Energy Substitution Potential in China's Non-metallic Mineral Products Industry-based on the Translog Function and Corrected Formula for Elasticity

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The Asian Conference on Sustainability, Energy and Environment 2019
Official Conference Proceedings

Abstract
The non-metallic mineral products industry (NMMPI) of China is the largest in the world and has a character of low energy efficiency, which made this sector energy-intensive and therefore one of leading contributors to CO2 and other pollutants. Therefore, researchers have been paying more and more attentions to the degree of non-energy factors substituting for energy, which is regarded as the most effective measure to address this issue. This study applying the transcendental logarithmic (translog) production function model to investigate the potential of substitution towards energy conservation among production factors in the Chinese NMMPI. Ridge regression is used to estimate the model parameters. Output elasticity and substitution elasticity are calculated. Results show that: during the period 2000-2016, there is significant substitution relationship between energy and capital as well as labor. The elasticities of substitution between energy and capital as well as labor are 1.018 and 1.019, respectively. So, it is possible for the Chinese government to allocate more capital or labor through upgrading technology or implementing policy to realize the CO2 mitigation purpose in the NMMPI. The results of scenario analysis indicate that both capital and labor factors inputs can substitute energy input effectively. In comparison, the substitution effect of labor factor is more obvious.

Keywords: Non-metallic mineral products industry (NMMPI), inter-factor substitution, elasticity of substitution, Translog production function, Ridge regression

Introduction

Massive energy consumption and CO_2 emissions, along with their resulting impacts on the environmental deterioration of China, have caused great concern internationally and domestically(W. Chen, Wu, He, Gao, & Xu, 2007; M. Zhang & Huang, 2012). To control energy consumption without hindering economic development is the biggest challenge for China (Zeng, Ding, Pan, Wang, & Gregg, 2008). The Chinese government has profoundly recognized the severe impact of environmental pollution on the Chinese economy and has elevated environmental governance to an unprecedented level (S. Chen, Chen, Economics, & University, 2018). Pollution prevention and control is prioritized and considered to be one of the three significant challenges in sustainable development of a well-off society. In fact, the Paris Agreement adopted on December 12th, 2015, China, as a contracting party, also proposed some emission reduction targets (Rogelj et al., 2016).

Non-metallic mineral products mainly include cement, refractory materials, flat glass and ceramic products, which are the primary raw materials for the construction industry. Considering the vital role of non-metallic mining products in the national economy, many scholars have listed it as one of the important indicators of economic development in a country or region (Hu & Kavan, 2014). China is the world's largest producer of non-metallic mineral products as well as one of the largest consumers (Lin & Ouyang, 2014). In 2016, China’s NMMPI received a sales value of 5998.82 billion RMB (902.43 billion U.S. Dollars) and a total profit of 3789.36 billion RMB (570.05 billion U.S. Dollars) with a year on year increase of 11.2% (2017). The factor efficiency and substitution in NMMPI have significant importance in Chinese economy, as NMMPI is considered to be a pillar industry contributing to about 1% of total GDP every year (Li & Sun, 2018).

Considering one of China's highest energy-intensive industries, NMMPI can effectively contribute to China's energy-saving and emission reduction strategy. Compared with developed countries, China's NMMPI has a substantial gap in factor productivity (Du, Gang, & Chuanwang, 2015). As mentioned in the third section of this article, although numerous studies conducted on energy conservation, but still no research have focused on the factor output elasticity and factor substitution in the NMMPI of China. Ma (Ma, Oxley, & Gibson, 2009) argued that there is lack of research on the estimation of China's energy demand factors and the possibility of substitution between fuels. Guo (Guo & Wang, 2005) stated that the factor substitution has been ignored by Chinese energy economics. Some related literature does exist (see (Fan, Liao, & Wei, 2007; Shi, 2010; Smyth, 2011; Xie, Hawkes, Lund, & Kaiser, 2015; Y. Zhang & Ye, 2014; Y. L. Zhang & A-Zhong, 2013; Zheng & Liu, 2004a)), contributing to China's factor efficiency and factor substitution with preliminary research on limited areas. However, as discussed by Hao (Feng & Statistics, 2015), most of these literatures suffered from formula mis-specification. The substantial gap of energy intensity between China and developed countries indicates that there is an enormous potential of energy conservation (Ouyang & Lin, 2014), however, plenty of work need to be done to achieve this goal. The primary purpose of this paper is to explore the output and substitution issues of input factors of Chinese NMMPI. Findings of this study can be significant regarding the huge potential of energy-saving, the considerable influence of low-carbon transition in China and even the international efforts of reducing greenhouse gases (GHG).

