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China's Energy Inefficiency: A Cross-Country Comparison

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Abstract

This paper constructs a total-factor energy technical efficiency index using the Data Envelopment Analysis (DEA) method following the total factor productivity framework. We then compare energy technical efficiency across 156 countries from 1980 to 2007. The results show that China’s energy efficiency considerably trails other countries’ although it has made significant gains within the last 28 years. A further analysis indicates that scale inefficiency rather than pure technical efficiency contributes to China’s energy inefficiency.

Key Words: Energy efficiency; DEA; Scale efficiency

JEL Classification: N70, O47, Q43

I. Introduction

The Fourth Assessment Report (AR4) has attested that energy efficiency has a key role to play in arresting climate change (see IPCC 2007c, Fig. TS 10; Urge-Vorsatz & Metz, 2009). As the largest Green House Gas (GHG) emitter in the world since 2007(IEA, 2007), improvement of energy efficiency has become a priority in order for China to pursue further economic development (Wei, Ni & Shen, 2009).

This paper explores China's level of energy efficiency by comparing it with 155 other countries. The evidence at the nation-wide level indicates that China's energy efficiency, represented as energy intensity, is relatively lower than other developed countries and the world's average level (Jefferson, Rawski, Li, & Zheng, 2000; Jiang, 2004; Wang, 2005).[1] The main reasons for lower energy intensity are China's extensive economy growth pattern, a high proportion of energy-intensive sectors, an irrational energy structure, the relatively low level of energy technology and management, as well as regulated pricing mechanisms for some energy products (State Council Information Office, 2007)[2]. However, Table 1 shows that at the micro-level, China's energy consumption per unit of product is close to the international average level. For some industry products (such as steel, calcium carbide, cement, and glass), some large-scale enterprises in developed provinces have performed more efficiently than those at the international advanced level. We need further evidence to indicate where China stands in terms of the energy efficient index.

(Table 1 about here)

To obtain more in-depth analysis, we utilized panel data of 156 countries from 1980 to 2007 to measure energy efficiency using the Data Envelopment Analysis (DEA) framework. DEA has been widely used to measure “Debreu-Koopmans” efficiency and productivity (Farrell, 1957). This method has been used to compare efficiency across firms in manufacturing sectors (Kumbhakar & Hjalmarsson, 1998), comparing energy efficiency across regions (Hu & Wang, 2006; Honma & Hu, 2008), and across countries (Chien & Hu, 2007 for OECD countries; Hu & Kao, 2007 for 14 APEC countries).

The advantage of using DEA, as Hu and Wang (2006) concluded, is that the energy index generated through DEA is more practical than the more commonly used index of energy intensity ratio, which was used in earlier studies (Wilson, Trieu & Bowen, 1994; Patterson, 1996). This is because the technical efficiency scores under the DEA framework reflect the ability to obtain maximal output from a given set of inputs, or reduce the inputs without sacrificing 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 China’s total-factor energy efficiency falls significantly behind other countries, but improves rapidly over the last three decades.

This paper further investigates the reasons for China’s energy inefficiency. To do so, we first decompose energy efficiency into two components: scale efficiency from economy of scale and pure technical efficiency. The data indicate that China performs better in pure technical efficiency, but ranks very low in scale efficiency, which directly leads to a low energy efficiency score. Furthermore, we propose that the excessive competition among local governments is the source of market segmentation and local protectionism, which constrains the expansion of efficient large-scale firms and therefore results in lower scale efficiency.

The structure of the paper is as follows. The next section introduces the DEA methodology, variables and data. Section 3 reports the total-factor energy efficiency for all of the countries and compares China with the rest of the countries using different criteria. Section 4 decomposes the total-factor energy efficiency and provides an explanation for China's energy inefficiency. The conclusion follows in the last section.

II. Methodology, Data and Variables

1. Methodology

Farrell (1957) defines efficiency as two parts: Technical Efficiency (TE) and Allocative Efficiency (AE). The former refers to the ability to make optimal use of existing resources; that is, the ability to maximize output given the constraints of the various inputs, or the ability to minimize the inputs given certain levels of output. The latter requires achieving input (output) optimal allocation under certain factor prices.

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, Seiford, & Zhu, 2000). The purpose of DEA is to construct a non-parametric envelopment frontier covering 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.

(Figure 1 about here)

Let us consider a simple example illustrated in Figure 1. Given the CRS assumption, each country needs to input energy and other factors (labor and capital) to produce a unit output. The isoquant is presented by piecewise linear SS'. According to Farrell's (1957) definition, point A is inefficient compared with the efficient points B and C 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, point A' is not an optimized reference point because we can reduce the energy input A'B without sacrificing any of the output.[3] Therefore, point A has excess inputs compared with its best reference point B. The Total Factor Energy Efficiency Index at point A is defined as:

$$TE_A = OB / OA. \tag{1}$$

Therefore, the further away target point A is from B, the larger the energy inefficiency. If the distance is 0, then energy input is optimum, i.e., the energy efficiency will be equal to 1. If the score equals 1, then this country is the best among all of the comparison samples. It should be noticed that a 100% energy efficiency score does not imply that these 'target countries' are perfect and without any energy loss or inefficiency during the production process. However, it does mean they can save energy relatively better than the other samples at certain given output levels.

