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Price Mechanism and Energy Efficiency: Evidence from ten countries

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Energy efficiency improvement is an eternal topic in the limited energy sources world. This paper analyzes the relationship between energy efficiency and energy price by using the panel data from ten economic giant. The results show that increasing energy price can promote energy efficiency improvement. If the energy price increases 10%, the energy intensity per unit of GDP could reduce 1%. Compared with other economic giant, the energy price of China is obvious low which is the main reason of China's low energy efficiency. This paper argues that increasing energy related taxes is necessary for improving energy efficiency.

Keywords: Energy Price, Tax, Energy Efficiency, Price Mechanism

Introduction

The economic development of developing countries shows that the demand for energy will increase with the rapid growth of economy. Are energy efficiency and economic growth mutually reinforcing each other or suppression? China academic scholars Wei C & Shen M H measured China's total factor energy efficiency and compared with 35 sample countries. The results showed that the total factor energy efficiency of China was just about half of America and European countries, and only 75% of India[1]. Jin P Z et.al. calculated the total factor energy efficiency and energy saving potential of 10 OECD countries and China from 1995 to 2007 based on super-efficiency DEA approach. They found that China's energy efficiency was increasing year by year while energy saving potential is decreasing which reduces the gap with the developed countries [2]. Wang J J also calculated the total factor energy efficiency of China which was only 44% of America [3]. Why is China's energy efficiency low? It is a problem worthy to be discussed.

Methods and Data

Method

There are two main approaches about estimating energy efficiency which are energy consumption per unit of GDP and total factor energy efficiency [4-6]. The low price of Chinese energy may lead the low energy efficiency in China from further study. In fact, some literature proved that improving energy price could increase energy efficiency [7-9]. Interestingly, China's energy supply is strong monopoly. How can lower energy price happen in monopoly market? The main reason may be distortion of energy price. In the field of production factors, Chinese government still dominate the initial configuration and prices of elements resources, including coal, natural gas, electricity and other resources. The prices of these resources are in the low state for a long time. Zhang J & Zhou X Y thought that the distortion of factors market prompts enterprises to carry out rent-seeking activity, which suppresses the enterprises carry out research and development (energy utilization technology) [10]. Zhang S G & Cheng L thought that factors market regulation in China is largely out of the two big policies, economic growth and price stability consideration [11]. Hsieh C T & Peter J K found that the factor market of China existed serious distortion compared with America. If China could eliminate distortion, the total factor energy efficiency of China's manufacturing industry would improve 30%~50%[12]. Niu C indicated that China's current tax system has some problems, which lead the energy prices cannot reflect the supply and demand situation [13]. Shi D pointed out that the main reason caused China's

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energy price lower is incomplete cost calculation. The cost of resource starvation and environmental destruction which is caused by unreasonable resource exploitation and utilization does not been fully compensated. Therefore, China should improve energy taxes [8].

In this paper, we assume that enterprises are homogeneous. The enterprises all use the three most important factors of production which are labor, capital, and energy. The form of production function is C-D. For simplicity, the study of this paper is constructed on an assumption which is constant returns to scale. The production function of each enterprises is as Eq.(1).

$$Y=F\ (N,\ L,\ K)=AN^{\alpha}L^{\beta}K^{(1-\alpha-\beta)} \quad \ldots (1)$$

If the price level is P, the prices of energy, labor and capital are pn, pl and pk, respectively. Under the given output Y, the equilibrium conditions of enterprises to select each factor are as the following equations.

$$P\cdot(dY/dN)=p_n \quad ...(2)$$

$$P\cdot(dY/dL)=p_l \quad \ldots (3)$$

$$P\cdot(dY/dK)=p_k \quad \ldots (4)$$

According to Eq.(2), Eq.(3) and Eq.(4), we can get Eq.(5).

$$N^*=\alpha P\cdot Y/p_n \quad ...(5)$$

Therefore, the inputs of energy are inversely proportional to energy prices. The more inputs of energy N, the lower energy efficiency is for a given output Y. We can infer that energy efficiency is proportional to energy price. We can also say unit GDP energy consumption is inversely proportional to energy prices. In addition, the input of each factor that the enterprises choose should satisfy Eq.(6).

$$MP_N/p_n=MP_L/w=MP_K/r \quad \ldots (6)$$

MP_N, MP_L and MP_K represent the marginal output of energy, labor and capital. Therefore, if the prices of labor and capital rise up, the enterprises will choose energy to replace labor and capital. We can infer that energy efficiency is inversely proportional to the prices of labor and capital. According to Eq.(1), given an output Y, the higher technical production A, the less input of energy E. therefore, energy efficiency is proportional to technical efficiency A. Thereupon, we can construct a dynamic model of energy efficiency as Eq.(7).