Specifically, this article focuses on the following problems:

- What is the productivity of China's NMMPI input factors?
- What is the relationship between the input factors of China's NMMPI industry?
- Can China achieve substitution between input factors, especially for energy?
- If substitution is available, how much is the extent to which labor and capital can substitute for energy? What effect of such substitution is on the economy?

In this paper, we will 1) sort out the present state of Chinese NMMPI, 2) employ the latest data from the Chinese NMMPI, 3) derive and apply the corrected formula for the elasticity of substitution, and 4) firstly discuss the output and substitution elasticity of the Chinese NMMPI. The results will undoubtedly answer the four questions mentioned above.

A brief synopsis of China's NMMPI

China's NMMPI has been developing rapidly since the introduction of the market economy and the implementation of reforming and opening up policy. Taking the output of cement and plate glass, which are typical products of the NMMPI, as an example, it increases from 680,000 tons and 4.3 million weight boxes in 1955 to 236 million tons and 78,600 boxes in 2015, respectively. As shown in **Fig. 1**, especially since around 2000, the number of products increases rapidly, which was consistent with the acceleration of industrialization and urbanization in China. China had raised the urbanization rate of one-fifth of the world's population from 20% (1981) in the initial period of reforming and opening up to 53% (2012) (Source: *National Bureau of Statistics of China*) during 30 years.

Along with this remarkable figures, massive amount energy consumption also been reported. In 2015, China's industrial industry consumed a total of 2802.06 million tons of standard coal in energy, of which manufacture industry consumed 2489.31 million tons, accounting for 89% of total industrial energy consumption (see **Fig. 2**). NMMPI consumed 350.60 million tons, ranking third in the manufacturing industry, second only to the "ferrous metal smelting and rolling industry" (747.31 million tons) and "manufacture of chemical raw materials and chemical products industry" (483.35 million tons), accounting for 14.1% of the total energy consumption in the manufacturing industry, 12.5% of the total energy consumption in the industrial sector, and 8.2% of the total energy consumption in China (4299.05 million tons). Of the energy consumed in NMMPI, coal (206.4497 million tons) and petroleum (206.67 million tons) accounted for 59.5% of the total energy consumption (Data source: *China Industrial Statistics Yearbook*).

Unfortunately, China's massive energy and resource consumption are resulted by lower energy and resource utilization efficiency. First, taking the cement industry as an example, almost one-third of the cement produced in China is the low-end cement that can only be used domestically. The service life of concrete is generally between 20-30 years, much lower than the standards of developed countries such as Japan, the United States, and the United Kingdom. In recent years, frequent building collapses have been reported in various parts of China. There were many reasons for the destruction of houses, but inferior construction materials were an indispensable incentive. This directly led to a significant amount of waste of resources, accumulating a considerable amount of construction waste that was difficult to handle, and posing a substantial threat to the environment. Second, waste also contains a vast amount of carbon emissions. As one of the six high-energy industries, carbon emissions from the NMMPI of China accounted for almost one-tenth of that caused by energy consumption all over the country.

Methodology

A twice-differentiable translog production function connecting NMMPI output (Y) with capital (K), labor (L) and energy (E) was employed to describe the relations between them as:

$$\begin{aligned} \mathrm{Ln}\, Y_t = {} & \alpha_0 + \alpha_K \ln X_{Kt} + \alpha_L \ln X_{Lt} + \alpha_E \ln X_{Et} + \alpha_{KK}(\ln X_{Kt})^2 + \alpha_{LL}(\ln X_{Lt})^2 \\ & + \alpha_{EE}(\ln X_{Et})^2 + \alpha_{KL} \ln X_{Kt} \ln X_{Lt} + \alpha_{KE} \ln X_{Kt} \ln X_{Et} + \alpha_{LE} \ln X_{Lt} \ln X_{Et} \end{aligned} \tag{1}$$