If we further consider the DEA model under the Variable Return to Scale (VRS) assumption (Afriat 1972), then the technical efficiency based on maximum output will be different from minimization costs. The ratio will be defined as Scale Efficiency (SE) (Färe & Lovell, 1978; Førsund & Hjalmarsson, 1979):

$$SE = TE_{CRS} / TE_{VRS} \tag{2}$$

where TE_{VRS} is "pure technical efficiency" (PTE), and TE_{CRS} is defined as equation (1). If scale efficiency equals 1, it means that they are operating at the most productive scale size (Cooper, Seiford, & Tone, 2006).

Based on equation (2), TE_{CRS} can be represented as the product of TE_{VRS} and SE. That said, Total Factor Energy Efficiency Index (TE_{CRS}) can be decomposed into PTE (TE_{VRS}) and SE. Doing this helps to identify whether the inefficiency is caused by inefficient operation (PTE) or by disadvantageous conditions (SE) or by both (Cooper et al., 2006).

Assume there are K inputs and M outputs for N DMUs. For the i-th DMU, its input and output is represented by the vectors x_i and y_i, respectively. The $K \times N$ input matrix X and $M \times N$ output matrix Y represent the data of all N DMU's. The value of TE_{CRS} for i-th DMU can be calculated by solving the following input-oriented linear programs (Coelli, 1996).

$$\begin{aligned} & min_{\theta,\lambda}\theta \\ \text{s.t}\quad & -y_i + Y\lambda \geq 0 \\ & \theta x_i - X\lambda \geq 0 \\ & \lambda \geq 0 \end{aligned} \tag{3}$$

where θ is a scalar and λ is an Nx1 vector of constant. The value of θ obtained will be the efficiency score for the i-th DMU. That is the value of TE_{CRS}.

The value of TE_{VRS} can be obtained via a similar approach by adding the convexity constraint: $N1'\lambda=1$ to model (3), where N1 is an N×1 vector of ones. Once we obtain the value of TE_{CRS} and TE_{VRS}, the value of SE can be generated based on equation (2).

2. Data and Variables

Using capital stock, labor, and energy consumption as input factors for the 156 countries during the period 1980-2007, this paper carries out an analysis of energy efficiency based on GDP output (by PPP deflator). Major economic and labor data sources come from Penn World Table (PWT 6.3). Energy data come from Energy Information Administration (EIA). Specifically:

(1) Sample countries and period. In the latest PWT 6.3, there are 190 samples from 1950 to 2007. We drop 26 countries without GDP data and seven countries without labor data. In addition, as a new feature, PWT 6.3 offers a choice of two sets of China data.[4] We adopt the "China Version 2" because it provides a more consistent and recent economic history of China relative to other countries. Finally, there remain 156 valid samples from 1950-2007. However, the energy consumption data from EIA cover 232 countries (regions) across 1980-2007, and in order to combine the EIA's data with PWT in terms of same country group, we adjust the sample period and yield 156 countries (regions) from 1980 to 2007.[5]

All countries are placed in different income groups based on the World Bank's definition. The complete country list in our sample is provided in Appendix 1.

(2) Output. The Gross Domestic Product (GDP) is selected as output. It can be calculated by population and GDP per capita. All GDP serials are deflated to the constant price in 2005.

(3) Labor. The amount of labor involved in the actual production can be calculated by real GDP output and GDP per labor from PWT 6.3.

(4) Capital. In the cross-country studies, the national capital stock series data are difficult to process. We estimate this serial using the following perpetual inventory method:

$$K_{i,t} = I_{i,t} + (1-\delta_i)K_{i,t-1} \tag{4}$$

where $I_{i,t}$, δ_i and $K_{i,t-1}$ represent gross investment, depreciation rate and capital stock for the country *i* at time *t*, respectively. If we choose certain K_0, then the above equation can be converted to:

$$K_{i,t} = K_{i,0}(1-\delta_i)^t + \sum_{k=1}^{t} I_{i,k}(1-\delta_i)^{t-k} \quad . \tag{5}$$

Here we chose δ_i = 7% (King and Levine 1994). $I_{i,t}$ = GDP* (percentage of investment in GDP) from PWT. $K_{i,0}$ can be estimated by the following formula (King & Levine, 1994):

$$k_i = i_i /(\delta + \lambda g_i + (1-\lambda) g_w) \tag{6}$$

where i_i is the steady state investment, using a country's average investment rate over the period 1970—2007. $\lambda g_i + (1-\lambda) g_w$ is the steady state growth rate, where the weight λ is a parameter valued as 0.25 (Easterly, Kremer, Pritchett, & Summers, 1993), g_i is the average growth rate for country *i* over 1970—2007, while g_w is the economics growth rate for the world economy, about 4%. Initial capital starts at 1970, that is:

$$K_{i,70} = k_i \cdot Y_{i,70} \tag{7}$$

where *Y* is the real GDP. We then can estimate the capital stock series.

(5) Energy. This mainly refers to the world's primary energy consumption data since 1980 from EIA's international energy consumption dataset.[6]

The statistical description for all variables is listed in Table 2.

(Table 2 here)

III. Results and Comparisons

DEAP2.0 provided by Coelli (1996) is applied to our data to construct the frontier for each year. Three inputs (Labor, Capital and Energy) and one output (GDP) is used to calculate the TE_{CRS}, TE_{VRS} and *SE* in accordance with Equations (2) and (3). We list the top and the bottom 10 countries of total-factor energy efficiency in Table 3. The energy intensity and its rank for these countries are also provided.