$$\ln EE_{it}=\alpha_0+a_1\ln EE_{it1}+\alpha_2\ln A_{it}+\alpha_3\ln pn_{it}+\alpha_4\ln l_{it}+a_5Z_{it}+u_i+\varepsilon_{it} \quad \ldots (7)$$

Here, EE denotes energy efficiency which can be represent by the reciprocal of energy consumption per unit of GDP. The energy consumption per unit of GDP is also recorded as eea which could be denoted by total factor energy efficiency (eeb). Z denotes control variable. i represents country. t refers to time. The reason of introducing the first-order lag of explained variable is that technology will not retrogress. So energy efficiency is always associated with past times. ui denotes the unobservable differences between countries. ε_{it} is stochastic disturbance term. In order to avoid the endogenous of the dynamic models as far as possible, the Eq.(7) need to use the generalized moment of method (GMM) to estimate. If we remove the second item in the right of equation, the model becomes a static one which can be directly estimated using ordinary least squares (OLS). In the model, we introduce the price of labor, but do not add the price of capital. This is because that there is an obvious capital price controls and distortion in China. Therefore, the relative price of energy and capital does not reflect the degree of their relative scarcity. However, the supplier in the labor market is a basic unfettered countless individuals, and thus the labor market can be considered to be more close to the competitive market. The price of labor market is less likely to be distorted. Therefore, the relative price of energy and labor force can reflect the distortion of energy price more accurate. In empirical analysis, the A in Eq.(7) we can use the per capita GDP to represent, which can be recorded as gdp. The reason is that the technical level is proportional to per capita GDP. Therefore, we take per capita GDP as the proxy variable A. we select industrial structure as control variable. Industrial structure is considered to be important factors which affect energy efficiency. Thus the industrial structure is often added to the model as control variable to analyze energy efficiency. In this paper, we apply the proportion of the tertiary industry as industrial structure variables. The energy consumption of tertiary industry is low. So the higher the proportion of the tertiary industry is, the higher the energy efficiency obtains. Based on the above theory, we predict that a1>0, a2>0, a3>0, a4<0, a5>0.

We apply DEA method to estimate total factor energy efficiency EE. Specifically, we choose capital, labor and energy as input factor. GDP is the induced

output. The optimal energy input to actually inputs of an output is the total factor energy efficiency. The greater the ratio value indicates that the actual investment is closer to optimal investment and the energy efficiency is high, and vice versa. The efficiency value scope is (0, 1].

The Correlation between Price and Energy Efficiency Analysis

Energy Efficiency Measures

This paper uses the reciprocal of energy consumption per unit GDP to represent energy efficiency. The unit of GDP is converted to 2005 constant international dollars. This paper applies the total factor productivity to measure energy efficiency. Firstly, we calculate the capital stock of these ten countries by using perpetual inventory method. Then, we apply the DEA method to calculate the energy efficiency through regarding the capital stock, energy investment, labor as three inputs and GDP as output. We use DEAP software to calculate the optimal energy consumption of these ten countries every year. Then we can obtain the total factor productivity through the optimal energy consumption dividing the actual energy consumption of corresponding year. The changeable tendency of these ten countries' total factor productivity is basically in accordance with the energy efficiency value which is calculated by energy consumptions per GDP. Here, we do not present specific numerical. The energy efficiency values of other nine countries are higher than China. The values of other eight countries are all higher than China. Table 1 depicts the per capita GDP of nine countries.

Energy efficiency is closely related to the income level. Meanwhile, the country with higher income usually has higher technical level. The proportion of the tertiary industry is also higher. Through the comparison for table 1, concluded that high-income countries have higher energy efficiency. However, there are two problems worthy of note. Firstly, the income of India is lower than China, but energy efficiency is obviously higher than China. The income level of other countries is not completely corresponding to energy efficiency. Secondly, China's income level greatly increased from 1995 to 2012. The per capita GDP is quadrupled. However, the energy efficiency is comparatively with minor enhancements. Such as the UK, its growth rate of per capita GDP is not high, but the energy efficiency nearly doubled. Therefore, we need to make further analysis on energy efficiency. According to the related theory above, we analyze the influence of the relative energy prices on energy efficiency.