Where: $\boldsymbol{Y_t}$: Output of Chinese NMMPI at time *t;* $\boldsymbol{X_K}$, $\boldsymbol{X_L}$ and $\boldsymbol{X_E}$: Capital stock, labor

and energy consumption at time t, respectively; $\boldsymbol{\alpha}$: Parameters to be estimated. The

output elasticity for capital, labor, energy could be respectively written as:

$$\eta_K = \alpha_K + \alpha_{KL} \ln L_t + \alpha_{KE} \ln E_t + 2\alpha_{KK} \ln K_t \tag{2}$$

$$\eta_L = \alpha_L + \alpha_{KL} \ln K_t + \alpha_{LE} \ln E_t + 2\alpha_{LL} \ln L_t \tag{3}$$

$$\eta_E = \alpha_E + \alpha_{KE} \ln K_t + \alpha_{LE} \ln L_t + 2\alpha_{EE} \ln E_t \tag{4}$$

The elasticity of substitution among capital, labor, energy could be respectively written as:

$$\sigma_{KL} = \left[1 + 2\left(\alpha_{KL} - \frac{\eta_L}{\eta_K}\alpha_{KK} - \frac{\eta_K}{\eta_L}\alpha_{LL}\right)(\eta_K + \eta_L)^{-1}\right]^{-1} \tag{5}$$

$$\sigma_{KE} = \left[1 + 2\left(\alpha_{KE} - \frac{\eta_E}{\eta_K}\alpha_{KK} - \frac{\eta_K}{\eta_E}\alpha_{EE}\right)(\eta_K + \eta_E)^{-1}\right]^{-1} \tag{6}$$

$$\sigma_{LE} = \left[1 + 2\left(\alpha_{LE} - \frac{\eta_E}{\eta_L}\alpha_{LL} - \frac{\eta_L}{\eta_E}\alpha_{EE}\right)(\eta_L + \eta_E)^{-1}\right]^{-1} \tag{7}$$

Although the formula for the elasticity of substitution does not seem to be very complicated, it is still difficult to calculate elasticity of substitution concerning the translog production function. The crux of the problem that the model, as shown in (1), contains too many explanatory variables, which makes the collinearity very serious. Although many scholars participate in the research of this problem, there is still no perfect solution. There are three common treatment ideas for this problem: the first is the variable elimination method. Eliminating statistically insignificant variables, but this would undoubtedly undermine "flexibility", which is a core advantage over translog function method. The second is to impose theoretical constraints. For example, if the equation is evaluated under similar conditions, the parameters to be estimated can be effectively reduced, but the constraints may not pass the test. The third is the method of Ridge regression. Although the method pays the price of biased estimation, it can effectively improve the estimation accuracy and is widely used by many scholars.

Data

The time series data from 2000-2015 was selected as a sample for three reasons. First, Although China began to reform and open up in 1978, China's reform and opening up are gradual, both geographically and economically. In other words, it was not until 2000 that the market economy began to play a leading role in various economic sectors of China (Ding & Li, 2017). The significance of the factor substitution rate depends to a large extent on the energy market structure. If the energy market is not a competitive market but is in a monopoly state, the energy substitution rate will lose its meaning(T. Azomahou, Boucekkine, & Nguyen-Van, 2008). Second, China's resource and environmental problems were not evident before 2000, and they have not received the attention of the society. As can be seen from the Fig. 2, energy consumption began to increase sharply after 2000, but then it entered a period of stability. At the same time, China's environmental deterioration problems started to become more prominent. In particular, the severe smog problem across the country characterized by an unprecedentedly high level of PM2.5 concentrations brought a violent shock to all Chinese people (S. Chen et al., 2018). Then the energy conservation and emission reduction became the consensus of the whole society. The third is that China's national statistical work has also undergone a process of gradual improvement. Under the planned economic system, all economic activities are in compliance with national directives and cannot reflect the real supply and demand situation of the market.

According to the structure of the model, four types of data need to be collected, including output, labor input, capital investment, and energy consumption. Capital investment is measured by the capital stock. Since there is no direct access to the capital stock, the capital stock is obtained by estimation. In general, the method of estimating the capital stock is based on the perpetual inventory method (PIM), which was proposed by Goldsmith in 1951. This method is operable and widely used by scholars. The core assumption is that the relative efficiency uses a geometrically decreasing model. The commonly used estimation models are as follows:

$$K_t = I_t + (1-\delta_t)K_{t-1} \tag{8}$$

Where, K_t, K_{t-1}represent the capital stock of year $t, t-1$,respectively;while, I_t, δ_t denote the new investment amount and depreciation rate of year t , respectively. Using this method to estimate the capital stock, the key indicators that need to be determined are shown in the formula: the capital stock of the base year, the actual investment amount series, the industry depreciation rate, and the fixed asset investment price index. The literature (Yong-Ze, Liu, & Zhang, 2017) uses this method to estimate the capital stock of the industrial sector in China. This paper refers to the NMMPI data in (Yong-Ze et al., 2017) and expands the data from 2014 to 2016 according to its method.

