Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Environmental Sciences 11 (2011) 824 – 830

Procedia Environmental Sciences

# Analysis of China's energy consumption impact factors

Huanan Li[1,a], Hailin Mu[1], Ming Zhang[2]

[1]*Key Laboratory of Ocean Energy Utilization and Energy Conservation of Ministry of Education Dalian University of Technology Dalian, China*

[2]*School of Management China University of Mining and Technology Xuzhou, China*

[a]*huanan3721@163.com*

**Abstract**

Energy shortages have become the bottleneck restricting China's economic development increasingly, thus the study of factors affecting China's energy consumption is necessary for energy conservation. In this article, we analyze the impact factors of energy consumption in China firstly using a simplified cubic polynomial model, finding out important factors of them. Then, a three-variable demand model based on econometric theory and the translog production function is established. We find that urbanization, population, economy are the main factors affecting China's energy consumption. The demand elasticity of impact factors change regularly. The half-cycles of demand elasticity of urbanization and population on China's energy consumption are both about 6 to 8 years, while that of economy is around 14 years. The total value of China's energy consumption will increase irreversibly in the next decade. Thus, it's a formidable task for China's energy conversation in the short-term future.



*Keywords*:Energy consumption; Impact factors; Demand elasticity； China

## 1. Introduction

Energy is essential for human's survival and the driving force for socio-economic development. Since the policy "reform and open up" implemented in 1978, China has experienced enormous development in its economy. During the same time, there is a continued rapid growth in China's energy consumption. In 1990, the country's total energy consumption was 9.87 million tce(tons of coal equivalent), which increased to 2.85 billion tce in 2008, with an average annual growth rate of 6.07%. Energy shortages, energy security, environmental pollution issues have become the key elements of restricting China's sustainable development now. Therefore, the study of the impact factors of energy consumption for energy policy makers is essential.

Currently, there are many researches on energy consumption impact factors. In the early 70s of 20th century, Meadows et al. firstly studied the issue of energy resources systematically through analyzing the relationship among the factors of the world's population, industrial development, pollution, food



doi:10.1016/j.proenv.2011.12.126

production and consumption of resources [1], whose views were proved by the later two oil crises. Since then, energy issues have been concerned by economists, engineering and technical experts more and more. Some scholars established the energy demand model considering the energy factor based on the Cobb-Douglas production function, which was improved and developed in later researches. After 80s of the 20th century, there were some panel data models with the extensive application of econometrics. Prosser, Wu Yuming et al. analyzed the relationship between energy consumption and factors of economic growth and others based on economic demand theory, which is one of the widely used methods currently [2,3]. In addition, some scholars study the impact factors of energy consumption and carbon dioxide emissions using the decomposition method. For example, Shyamal Paul etc. investigated the factors of energy-related carbon dioxide emissions in India [4]. At present, most of the studies are focusing on the relationship between energy consumption and economic impact, rarely discussing energy consumption as the main subject. In this paper, we analyze the related impact factors of China's energy consumption using a simplified cubic polynomial model to identify the important impact factors. Then, a three-variable demand model is established based on econometric theory and the translog production function, obtaining the elasticity coefficients of the impact factors and finding out the regularity of elasticity coefficients' cyclical fluctuations.

The remainder of this paper is organized as follows. Section 2 presents the methods used in this analysis, while section 3 clarifies the data resource. Section 4 provides the empirical analysis and useful results. Conclusions are reported in section 5.

## 2. Methodology

### *2.1Simplified Cubic Polynomial Model*

In this paper, the time series data during 1990 and 2008 on energy consumption are fitted to analyze the main factors affecting China's energy consumption based on a simplified cubic polynomial model, which is expressed as follows:

$$C_t=a+b_1 X_{it}+b_2 X_{it}^2+b_3 X_{it}^3 \quad (1)$$

Where C represents the energy consumption value; t denotes the year; $X_i$ is the impact factor, such as economy and urbanization; a is the constant, while $b_i$ (i=1, 2, 3) is the coefficient. Different values of $b_i$ have different meanings. When $b_1> 0$, $b_2<0$ and $b_3>0$, that is cubic curves, showing N-type relationship; adversely, if $b_1<0$, $b_2>0$ and $b_3<0$, showing inverted N-type relationship. When $b_1>0$, $b_2<0$ and $b_3=0$, that is quadratic curve, indicating the Kuznets inverted U-curve relationship; on the contrary, when $b_1<0$, $b_2>0$ and $b_3=0$, that is U-curve. If $b_1\neq0$, and $b_2=0$, $b_3=0$, showing a linear relationship.

