9-17-2009

Empirical Analysis of Provincial Energy Efficiency in China

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Abstract

This paper generates an energy efficiency index based on the Data Envelopment Analysis (DEA) approach and then examines the energy efficiency in China. Using panel data including 29 provinces from 1995 to 2007, we find that energy efficiency is negatively associated with the secondary industry share in GDP, the state-owned share in GDP and the government expenditure share in GDP, and is positively associated with the technical level and non-coal share in energy consumption. In addition, we find that there exists a big gap of energy efficiency among three regions (costal eastern region, middle region and western region). The eastern region has significant higher energy efficiency level than the middle and western regions. We conclude that the different levels of the industry structure, the government power, energy structure, and technology content in three regions contribute the differences in energy efficiency.

Keywords: Energy Efficiency, Determinants, Data Envelopment Analysis, China
JEL codes：D24; O13; Q43

I. Introduction

Energy efficiency is an important issue for China's sustainable development. Currently there still exists extensive energy shortage (China Daily, 2004) which becomes worse under the substantial increases in world oil price. In 2007, the revision of the energy conservation law (published in 1998) emphasizes the importance of energy efficiency in all sectors of the economy. In addition, to cope with the global warming caused by the burning of fossil fuels, China, the largest emitter of greenhouse gas since 2007 (IEA, 2007) , should contribute more to global environment although there is no any rigorous reduction target in Kyoto protocol. The improvement of energy efficiency has become an urgent step to further

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economic development.

The purpose of the paper is to examine the factors affecting provincial energy efficiency in China. To do so, we utilize latest panel data set, which cross 29 provinces from 1995 to 2007 to measure the energy efficiency score under the Data Envelopment Analysis (DEA) framework. DEA have been widely used to measure "Debreu-Koopmans" efficiency and productivity (Farrell, 1957). It has been used in comparing efficiency across firms in manufacture sectors (Kumbhakar and Hjalmarsson, 1998; Vaninsky, 2006; Sarica and Or, 2007; Barros, 2008), comparing energy efficiency across regions (Hu and Wang, 2006 for Chinese studies, Honma and Hu, 2008 for Japanese study), and cross countries (Chien and Hu, 2007).

The advantage of using DEA, as Hu and Wang (2006) concluded, are in that the energy index generated through DEA is more practical than commonly used index of the energy productivity ratio, which is used at earlier studies (Wilson et al. 1994; Patterson 1996). This is because that the technical efficiency scores under the DEA framework reflects the ability to obtain maximal output from a given set of inputs, or reduce the input without sacrifice the output (Lovell, 1993). In our paper, we use one output (GDP) and three inputs (Labor, Capital, and Energy Consumption) to generate an index of energy efficiency. The energy index generated by DEA indicates that there exists remarkable difference on energy efficiency among provinces and regions in China. The East region and many provinces in it are the most efficient on energy utilization over three regions, while the underdeveloped West area and some of its member have the lowest energy efficiency level.

The main contribution of the paper is that it is the first paper to identify the source of variation of provincial energy efficiency in China using econometric model. Hu and Wang (2006) calculated and compared the energy index through DEA with other traditional measurement, but they did not do further regression analysis to explain the patterns they found. This paper extends those studies by identifying economic factors and analyzing the impact of these factors on the energy efficiency.[1]

Specifically, our detailed regression results indicate that, in general, energy efficiency is negatively associated with the secondary industry share in GDP, the state-owned share in GDP and the government expenditure share in GDP, and is positively associated with the technical level and non-coal share in final energy consumption. Our findings are consistent with earlier firm/sub-sector level studies that acknowledged the technological change to be the primary factor behind China's past energy efficiency improvements (Lin and Polenske, 1995; Garbaccio et al., 1999; Ma and Stern, 2008). The structural change—especially the shift from energy-intensive sectors to less intensive sectors, were also found to lead to higher energy productivity (Sinton and Levine, 1994; Lin and Polenske, 1995; Garbaccio et al., 1999; Liao et al., 2007). However, most of these studies found that, compared with the technology effect on energy efficiency, the changes in industrial composition contributed to a minority of the decline in China's energy intensity.[2]

[1] Some other studies (Garbaccio et al., 1999; Ma and Stern, 2008a) used a decomposition way to evaluate each factor's contribution.

