE \quad (2)$$

$$\sigma_L = \frac{dY/Y}{dL/L} = \frac{dInY}{dInL} = a_L + a_{LL} InL + a_{KL} InK + a_{LE} InE \quad (3)$$

$$\sigma_E = \frac{dY/Y}{dE/E} = \frac{dInY}{dInE} = a_E + a_{EE} InE + a_{KE} InK + a_{LE} InL \quad (4)$$

Where, σ_K,σ_L,σ_E represent the output elasticity of capital, labor force and energy consumption respectively.

The Solow Residual Value can be calculated upon the above analysis.

$$\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - \sigma_K \cdot \frac{\Delta K}{K} - \sigma_L \cdot \frac{\Delta L}{L} - \sigma_E \cdot \frac{\Delta E}{E} \quad (5)$$

Where, A represents the other factors have influence on economic growth besides the input factors., $\frac{\Delta A}{A}$ denotes these factors' comprehensive growth rate (Li, Zhu & Guo, 2011).

$\frac{\Delta Y}{Y}$, is economic output growth rate

$\frac{\Delta K}{K}$, is capital input growth rate

$\frac{\Delta L}{L}$, is labor force input growth rate

$\frac{\Delta E}{E}$, is energy input growth rate

The two sides of above equation are divided coincidently by $\frac{\Delta Y}{Y}$,it is derived after items transformation:

$$\frac{\Delta A/A}{\Delta Y/Y} + \sigma_K \frac{\Delta K/K}{\Delta Y/Y} + \sigma_L \frac{\Delta L/L}{\Delta Y/Y} + \sigma_E \frac{\Delta E/E}{\Delta Y/Y} = 1 \quad (6)$$

Therefore, the 3 input elements' contribution rates to economic growth are:

$$\eta_K = \sigma_K \frac{\Delta K/K}{\Delta Y/Y} \times 100\% \quad (7)$$

$$\eta_L = \sigma_L \frac{\Delta L/L}{\Delta Y/Y} \times 100\% \quad (8)$$

$$\eta_E = \sigma_E \frac{\Delta E/E}{\Delta Y/Y} \times 100\% \quad (9)$$

It can be conducted that the key step of calculating the economic growth contribution rate of all input factors is to settle down the model coefficients in translog production functions, consequently to calculate the input factors' output elasticity. From the model structure of formula 1, it is seen that it is essentially a multiple linear regression model. The model parameters can be derived by regression analysis. However, because of the strong

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correlation among the variables, the general multivariate linear regression method is inevitable of multi-collinear effects. Therefore, this article will use the Ridge Regression Analysis to calculate the model parameter. It reduces the impact of multi-collinear among the variables in order to ensure the accuracy of model parameters.

3.2 Ridge Regression

The ridge regression is essentially a format of improved least squares estimation method, firstly raised by A. E. Hoerl in 1962 (Liu & He, 2001). It is mainly to solve the problems that the ordinary least squares estimation method is not able to overcome the influence of multi-collinear among variables in the solution process, which leads to large estimation variance and affects the accuracy of model. The basic idea is as follows:

A multiple linear regression equation is:

$$Y=X\beta+\varepsilon \tag{10}$$

Where, Y is the matrix of dependent variables, $X$is the matrix of independent variables, β is the matrix of regression coefficient, ε is the uneven matrix. Then the general least square estimation is:

$$\hat{\beta}=(X^{'}X)^{-1}X^{'}Y \tag{11}$$

When there is a strong correlation among independent variables, the collinear is strong, and the matrix of correlation coefficients among independent variables is approximate to 0. At the same time, $\left|X^{'}X\right|\approx 0$, thus the model parameters calculations can not be solved or the estimated variance is over big by applying the formula 11. In order to solve this problem, a positive constant matrix KI is added on $X^{'}X$. At this stage the variance extent of $X^{'}X+KI$ is much smaller than the $X^{'}X$,so as to reduce the influence of multi-collinear effect among independent variables. The least square estimation of parameters is:

$$\hat{\beta}(K)=(X^{'}X+KI)^{-1}X^{'}Y \tag{12}$$

Where, $\hat{\beta}(K)$, is defined as ridge estimation of regression coefficient

K, is ridge parameter

It can be seen from formula 12, the ridge estimation of regression coefficient $\hat{\beta}(K)$ is more stable than the one estimated by general least square. When K=0, $\hat{\beta}(K)=\hat{\beta}$, that is the ridge estimation degrades down to the general least square estimation. When $K\to\infty$, $\hat{\beta}(K)$ approaches 0. With the increment of K value, the regression formula' fit goodness declines, therefore,K's value is not supposed to be over big, it needs meeting the minimum value that the research required.