### *2.2Three-variable Energy Demand Model*

Translog production function is a variable elasticity production function model with a strong inclusivity and easy to estimate, which is developed from the Cobb-Douglas production function and commonly used to analyze the interaction of inputs in production. In general, the model can calculate the output elasticity and the substitution elasticity of each factor considered in model such as the capital, labor, technology and others, while there are certain requirements for the data's quantity and quality [5]. Energy consumption needs to create a consumer demand function. But as we know, energy is a large consumer product, which is intensively bought by government and enterprises generally, rather than individual behavior. Thus, we can't obtain the demand equation using the traditional utility function method. In this paper, we establish a three-variable demand model of energy consumption based on the econometrics theory and the idea of translog production function. The model is expressed as follows:

$$C_t=\alpha+\beta_1 X_{1t}+\beta_2 X_{2t}+\beta_3 X_{3t}+\beta_{12} X_{1t}\times X_{2t}+\beta_{13} X_{1t}\times X_{3t}+\beta_{23} X_{2t}\times X_{3t}+\beta_{11} X_{1t}^2+\beta_{22} X_{2t}^2+\beta_{33} X_{3t}^2+\varepsilon_t \quad .$$

Where C represents the energy consumption value; $X_i$ indicates the impact factors of energy consumption, i=1, 2, 3; t denotes time, and a is the constant; $\beta_1$, $\beta_2$, $\beta_3$, $\beta_{11}$, $\beta_{12}$, $\beta_{13}$, $\beta_{23}$, $\beta_{22}$, $\beta_{33}$ are the coefficients to be estimated, while $\varepsilon_t$ is the residual series.

Then, the demand elasticity of $X_{1t}$, $X_{2t}$, $X_{3t}$ are as follows:

$$\eta_{X1t}=(dC/C_t)/(dX_{1t}/X_{1t})=dC/dX_{1t}\times X_{1t}/C_t=(\beta_1+\beta_{12}X_{2t}+\beta_{13}X_{3t}+2\beta_{11} X_{1t})\times X_{1t}/C_t \quad (3)$$

$$\eta_{X2t}=(dC/C_t)/(dX_{2t}/X_{2t})=dC/dX_{2t}\times X_{2t}/C_t=(\beta_2+\beta_{12}X_{1t}+\beta_{23}X_{3t}+2\beta_{22} X_{2t})\times X_{2t}/C_t \quad (4)$$

$$\eta_{X3t}=(dC/C_t)/(dX_{3t}/X_{3t})=dC/dX_{1t}\times X_{1t}/C_t=(\beta_3+\beta_{13}X_{1t}+\beta_{23}X_{2t}+2\beta_{33} X_{3t})\times X_{3t}/C_t \quad (5)$$

## 3. Data resource

There are a lot of factors affecting energy consumption, such as the consumption structure, energy efficiency, weather, population, economy, etc., some of which are indirect factors and can't be quantified. Through summarizing previous literatures, we select five factors to consider in this paper: population (P), population is a traditional factor determining the energy consumption, and the growth in population will increase the demand for energy consumption directly; industry Structure (STR), industrial structure is another important factor affecting energy consumption. In general, energy consumption will increase with the rise of the proportion of secondary industry output over the total output; urbanization (R), for China is in the period of economy transformation, the impact of urbanization on energy consumption can't be ignored; energy prices (EP), the energy price has more direct impact on energy consumption generally. In this paper, we use the price indices of raw materials, fuel, power to represent the energy prices; economy (GDP), economy growth depends on the energy consumption growth, between which there is a stable positive correlation [6].

The data we used in this paper are given by China Statistical Yearbook (CSY)(1991-2009)[7], China Energy Statistical Yearbook (CESY) (1991-2009)[8], where the GDP data and energy data are in $10^8$ yuan in constant 1978 price and in $10^4$ tce respectively. Population is measured by $10^4$ units.