[2] However, as Sinton and Fridley(2000), Rawski(2001) argued, China's energy data may be under-reported, and the GDP data may be overestimated, these inaccurate statistics data might result in a lower energy intensity value

Finally, our results are also consistent with current literature that ownership reform and government policies affected energy efficiency in micro-level through multiple channels (Fisher-Vanden et al., 2004; Jefferson and Su, 2006; Fisher-Vanden, et al., 2006; Sinton and Fridley, 2000).

Our findings have important policy application. Chinese government has proposed several policies to prompt the energy efficiency. In 2006 the National People's Congress passed the "11th five-year plan", which set a constraint rule to decrease the energy intensity 20% in the next five years, However, the latest official report shows that until now, most provinces did not meet this reduction objective in the last two years (National Bureau of Statistics, 2008). Our results show that the government should apply different energy policy across regions. To improve energy efficiency, we should induce the industry development structure from the secondary industry to tertiary industry, change the energy consumption structure dominated by coal to diversified cleaning energy, prompt the private and foreign economy, eliminate the government's intervention on economy and boost the inside technology activity.

This paper is organized as follows. Section 2 constructs a relative energy efficiency index based on DEA method. Section 3 introduces the variables and data. Section 4 measures the energy efficiency score by provinces and regions, and then a econometric model is estimated to investigate the sources of difference of provincial energy efficiency. Conclusions follow in Section 5.

II. Methodology

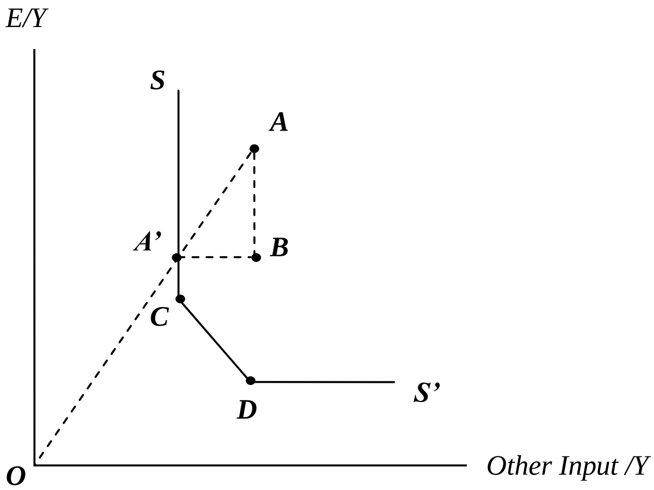
The DEA, is a well established non-parametric approach used to evaluate the relative efficiency of a set of comparable entities called Decision Making Units (DMUs) with multiple inputs and outputs (Cooper et al., 2000). The purpose of DEA is to construct a non-parametric envelopment frontier over all sample data such that all observed points lie on or below the frontier (Coelli, 1996). The points lying on the frontier are regarded as the best performers and thus become the benchmark line relative to other sample points.

We consider a simple example illustrated at Figure1: given the CRS assumption, each province needs to input the energy and other factors (labor and capital) to produce a unit output. The isoquant is presented by piecewise linear SS'. According to Farrell's definition (Farrell, 1957), point A is inefficient compared with the efficient points C and D lie on the frontier. We define the score of technical efficiency of point A as OA'/OA, which means that it can keep the same output by reducing the radial adjustment AA'. However, the point A' is not an optimized reference point because we can reduce the energy input CA' without any sacrifice of the output[3]. Therefore, the point A has excess input compared with its best reference point C. Further the quantity of energy input loss can be decomposed into two parts.

[3] This is so called 'input slack' that can essentially be viewed as allocative inefficiency(Ferrier and Lovell,1990)

One part is AB as a result of technical inefficient for each input. The other part is the slack CA' that is due to the inefficiency of allocation. So the sum of AB and CA' is the energy that can be saved for point A to reach the target reference point C.