The Influence of Price on Energy efficiency

This paper applies GMM method to estimate the dynamic panel data model (7). We use two modes to represent energy efficiency. One is energy consumption per unit GDP. The other one is total factor energy efficiency. In addition, we also give the OLS estimation results of the static panel data model for comparison. The results are shown in table 2 and table 3. Model 1 and model 3 are OLS models without control variable. Each coefficient in these two models is significant and the sign is consistent with the theoretical expectations except the wage (lnw). In model 2 and model 4, we bring in the industrial structure control variable. As the results show, including control variables, all variables are

Table 1—The per capita GDP of nine countries (constant 2005 international dollars)

Year	1995	2003	2012
Australia	26566	32443	37242
Canada	27821	33692	36123
China	778	1429	3348
The UK	28772	36545	37609
Germany	29980	32906	38220
India	469	647	1123
Japan	32942	34521	36942
Korea	12142	16231	21562
America	35112	42078	45336

Data are from the World Bank database.

Table 2—OLS estimation results

Explained variable	energy consumption per unit GDP		total factor energy efficiency	
	Model 1	Model 2	Model 3	Model 4
c	-3.12*** (0.00)	-10.06*** (0.00)	-6.23*** (0.00)	-12.33*** (0.00)
ln(pe)	0.08** (0.01)	0.26*** (0.00)	0.12*** (0.00)	0.105*** (0.00)
ln(w)	-0.12 (0.15)	-0.26 (0.03)**	-0.08 (0.34)	-0.30*** (0.00)
ln(gdp)	0.20*** (0.10)	0.23*** (0.00)	0.78*** (0.00)	0.81*** (0.00)
ln(ser)		1.16*** (0.00)		1.45*** (0.00)
Entity fixed effect	yes	yes	yes	yes
A-R^2	0.79	0.85	0.86	0.88

Note: In the parenthesis is the p value. *** and ** respectively, express at the level of 1% and 10% significantly

Table 3—GMM estimation results

Explained variable	energy consumption per unit GDP		total factor energy efficiency	
	Model 5	Model 6	Model 7	Model 8
ln(ee)(-1)	0.69*** (0.00)	0.78*** (0.00)	0.73*** (0.00)	0.68*** (0.00)
ln(pe)	0.102*** (0.00)	0.146*** (0.00)	0.05*** (0.00)	0.047** (0.05)
ln(w)	-0.062 (0.43)	-0.19 (0.26)	-0.01 (0.95)	-0.08 (0.81)
ln(gdp)	0.069 (0.63)	0.04 (0.85)	0.11 (0.20)	0.16 (0.50)
ln(ser)		0.31 (0.19)		0.45 (0.31)
J statistics	9.81	8.35	6.21	5.40

Note: In the parenthesis is the p value. *** and ** respectively, express at the level of 1% and 10% significantly.

significant and the sigh is consistent with the theoretical expectations. In particular, the coefficient of energy price (lnpe) is significantly positive under 1% significance level which explains that energy prices are positively related to the energy efficiency. The coefficient of wage is negative. Although it is not significant in model 1 and model 3, significantly after joining the control variable. The sign of wage in the four models are negative which explains that higher wages negatively related to the energy efficiency. The coefficient of per capita GDP in four models are significantly positive, suggests that income level is positively related to the energy efficiency. The tertiary industry proportion coefficient is significantly positive; indicating the rising of proportion of the tertiary industry can improve energy efficiency. These are preliminary verified our judgment. Because the continuity and inertia of technology, it generally won't appear technological step backwards. Therefore, the change of energy efficiency is a dynamic process. Static panel data may have overestimated the influence of other factors on energy efficiency. Here, we apply the dynamic panel data for further analysis, namely model 5, model 6, model 7 and model 8 in table 3. As shown in table 3, the coefficients of wage, per capita GDP and industrial structure are not significant using dynamic panel model. The coefficient of energy price is still significantly positive. The results further validate our conclusion. Specifically, according to the model 5 and model 6 in table 3, a 1% increasing in energy price will promote 0.1% of energy consumption of unit GDP. It also means that a 1% increasing in energy price will reduce 0.1% of energy consumption of unit GDP. This means that if a 10% increasing in energy price will make the energy consumption fell by more than 1%. We can also explain the influences that the price on energy efficiency more clearly by comparing China, India and the United States. The improvement trend of energy efficiency was consistent with per capita GDP in the United States before 2005. The situation of India is very similar to the United States. However, China's situation is absolutely different from the United States. The improvement speed of energy efficiency of China is obviously slower than the growth rate of GDP. China's per capita GDP grew by 328% from 1995 to 2012. However, energy efficiency increased only 77% in this period. Comparatively speaking, per capita GDP grew by 62% in the United States, and energy efficiency increased by 55% from 1995 to 2012. In this period, India's per capita GDP increased by 141% and the energy efficiency improved by 53%. Therefore, the GDP growth of China (to some extent can be said technology) does not bring the corresponding energy efficiency improvement. China is the only country whose relative energy prices fall. China's relative energy prices reduced by 59% from 1995 to 2012. In the case of the cheaper energy price, enterprises obviously have little incentive to improve energy efficiency. The above analysis shows that the relative energy prices increasing helps to improve energy efficiency. The increasing energy price will encourage companies to use other production factors to substitute for energy sources, or choosing more efficiency production methods. China's relative energy price continuously declined, which hindered China's energy efficiency improvement from 1995 to 2012. The prices of petroleum products do not on the high side, despite that the oil product market presents the oligopoly structure. In fact, due to historical reasons, China's energy price long-term is implemented by government. The public are accustomed to relatively low energy prices. So public are sensitive to higher energy prices. Like that, are China's energy prices really low? What factors lead to China's low energy price? How to improve the relative price of energy? The next part of this article will discuss the content.