(Table 3 here)

From Table 3 we find that some poor countries in Africa (Guinea, Uganda, Chad) and some island countries (Brunei and Macao SAR) increased their total-factor energy efficiency. For the least efficient countries, most of them belong to lower or middle income groups. This finding is consistent with Hu and Wang's (2006) conclusion. They revealed a U-shaped curve between total-factor energy efficiency and per capita income, which means that an improvement of energy efficiency is usually accompanied by economic growth (although it declines in the beginning period). The least developed countries hold a relatively higher energy efficiency score mainly due to their agriculture-based economy's decreased dependence on energy consumption. Furthermore, the rank of energy intensity indicator is mostly consistent with the rank of total-factor energy efficiency except in two island countries, Brunei and Cuba. Among all 156 samples, China ranks 147 with an average value of total-factor energy efficiency of 0.304 (ranks 134 when compared by energy intensity indicator).

If we observe all sample performances in 2007 as shown in Table 4, there are 150 valid samples. We can find that the most efficient economies are featured by either low income such as Chad, Guinea etc., or by developed islands or small-scale countries (regions), such as Luxembourg, Macao SAR, etc. In contrast, all of the most inefficient countries are in low income countries in Africa or South America. Again, the rank of energy intensity is consistent with the rank of total-factor energy efficiency except for some islands or small-scale countries. China's rank of total-factor energy efficiency and energy intensity is 127 and 112 among 150 samples, respectively.

(Table 4 Here)

As shown in Tables 3 and 4, most of the inefficient countries are in the middle or low income groups; however, some poor countries with low economy outcomes and low energy consumption, gained higher total-factor energy efficiency scores. To eliminate the possible bias caused by different objects, we compare the total-factor energy efficiency in 2007 by similar income groups. In the middle income group, China ranks 56 among 66 samples with a total-factor energy efficiency of 0.394. If we drill down further to the lower-middle income group, China ranks 32 among 41 samples with a total-factor energy efficiency score of 0.5. When we select 30 large-scale countries in terms of GDP and population, China ranks 28 and 27, respectively. The detailed results are listed in Appendix 2.

In addition, we group countries that are geographically close and compare the results again. As Hu and Kao (2007) have applied DEA on 17 countries (regions) of APEC, we add geographical and organizational marks for each country according to EIA's definitions and choose the same sample countries and compare our result to theirs. It shows the same estimation of frontier, including Hong Kong SAR, Philippines, Taiwan and the United States. China is in last position, but our results indicate that China is slightly higher than Thailand, ranking second to last. This slight difference may be due to the choice of original data.[7]

(Figure 2 here)

Clearly, China's energy efficiency lags behind most other countries across different comparison groups. However, over time China's energy efficiency has increased rapidly as shown in Figure 2. From Figure 2 we find that the high-income group is in the lead, including most of the countries which have completed the industrialization process. They continue increasing during this period, where the annual growth rate for high income in OECD and non-OECD is 2.381% and 1.094%, respectively. The upper-middle and lower-middle income groups (excluding China) fluctuate around the world's average, with growth rates of 0.585% and 0.244%, respectively. On the contrary, the low income group's energy efficiency declines gradually by 0.205% every year, indicating that their energy efficiency is deteriorating. China's total-factor energy efficiency, although lagging behind other income groups, advances from 0.175 in 1980 to 0.356 in 2007. Its annual growth rate reaches 2.665% and ranks highest among all income groups. The shrinking gap within the frontier shows that China is a good "chaser" and that total-factor energy efficiency has improved significantly in China over the last 28 years.

This result is consistent with previous findings that use the traditional energy intensity indicator. IEA (2008) demonstrates that China experiences the greatest decline of energy intensity (defined as the final energy consumption per unit of GDP) by nearly 60% during the 1990 to 2005 period. ECOFYS (2010) compares the energy efficiency of fossil power generation for 11 economies. The results show that China's energy efficiency of fossil-fired power production in 1990 was lowest among all economies and performs 14% below the benchmark average level. However, in 2007, China's energy efficiency of fossil-fired power generation (34.3%) has surpassed India (32%) and Australia (33.3%) and is only 3% below the average in 2007.

Why is China's energy efficiency getting closer to the frontier over time? According to Los and Timmer (2005), technical and intellectual expansion grounded in cumulative capital investment or foreign investment strengthens the ability to absorb new technology and knowledge which pushes the energy efficiency closer to the frontier. As China has a "late-developing advantage", technical progress can be raised by importing advanced technology, which improves energy efficiency (Lin, 2002). The opening-up policy of the 1970's makes importing advanced technology from developed countries on a large scale possible. However, we also note that the growth rate of China's energy efficiency slowed and began to decline in 2002 and then climb again in 2005. It is consistent with the trend of energy intensity and may result from the accelerated industrialization and urbanization process and infrastructure development, which accompany high expansion of energy-intensive sectors and energy-consuming investments (Levine et al., 2010; Liao, Fan, & Wei, 2007). Moreover, the increase share of coal in the energy mix also contributes to the change of energy intensity (Andrews-Speed, 2009).

IV. Scale Efficiency and Energy Efficiency

Our measurement of China's energy efficiency in the last 28 years shows that whether compared with middle-income countries or similar scale countries, China's energy efficiency falls behind. Why is China’s energy efficiency still low after nearly 28 years of economic reform and development? Why isn’t the efficiency of micro-scales equally matched to developed countries? To answer this, we try to decompose energy efficiency.

According to equation (2), we decompose total-factor energy efficiency to pure technical efficiency (PTE) and scale efficiency (SE). We perform the analysis by grouping countries based on economic income level and economic scale level in 2007. As we can see in Table 5, most countries that have high scores in energy efficiency rank high in pure technical efficiency as well. In particular, their scale efficiency scores are ranked at a very high level, meaning that there is no inefficient loss or ineffectiveness of input factors when output increases.