As for the remaining three types of data, they can be obtained from the *China Industrial Statistical Yearbook* series and *China industrial statistic yearbook* series, but the base period is set to 1990 according to the literature (Yong-Ze et al., 2017). According to the fixed asset investment price index of *China Statistical Yearbook* (2017), the output of NMMPI has been deflated. To remove the unit limit of the data, the zero-mean normalization method is used to convert the original data into a pure dimensionless value before regression.

Results and analysis

Although it is empirically known that the model has severe collinearity, the collinearity is tested before using the Ridge regression. The collinearity can be detected by various methods, for example, 1) Pearson correlation test; 2) Variance inflation factors; 3) Eigenvalues of the correlation matrix of the independent variables, and 4) Pairwise scatter plots of pairs of independent variables. The first two methods are used in this paper, and the results of the Pearson and VIF tests are shown in the Table 1 and Table 2, respectively.

In the field of Statistical Science, the Pearson correlation coefficient is widely used to measure the degree of correlation between two variables X_1 and X_2, which was proposed by Carl Pearson and Francis Galton in the 1880s. The Pearson correlation coefficient varies from -1 to 1. Where, 1, 0, -1 represent positive correlation, irrelevant or no correlation and negative correlation, respectively.

We can also detect the multi-collinearity by the variance expansion factor (VIF). VIF refers to the ratio of the variance between the explanatory variables with and without multi-collinearity and it is the reciprocal of tolerance. The larger the VIF, the more severe the collinearity is. A rule of thumb is that there is no multi-collinearity when $0 < VIF < 10$; when $10 \leq VIF < 100$, there is strong multi-collinearity; and when $VIF \geq 100$, there is severe multi-collinearity. Selecting the coefficient λ is a process to solve a dilemma. A smaller λ value can guarantee a lower bias, but VIF will be relatively larger. On the contrary, a larger λ value will ensure a smaller VIF, but the deviation will increase. Our goal is to find the most appropriate λ value for the intended purpose.

Observing Table 1 and Table 2, the correlation coefficients are all above 0.82 in Table 1, and statistically significant at the 0.01 level. In Table 2, the VIF far exceeds the critical value of severe collinearity. Both cases indicate that there is severe collinearity in the model. This provides evidence for the use of the Ridge regression method.

According to the Ridge trace in Fig. 3 and the VIF diagram in Fig. 4, we choose $\lambda=0.007$ as the Ridge regression parameter. At this point, the coefficient is basically in a stable state (see Fig. 3, λ is denoted as k). The VIF values (see Fig.4) fall sharply at the initiation phase, and decrease gently as the λ becoming greater. When it comes to 0.007, the VIF values has entered to a suitable small level (<5), which illustrates that the method of Ridge regression effectively overcomes the problem of multi-collinearity. The regression results are shown in Table 3. Firstly, when $\lambda=0.007$ is selected as the Ridge regression parameter, the equation has an ideal goodness of fit, and its statistic (**Adj. R-Square**) reaches 0.99; Secondly, the estimated coefficients of the explanatory variables are all positive (**see B),** which is in line with the economic sense of the NMMPI industry, and the statistical test results of the coefficients are significant (see Table 3). In short, the estimation results are reasonable and satisfy the expected objectives, and the model equation can be rewritten as:

$$
\begin{aligned}
\mathrm{Ln}\, Y_t = & -7.59448765 - 0.25387248 \ln X_{Kt} + 0.57220483 \ln X_{Lt} - 0.28931539 \ln X_{Et} \\
& + 0.01510996 (\ln X_{Kt})^2 + 0.04593982 (\ln X_{Lt})^2 - 0.01452651 (\ln X_{Et})^2 \\
& - 0.02671263 \ln X_{Kt} \ln X_{Lt} + 0.01595996 \ln X_{Kt} \ln X_{Et} - 0.02856042 \ln X_{Lt} \ln X_{Et}
\end{aligned} \tag{9}
$$

With the estimated coefficients, the output elasticity of the input factors can be calculated according to the (2), (3) and (4). Then, according to the estimated coefficients and computed output elasticities, the elasticity of substitution between the input factors can be obtained according to (5), (6) and (7). The results are shown in Table 4.