Price and Energy Tax Relationship Analysis

China's residential electricity prices significantly lower than most developed countries in terms of purchasing power parity (PPP). If in name of the

official exchange rates, China's residential electricity price will be lower than those developed countries. Since 2012, China has carried out tiered electricity pricing mechanism. The first gear average electricity price is 0.553 yuan per degree. If we calculate the electricity price by nominal exchange rate will be 87.6 dollars per megawatt hour. This shows that China's electricity price is not high as the public think. Comparing the above empirical analysis, we can defer that China's energy prices are low. Low energy price is the important reason for China's low energy efficiency. This is also an important reason for the slowly rising energy efficiency. A large proportion of the petrol price is the price of crude oil. For example, the retail prices of gasoline comprise 67% crude oil, 14% smelting cost, 85% sales cost and 12% tax revenue in the United States in June 2014. Under the condition of crude oil price world synchronization, why does the gasoline price have such a big gap? The tax revenue should be an important reason. China's gasoline price comprises various tax revenues 30.5%, which much lower than European Union countries. It shows that the differences of gasoline price mainly lies in the different taxes. To improve China's refined petroleum products prices, the government needs to increase consumption tax of refined petroleum products. Low energy prices is a kind of market failure which makes the energy price cannot reflect the true marginal cost. The main reasons include the negative externalities of energy production and consumption, the average cost of government pricing, etc. There are lots of greenhouse gases and other harmful matters been produced in the process of energy production and consumption that is a kind of social cost. However, it usually is not in the calculation of marginal cost. The price of China's main energy, coal, for example, was almost completely control before 2002. Until 2013, the government canceled the coal double-track pricing system. The price of coal realizes marketization. There are some unreasonable price's forming mechanisms, which perform that the price does not fully reflect the extent of the coal resource scarcity. Therefore, the energy tax system reform will be the key factor for promoting the reasonable energy prices along with China's deregulation of energy price. Through the international comparison in this paper, China's refined oil prices are lower than other countries. The consumption tax of refined oil products is still low. In addition, China's has not levied coal consumption tax. It is necessary to raise the prices of coal and refined oil products through levying coal consumption tax and raising refined oil consumption tax. Raising energy prices will, of course, be opposed by many consumers, but in order to meet the demands of energy conservation and emissions reduction, it is a very effective method. According to the calculation of this paper, a 10% increase in energy prices will lead 1% energy consumption reduction. In 2013, the total energy consumption is 3.75 billion tons of standard coal in China, which means that a 10% increase in energy prices could save 37.5 million tons of standard coal.

Conclusions

By selecting 10 major economies countries as samples, econometric analysis shows that if the energy price increases 10%, the energy intensity per unit of GDP could reduce 1%. This means that raise energy prices could significantly reduce energy consumption. Gasoline, for example, compared with other countries, we could found that China's energy prices has been significantly lower than European countries, Japan, South Korea, India and other countries in a long time. This is an important reasons that China's energy efficiency is lower than many other countries. Further analysis shows that the lower taxation is an important reason for low prices of energy in China. Thus, the government can increase energy prices by raising energy consumption tax. For the above conclusions, we make the following suggestions. Firstly, the government of China should improve the overall tax rate of energy through various measures, such as, raising the refined oil and electricity consumption tax. Secondly, in order to reduce energy prices burden on residents and enterprises, the government can provide more subsidies. Finally, China should further promote integration of coal enterprises; reduce the number of coal enterprises, thus lessen vicious competition among them.

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