(Table 5 here)

For the least efficient countries, most of them have lower scores in pure technical efficiency, but their scale efficiency performance is not too bad. It is impressive that when compared with similar incomes, and similar economies and population scale countries, China's pure technical efficiency is not low. However, the scale efficiency is close to the lowest, and thus significantly drags down the overall energy efficiency score. That is, China's pure technical efficiency is advanced compared with other countries, even obtaining the lead position in 2007. However, the overall energy efficiency is low due to the fact that China's scale efficiency is far below the average.

We examine the trends in energy efficiency, pure technical efficiency and scale efficiency in China during the period of 1980 to 2007. The results are shown in Figure 3. China's total-factor energy efficiency has been on an upward trend, which mainly benefits from the continuous improvement of pure technical efficiency. In particular, pure technical efficiency has experienced rapid growth since 1989 and reached the frontier in 1993. In contrast, scale efficiency had experienced a sustained improvement prior to 2002, but then trended downward. Because pure technical efficiency has been on the frontier since 1989, the total-factor energy efficiency is determined by the change of scale efficiency.

(Figure 3 here)

Figure 3 raises another question: Why does China’s scale efficiency advance so slowly and is so much lower than other countries? Our conjecture is over-competition among provinces.

Young (2000) argues that the reform of fiscal decentralization makes local government compete with each other and thus leads to market segmentation. As a result, the local protectionism and market segmentation makes merging among domestic inter-region companies more difficult. Urandaline (2006) observes that in China’s cement sector, to protect the local benefit of tax revenues and employees, the local government tends to set up trade and transport barriers to enhance the market power of small plants, which reduces inter-provincial trade in cement. Andrews-Speed (2009) also points out that China’s energy intensive industries will continue to have numerous inefficient and high-pollutant small-scale plants. It mainly results from the competition between local governments in pursuing high investments and growth rates under the GDP-driven performance assessment system. In addition, in Bai, Du, Tao, and Tong’s (2004) paper on the determinants of regional specialization, they argued that local government tends to protect industries with high past tax-plus-profit margins and high state-ownership shares. We select the detailed data on iron and cement products, the most energy-intensive sectors in China, to further analyze scale efficiency.

Table 6 lists the energy intensity of steel products in China and Japan. Usually Japan is regarded as the international leader in steel production. The data shows that, on average, China consumed 8-17% excessive energy to produce one unit of steel in 2003 compared with Japan's 2004 level.[8] However, a large energy efficiency difference exists among domestic firms. In 2005, small-scale firms and the large- and medium-scale firms consumed 55% and 13% of the extra energy, respectively, to produce one ton of steel compared with Japan's average level in 2004. But the efficiency difference shrinks to 1.2-3.6% for those advanced large-scale firms. Although these efficient firms were equipped with advanced machines, production technology and management, it is difficult to spread their advantage to the whole industry sector. For example, in the steel industry, the top 18 largest steel companies in China possessed only 46.3% of the rough steel production in 2005. However, the top four largest steel companies in Japan already possessed 73.22% of the rough steel production in 2004.

(Table 6 here)

Table 7 lists the comparison of the energy intensity of cement products between China, India and Japan. We find that when compared with the most efficient production process in India, Chinese firms input 15-20% extra energy to produce one unit of cement.[9] However, the production scale also affects the energy efficiency. For the large-scale firms with a production capacity of 4000-5000 tons/day and small-scale firms with a capacity of 700-2000 tons/day, they need to consume 12% and 27% more electricity power, or 8% and 28% more heat value to produce one ton of cement, respectively. However, the degree of concentration of the cement industry in China is considerably less than in India and Japan. In 2005, the first 10 largest companies in China possessed only 15% of the cement production in 2005, but in India the top five largest plants possessed 50.7% of the cement production. A lower industrial concentration degree indicates that efficient firms can only contribute less to the industry and national efficiency.

(Table 7 here)

From these comparisons we find that although some large-scale firms have made efforts to narrow the efficiency gap of micro-products within the internationally advanced level, by either import production line or technology patent transfer, the market segmentation and local protectionism prevent its efficiency advantage from spilling over to other inefficient firms. Thus, the micro-scale energy efficiency of most advanced companies in China was already as high as or exceeded the top level, while the macro-scale energy efficiency was still lagging due to lack of scale advantages. In addition, following the government guidance of pursuing high GDP growth, large numbers of new industrial programs were implemented without thorough consideration. This further caused the separation of the current scale of economy. For instance, on September 2006, the top 4, 20, 50 and 100 largest thermoelectricity power generation companies only possessed 3%, 11.3%, 22.8% and 38.7% of the whole power generation, respectively. Furthermore, as investment in local electricity generation increased, the numbers declined consistently and the high-efficient thermal power generating units (more than 0.6 million kilovolt) were no more than 40%. There is absolutely no apparent scale of economy, because in these small enterprises, no matter the scales, the management of producing the equipment or the techniques, is all far below the advanced levels. Consequently, low-efficient production leads to a huge excess of local products and the local government refused to close them down.

V. Conclusion

This paper constructs the total-factor energy efficiency index using the DEA method following the framework of total factor productivity. We then compare total-factor energy efficiency across 156 countries from 1980 to 2007. The results show that China's average total-factor energy efficiency during this period ranked 147 among 156 countries. In 2007, it ranked 127 among 150 samples. Compared with a similar economy, population scale or income group, China lags far behind other countries. However, we do see that it made significant gains in the last 28 years.