4. THE DYNAMIC ANALYSIS OF CONTRIBUTION RATE OF PRODUCTION FACTORS IN CHINA.

4.1 Data Processing

China's 2000 - 2011 Gross Domestic Product (GDP), capital stock, labor inputs and total energy consumption data are shown in the following table (National Statistic Bureau, 2012).

Table 1
China's 2000 - 2011 GDP, Capital Stock, Labor Force, Energy Input

Year	GDP (Hundred Millions)	Capital Stock (Hundred Millions)	Labor Force (Ten Thousand)	Energy Consumption (Ten Thousand Tons Standard Coal)
2000	99214.60	189318.00	72085	145531
2001	108892.92	208208.71	73025	150406
2002	120459.89	231460.79	73740	159431
2003	134354.09	263286.30	74432	183792
2004	152213.23	302924.13	75200	213456
2005	172957.62	354320.81	75825	235997
2006	199312.47	418550.78	76400	258676
2007	233700.43	496416.84	75321	280508
2008	260725.92	585186.36	75564	291448
2009	285018.51	710659.61	75828	306647
2010	324968.72	859559.43	76105	324939
2011	363123.14	1005155.29	76420	348002

The GDP values in the table are referred as the price level in 2000, with adjustment of consumer price index. Due to no official statistical data of capital stock, this paper estimates the capital stock through continuous inventory method, based on China's 2000 capital stock data estimated by Zhang Jun et al. the calculation formula is $K_t=I_t+(1-\delta_t)K_{t-1}$,in which K_t represents No.t year's capital stock, K_{t-1} means the capital stock in No.t-1 year, I_t is the capital amount generated in No. t year, δ_t is the assets depreciation rate, defined as 9.6% (Zhang, Wu & Zhang, 2004). Every year's I_t is referred as the price level in 2000,with adjustment of price index for investment

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in fixed assets. Due to the lack of statistical information about the quality of China labor force, this study only considers the amount of labor factors, without taking into account the labor quality factors, specifically expressed by the total social employment population. The energy input is represented by the total energy consumption.

4.2 Ridge Regression Analysis

It calculates the values of dependent and independent variables of translog production functions (formula 1) according to Table 1. Based on that, the ridge regression is conducted by SPSS13.0[12]. The variances of fit goodness RSQ and their standardized regression coefficient of each independent variables following K different values are shown in the following table.

Table 2
Goodness of Fit and Standardized Regression Coefficient Variances

K	*RSQ*	*InK*	*InL*	*InE*	*(InK)*^{2}	*(InL)*^{2}	*(InE)*^{2}	*InK·InL*	*InK·InE*	*InL·InE*
0.00	1.000	291.388	-13.388	-132.770	11.882	16.495	20.877	-300.970	-16.912	125.559
0.05	0.998	0.174	-0.005	0.113	0.174	-0.005	0.115	0.168	0.154	0.107
0.10	0.997	0.166	0.005	0.114	0.167	0.005	0.116	0.161	0.150	0.108
0.15	0.997	0.160	0.013	0.114	0.162	0.012	0.116	0.156	0.146	0.108
0.20	0.996	0.155	0.019	0.114	0.157	0.019	0.115	0.151	0.143	0.108
0.25	0.995	0.151	0.025	0.113	0.153	0.025	0.115	0.147	0.140	0.108
0.30	0.994	0.147	0.030	0.113	0.149	0.030	0.114	0.144	0.137	0.108
0.35	0.993	0.144	0.034	0.112	0.146	0.034	0.113	0.141	0.135	0.108
0.40	0.992	0.142	0.037	0.111	0.143	0.037	0.113	0.139	0.133	0.107
0.45	0.991	0.139	0.041	0.111	0.140	0.040	0.112	0.136	0.131	0.107
0.50	0.990	0.137	0.043	0.110	0.138	0.043	0.111	0.134	0.129	0.107
0.55	0.989	0.135	0.046	0.109	0.136	0.046	0.111	0.132	0.127	0.106
0.60	0.987	0.133	0.048	0.109	0.134	0.048	0.110	0.130	0.126	0.106
0.65	0.986	0.131	0.050	0.108	0.132	0.050	0.109	0.129	0.124	0.105
0.70	0.985	0.129	0.051	0.108	0.130	0.051	0.109	0.127	0.123	0.105
0.75	0.984	0.127	0.053	0.107	0.128	0.053	0.108	0.126	0.122	0.104
0.80	0.983	0.126	0.054	0.106	0.127	0.054	0.107	0.124	0.120	0.104
0.85	0.982	0.125	0.055	0.106	0.125	0.055	0.107	0.123	0.119	0.103
0.90	0.980	0.123	0.056	0.105	0.124	0.056	0.106	0.121	0.118	0.103
0.95	0.979	0.122	0.057	0.105	0.123	0.057	0.105	0.120	0.117	0.102