Figure 1. Energy Efficiency in an input-oriented CRS model



Source: Hu and Wang (2006)

According to Fig.1, we can define energy efficiency by province with the following equation (Hu and Wang, 2006).

$$EE_{i,t} = \frac{AEI_{i,t} - LEI_{i,t}}{AEI_{i,t}} = 1 - \frac{LEI_{i,t}}{AEI_{i,t}} = \frac{TEI_{i,t}}{AEI_{i,t}} \tag{1}$$

where *EE* is energy efficiency score, *AEI* denote the actual energy input, *LEI* means the lost energy input that can present as the sum of *AB* and *CA'* illustrated in Fig.1, *TEI* express the target energy input such as the optimized point C, all subscript variable present the *i*-th province at *t* time. If the score of *EE* equals to 1, it means that this province is the best one among all the comparing samples. It should be noticed here that a 100% energy efficiency score doesn't imply that these 'target provinces' are perfect and without any energy loss or inefficiency during production process. They can save the energy with same output level relatively better than the other samples.

III. Variable and Data Description

1. Measurement of the Energy Efficiency

There are 31 provinces, autonomous regions and municipalities (for simplification, we name as 'provinces') in mainland[4]. We combine Chongqing, the fourth

[4] The mainland of China doesn't include the Hong Kong (SAR), Macro (SAR) and Taiwan province.

municipality in China, with Sichuan province since the former was part of Sichuan province before 1997. Tibet is excluded due to the absence of energy data. This leads to sample data across 29 provinces from 1995 to 2007 that can be divided into three main areas: the east, middle and west[5] as shown in Table 1.

Table 1.Three Major Areas in China

Area	Provinces included	Economy share in 2007	Population share in 2007
East	Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan	59.3%	39.9%
Middle	Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan	23.4%	32.3%
West	Inner Mongolia, Guangxi, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang	17.3%	27.8%

Source: China Statistical Yearbook 2008 (NBS)

One output and three inputs are considered in this paper. The gross domestic production (GDP) is selected as output and deflated to constant price in 2000. The labor input is calculated as the value of employment at the end of current year; both are obtained from China Statistical Yearbook (National Bureau of Statistics, 1996-2008). Each province's energy consumption, including the conventional coal, petroleum, natural gas and electricity, are converted to standard coal equivalent and collected from China Energy Statistical Yearbook (National Bureau of Statistics, 1998, 2000, 2004, 2008). The capital stock are unavailable in any statistical yearbook, we have to estimate this serial by the followed perpetual inventory method:

$$K_{i,t} = I_{i,t} + (1-\delta_i)K_{i,t-1} \tag{3}$$

Where $I_{i,t}$, δ_i and $K_{i,t-1}$ present gross investment, depreciation rate and capital stock for the province i at time t, respectively. Here we select 1952's as initial capital stock provided by Zhang et al. (2007) and extend them up to date, all serial data are converted in 2000's price.

The descriptive statistics of input and output for China and three regions are reported in Table 2. As the data in this table show, the mean and standard deviation of GDP in East region is much higher than the Middle and West region. Meanwhile, the East area consumes the largest portion of energy amount and capital stock to support its rapid economic growth.

5 According to the classification of China's western development strategy, the Inner Mongolia and Guangxi belong to the west area.

Table 2 . Summary Statistics for Output and Input from 1995 to 2007

Region	Output	Input		
	GDP	Labor	Capital	Energy
	Billion Yuan in 2000 prices	10000 person	Billion Yuan in 2000 prices	10000 tons of coal equivalent
China	4186.8 (3911.2)	2238.8 (1570.3)	8240.3 (7427.2)	6526.6 (4676.4)
# East	6512.0 (4937.3)	2286.1 (1569.4)	12500.4 (9202.9)	8261.3 (5830.7)
# Middle	3628.0 (1911.1)	2649.0 (1332.0)	6590.5 (4015.1)	6694.0 (3056.4)
# West	2076.2 (2026.2)	1858.7 (1666.0)	4874.1 (4577.6)	4481.5 (3359.4)

Source: The real GDP in 2000 constant price and the labor data come from China Statistical Yearbook (NBS). The energy consumption comes from China Energy Statistical Yearbook (NBS). The capital stock is author's calculation based on the study of Zhang et al. (2007)

Note: We report the mean values, the standard deviations are in parentheses

2. Data and Variables

The second step is to identify the factors that determine the efficiency level of each province. Based on the previously literatures, we mainly consider some factors as the following.