We then decompose the total-factor energy efficiency into two parts: pure technical efficiency and scale inefficiency. A further analysis indicates that scale inefficiency rather than pure technical inefficiency contributes to China's energy inefficiency. We conjecture that excessive competition of local government produces lower scale efficiency. Our discussion indicates that the market segmentation and local government competition which result from fiscal decentralization may lead to low scale efficiency. In our future research, we will use provincial-level data to conduct more detailed analysis to examine this issue.

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Endnotes

[1] Arguments exist about this indicator. Although the energy intensity is explicit and easy to calculate, many researchers believe that it may be affected by structure changes and cannot depict efficiency (Hu & Wang, 2006). In addition, the choice of outcome variable between PPP and exchange rate is also debated and will change the final efficiency rank considerably.

[2] The market-oriented pricing mechanism for coal has been established, the price of other energy products, like petroleum, electricity and natural gas, are still controlled by the government. For example, when the international oil price rose to $140/barrel in June 2008, China's petrol price was only 85% of the international level (Zhao, Ma, & Hong 2010). Also, the government has been reluctant to raise consumer prices for oil products, electricity and natural gas (Andrews-Speed, 2009).

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

[4] "China version 1" uses the official growth rates for the whole period as in PWT 6.2; in 'China version 2', PWT 6.3 uses the recent modifications of official Chinese growth rates contained in Maddison and Wu (2007 in the G Papers section of the PWT site) for the period before 1990, and apply the modification of the official rate from 1995-2000 to the official rate after 2000.

[5] However, some countries are still missing data in some years: GDP and labor is missing for BHR (2007); Labor data is missing for AFG (1995-2007), DMA (1997-1999;2001-2007), GRD (2001-2007), IRQ (2004-2007), KWT (1992-1994) and SYC (2001-2007); Energy data is missing for GER (1980-1990) and NAM (1980-1989)

[6] EIA's data is public and available at http://www.eia.doe.gov/.

[7] For example, Hu and Kao (2007) derive the energy consumption data from IEA, while we adopt EIA's dataset. In addition, their GDP and labor data are based on PWT 6.1, but we use the latest PWT 6.3.

[8] It is notable that small private firms and other illegal firms are not included in the survey samples, so if we take all firms into account, the current average level of energy intensity is under-estimated.

[9] It is notable that China's data are derived from a firm survey of 177 latest cement production lines and does not cover all out-sample cement factories. Likewise, China's energy intensity in Table 7 is also underestimated. The efficiency gap between China and the international advanced level should be greater.

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Table 1 International comparison of energy intensity for selected industry products

Industry product	Units	China				
		(I) Zhejiang survey	(II) Guangdong survey	(III) China's survey	(IV) Average	(V) International advanced level
Steel	Kgce/t	512	**495.79**	618	741	**642**
Thermal power plant	Gce/t	348	**328.88**	365	366	**312**
Aluminum	kWh/t	**14080**	-	14733	14795	**14100**
Ammoniate	Kgce/t	**1360**	1426.27	1453	1650	**990 (gas)** **1570 (coal)**
Alkali	Kgce/t	368	435	983	1080	**910**
Pure Alkali	Kgce/t	-	498.14	**422**	461	**345**
Calcium carbide	Kgce/t	3326		**1206**	2300	**1800**
Oil product	Kgce/t	86.3	**64.59**	77	104	**73**
Ethane	Kgce/t	-	**859.8**	972	1003	**786**
Cement	Kgce/t	93	**89.84**	113	156	**102**
Glass	Kgce/u	14.7	**14.03**	16	22	**15**

Note: The survey data in columns (I), (II), and (III) are based on large-scale firms; the data in columns (IV) and (V) report nation-wide average level.

Data Source: Column (I) comes from “White paper of energy consumption and utility of Zhejiang province in 2006” (Zhejiang Statistic Bureau, 2007); Column (II) comes from “Energy usage report for 1000 industry firms” (Guangdong Statistic Bureau, 2007); Columns (III), (IV) and (V) come from “Energy usage report for 1000 industry firms” (China Statistic Bureau 2007).

Table 2 Statistical description for variables

Variable	GDP (PPP in 2005 constant price, billion $)	Labor (ten thousand person)	Capital (in 2005 price, billion $)	Energy (trillion Btu)
Obs	4367	4323	4368	4347
Mean	260.37	1490.93	634.37	1957.76
Std. Dev.	916.78	6242.13	2322.58	8102.33
Min	0.16	2.33	0.20	0.15
Max	12920.95	78782.62	34479.49	101553.90

Table 3 The most efficient and inefficient country (1980-2007)

Top 10			Bottom 10		
Country	Total-factor energy efficiency	Energy intensity	Country	Total-factor energy efficiency	Energy intensity
Guinea	1.000 (1)	0.88 (2)	**China**	0.304 (147)	**10.37** (134)
Brunei	0.997 (2)	5.09 (82)	Zambia	0.254 (148)	10.36 (132)
Uganda	0.994 (3)	1.35 (11)	Bulgaria	0.249 (149)	20.26 (153)
Chad	0.989 (4)	0.34 (1)	Somalia	0.245 (150)	2.96 (43)
Macao SAR	0.982 (5)	1.98 (24)	Romania	0.244 (151)	14.27 (149)
Congo, Republic of	0.946 (6)	1.80 (22)	Guinea-Bissau	0.233 (152)	5.12 (83)
Oman	0.934 (7)	5.18 (87)	Albania	0.224 (153)	12.19 (145)
Equatorial Guinea	0.908 (8)	2.51 (36)	Liberia	0.190 (154)	8.47 (119)
Cuba	0.863 (9)	5.18 (88)	Mongolia	0.189 (155)	20.34 (154)
Cambodia	0.862 (10)	1.1 (8)	Guyana	0.173 (156)	11.37 (139)

Note: We report the mean value across 1980-2007, the rank is listed in parentheses. The energy intensity is reciprocal with energy productivity.

