Energy Saving Targets for APEC Economies: An Application of DEA Approach

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Abstract. A total factor energy saving target ratio (ESTR) for seventeen APEC economies over 1991-2000 is computed in this paper. All nominal terms are transformed into real terms at the 1995 price level. The data envelopment analysis (DEA) approach is used to find the energy-saving target (EST) for APEC economies without reducing their maximum potential GDPs. Energy, labor, and capital are the three inputs, while the real GDP transformed by purchasing power parties is the single output. Our major empirical findings are as follows: 1. China has the largest energy saving target with almost half amount of its current usage. 2. Hong Kong, Philippines, the United States have the highest energy-usage efficiency. 3. The energy-usage efficiency is generally increasing for APEC economies except for Canada and New Zealand. 4. Chile, Mexico, and Taiwan have significantly improving their energy-usage efficiency in the recent five years. 5. An EKC relation exists between per capita ESTR and per capita GDP.

Keywords: data envelopment analysis (DEA), energy saving target (EST), energy saving target ratio (ESTR)

JEL Classification: O13, Q43

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1. Introduction

Energy saving has been a crucial issue for sustainable development. During the past three hundred years, economic development all over the world has been relying on depletable petro-fossil fuels. Therefore, before new and substitute fuels are available, energy saving is a must to keep economic growth possible. Asian-Pacific Economic Cooperation (APEC) economies includes the fastest economies in the world have attracted the most foreign capital, technology, as well as managerial know-how during the past twenty years. Fast-developing economies and fast-growing energy consumption definitely add pressure to petro-fossil fuels depletion. However, many people worry that a drastic energy saving will hamper economic growth. Therefore, finding efficient energy saving targets for APEC economies without reducing the potential maximum economic growth becomes a very important issue.

Since the Kyoto Protocol became effective in February 2005, reducing the consumption of fossil fuels has been a focal point of environmental policy in many economies including developed and developing ones (de Nooij et. al., 2003). The relationship between economic growth and energy consumption has been the focus of many recent studies. The correlation of energy's environmental costs (e.g., carbon emissions) and energy efficiency (e.g., cost-effective improvements) has attracted considerable attention. The energy system plays a central role in the interrelated economic, social and environmental aims of sustainable human development (WCED, 1987). The present energy system must be transformed on the supply side as well as on the demand side in order to fulfill sustainability criterion (Nässén and Holmberg, 2005).

Energy is the prime source of value because other factors of production such as labor and capital cannot do without energy (Ghali and El-Sakka, 2004). Given the limited availability of economically viable alternative energy sources, reducing total domestic energy use without sacrificing economic growth becomes an important issue for economies all over the world (de Nooij et al., 2003). Energy saving targets is hence important for each economy. On the same way, energy efficiency improvement should rely on total factor productivity improvement (Boyd et al., 2000). Therefore, a multiple-input-output model should be applied for evaluating energy saving target with a total-factor model.

Data envelopment analysis (DEA) finds out the efficient outputs and inputs in a total-factor framework. This technique makes use of information available in considering factors simultaneously. Efficiency is defined by the difference in 'best practice' production frontier, as measured by DEA. The 'best practice' in the frontier is the benchmark to calculate the projected and possible energy saving for those not in the frontier. By comparing the relative practice of various inputs and output in different economies, we can identify the main amount (target) in energy saving is likely to be found. Thus, the performance of the economies that have the 'best practices' can serve as a benchmark to evaluate a particular economy's energy consumption.

Few studies apply DEA to compare productivity and efficiency considering energy use across countries: Färe et al. (2004) used DEA to construct an environmental performance index focusing on pollution. In the study, energy was just part of inputs taken into account. Since their major objective was to find a method considering undesirable outputs, they used output-oriented DEA models. Edvardsen and Førsund (2003) and Jamasb and Pollitt (2003) analyzed the benchmarking of electricity industry in Europe and Northern Europe at plant level. A special feature of the present across economies study is that the data (for 1990s) is based on a sample of APEC economies at economy level and the focus is on the use of energy.