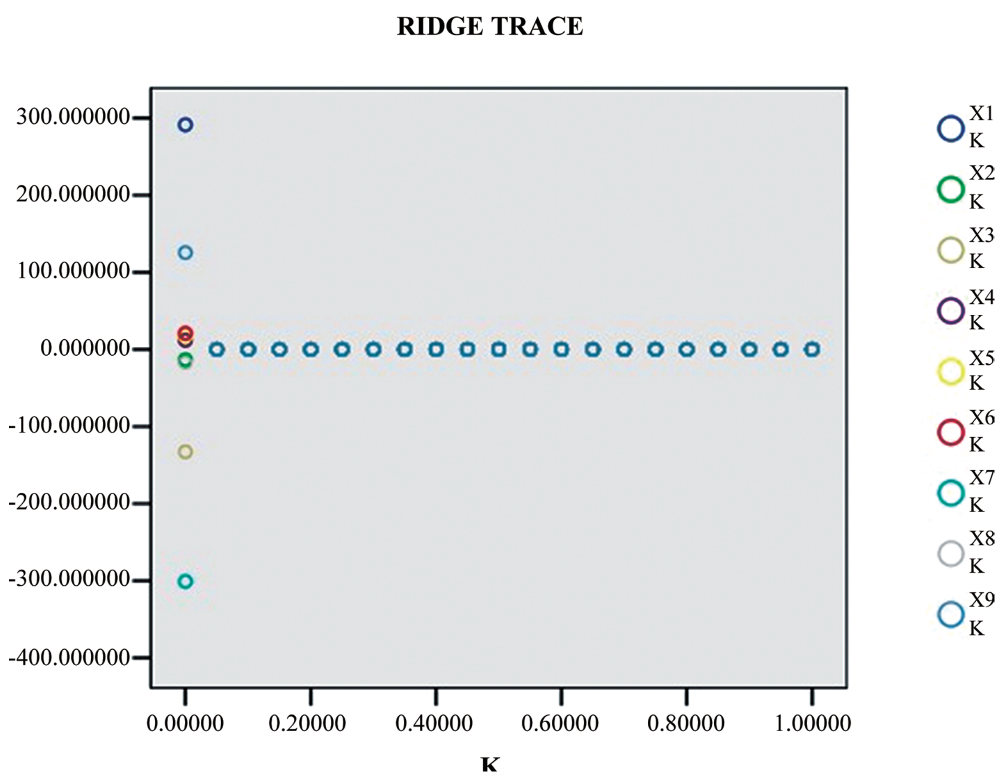

Figure 1
The Ridge Trace

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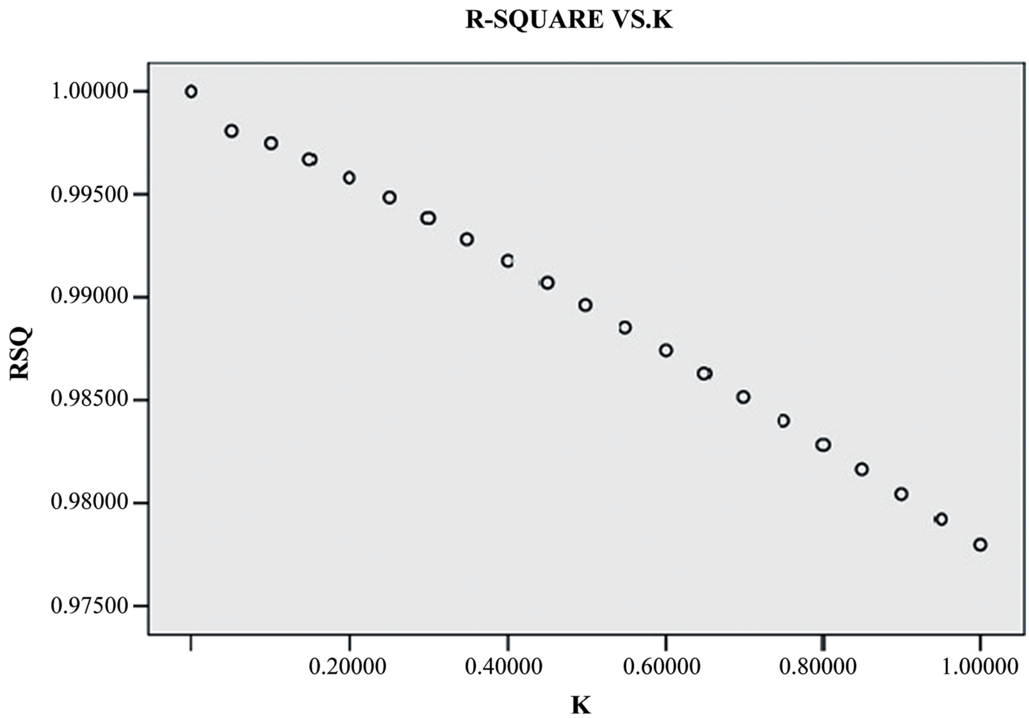

Figure 2
Goodness of Fit

The ridge trace and goodness of fit corresponding to Table 2 are shown in Figure 1 and 2. It can be seen from Figure 1 that with the increment of K value, the standardized regression coefficient of each independent variable approaches stable. when *K*=0.1, it is basically stable, and it is not shown in Figure 1 that the regression coefficient changes with K's value increment.

It can be seen from Figure 2 that as the increment of K value, the coefficient of determination of regression equation (RSQ) gradually decreased. In addition, when $K \geq 0.1$, it approaches to be stable, after which no obvious fluctuation appears. So the 3 points before which it approaches to be stable are selected. Their average value *K* =0.15 is regarded as ridge coefficient for regression analysis, the results shown in Figure 3 and 4.

******Ridge Regression with k=0.15 ******

Mult R	.9983465890		
RSquare	.9966959118		
Adj RSqu	.9818275150		
SE	.0593615181		
	ANOVA table		
	df	SS	MS
Regress	9.000	2.126	.236
Residual	2.000	.007	.004
	F value	Sig F	
	67.03452460	.01478266	

Figure 3
The Significance Test Results of Ridge Regression Formula

Variables in the Equation			
	B	SE(B)	B/SE(B)
InK	.124698	0.14591	8.546246
InL	.293984	.085744	3.428642