(1) It is apparent that the industrial structure change can exert great influence on the energy efficiency; especially a shift from the high-energy-consumption sectors such as Secondary industry to the low-energy-consumption sectors, such as the Tertiary industry will increase the total energy efficiency as mentioned by most studies (Zhang, 2003; Fisher-Vanden et al., 2004). Hereby we use the ratio of value added in industrial sector to total GDP and the share of tertiary sector in whole GDP to present each province's structural change. We expect that the share of industrial sector in GDP will take a negative impact on the energy efficiency, while the share of service sector in GDP will impose a positive influence on the energy efficiency.

(2) Jefferson et al. (2000, 2006) , Watanabe and Tanaka (2007) suggested that the non-state-owned enterprise are more efficient than the state-owned firms, here we use the share of state-owned enterprises (SOEs) in industry gross value added to capture the shift towards a private sector economy. We expect a negative relationship between the SOEs share and the energy efficiency.

(3) Fisher-Vanden et al. (2006) discussed that technical level exhibits an energy-saving bias no matter by internal research activity or imported. Therefore it can save the energy input during the product process while keep the output constant at the same time. In the past three decades, China's opening-up to the world had attracted rich foreign direct investment, a great deal of advanced technology has been transfer or bought into China, here we use the proportion of high-technology products in imports for each province from 1997 to 2006 to denote the difference on technology level. Otherwise, the proportion of high-technology products in exports, the share of R&D expenditure in GDP, as well as the share of Science and Technology appropriate in government's financial expenditure are used to proxy the provincial technology level for robust test.[6]

(4) Government plays an important role in transition and developing countries. One the one hand, some governmental policies that aims to close down small power generators and small mining factory can decrease inefficiency energy consumption (Sinton and Fridley, 2000). On the other hand, the intervention to economy by government is usually associated with corruption, rent-seeking and economy inefficiency (Acemoglu and Verdier, 2000). To measure what extent of the government may effect on the energy efficiency, we use the share of financial expenditure in GDP to present the power of local government on the economy and assume that this coefficient will be less than zero.

(5) Sinton and Fridley (2000) argued that the improvement in coal quality and greater use of gas and electricity in households may contribute to the decline trends of China's energy consumption since 1996. Chien and Hu (2007) also suggested that increasing the input of traditional energy, such as coal, will decrease the technical efficiency. Because various energy products release different calorific value during thermal processing, the energy consumption structure should be taken into account as an important factor. Here we define the energy structure as the share of natural gas, the share of oil products, as well as the share of electricity in total final energy consumption.[7] The coefficient of these variables is expected to be positive.

Table 3 shows the summary statistics for independent variables. The East rank highest in technology level during this period with lowest government intervention and SOEs share in economy, as well as highest non-coal energy consumption share, however, the difference of industrial structure among three regions is not remarkable.

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[6] As the reviewer mentioned, the proportion of high-technology products in all exports may result in systematically bias. To follow his suggestion, three alternative proxy variables are used to check the reliability.

[7] The total energy consumption includes four energy products: the conventional coal, petroleum, natural gas and electricity, all are converted to standard coal equivalent. The final consumption data of each energy product are derived from the "Energy Balance Table" in China Energy Statistical Yearbook.

Table 3. Descriptive Statistics of all Variables, 1997-2007

Independent Variables		China	# East	# Middle	# West
Industry share	*Industry*	0.279 (0.088)	0.305 (0.104)	0.271 (0.079)	0.257 (0.067)
Service share	*Service*	0.392 (0.067)	0.417 (0.09)	0.366 (0.043)	0.386 (0.035)
State-owned share	*State*	0.689 (0.126)	0.596 (0.137)	0.712 (0.069)	0.771 (0.072)
Natural gas share	*Gas*	0.041 (0.064)	0.036 (0.065)	0.016 (0.021)	0.068 (0.077)
Oil products share	*Oil*	0.259 (0.128)	0.361 (0.116)	0.217 (0.102)	0.184 (0.079)
Electricity share	*Electricity*	0.187 (0.056)	0.206 (0.061)	0.162 (0.035)	0.187 (0.057)
Government intervention	*Gov_scale*	0.136 (0.056)	0.105 (0.032)	0.119 (0.028)	0.184 (0.061)
High-Technology product share in imports	*Imp_highTech*	0.196 (0.18)	0.231 (0.102)	0.137 (0.065)	0.204 (0.275)
High-Technology product share in exports	*Exp_highTech*	0.082 (0.105)	0.159 (0.131)	0.035 (0.029)	0.036 (0.046)
R&D share in GDP	*RD*	0.01 (0.009)	0.014 (0.013)	0.007 (0.002)	0.008 (0.007)
Science and Technology appropriate share in financial expenditure	*Gov_st*	0.018 (0.012)	0.026 (0.017)	0.015 (0.006)	0.013 (0.003)