The causes of rapid Asian economic growth and its sustainability have generated considerable debates since the early 1990s (e.g., World Bank, 1993; Krugman, 1994; Kim and Lau, 1994, 1995; Young, 1994, 1995; Chen, 1997; Drysdale et al., 1997; Krüger et al., 2000; Chang and Luh, 2000). Focusing on the international association as a partnership in sharing technology and resources, we apply the DEA approach based on multiple inputs containing capital, labor, and energy to analysis APEC economies.

Within this approach, the empirical findings from the analysis show the possible energy saving without scarifying the maximum potential economic output of APEC economies.

The paper is organized as follows: Section 2 explains how to identify the 'best practice' and construct the total-factor energy efficiency indicator based on DEA. Comparing with the frontier, the total adjustments of energy input can be obtained and calculated the energy saving amount and ratio comparing with the actual energy output in individual economy. Section 3 includes a summary statistics of the empirical data. Section 4 presents and discusses the empirical results. Finally, section 5 concludes this paper.

2. Methods

2.1 Methodology of Data Envelopment Analysis (DEA)

This paper uses DEA to measure efficiency by the frontier production function, $y = f(X)$ where y is the maximum level of output that can be produced in a given set of inputs, X. The question we want to ask is: "By how much can input quantities (energy) be proportionally reduced without changing the output quantities (GDP) produced?" Since it is an input-reducing focus, this paper uses input-orientated measures following Farrell's (1957) original ideas. In order to pursue overall technical efficiency with energy inputs, our study adopts the constant returns to scale (CRS) DEA model (Charnes et al., 1978).

Our measure of relative efficiency is based on non-parametric techniques (Färe et al., 1985). The input set L(y) is defined as $L(y) = \{X: y \geq f(X)\}$. The efficiency is based on the distance function, $D(y, X) = \min \{\lambda: x\lambda \in L(y)\}$ (Shephard, 1970). The set $L(y)$ can be defined by linear programming using observed data. These linear programming (LP) methods for implementing the distance function, also known as data envelopment analysis (DEA), use K inputs and M outputs for N observations as the basis of the production technology by solving the following LP:

$$D(y_i, x_i) = \text{Min}_{\theta, \lambda}\ \theta$$

$$\text{subject to} \quad -y_i + Y\lambda \geq 0,$$

$$\theta x_i - X\lambda \geq 0,$$

$$\lambda \geq 0, \qquad (1)$$

where θ is a scalar and λ is a Nx1 vector of constants. The value of θ will be the efficiency score for the i-th observation, with $0 \leq \theta \leq 1$. The rule of unity indicates a point on the frontier and hence a technically efficient economy, according to the Farrell (1957) definition. It measures the maximal radial reduction of the inputs given the level of outputs. The frontier is a piece-wise linear isoquant, determined by the observed data points i.e., all the economies in this study (Coelli et al., 1998). The economy that constructs the frontier is 'best practice' among those observed economies. The weight λ serves to form a convex combination of observed inputs and outputs.

Fig. 1 illustrates the efficiency measurement. Each point on Fig. 1 represents a combination of inputs that all produce the same output level. Economies C and D are on the frontier and they cannot maintain the given output level by further reducing their inputs. Economies A and B are hence inefficient economies.

[Figure 1 inserts here]

2.2 slack and radial adjustment

An important issue in efficiency studies is the credibility of the assumption that all production process can actually reach the best practice production frontier (Zofío and Prieto, 2001). In the present study, when measuring energy use efficiency it is assumed that all economies have access to the best practice. This assumption seems to be adequate since only APEC economies are considered. Currently, specialized journals, technological fairs, multi-nationals' global marketing strategies, etc., guarantee that new innovations are readily available to all economies (Zofío and Prieto, 2001). The international trade agreements among APEC force economies to be more competitive and the pressure of Kyoto Protocol requires updated technologies and improves input usage efficiency.

The *f*(X) set in the frontier is the 'best practice' production among the observed economies. The inefficient economy could reduce inputs by the amount indicated by the arrow and still remain in the input set L(*y*) (Boyd et al., 2000). For the *i*-th economy, the distance (amount) of it to the projected point on the frontier by radically reducing without reducing output level, $(1-\theta)x_i$, is called 'radial adjustment'. We can illustrate from Fig. 1. Point B is the actual input set and point B' is the ideal or best practice input set for economy B by reducing the radial adjustment BB'.