## 4. Main results

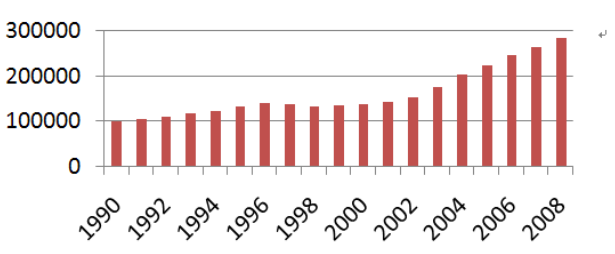


Fig.1 The trend of energy consumption in China between 1990 and 2008

Fig.1 shows the trend of China's energy consumption during 1990 and 2008. We can obviously see that the total energy consumption in China changes by three stages. The first stage is from 1990 to 1996, during which energy consumption experienced a linear growth with an average annual growth rate of 5.87%. At this period, the scale of China's foreign trade and foreign investment expanded rapidly with the accelerated pace of reform and opening up, leading to the increase in energy demand as a direct result.

The second stage is from 1997 to 2001. China's energy consumption suddenly decreased during 1997 and 1998, then gradually stable between 1999 and 2001 while changed slightly. This may be due to the following two causes. First, China slowed down the pace of economic development during this period for being affected by the Asian financial crisis, thus energy consumption reduced. Second, maybe the statistic data are inaccurate. The third stage is from 2002 to 2008, during which China's energy consumption increased rapidly with an annual growth rate of 11.07%. As economic recovery after the financial crisis and China's accession to WTO to expand exchanges with the world, there is a rapid development in China's economy once again, especially the blossom in heavy industry, construction industry and high energy-consuming industries, leading to the quick increase in China's energy consumption.

Fig. 2 shows the XY line graph between the energy consumption and its various impact factors. Significantly, there are correlations between energy consumption and urbanization, population, economy, while the correlations between energy consumption and industrial structure, energy prices are uncertainty.

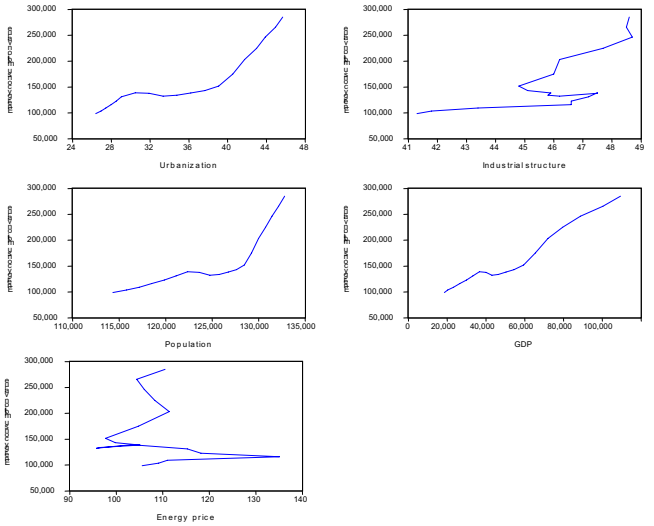


Fig.2 The XY line between energy consumption and its impact factors

Based on the 2009 statistical data of China, we obtain the fitted cubic polynomial results of the five factors as shown in Table 1.

Table 1 The fitting result of every influence factor

| Impact factor | a | Xi | $Xi^2$ | $Xi^3$ | $R^2$ | Curve type |
|---|---|---|---|---|---|---|
| R | -2.64E+05 (-6.13) | 2.47E+05 (-6.67) | -7355 (-7.06) | 73.54 (-7.63) | 0.99 | N-type |
| STR | -1.93E+08 (-2.26) | 1.3E+07 (-2.29) | -2.93E+05 (-2.32) | 2188.3 (-2.36) | 0.73 | |
| P | -1.93E+08 (-7.18) | 4779.135 (-7.32) | -0.039 (-7.46) | 0.00 （-7.61） | 0.98 | N-type |
| GDP | 1.14E+05 （-4.89） | -1.0401 (-0.74) | 4.20E-05 （-1.67） | 0.00 (-1.23) | 0.98 | Inverted N-type |
| EP | -1.94E+07 (-1.03) | 5.09E+05 （-1.02） | -4359.97 (-0.99) | 12.34 （-0.96） | 0.14 | |

Note: t test values are in parenthesis.