Source: The data for variable *Industry, Service, State, Gov_scale* come from China Statistical Yearbook (NBS). The data for variable *Gas, Oil* and *Electricity* come from China Energy Statistical Yearbook (NBS). The data for variable *Imp_highTech, Exp_highTech, RD* and *Gov_st* come from China Science and Technology Statistical Yearbook (NBS)

Note: We report the mean value, the standard deviations are in parentheses.

IV. Empirical Analysis of Energy Efficiency

1. First-stage Analysis

The first step of our study is to measure the energy efficiency score for each province; the results are listed in Table 4[8].

[8] These score are calculated by DEAP 2.1, a LP solve program developed by Coelli (1996).

Table 4 .Energy efficiency score for all provinces

Province	Period				Mean (1995-2007)	Rank
	1995-1997	1998-2000	2001-2003	2004-2007		
Beijing	1.000	0.881	0.921	0.904	0.884	5
Tianjin	0.645	0.722	0.763	0.747	0.699	13
Hebei	0.656	0.448	0.380	0.383	0.532	18
Shanxi	0.327	0.207	0.215	0.231	0.318	27
Inner Mongolia	0.607	0.358	0.334	0.310	0.463	24
Liaoning	0.511	0.490	0.507	0.488	0.481	22
Jilin	0.443	0.445	0.432	0.452	0.500	20
Heilongjiang	0.414	0.546	0.541	0.550	0.514	19
Shanghai	1.000	1.000	1.000	1.000	1.000	1
Jiangsu	0.752	0.940	0.938	0.889	0.857	7
Zhejiang	0.916	0.796	0.800	0.813	0.858	6
Anhui	0.675	0.558	0.597	0.621	0.673	15
Fujian	1.000	1.000	0.912	0.910	0.969	3
Jiangxi	0.843	0.709	0.689	0.709	0.808	8
Shandong	0.853	0.606	0.606	0.600	0.736	12
Henan	0.845	0.576	0.547	0.510	0.693	14
Hubei	1.000	0.543	0.521	0.495	0.746	10
Hunan	0.811	0.722	0.637	0.599	0.745	11
Guangdong	1.000	1.000	1.000	1.000	1.000	2
Guangxi	0.987	0.688	0.675	0.640	0.792	9
Hainan	1.000	0.864	0.880	0.908	0.916	4
Sichuan	0.770	0.566	0.525	0.511	0.655	16
Guizhou	0.569	0.236	0.211	0.219	0.337	26
Yunnan	0.478	0.465	0.492	0.473	0.465	23
Shaanxi	0.519	0.502	0.502	0.501	0.544	17
Gansu	0.659	0.343	0.343	0.349	0.493	21
Qinghai	0.367	0.290	0.287	0.268	0.314	28
Ningxia	0.275	0.224	0.174	0.170	0.257	29
Xinjiang	0.480	0.389	0.384	0.363	0.382	25
China	0.704	0.590	0.580	0.573	0.643	
# East	0.848	0.795	0.792	0.786	0.812	
# Middle	0.670	0.538	0.522	0.521	0.625	
# West	0.571	0.406	0.393	0.380	0.470	

Source: Author's calculation.

Note: Due to the table limitation, we divide the sample period into four sub-samples: 1995-1997, 1998-2000, 2001-2003, 2004-2007 and report the average score for each period.