However, when the frontier runs parallel to the axes could be a problem. In Fig. 1, point A' is the best practice for Economy A by reducing the redial adjustment AA'. Point A' can reduce some input to maintain on the same output level. The reduced amount is called 'input slack' (by the amount CA'). For economy A, the best practice is point C instead of point A' by reducing the radial adjustment AA' and slack CA'.

The summation of slack and radial adjustment is the total reducing amount ('target') that could be reduced without scarifying output levels. For energy input, the summation is 'energy saving target' (EST). The formula is as follows:

$$\text{EST} = \text{radial adjustment} + \text{slack}. \tag{2}$$

An inefficient economy can reduce or save EST in energy use without scarifying the real economic growth. In DEA, the CRS model can suggest the slack and radical adjustment of individual input for all observed units to be efficient and either amount of actual energy input can be calculated accordingly. Since the actual practice can be improved to the best practice, the actual energy consumption is always larger than or equals to the ideal energy input.

2.3 energy saving target ratio (ESTR)

Efficiency is generally defined in terms of the ratio with which best practice compares with actual operation. Indicator of energy efficiency, therefore, should be the ratios of the aggregate energy saving target from equation 2 to actual energy use. Based on slack and radial adjustment of energy obtained from DEA, we can calculate an energy saving target ratio considering other factor simultaneously. The formula is as below:

$$\text{ESTR}_{(i,t)} = \frac{\text{Eenrgy-Saving Target}_{(i,t)}}{\text{Actual Energy Input}_{(i,t)}}, \tag{3}$$

where in the *i*-th economy and the *t*-th year.

As equation (3) shows, the ESTR represents each economy's inefficiency level of energy saving and energy consumption. Since the minimal value of ESTR is larger or equals to zero, the value of EUE is between zero and unity. A value of 0 indicates an economy on the frontier that is the best energy-usage and energy saving efficiency among the observed economies. A zero ESTR means that no redundant or over-consumed energy use exist (the amount of target zero) in this economy. Otherwise, the inefficiency economy with the value of ESTR larger than 0 means the energy should and could be saved at the same economic growth level. Higher the value of ESTR, higher degree of energy-usage inefficiency companies with more energy saving amount.

The commonly used indicator of energy inefficiency is the energy intensity, direct analogue of the energy input: GDP ratio proposed by the Joint Economic Committee of the Congress of the United States (1981). There has been a widespread criticism of the use of this indicator for measuring energy efficiency (Patterson, 1996). One aspect is it does not consider the substitution and complement among inputs (e.g., Patterson, 1989; Renshaw, 1981). The ratio is only partial-factor energy efficiency indicator since energy input is the only input-considered factor. We assess the energy efficiency concerned energy with labor and capital simultaneously by ESTR as a total-factor energy efficiency indicator. A total-factor efficiency indicator can provide more information and a truly comparative base to examine the real situation across economies.

3. Data Description

Three analytical measure described in the preceding section is applied to a data set of seventeen Asian Pacific Economic Cooperation (APEC) economies for the period 1991-2000. The economies include Australia, Canada, Chile, China, Hong Kong, Indonesia, Japan Korea, Malaysia, Mexico, New Zealand, Peru, Philippines, Singapore, Taiwan, Thailand, and the United States. Brunei Darussalam, Papua New Guinea, Russia, and Vietnam are not included due to lack of data.

For solving the problem of comparability of data, there are only two practical alternatives: the average rates of exchange and the purchasing power parity (PPP) as measured by OECD (Edvardsen and Førsund, 2003). The latter approach is chosen here. There are three inputs and one output factor analyzed in this study: the three inputs are capital stock, labor employment and energy consumption. The single output is selected as real growth, gross domestic production (GDP) using purchasing power parties. It is expressed in 1995 US dollars. The data of GDP using purchasing power parties and total energy consumption come from *International Energy Agency (IEA) Statistics.*

The data of labor and capital stock come from the Penn World Tables. Multiplying capital stock per work by labor retrieves the capital stock. However, for China, Indonesia, Malaysia, and Singapore, the data on capital stock per work is not available. They are calculated using the perpetual inventory method; that is,

$$K_t = I_t + (1-\delta)K_{t-1}, \tag{4}$$

where I_t denotes gross investment, which is estimated by first multiplying the real investment share by real GDP, at time *t*; and δ is the depreciation rate.