The factors of urbanization, population and economy fit better overall with significant t-test values, whose $R^2$ are 0.99, 0.98 and 0.98 respectively. Urbanization and population present the N-type relationship with energy consumption respectively. Industrial structure and energy price fit badly, with $R^2$ of 0.73, 0.14 respectively.

In theory, the industrial structure is a very important factor impacting energy consumption for the secondary industry is the main consumer of energy. But it is special in China's situation. From 1990 to 2008, the proportion of secondary industry changed from 41.3% to 48.6% with an average annual growth rate of only 0.9%. There are many reasons for this situation. Firstly, the development of the tertiary industry decreased the proportion of the secondary industry largely. From the "eighth five-year plan" period to the "tenth five-year plan" period, the average proportion of secondary industry increased only from 45.8% to 46%, while that of the tertiary industry increased from 33.8% to 40.9%; Secondly, China has increased the energy conservation efforts in recent years, and many production equipments of the energy-intensive industries have been upgraded, which substantially increased the energy use efficiency, inhibiting the growth of energy demand in the secondary industry to some extent. The impact of the industrial structure on energy consumption may be reflected in a more long-term development.

Energy price is another important factor affecting the energy consumption. In a market economy, people's consumption behaviors comply with economic laws, but energy is a special commodity. Different from general competitive industries, the monopoly exists in the energy industry. The formation of energy prices is not a complete market process, which largely reflects the government's dominant. Energy prices can't truly reflect the supply and demand pattern in the national and the international energy market, which also can't reflect the scarcity of energy resources in China. In addition, energy demand is rigid in China due to its industrialization. Energy supply and demand also mix with many political factors such as price subsidies on a particular species or energy consuming industries for economic development at a specific time by the Government, etc., so the impact of energy price on energy consumption is limited.

Through above analysis, we select the three factors of urbanization, population, economy as the dominant factors in China's energy demands to establish a three-variable model, and calculate the demand elasticity of them. The economic meaning of demand elasticity expressed in this article is that the percentage change in energy consumption caused by single factor change one percentage point.

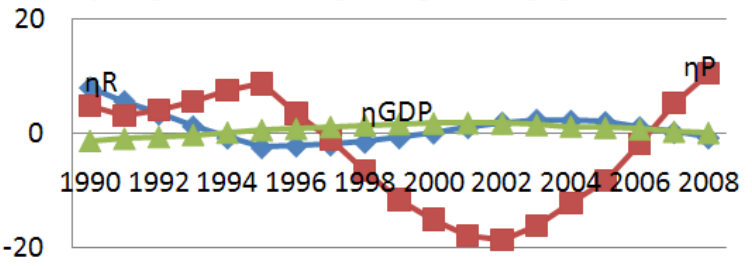


Fig.3 The demand elasticity of every impact factor

Figure 3 shows the demand elasticity of every impact factor. The impact of urbanization on energy consumption decreased during 1990 and 1996, in other words, the energy demand elasticity declined caused by one percentage increase in urbanization rate. The energy consumption caused by urbanization actually has a negative growth since 1994, while a positive growth since 2000, during which there is a fluctuation. During 2000-2008, the similar situation appeared that the impact of urbanization on energy consumption first increased then decreased. It's obvious that the impact's half-cycle of urbanization on

China's energy consumption is about 6 to 8 years, the same change as in energy consumption values to some extent.

The impact of population on energy consumption represented a growth trend during the period from 1990 to 1995. Before 1997, the impact of population on energy consumption was positive with some fluctuation, while after that population had a negative impact on energy consumption. During 1997 and 2007 there was another change trend like sine wave curve. The impact's half-cycle of population on China's energy consumption is about 6 to 8 years.

Overall, the impact of economy has a wave trend's impact on China's energy consumption. Before 1994, the impact is negative, while that changed into positive after that. That the impact's half-cycle of economy on China's energy consumption is about 14 years.

As shown in Fig.3, the demand elasticity of population changes the most, followed by that of urbanization and economy, and they all change as the wave trends to some extent. Because China is in economy transition period, there will be some counterintuitive changes in impact factors of energy demand sometimes. For example, the demand elasticity of population appeared negative, which must be interpreted on China's macro-environment of economic development. The demand for energy by rural population will be less compared to urban population, which is the majority of China, even the demand is zero or negative (In rural areas, people still use straw and other biomass sources, which are not counted in the statistics of energy consumption). There are many other factors leading to this phenomenon, need to explore in depth.