It can be seen from the Table 4. that during the sample period, the output elasticities of all input factors are positive and they have gentle upward trends, indicating that with the growth and development of China's economy and technology, the productivity of China's NMMPI has been continuously improved. Among the output elasticities of the three factors, only the output elasticities of labor are greater than 1($\eta_L > 1$), indicating that the output is growing faster than factors input. At this time, increasing the amount of labor input, the average output will increase. The output elasticity of capital and energy are less than 1($\eta_K, \eta_E < 1$), indicating that the output is growing less than factors input. At this time, increasing the input of capital and energy, the average output will decrease. However, the average of the output elasticity of the three factors is greater than 1($\bar{\eta} > 1$), and there is also a rising trend, indicating China's NMMPI is still in the stage of progressively increasing with respect to returns to scale. This result is also consistent with several literatures that studied the output elasticities in other industries, such as (Lin & Jr, 2013; Shi, 2010; Xie et al., 2015), but they did not consider the average output elasticity.

Turn to the substitution elasticities of the three input factors over sample time showed in Table 4. First, as discussed in the third part of this paper, the conclusions of the elasticity of substitution in the world are still unclear. In theory, input factors can be complementary or substitutable (Ma et al., 2009). However, because of differences in economic development levels, industrialization levels, and even different region, the relationship between factors is significantly different. Taking the relationship between energy and capital as an example, some scholars have concluded that they are substitutes, while others have complementary results. Even with the same substitute relationship, the degree of substitution varies significantly from industry to region. (Griffin & Gregory, 1976; Ma, Oxley, Gibson, & Kim, 2008) argued that China's energy and capital substitution elasticity was between 0.6-0.8, while (Zhaoning & Deshun, 2004) proved it to be higher than 2.5, and (Zheng & Liu, 2004b) clarified that China's energy and capital substitutions are highly uncertain. From a global point of view, the substitution elasticity between energy and capital of Greece, Portugal, and South Korea is 0.97, 0.89, and 0.79, respectively (Cho, Nam, & Pagán, 2004; Christopoulos & Tsionas, 2002; Vega-Cervera & Medina, 2000). The results of this paper show that during the sample period, the relationship between energy and capital in China's NMMPI is substituted, and the substitution elasticity is around 1.01.

Implications and recommendations

Currently China is facing immense environmental pressures, and factor substitution is an effective way to achieve energy conservation and emission reduction targets. Given China's vast territory and varying levels of economic development, scholars are increasingly focusing on the issue of factor substitution more effectively from a regional or industry perspective. This paper takes the NMMPI in China as a perspective and studies the factor substitution problem by establishing a translog function model. Through analysis, we found that, during the sample period, there is a good substitution relationship between the input factors of NMMPI of China. Both labor and capital can replace energy to a certain extent, which suggests that we can achieve energy substitution through measures such as relaxing energy price controls, raising labor wages, and increasing capital investment and so on. That the elasticity of substitution for energy and labor is higher than that for energy and capital ($\sigma_{LE} > \sigma_{KE}$) and the output elasticity of labor is the highest among three factors ($\eta_L > \eta_K, \eta_E$) should be considered in policy design because the relatively abundant of labor of China. Although capital's alternative to energy is a little less than labor's alternative to energy($\sigma_{KE} < \sigma_{LE}$), capital's replacement of energy should also be fully utilized, given China's current abundant funds and insufficient investment.

Taking the cement industry in the NMMPI as an example, China has not only overcapacity but also a significant proportion of low-end cement. There are still quite a few pre-calciners in China that still have high energy consumption and heavy environmental load. Compared with developed countries such as Japan, France, and Denmark, there are considerable gaps in resource utilization and technology levels. The problems caused by excessive and rapid development in the past 10 years have been fully revealed, which has become the status quo of China's NMMPI. Based on this, the Chinese government should start from the following aspects to improve the status quo of the NMMPI. First, we should actively guide NMMPI enterprises from energy-intensive to technology-oriented, capital-intensive, and from small-scale woolen growth to large-scale. It could be realized through factor substitution. The second is to accelerate the pace of reform of the supply side structure of NMMPI, impose strict access to the market, and eliminate backward production capacity. From the aspects of institutional setup, human resource allocation, R&D investment, and intellectual property protection, the government should strive to improve the investment capacity of large and medium-sized enterprises, improve the resource utilization rate of large and medium-sized enterprises in China's NMMPI, and transform the development mode. The main purpose of this is to take advantage of the current high output elasticities of labor and capital. Finally, since China's large and medium-sized enterprises are mostly state-owned enterprises, enterprises should also make full use of the favorable environment of internationalization, globalization, and integration of the world economy, actively introduce advanced technologies from developed countries, increase productivity, and help the government to achieve its established strategy. These measures could be applied to the entire NMMPI of China.