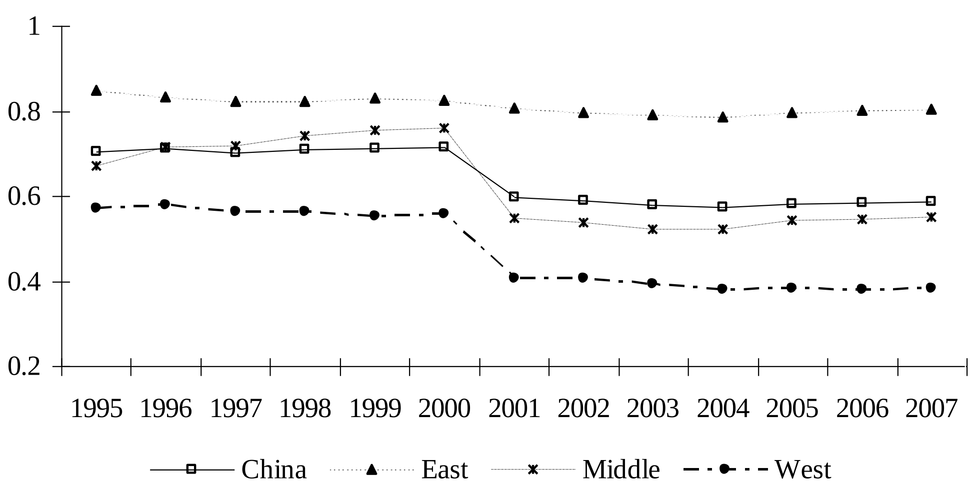
We can conclude some main results from Table 4:

(1). Shanghai always lies on the frontier as benchmark from 1995 to 2007, and Guangdong, Fujian and Hainan gain a score higher than 0.9, which means that these provinces are close to the frontier and had better performance. On the contrary, Ningxia, Qinghai, Shanxi and Guizhou's average score is less than 0.35, so as to be the most inefficiency provinces during this period.

(2). the bottom three rows in Table 4 indicate that the East region is more efficient among all regions. The Middle area catches up fast and seems to be narrowing the gap to the East. The West region, however, lags behind the East and Middle. This observation is similar to the most previous conclusions which focus the TFP variation between the three major areas (Jefferson et al., 2000; Zheng and Hu, 2006). However, it differs from Hu and Wang (2006) in that their estimation shows that West area (0.644) has a higher score than the Middle's (0.557), while our result shows that the Middle region (0.625) has significant better performance than the West area (0.47). There are two reasons may contribute to this distinct rank between the Middle and West area. One is associated with the different capital stock data. In Hu and Wang's paper, they obtained the initial provincial capital stock in 1978 price from Li (2003) and transformed them into 1995 price with GDP deflators, while we adopted Zhang et al (2007)'s initial capital stock data and expressed them in 2000 price with the capital deflators. Another interpretation is for our different classification for provinces—the Inner Mongolia and Guangxi were fallen into the category of Middle and East respectively in Hu and Wang's study. However, both belong to the West area in our paper based on the classification of National Western Development Strategy.

(3). Figure2 indicates the four patterns of energy efficiency by regions (East, Middle, West and the whole China). As we can see, overall pattern suggests that the energy efficiency is improving before 2000, and declines after that, and goes slight up again in 2005. This fluctuate trend and its turning point are consistent to recently studies that used energy intensity as indicator of energy efficiency (Liao et al., 2007; Ma and Stern, 2008). In addition, the trace for East region is stable while the Middle and West areas have greater variation during this period.

Figure 2. Trajectory of energy efficiency of China and three major area



Source: Author's calculation.

2. Second-stage Analysis

The second-stage analysis aims to explain the provincial energy efficiency difference. An econometric model is presented at following equation.

$$EE_{i,t}=\beta_0+\beta_1*Industry_{i,t}+\beta_2*Service_{i,t}+\beta_3*State_{i,t}+\beta_4*Gas_{i,t}+\beta_5*Oil_{i,t}$$

$$+\beta_6*Electricity_{i,t}+\beta_7*Gov\_scale_{i,t}+\beta_8*Tech_{i,t}+\alpha_i+\alpha_t+\varepsilon_{i,t} \quad (4)$$