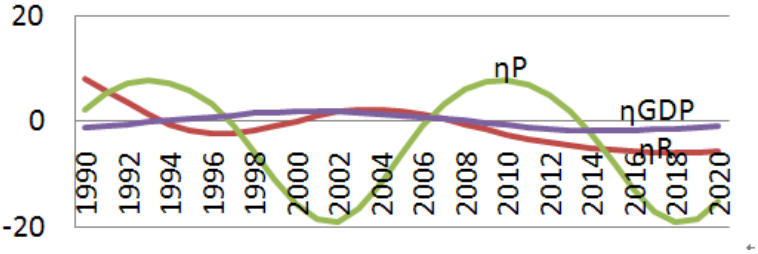


Fig.4 The future trend of the elasticity of demand of every influence factor

Through above analysis, we assume that the trends of each factor's demand elasticity are in line with the sine or cosine wave, not considering the attenuation of the trend in future, getting the trends of demand elasticity in short-term through the Fourier curve fitting as shown in Fig.4. The impact of urbanization, population and economy on China's energy consumption will first decrease then increase in the next decade. Different from the previous period, change trends are almost synchronous in next decade, which means the effects of three factors will cumulative appear. It's crucial for China's economic transformation during the next decade. Even if the energy-saving measures are taken by China's government, the primary energy consumption in China will reach 4.77 billion tce in 2020 according to the National Energy Research Institute forecast. From the trends of demand elasticity, a series of measures on economic and population development policies taken by China's government have certain effects at this stage, which is good for energy conservation in the "twelfth five-year plan" period. However, due to the strong momentum of economic development, China's energy consumption will increase in the long term.

## 5. Conclusion

The conclusions are as follows:

(1) Urbanization, population, economy are three main factors affecting China's energy consumption, while industrial structure and energy price are not the dominant factors. As China is still in the stage of rapid development, its industrial structure will not change much in the short-term future, and the energy consumption is mainly used to support the development of secondary industry. Energy price has little impact on China's energy consumption, which reflects the irrational mechanism of energy prices to some extent. China's government should speed up the reform of energy price mechanism.

(2) The demand elasticity of three factors change regularly, similar to sine or cosine wave trends, and their values have different symbols. It's worthy for us to concern this phenomenon of cyclical changes in the demand elasticity and make some in-depth studies of its economic significance.

(3) The half-cycle of demand elasticity of urbanization, population on China's energy consumption is about 6 to 8 years, the same as the trend in energy consumption values to some extent, while that of economy is around 14 years.

(4) The impact of China's urbanization, population and economy on energy consumption will first decrease and then increase in the next decade, and the total value of China's energy consumption will increase irreversibly. Thus, it's a formidable task for China's energy conversation in the short-term future.

## Acknowledgment

The authors gratefully acknowledge the financial support from the National Natural Science Foundation of China (No:70873013), the Social Science Foundation Fund of Ministry of Education of China(10YJC790381)and the Doctoral Fund of Ministry of Education of China (No:20100095120013).

## References

[1]Donella Meadows, Dennis Meadows, Jorgen Randers, The Limits to Growth, New York: University Books, ISBN 0-87663-165-0.

[2]Prosser，R.D. Demand Elasticity in OECD: Dynamical Aspects. Energy Economics. January，1985，9-12.

[3]WU Yu-ming, Panel Data of Population, Economic Growth, and Energy Consumption in China's Provinces, China population, resources and environment，2007.

[4]Shyamal Paul, Rabindra Nath Bhattacharya. CO2 emission from energy use in India: a decomposition analysis. Energy Policy 32(2004), 585–593.

[5]ZHENG Zhao-ning，LIU De-shun, China's Trans-log Production Function Using Capital, Energy and Labor as Input, Systems Engineering Theory & Practice, 2004 24(5).

[6]LIN Bo-qiang. The Econometric Research on Energy Demands of China[J]. STATISTICAL RESEARCH，2001（10）：34-39.

CSY, CESY, 1991–2009. China Statistical Yearbook, China Energy Statistical Yearbook, National Bureau of Statistics of China.