Conclusions

In this paper, the translog production function model, which was widely used by scholars, was employed to study the elasticity of substitution between the three production factors of capital, labor, and energy in China's NMMPI, which has filled the gap in the literature of inter factor substitution for specific industries. Ridge regression is used to solve the problem of severe collinearity of the model. As a typical representative of China's high energy consumption, high emission, and low-efficiency industries, NMMPI is a pillar to China's industrialization and urbanization. As a regular industry with high growth and profit accumulation capacity, China's NMMPI should make outstanding contributions to China's strategic goals such as energy conservation and emission reduction, the shift of development mode, and green development. According to the results and analysis above, several conclusions are summarized as follows:

1) During the sample period, the output elasticities of the three input factors of capital, labor, and energy in China's NMMPI are positive. The output elasticity of labor(η_L) is 1.594~1.699, and that of energy(η_E) and capital(η_K) are 0.855~0.921 and 0.795~0.864, respectively. In general, they showed a relatively gradual growth trend indicating the improving of the utilization efficiency of input factors in NMMPI of China. In comparison, the output elasticity of capital is relatively low, which is closely related to the backwardness of equipment in the NMMPI of China.

2) During the sample period, the elasticities of substitution of the three input factors of capital, labor, and energy in China's NMMPI are positive. The substitution elasticity of energy-labor (σ_{KL}) is 1.021~1.023, and that of labor-energy (σ_{LE}) and capital-energy (σ_{KE}) are 1.018~1.019 and 1.017~1.019, respectively. During the sample period, the substitution elasticity has a downward trend, but at the end of the sample period, the downward trend tends to be stable and has a growth trend.

3) China's NMMPI industry is still in the stage of increasing returns to scale, and growing investment would accelerate output. China's NMMPI has good substitution relationship between input factors of capital, labor, and energy. Through relevant policies and institutional design arrangements, China stimulates and increases the input of capital and labor factors, restrains and reduces the contribution of energy factors, realizes the re-allocation of input factors, and realizes the strategic goal of energy conservation, emission reduction, and development mode transformation.