The choice of the rate of depreciation is problematic due to the difference between the developed economies and the developing ones. The perception is that developed economies can afford to update their equipment and apply new technology. Thus, the rate of depreciation of those economies may be greater than that of the developing ones. However, due to their backwardness and hence the leapfrogged effects, some developing economies may actually be able to adopt new technology faster than the developed ones. Unless detailed data at the sector or firm level are available, it is difficult to derive a precise rate of depreciation (Wu, 2004). While the potential impact of the choice of the rate of depreciation is noted, due to data constraints, this paper applies a unified rate of depreciation of 5%.

The average annual growth rates of real GDP, labor, capital and energy for each economy are listed in Table 1: The East Asian economies with the exception of Japan, Indonesia, and the Philippines had indeed achieved high economic growth in 1990s. High growth was match by the rapid expansion of capital stock in those economies. On the other hand, the average labor growth was rather modest and even across all APEC economies. Energy exhibited a similar growth pattern with real GDP. As seen in Table 1, the East Asian economies but two (Japan and China) had the highest average annual growth. Hong Kong had the highest average growth rate 9.4% in energy consumption, and Mexico had the lowest rate with only around 0.2%.

[Table 1 inserts here]

Table 2 shows the percentages in total energy consumption of APEC economies. The United States was the largest energy-consumed economy with almost half amount of the total used by all APEC economies. About the rest half energy amount, China consumed around 20%, Japan 11%, and Canada 7% during the analytic period. The rest thirteen economies used only less than 13% of the total final energy consumption.

[Table 2 inserts here]

A correlation matrix is given in Table 3 that shows high correlation existing between input and output factors selected for this analysis. Table 3 shows that labor employment, capital stock, and energy consumption do actually correlate to GDP performance in this analysis model. The correlation coefficient between energy input and GDP output is calculated as 0.980 which is statistical significant. The relation reveals that more energy is consumed; more GDP is generated. However, the energy efficiency needs to be analyzed in this study in order to learn individual efficiency scores for all APEC economies.

[Table 3 inserts here]

4. Results

We use the software DEAP 2.1, kindly provided by Coelli (1996), to solve the linear programming problems as specified in equation (1). Table 4 reports the summary of ESTR based on equation (3) for each economy. Each economy's energy saving target was also calculated. Figure 2 shows the percentage of total APEC energy saving target. Table 5 presents the per capita EST for each economy. Several interesting observations are summarized as follows:

[Table 4 inserts here]

(1) The ESTR score was generally decreasing for APEC economies during the period considered. As seen in Table 4, APEC economies except Canada and New Zealand had become more efficiency in energy-usage and energy saving over time. In the late of 1990s, they had improved their energy-use efficiency and were closer to the frontier than the beginning. We separated samples into developed and developing groups: developed economies included Australia, Canada, Hong Kong, Japan, New Zealand, Singapore, and the United Sates. Other economies were belonged to the developing group. Since developed economies could afford to update equipments and

apply new technologies, they had lower ESTR scores than those in the developing group.

(2) The ESTR scores of Asian economies but four (Hong Kong, Japan, Singapore and Taiwan) were higher than the average score during the analytic period. Even none of a Middle and Southern American economy was an efficiency energy-saving target economy. Their ESTRs are much lower than the Asian economies under the similar growth level.

(3) China had the largest EST with almost half amount of its current usage even it had the highest development growth rate from 1990-2000. China can save around 50% amount of its current energy consumption by improving technology efficiency without scarifying the high production level. As seen in Figure 2, the EST of China in 2000 was by 65% of the total APEC EST. China plays a role key in energy saving and environment protection in the association of APEC economies. However, the ESTR score was decreased from 83% in 1991 down to 50% in 2000. Improvement in energy efficiency and technical and structural changes have been identified as the main factors that caused the fall in ESTR in China (Crompton and Wu, 2005).