Table 4 Top 10 efficient and inefficient countries in 2007

Top 10			Bottom 10		
Country	CRS_TE	EI	Country	CRS_TE	EI
Chad	1 (1)	0.15 (1)	Jamaica	0.265 (141)	7.82 (118)
Cuba	1 (1)	2.81 (37)	Togo	0.248 (142)	7.86 (122)
Guinea	1 (1)	0.68 (2)	Nicaragua	0.244 (143)	6.07 (95)
Luxembourg	1 (1)	5.31 (84)	Bhutan	0.237 (144)	10.38 (133)
Macao SAR	1 (1)	1.44 (14)	Guinea-Bissau	0.208 (145)	6.17 (97)
Mozambique	1 (1)	3.84 (55)	Somalia	0.208 (146)	2.56 (32)
Oman	1 (1)	7.25 (110)	Mongolia	0.203 (147)	13.47 (146)
Qatar	1 (1)	12.97 (144)	Liberia	0.193 (148)	7.07 (108)
Uganda	0.945 (9)	1.28 (10)	Zimbabwe	0.191 (149)	8.49 (128)
Ethiopia	0.934 (10)	1.20 (5)	Guyana	0.146 (150)	11.86 (142)

Note: The rank is listed in parentheses.

Table 5 Ranking of the energy efficiency and its decomposition: pure efficiency and scale efficiency (in 2007)

By Income				By Scale			
# Middle income group (66 economies)				**# Top 30 in economy scale**			
Country (Region)	Energy efficiency	Pure technical efficiency	Scale efficiency	Country (Region)	Energy efficiency	Pure technical efficiency	Scale efficiency
Cameroon	1 (1)	1 (1)	1 (1)	United States	1 (1)	1 (1)	1 (1)
Cape Verde	1 (1)	1 (1)	1 (1)	United Kingdom	1 (1)	1 (1)	1 (1)
Congo, Republic of	1 (1)	1 (1)	1 (1)	Italy	1 (1)	1 (1)	1 (1)
Cuba	1 (1)	1 (1)	1 (1)	Saudi Arabia	1 (1)	1 (1)	1 (1)
Equatorial Guinea	1 (1)	1 (1)	1 (1)	Egypt	1 (1)	1 (1)	1 (1)
…				…			
China	**0.394 (56)**	**1(1)**	**0.394 (65)**	…			
…				…			
Paraguay	0.329 (62)	0.342(64)	0.963(19)	Turkey	0.723(26)	0.727(27)	0.994(11)
Nicaragua	0.305 (63)	0.316(65)	0.966(17)	Korea, Republic of	0.677(27)	0.706(28)	0.959(19)
Bhutan	0.277 (64)	0.345(63)	0.802(35)	**China**	**0.664(28)**	**1(1)**	**0.664(30)**
Guatemala	0.247 (65)	0.557(49)	0.443(63)	Iran	0.664(29)	0.678(30)	0.979(16)
Guyana	0.178 (66)	0.241(66)	0.738(40)	Thailand	0.663(30)	0.69(29)	0.962(18)

Table 5 (Continued)

# Lower-middle income group (41 economies)				**Top 30 in population**			
Country (Region)	Energy efficiency	Pure technical efficiency	Scale efficiency	Country (Region)	Energy efficiency	Pure technical efficiency	Scale efficiency
Cameroon	1 (1)	1 (1)	1 (1)	United States	1 (1)	1 (1)	1 (1)
Cape Verde	1 (1)	1 (1)	1 (1)	Nigeria	1 (1)	1 (1)	1 (1)
Congo, Republic of	1 (1)	1 (1)	1 (1)	Philippines	1 (1)	1 (1)	1 (1)
Cuba	1 (1)	1 (1)	1 (1)	Egypt	1 (1)	1 (1)	1 (1)
Tunisia	1 (1)	1 (1)	1 (1)	Ethiopia	1 (1)	1 (1)	1 (1)
…				…			
China	**0.5 (32)**	**1(1)**	**0.5 (40)**	…			
…				…			
Albania	0.415(37)	0.425(37)	0.977(14)	Korea, Republic of	0.677(26)	0.816(25)	0.83(26)
Bolivia	0.403(38)	0.406(38)	0.993(8)	**China**	**0.668(27)**	**1(1)**	**0.668(28)**
Paraguay	0.379(39)	0.385(39)	0.986(10)	Thailand	0.663(28)	0.671(30)	0.988(14)
Nicaragua	0.305(40)	0.32(40)	0.953(18)	Tanzania	0.598(29)	1(1)	0.598(29)
Guyana	0.215(41)	0.264(41)	0.813(27)	Congo, Dem. Rep.	0.518(30)	1(1)	0.518(30)

Note: The rank is listed in parentheses.

Table 6 Comparison of energy intensity of steel product

Sample	China(1)				Japan (average level)
	Average level	Small firm	Key Large & Medium firm	Advanced large-scale firm	
Year	2003	2005	2005	2005	2004
Comprehensive energy consumption per ton steel	770	1018	741.05	679.76	656
Comparable energy consumption per ton steel	698		714	650	642

Note: (1) All data come from Association of Steel Industry of China.