InE	.161547	.028481	5.672055
$(InK)^2$	.004859	.000620	7.831030

To be continued

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Continued

Variables in the Equation			
$(InL)^2$	.13038	.003804	3.427048
$(InE)^2$	.006665	.001121	5.947596
InK-InL	.010476	.001198	8.747464
InK-InE	.005886	.000439	13.407407
InL-InE	.012912	.002196	5.880128
Constant	-2.484043	11.078968	-.224212

Figure 4
The Ridge Regression Coefficient and its Significance Test Results

The Figure 3 shows that the determinant coefficient of regression formula(Adj RSqu)is 0.9818, close to 1, when K=0.15. This implies the equation fits better. The F statistic value of significance test of regression equation is 67.0345, the corresponding value of P is 0.01478<0.05, which illustrates the regression equation is significant in α=0.05 level.

The Figure 4 shows that B is the non-standardized regression coefficient when K=0.15, the SEB is standard errors, B/SEB is the T value of regression coefficient significance test. The ridge regression formula derived from that Figure is followed:

$InY=-2.4840+0.1247InK+0.2940InL+0.1615InE+0.0049(InK)^2+0.01304(InL)^2+0.0067(InE)^2+0.0105InK\cdot InL+0.0059InK\cdot InE+0.01291InL\cdot InE$

Checking T value distribution table, when the freedom is 9, α=0.01presents T=3.36, Figure 4 shows each regression coefficient T test values are all bigger than 3.36, it implies the regression coefficient is significant under the level α=0.01.