[Figure 2 inserts here]

(4) Hong Kong, the Philippines, and the United States had the 'best practice' among APEC economies and had the complete know-how of production function. They had the lowest ESTR rankings with unity over 1990s among APEC economies. Chile, Mexico, and Taiwan had significantly improving their energy-usage efficiency in the late seven years of 1990s. Mexico and Taiwan got the ESTR value of zero in the latter part of research period. Chile's ESTR scores were at zero from 1995 to 1998, but then increased slightly in the last two years. These economies can share their know-how with others to improve energy-usage efficiency in the international association by trade agreement.

(5) Canada and New Zealand were the two exceptions among APEC economies with decreasing energy-usage efficiency with energy considered. Canada's ESTR score

was 0.23 in 1991 and added up to 0.30 in 2000. New Zealand had improved its energy-usage efficiency in the middle of the observed period. However, its ESTR score increased to 0.22 in 2000 that was higher than that in 1991. The same pattern applies to per capita EST in Table 5. These two developed economies have to face the situation seriously in order to be part of APEC economies.

[Table 5 inserts here]

(6) Chile, Malaysia, Mexico, and Taiwan had a jump in ESTR from 1993 to 1994. The increment rage was from 26% to 38%. There are two opposite reasons for this situation. One is that these three economies improved their productivity and efficiency, pushing them closer to the frontier. The opposite one is that other economies' efficiency got lower and hence pushes these economies up to the efficiency frontier. Maybe the result is caused by the combination of these two reasons. However, the distance between the frontier and these three economies (i.e., EST) was shortened and hold for the rest period.

(7) As seen in Table 5, Canada had the much highest of per capita EST with by 2 tons of oil equivalent (toe). Canadian has to do hardly to save energy in agriculture, residential and commercial, industry, and transport sectors to reduce the energy saving target. However, Canada is an outlier. It is too high comparing with other economies in terms of per capita EST. People in Korea and New Zealand also have to save more energy than other economies for their high per capita total energy saving target.

(8) We use Hausman test and get the rejection of random effects (CHISQ = 11.57, p-value = .01). Table 6 represents the relation of per capita EST and per capita GDP within (fixed effects) estimates. Table 6 shows a similar scenario to the environmental Kuznets curve (EKC). An inverted U-type relationship, commonly referred as the environmental Kuznets curve, has been established between the environmental degradation increases with income at low levels of income and then decreases once a threshold level of per capita income level is reached (Grossman and Krueger 1995). We also find an inverted U-type relation between per capita EST and per capita real GDP.

Being different from the traditional EKC discussing the emission by-product of the production, the energy saving Kuznets curve (ESKC) in this paper focuses on energy inputs. According ESKC, a developing economy should pay more attention in the energy usage and saving issues than developed and less-developing economies.

[Table 6 inserts here]

(9) Comparing the total-factor ESTR to energy intensity, partial-factor energy efficiency. Table 7 shows that energy intensity of all economies but two (China and Hong Kong) was steady with small changes. Peru and the Philippines were the two most efficiency economies, and Canada was the worst. China improved its energy efficiency, but Hong Kong's efficiency was decreasing in the same time. The result of partial-factor energy efficiency was different to ESTR. The relation between energy intensity and GDP per capita does not have the EKC. This proves that the substitution effect of accompanied inputs labor and capital stock to single energy inputs in producing GDP output is significant. The energy efficiency could be over- or under-estimated if energy is taken as single input in the production. Certain portion of GDP output is produced not only by energy input but also by labor employment and capital stock. These points are considered integrally in a multiple-input model to produce GDP output, with which the total-factor ESTR is established.