where *EE* is the energy efficiency score we have obtained from the first-stage analysis. The independent variables *Industry*, *Service, State*, *Gas*, *Oil*, *Electricity*, *Gov_scale* denote the industrial sector's share, service sector's share, state-owned sector's share, natural gas consumption share, oil products consumption share, electricity consumption share and government power, respectively. *Tech* including four proxy variables, the share of high-technology products in imports (*Imp_highTech*), the share of high-technology products in exports (*Exp_highTech*), the share of research and development expenditure in economy (*RD*), as well as the share of science and technology appropriate in government's financial expenditure(*Gov_st*), each of them will be used to proxy the technology level in turn. α_i , α_t and $\varepsilon_{i,t}$ are individual effect, period effect and the stochastic error item for the *i*-th province at *t* time respectively. To avoid the potential problem caused by the impacts of unobserved variables, we use a two-way fixed effect model to control the provincial and period effect both. Furthermore, considering the energy efficiency value is between 0 and 1, the Tobit estimation on equation (4) is necessary (Lam and Shiu, 2001; Watanabe and Tanaka, 2007). Table 5 reports the final regression result based on GLS and Tobit estimation.

Table 5. GLS and Tobit Regression Results

Independent variables	GLS				Tobit			
	I	II	III	IV	V	VI	VII	VIII
Industry	-1.03 ***	-1.19 ***	-1.01 ***	-1.026 ***	-1.06 ***	-1.24 ***	-0.97 ***	-1.06 ***
	(-7.67)	(-8.52)	(-6.68)	(-7.63)	(-7.3)	(-8.13)	(-6.13)	(-7.29)
Service	0.138	-0.04	0.209	0.125	0.128	-0.06	0.38	0.09
	(0.876)	(0.79)	(0.778)	(0.779)	(0.75)	(-0.36)	(1.34)	(0.52)
State	-0.446 ***	-0.323 ***	-0.502 ***	-0.427 ***	-0.484 ***	-0.356 ***	-0.52 ***	-0.449 ***
	(-4.508)	(-3.14)	(-4.56)	(-4.24)	(-4.52)	(-3.21)	(-4.5)	(-4.08)
Gas	0.106	0.06	0.235 *	0.133	0.037	-0.005	0.21	0.076
	(0.779)	(0.47)	(1.85)	(0.979)	(0.25)	(-0.04)	(1.55)	(0.52)
Oil	0.813 ***	0.77 ***	0.976 ***	0.802 ***	0.899 ***	0.85 ***	1.04 ***	0.879 ***
	(10.03)	(9.58)	(11.67)	(9.74)	(10.2)	(9.78)	(11.76)	(9.81)
Electricity	0.544 ***	0.53 ***	0.881 ***	0.548 ***	0.607 ***	0.595 ***	0.98 ***	0.607 ***
	(3.571)	(3.55)	(4.74)	(3.59)	(3.71)	(3.71)	(5.03)	(3.71)
Gov_Scale	-2.1 ***	-1.96 ***	-1.683 ***	-2.09 ***	-2.07 ***	-1.92 ***	-1.7 ***	-2.03 ***
	(-9.83)	(-9.19)	(-7.07)	(-9.69)	(-9.03)	(-8.39)	(-6.81)	(-8.72)

Independent variables	GLS				Tobit			
	I	II	III	IV	V	VI	VII	VIII
Imp_highTech	0.051				0.058			
	(1.144)				(1.23)			
Exp_highTech		0.428 ***				0.45 ***		
		(3.56)				(3.48)		
RD			-0.286				-1.48	
			(-0.184)				(-0.9)	
Gov_st				0.73				1.43
				(0.96)				(1.36)
Individual Effect	YES	YES	YES	YES				
Period Effect	YES	YES	YES	YES				
Obs.	284	284	197	284	256	256	181	256
Sample Period	1997-2006	1997-2006	2000-2006	1997-2006	1997-2006	1997-2006	2000-2006	1997-2006
Log likelihood					112.21	117.38	119.3	112.5
Adj.R^2	0.693	0.705	0.781	0.692				
F.stat	80.77	85.5	88.3	80.6				

Notes: ***, ** and * denote that the variables are statistically significant at the 1%, 5% and 10% levels, respectively; t-Statistics for (I)-(IV) and z-Statistics for (V)-(VIII) are in parentheses.

In Table 5, the column (I)-(IV) shows the result that estimated by GLS with individual effect and period effect are controlled both, the column (V)-(VIII) shows the result that estimated by Tobit. The proxy variables for *Tech* are induced in turns.