4.3 Contribution Rate Estimation

Each factor's output elasticity can be calculated by using the formula 2-4. Each factor's annual input growth rates are calculated according to Table 1, then the contribution rate to economic growth of each factor can be calculated by using formula 7-8, the results are below:

Table 3
2001 - 2011 China's Capital, Labor Force, and Energy Contribution Rate to Economic Growth

Year	Capital	Labor Force	Energy	Residualvalue
2001	38.12%	9.65%	15.73%	36.50%
2002	39.28%	6.67%	25.94%	28.11%
2003	44.72%	5.92%	61.08%	-11.72%
2004	42.68%	5.67%	56.22%	-4.57%
2005	47.09%	4.48%	36.01%	12.42%
2006	45.17%	3.67%	29.42%	21.74%
2007	41.07%	-6.05%	22.88%	42.10%
2008	59.06%	2.07%	15.82%	23.05%
2009	88.19%	2.79%	26.34%	-17.32%
2010	57.48%	1.95%	20.09%	20.48%
2011	55.65%	2.64%	28.63%	13.07%

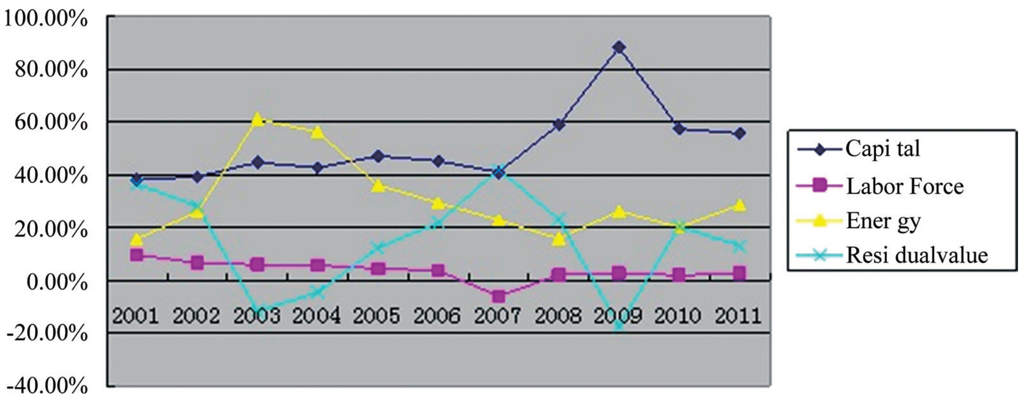

Figure 5
The Variation Tendencies of Contribution Rate of Production Fators During 2001-2011 in China

The Development Variation Tendencies of contribution rate of Capital, Labor Force and Energy during 2001-2011 are shown in Figure 5.

It can be seen from Table 3 and Figure 5, the capital contribution rate basically maintained stable in the years of 2001-2007, with an average value 42.59%. In 2008, it rose to nearly 60%, its peaking value 88.19% appeared in 2009. It indicates that the 4,000 billion investment plan implemented in China during the past two years has played a key role on overcoming the negative influence of international economic crisis and maintaining the sustainable and rapid economic growth. Regarding the situation in 2010 and 2011, the capital contribution rate showed a declining trend, but maintained above 55%, the average value was 56.56%, which was about 14 percentage points higher than the average level before the crisis. It may indicate that in the post-crisis time, the investment driving effect on China' economic development will be further strengthened maintaining the high level comparing to the level prior to crisis. The labor contribution rate showed a downward trend continued in the years 2001-2011, getting down from 9.65% in 2001 to 2.64% in 2011, compared to Table 1, in which the total labor force has increased year by year, it can be seen that simple expansion of labor supply does not behave promoting economic growth. In 2003, the energy contribution rate reached the maximum 61.08% , then it decreased year by year, reaching its lowest value 15.82% in 2008, after which, it presented the upward trend of shock. The residual value of contribution rate besides the input factors (referred as the efficiency contribution rate) occurred significant fluctuation in 2001-2011, had negative values in some years. The reasons may be decline of production efficiency due to low utilization ratio of input factors, the error resource allocation, and weakness of management level. In addition, as it can be seen from Figure 5, it has reverse fluctuation tendencies between the energy contribution rate and efficiency contribution rate. It notes that the energy utilization efficiency occupies an important position in the total social production efficiency.

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