[Table 7 inserts here]

5. Concluding Remarks

In summary, this paper, using production frontier analysis, employs an alternative indicator to examine the energy efficiency for the purpose of cross country and overtime comparisons, and indicates it on APEC economies. The energy saving targets (EST) can be obtained by comparing ideal input amount based on the 'best practice' of production function and actual energy input. ESTR conducts as a total-factor energy-saving efficiency indicator constructed based on the theory of the frontier theory through DEA, which considers multiple inputs and outputs simultaneously. ESTR advises energy-usage efficiency and energy saving target without scarifying real economic output for every economy. When energy is the single input to produce GDP output, there might be over- or under-estimation of efficiency. EST and ESTR constructed in this paper are better ways to compute the energy efficiency and also the energy-saving level.

In terms of energy usage efficiency APEC members had improved their energy usage efficiency. In particular, APEC developed members had performed better than their developing counterparts. However, Canada appeared to be inefficient behind other developed economies in terms of ESTR.

Hong Kong, the Philippines, and the United States were always the best performers among APEC economies with their zero ESTR. Chile, Mexico, and Taiwan had caught up in latter of 1990s. In contrast, China had the largest ESTR with highest percentage of total APEC's ESTR. It can save half of current energy consumption while keeping the same output level. Further, the energy-usage efficiencies of Southern East Asian economies were lower than average. In contrast, the Middle and Southern American economies had lower energy saving target ratios.

All APEC economies should share the knowledge and know-how of the production function. They all be possible to reduce the energy input and can become efficient economies without scarifying their each economic development. Based on the data of 2000, the target energy saving of all APEC economies is 418.15Mtoe, taking 13.22% of their total energy consumption. The energy-saving amount will help APEC economies to reduce the pollution omission, and meet the principles of Kyoto Protocol.

An inverted U-type relation similar to the EKC was found between ratio of per capita ESTR and per capita real income among APEC economies. The developed economies except Canada owned better per capita income, so that energy saving target was concerned to minimum. The case did not happen to the developing economies since these economies consumed more energy but in lower efficiency. According to these findings, the condition of energy-usage efficiency and energy saving target in the Southern East economies should be paid with more attention. New technology, improved process, and industrial structural change are important for these developing economies in order to reduce wasteful energy use such that energy efficiency can be promoted without scarifying their maximum potential GDPs. Further improvements can be taken respectively in the sector level and more detailed analyses can be conducted for each economy.

Industrial structure, energy policies, energy consumption type, and treatments from economies base can be further included. The efficiency frontier shift is another interesting topic to study, which can be conducted by DEA-Malmquist models. As long as the balance between economic growth and energy consumption is reached, sustainable development for APEC economies can be achieved.

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Table 1
Average annual growth rate of real GDP, Labor, Capital and Energy (1991-2000)

Economies	GDP	Labor	Capital	Energy
Australia	3.656	1.351	8.152	2.185
Canada	2.887	1.177	7.868	1.920
Chile	5.781	1.993	13.277	5.580
China	9.167	0.935	14.711	1.091
Hong Kong, China	3.228	-0.152	15.484	9.378
Indonesia	3.323	1.859	6.981	6.122
Japan	1.117	0.295	7.893	1.350
Korea	5.169	1.225	12.743	6.141
Malaysia	6.074	2.510	16.630	7.177
Mexico	3.072	1.794	9.578	0.192
New Zealand	2.795	1.416	7.592	3.163
Peru	3.770	4.317	8.830	3.584
Philippines	2.914	2.513	9.721	6.220
Singapore	6.982	3.181	7.758	4.194
Taiwan	5.381	0.881	8.343	4.408
Thailand	3.512	0.908	13.577	6.341
USA	3.336	1.301	10.121	1.374
Mean	4.245	1.618	10545	4.142

Note:
(1) Statistics in the 'GDP,' 'Capital,' 'Labor,' and 'Energy' columns are mean percentage rates of growth.
(2) Source: Penn World Tables, IEA Statistics 2002 Edition.