Source: Chinese steel trade network, compiled by Shanghai Science and Technology Information Institution.

Table 7 Comparison of energy intensity of cement product

	China⁽¹⁾					India⁽²⁾	Japan⁽³⁾
	Average level	>5KT/D⁽⁴⁾	4-5KT/D	2-4KT/D	0.7-2KT/D		
Comprehensive power consumption per ton cement (kWh)	98.31	95.79	91.94	99.97	104.52	82	100-103
Heat consumption of clinker burning (kCal/kg)	828	761	783	830	924	723	<735

Note: (1) China's data come from firm survey of 177 latest cement production line in 2006; (2) India's data is at 2005; (3) Japan's data for comprehensive power consumption per ton cement is mean value of 2004-2006, data for heat consumption of clinker burning is after 1998; (4) KT/D is abbreviation of 1000 tons/day, it denotes the production scale.

Source: Chinese cement technology network, Haitong stock report.

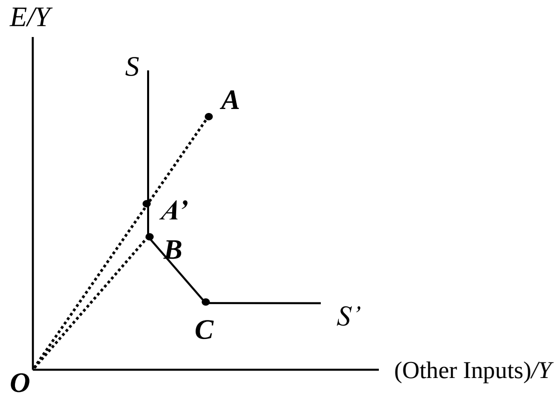

Figure 1 Energy efficiency in an input-oriented CRS model

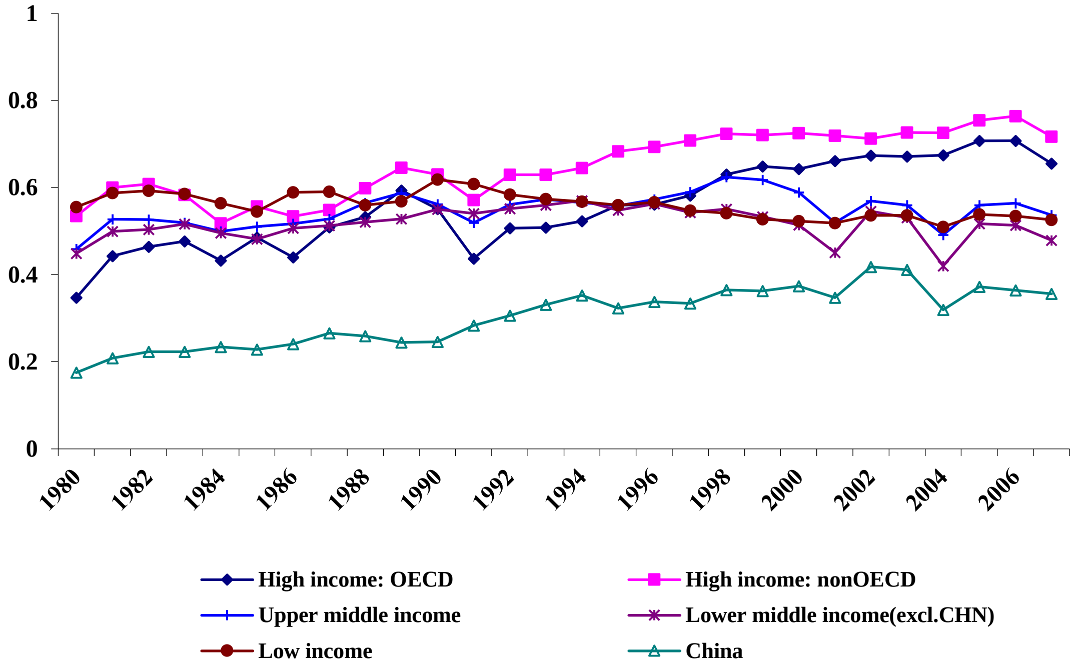

Figure 2 Comparison of energy efficiency between China and other income groups (1980-2007)