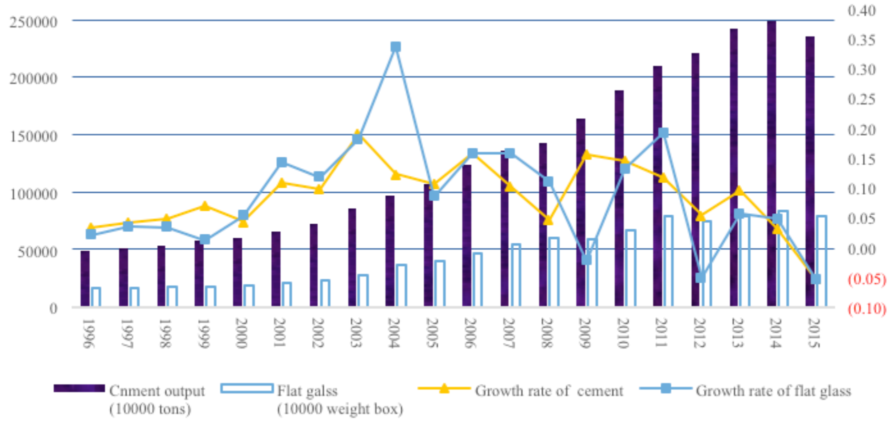

Fig. 1. The output of cement and plate glass in China's NMMPI during 1996-2015

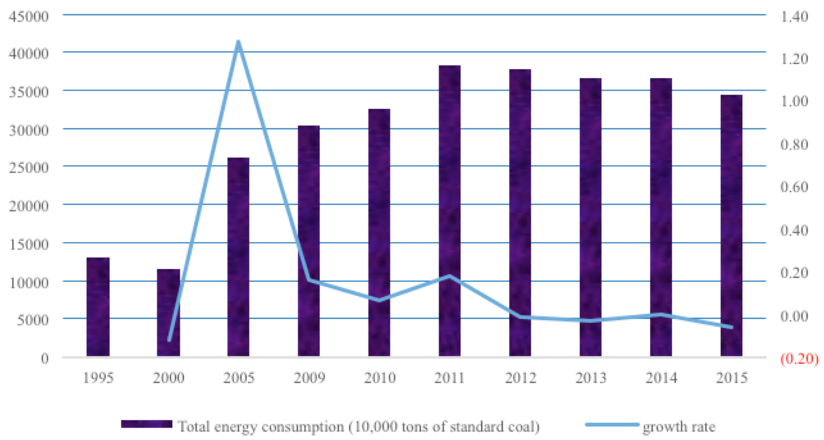

Fig. 2. The total energy consumption of NMMPI and growth rate during 1995-2015

Table 1. Pearson Correlation analysis

		K	L	E
K	Pearson	1	.981**	.840**
	Sig.(2-tailed)		.000	.000
	N	17	17	17
L	Pearson	.981**	1	.829**
	Sig.(2-tailed)	.000		.000
	N	17	17	17
E	Pearson	.840**	.829**	1
	Sig.(2-tailed)	.000	.000	
	N	17	17	17

**. Correlation is significant at the 0.01 level (2-tailed).

Table 2. The VIFs of all explanatory variables.

Variable	VIF	1/VIF
ln K	3717949.9	0.0000003
ln L	4551302.7	0.0000002
ln E	316426.0	0.0000032
ln K ln L	19274061.7	0.0000001
ln K ln E	765326.6	0.0000013
ln L ln E	1093068.2	0.0000009
ln K ln K	1932628.9	0.0000005
ln L ln L	11612977.5	0.0000001
ln E ln E	156117.0	0.0000064
Mean VIF	4824428.0	