Table 2
Percentage in total energy consumption of APEC economies (1991-2000)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Australia	2.18	2.16	2.18	2.14	2.16	2.15	2.20	2.26	2.26	2.26
Canada	6.01	6.01	6.00	5.98	5.93	5.92	6.02	5.93	6.04	6.09
Chile	0.31	0.34	0.36	0.36	0.38	0.40	0.45	0.44	0.45	0.45
China	18.95	19.17	19.32	19.61	19.83	20.18	18.90	19.13	17.93	17.68
Hong Kong, China	0.27	0.32	0.32	0.34	0.33	0.32	0.33	0.40	0.44	0.55
Indonesia	1.39	1.44	1.56	1.60	1.67	1.78	1.84	1.82	1.94	2.11
Japan	11.45	11.36	11.11	11.06	11.08	10.87	11.05	11.00	11.06	10.97
Korea	2.69	3.01	3.22	3.45	3.63	3.76	4.02	3.66	3.98	4.09
Malaysia	0.55	0.60	0.64	0.66	0.74	0.77	0.85	0.84	0.87	0.93
Mexico	3.47	3.47	3.38	3.36	3.23	3.04	3.09	3.10	2.98	2.96
New Zealand	0.38	0.38	0.38	0.39	0.40	0.40	0.41	0.41	0.43	0.44
Peru	0.24	0.23	0.23	0.24	0.26	0.26	0.27	0.27	0.29	0.28
Philippines	0.36	0.38	0.42	0.48	0.50	0.52	0.55	0.56	0.57	0.56
Singapore	0.26	0.25	0.26	0.28	0.29	0.30	0.33	0.33	0.33	0.33
Taiwan	1.24	1.30	1.33	1.38	1.39	1.41	1.45	1.53	1.57	1.59
Thailand	0.86	0.94	1.04	1.13	1.25	1.35	1.37	1.27	1.32	1.33
USA	49.39	48.65	48.24	47.54	46.92	46.56	46.85	47.03	47.53	47.40

Notes: The unit is percentage.

Table 3
Correlation matrix for all inputs and outputs (1991-2000)

	GDP	Labor	Capital	Energy
GDP	1.00			
Labor	0.464	1.00		
Capital	0.952	0.360	1.00	
Energy	0.980	0.407	0.899	1.00

Table 4
Summary of ESTR by economy (1991-2000)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Australia	0.11	0.11	0.13	0.15	0.13	0.11	0.08	0.05	0.04	0.06
Canada	0.23	0.25	0.26	0.27	0.29	0.30	0.29	0.29	0.29	0.30
Chile	0.47	0.38	0.38	0.04	0.00	0.00	0.00	0.00	0.03	0.02
China	0.83	0.80	0.75	0.70	0.67	0.65	0.59	0.56	0.50	0.49
Hong Kong, China	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indonesia	0.46	0.40	0.37	0.31	0.29	0.30	0.29	0.35	0.38	0.40
Japan	0.02	0.03	0.10	0.17	0.17	0.16	0.17	0.11	0.10	0.01
Korea	0.31	0.31	0.37	0.32	0.29	0.28	0.28	0.28	0.24	0.21
Malaysia	0.59	0.53	0.52	0.15	0.16	0.16	0.18	0.24	0.23	0.22
Mexico	0.59	0.52	0.52	0.04	0.08	0.03	0.00	0.00	0.00	0.00
New Zealand	0.21	0.23	0.32	0.15	0.13	0.16	0.13	0.15	0.15	0.22
Peru	0.31	0.15	0.23	0.13	0.13	0.16	0.12	0.08	0.12	0.09
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.22	0.2	0.19	0.19	0.17	0.16	0.15	0.12	0.08	0.04
Taiwan	0.27	0.25	0.43	0.17	0.09	0.05	0.01	0.00	0.00	0.00
Thailand	0.4	0.34	0.34	0.31	0.33	0.37	0.39	0.34	0.32	0.27
USA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average	0.295	0.265	0.289	0.182	0.172	0.170	0.158	0.151	0.146	0.137

Notes: Scores with gray background covered are those reached at the best efficiency with zero score.