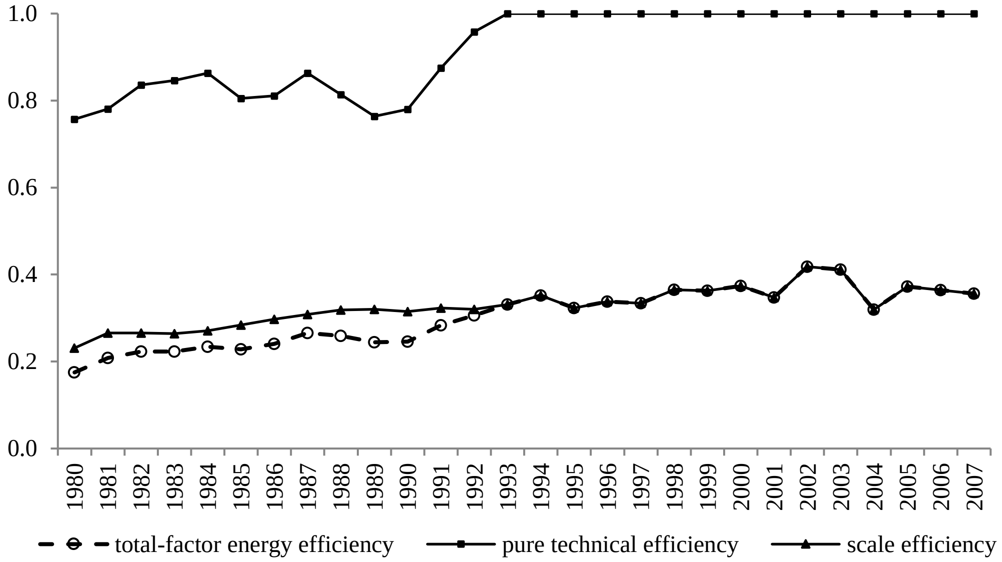

Figure 3 Trend of China’s energy efficiency, pure technical efficiency and scale efficiency over 1980-2007

Appendix 1: Sample country list

Table 8 Sample country (region) by income group

Income group	number	Country (region)
High income: OECD	24	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Korea(Republic of), Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States
High income: non-OECD	17	Bahamas, Bahrain, Barbados, Brunei, Cyprus, Hong Kong SAR, Israel, Kuwait, Macao SAR, Malta, Puerto Rico, Qatar, Saudi Arabia, Singapore, Taiwan, Trinidad &Tobago, United Arab Emirates
Upper middle income	28	Argentina, Belize, Botswana, Brazil, Bulgaria, Chile, Costa Rica, Dominica, Equatorial Guinea, Gabon, Grenada, Hungary, Lebanon, Libya, Malaysia, Mauritius, Mexico, Oman, Panama, Poland, Romania, Seychelles, South Africa, St. Lucia, St. Vincent & Grenadines, Turkey, Uruguay, Venezuela
Lower middle income	42	Albania, Algeria, Angola, Bhutan, Bolivia, Cameroon, Cape Verde, China, Colombia, Congo, Republic of, Cuba, Djibouti, Dominican Republic, Ecuador, Egypt, El Salvador, Fiji, Guatemala, Guyana, Honduras, Indonesia, Iran, Iraq, Jamaica, Jordan, Lesotho, Maldives, Morocco, Namibia, Nicaragua, Paraguay, Peru, Philippines, Samoa, Sri Lanka, Suriname, Swaziland, Syria, Thailand, Tonga, Tunisia, Vanuatu
Low income	45	Afghanistan, Bangladesh, Benin, Burkina Faso, Burundi, Cambodia, Central African Republic, Chad, Comoros, Congo, Dem. Rep., Cote d`Ivoire, Ethiopia, Gambia, The, Ghana, Guinea, Guinea-Bissau, Haiti, India, Kenya, Laos, Liberia, Madagascar, Malawi, Mali, Mauritania, Mongolia, Mozambique, Nepal, Niger, Nigeria, Pakistan, Papua New Guinea, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Solomon Islands, Somalia, Sudan, Tanzania, Togo, Uganda, Vietnam, Zambia, Zimbabwe

Appendix 2: Comparison by similar income group and scale

Table 9 Energy efficiency comparison by income group and scale in 2007

By middle-income group (66 economics)			By lower-middle income group (41 economics)			Top 30 in economy-scale			Top 30 in population-scale		
Country (Region)	TFEE	EI	Country (Region)	TFEE	EI	Country (Region)	TFEE	EI	Country (Region)	TFEE	EI
Cameroon	1 (1)	1.99 (5)	Cameroon	1 (1)	1.99 (5)	United States	1 (1)	7.86 (24)	United States	1 (1)	7.86 (27)
Cape Verde	1 (2)	1.27 (2)	Cape Verde	1 (2)	1.27 (2)	United Kingdom	1 (2)	4.84 (8)	Nigeria	1 (2)	2.88 (4)
Congo, Republic Of	1 (3)	2.28 (8)	Congo, Republic of	1 (3)	2.28 (7)	Italy	1 (3)	4.76 (7)	Philippines	1 (3)	2.89 (5)
Cuba	1 (4)	2.81 (12)	Cuba	1 (4)	2.81 (10)	Saudi Arabia	1 (4)	13.2 (30)	Egypt	1 (4)	5.92 (20)
Equatorial Guinea	1 (5)	4.17 (28)	Tunisia	1 (5)	3.08 (14)	Egypt	1 (5)	5.92 (15)	Ethiopia	1 (5)	1.2 (1)
…			…			…			…		
Paraguay	0.329 (62)	13.57 (65)	Albania	0.415 (37)	6.21 (27)	Turkey	0.723 (26)	7.47 (21)	Korea, Republic Of	0.677 (26)	8.38 (28)
Nicaragua	0.305 (63)	6.07 (38)	Bolivia	0.403 (38)	6.75 (29)	Korea, Republic of	0.677 (27)	8.38 (26)	China	0.668 (27)	7.48 (26)
Bhutan	0.277 (64)	10.38 (58)	Paraguay	0.379 (39)	13.57 (40)	China	0.664 (28)	7.48 (22)	Thailand	0.663 (28)	6.32 (23)
Guatemala	0.247 (65)	2.73 (10)	Nicaragua	0.305 (40)	6.07 (25)	Iran	0.664 (29)	11.62 (29)	Tanzania	0.598 (29)	2.97 (6)
Guyana	0.178 (66)	11.86 (64)	Guyana	0.215 (41)	11.86 (39)	Thailand	0.663 (30)	6.32 (18)	Congo, Dem. Rep.	0.518 (30)	4.18 (10)