As we expected, the variable *Industry* has a 1% significant negative effect on energy efficiency, its coefficient indicate that with 1% increase of the industrial share in economy, the energy efficiency will decline about 1%. However, the variable *Service* is not significantly, although its sign are positive in most columns.

The share of state-owned sector in economy is consistent with our expectation and significantly correlated with energy efficiency. This negative coefficient indicate that the more private and foreign enterprises composed in industrial sector, the higher the energy efficiency.

The energy structure, which including the share of natural gas, oil products and electricity in final energy consumption, are consistent with our expectations in whole sample. This indicates that the composition of energy consumption plays an important role to the fluctuation of provincial energy efficiency. The positive coefficient of *Gas*, *Oil* and *Electricity* both suggests that, compared with the coal, the larger share of the non-coal energy mixed, the larger improvement the energy efficiency gains. In addition, we noticed that the coefficient of *Gas* is not significant in most columns; it may result from the unbalanced data[9], or indicate that the mix of natural gas in final energy consumption, compared with the coal, has no remarkable difference of the influence on energy efficiency.

[9] Benefit from the West-to-East natural gas transmission project, many coastal provinces begin to use the natural gas until 2004.

Government's intervention is found to significantly depress the energy efficiency in all estimations. That is, the larger the proportion of government expenditure in whole economy, the more inefficient the provinces. However, the government's financial expenditure on the one hand damage the market mechanism, on the other hand provide the public goods, such as infrastructure, education, science and technology research etc, which can produce positive externality and promote the economy efficiency at the same time. So, the mixed final effects of government intervention on energy efficiency depend on both sides' power. To show this, we induce the variable *Gov_st*, which can proxy the technology level[10], as well as the government's supply on public goods. In column (IV) and (VIII), the positive but not significantly coefficient suggest that, with more attention and more governmental resource are allocated to the public affairs, the energy efficiency may get improvement.

The technical level is expected to improve the energy efficiency, but we don't find the direct evidence. The coefficient varies depends on the proxy variable we choose. If the technology level is denoted by the share of high-technology products in exports, the remarkable and positive coefficient is consistent with our expectation. However, in other case, the coefficient is not significant. A possible explanation is, the proxy variables *Imp_highTech*, *RD* and *Gov_st* are based on a input side for the technology research and development, more technology imported from abroad, more R&D funding input and governmental appropriate may not bound to the higher technology level and efficiency improvement. The internal R&D activity and absorb capacity are also necessary. From this perspective, the variable *Exp_highTech* is an output-oriented indicator, it denote the internal technology ability. Only these regions with more competitive firms and advanced technology can export more high-technology products to foreign countries. However, these possible explanations need to be verified in further study.

V. Conclusions

The DEA method is used to compute the energy efficiency score from 1995 to 2007 among 29 provinces and three regions in China. Several factors, including industrial structure, property structure, energy consumption structure, and government intervention and technology level are considered as the determinants to the provincial energy efficiency difference.

Using panel data from 1997 to 2006, we find that there exists remarkable difference on energy efficiency among provinces and regions in China. The East region is the most efficient on energy utilization over three regions. Most of eastern provinces, such as Guangdong, Fujian, are close to the benchmark frontier, and Shanghai always lies on the frontier during the whole period. On the contrary, the underdeveloped West area has the lowest energy efficiency level. Some members

[10] In China, most R&D activity are funded by government rather than firms, so the science and technology appropriate in government's financial expenditure can be used to be a proxy variable of technology development.

such as Ningxia, Qinghai, Guizhou are inefficient and far from the frontier. Policy maker should avoid setting uniform energy saving target for each province. By taking account of the discrepant energy efficiency and saving potential, those inefficient provinces should be prior concerned and be allocated more energy saving quota based on the principal of “easy first and difficult afterwards”.

Our detailed regression results indicate that, in general, energy efficiency is negatively associated with the industrial sector share in GDP and state-owned sector share in economy, while the effect of the share of service in economy on energy efficiency seems to be unremarkable. The energy consumption structure plays a key role in energy efficiency difference among provinces. The energy efficiency will be improved with more non-coal energy mixed, such as natural gas, oil products and electricity. The government’s intervention on economy, such as the financial expenditure share in GDP is negatively associated with the energy efficiency.

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