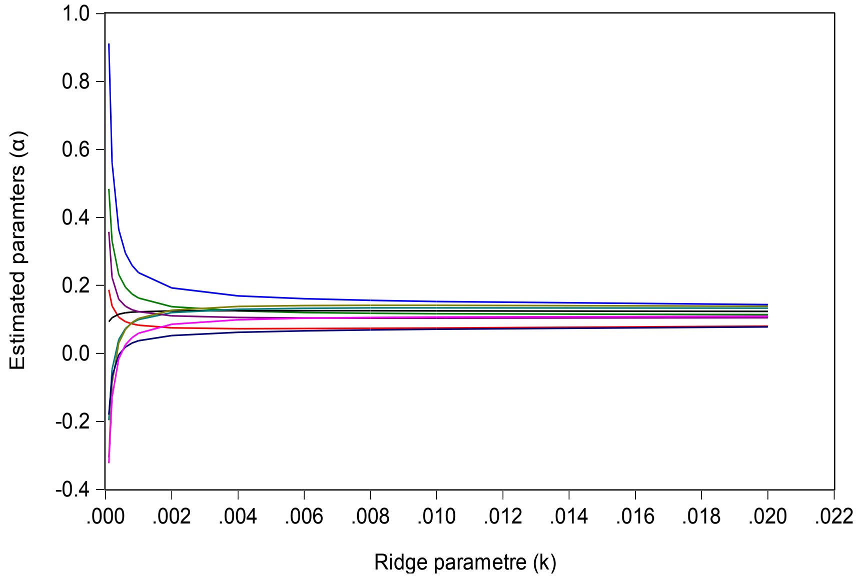

Fig. 3. Ridge trace of the coefficients of the Ridge regression

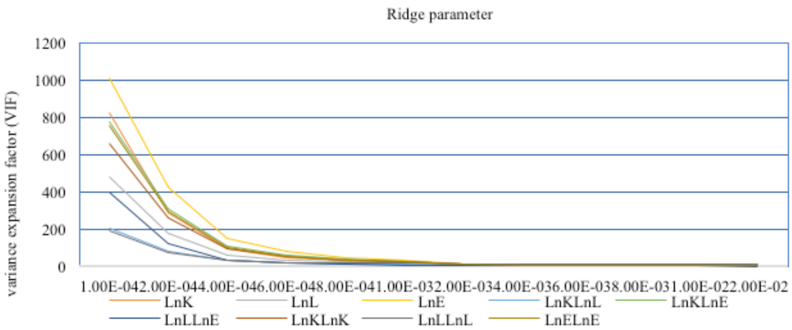

Fig. 4. The VIFs of the variables of the Ridge regression

Table 3 Model result of Ridge regression

Ridge Regression with λ = 0.007					
Mult.R			0.9977374370		
R-Square			0.9954799933		
Adj. R-Square			0.9896685561		
Standard Error (SE)			0.1045302299		
ANOVA Table					
	DF	**SS**		**MS**	
Regress	9.000	16.845		1.872	
Residual	7.000	0.076		0.011	
	***F* value**		**Sig. *F***		
	171.2966958		0.0000002		
Variables in the Equation					
	B	**SE(B)**	**Beta**	**B/SE(B)**	**Sig.**
LnK	0.25387248	0.03747404	0.13346173	6.77462341	0.00025912
LnL	0.57220483	0.17258862	0.08694789	3.31542629	0.01284544
LnE	0.28931539	0.04680642	0.11178325	6.18110511	0.00045353
LnKLnL	0.02671263	0.00252055	0.12001297	10.59794553	0.00001457
LnKLnE	0.01595996	0.00162699	0.13013288	9.80952661	0.00002428
LnLLnE	0.02856042	0.00335852	0.10681480	8.50388255	0.00006159
LnKLnK	0.01510996	0.00251090	0.13231770	6.01775060	0.00053275
LnLLnL	0.04593982	0.01375235	0.08617302	3.34050730	0.01241104
LnELnE	0.01452651	0.00228679	0.11193671	6.35237157	0.00038436
Constant	-7.59448765	1.10138624	0.00000000	-6.89539000	0.00023229

Table 4. Output elasticity and elasticity of substitution of factors input in NMMPI.

Year	η_K	η_L	η_E	$\bar{\eta}$	σ_{KL}	σ_{KE}	σ_{LE}	$\bar{\sigma}$
200	0.79	1.59	0.85	1.08	1.02	1.01	1.01	1.02
0	506	655	497	2194	2669	8682	9264	0205
200	0.79	1.59	0.85	1.08	1.02	1.01	1.01	1.02
1	451	444	609	168	2691	8679	9267	0212
200	0.79	1.59	0.85	1.08	1.02	1.01	1.01	1.02
2	583	587	809	3265	2659	8642	9237	0179
200	0.80	1.60	0.86	1.09	1.02	1.01	1.01	1.02
3	194	624	672	1636	2493	8479	9079	0017
200	0.81	1.62	0.87	1.10	1.02	1.01	1.01	1.01
4	184	232	849	4216	2233	8240	8857	9777
200	0.81	1.62	0.88	1.10	1.02	1.01	1.01	1.01
5	534	761	291	8622	2145	8155	8780	9693
200	0.81	1.63	0.88	1.11	1.02	1.01	1.01	1.01
6	859	227	557	2141	2065	8089	8724	9626
200	0.82	1.64	0.89	1.11	1.02	1.01	1.01	1.01
7	358	111	035	8345	1935	7982	8621	9513
200	0.83	1.65	0.89	1.12	1.02	1.01	1.01	1.01
8	354	782	806	9806	1684	7790	8443	9305
200	0.83	1.66	0.90	1.13	1.02	1.01	1.01	1.01
9	796	318	079	3978	1585	7711	8384	9227

2010	0.84614	1.67598	0.90743	1.143185	1.021390	1.017555	1.018243	1.019063
2011	0.85094	1.67903	0.91258	1.147514	1.021302	1.017454	1.018179	1.018978
2012	0.85463	1.68324	0.91451	1.150793	1.021224	1.017395	1.018136	1.018918
2013	0.85981	1.69270	0.91770	1.156736	1.021097	1.017308	1.018049	1.018818
2014	0.86394	1.69949	0.92056	1.161328	1.021002	1.017236	1.017983	1.01874
2015	0.86365	1.69776	0.91906	1.160158	1.021015	1.017252	1.018006	1.018758
2016	0.86380	1.69571	0.91782	1.15911	1.021024	1.017261	1.018030	1.018772
Mean	0.83124	1.65067	0.89304	1.12498	1.021777	1.017877	1.018546	1.019400

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