Table 5
Per Capita Total Energy Saving Amount (1991-2000)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Australia	0.36	0.36	0.44	0.51	0.47	0.39	0.31	0.19	0.16	0.24
Canada	1.29	1.45	1.52	1.57	1.61	1.77	1.83	1.73	1.81	1.90
Chile	0.29	0.26	0.27	0.03	0.00	0.00	0.00	0.00	0.03	0.02
China	0.36	0.35	0.34	0.33	0.33	0.33	0.28	0.26	0.22	0.22
Hong Kong, China	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indonesia	0.09	0.08	0.09	0.08	0.07	0.08	0.08	0.10	0.11	0.13
Japan	0.04	0.08	0.25	0.41	0.45	0.44	0.46	0.28	0.27	0.04
Korea	0.51	0.59	0.74	0.71	0.68	0.71	0.74	0.67	0.63	0.58
Malaysia	0.46	0.45	0.47	0.14	0.17	0.19	0.22	0.28	0.27	0.28
Mexico	0.64	0.57	0.55	0.04	0.08	0.03	0.00	0.00	0.00	0.00
New Zealand	0.60	0.68	0.95	0.48	0.42	0.52	0.43	0.50	0.53	0.79
Peru	0.09	0.04	0.07	0.04	0.04	0.06	0.04	0.03	0.04	0.03
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.48	0.42	0.41	0.46	0.43	0.41	0.39	0.30	0.21	0.10
Taiwan	0.43	0.43	0.76	0.32	0.18	0.10	0.02	0.00	0.00	0.00
Thailand	0.16	0.15	0.17	0.17	0.21	0.26	0.28	0.22	0.22	0.19
USA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average	0.341	0.348	0.414	0.311	0.302	0.311	0.299	0.268	0.265	0.266

Notes: The unit is tons of oil equivalent (toe) per person.

Table 6
Relation between Per Capita Energy saving targets and Per CapitaGDP

Variable	Coefficient	t-statistic	p-value
time	-1055.24	-3.043	0.003
per capita GDP	244.76	4.671	0.000
(per capita GDP)2	-7.66	-4.167	0.000
R-squared	.261134	Durbin-Watson	2.07189 [.588,.766]

Table 7

Partial-factor energy efficiency – the energy intensity (1991-2000)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Australia	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.15	0.15	0.15
Canada	0.26	0.26	0.26	0.26	0.25	0.26	0.25	0.24	0.24	0.23
Chile	0.11	0.10	0.10	0.10	0.10	0.10	0.11	0.10	0.11	0.10
China	0.25	0.23	0.21	0.19	0.18	0.18	0.15	0.14	0.12	0.12
Hong Kong, China	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.09	0.09	0.11
Indonesia	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.11	0.11
Japan	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Korea	0.15	0.16	0.17	0.17	0.17	0.17	0.18	0.17	0.17	0.16
Malaysia	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15
Mexico	0.14	0.14	0.14	0.14	0.15	0.14	0.13	0.12	0.11	0.11
New Zealand	0.18	0.19	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19
Peru	0.08	0.07	0.08	0.07	0.07	0.08	0.07	0.07	0.08	0.07
Philippines	0.04	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Singapore	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.11
Taiwan	0.13	0.13	0.13	0.14	0.13	0.13	0.13	0.13	0.12	0.12
Thailand	0.09	0.09	0.09	0.10	0.10	0.11	0.11	0.11	0.11	0.11
USA	0.20	0.19	0.19	0.19	0.19	0.19	0.18	0.17	0.17	0.16
Average	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13

Notes: The unit is Mtoe/$1000 Purchasing Power Parity, at 1995 international prices.

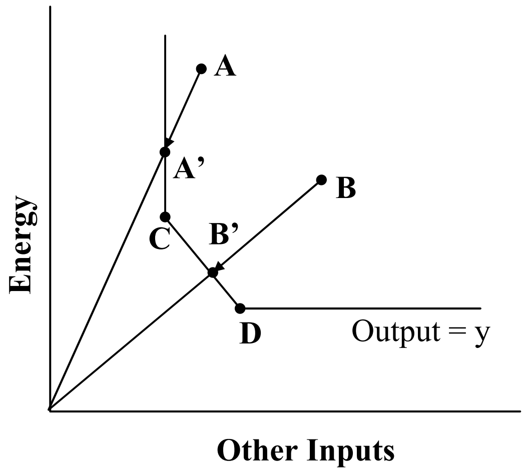

Figure 1
DEA representation of 'best practice', target, radical adjustment and input slacks

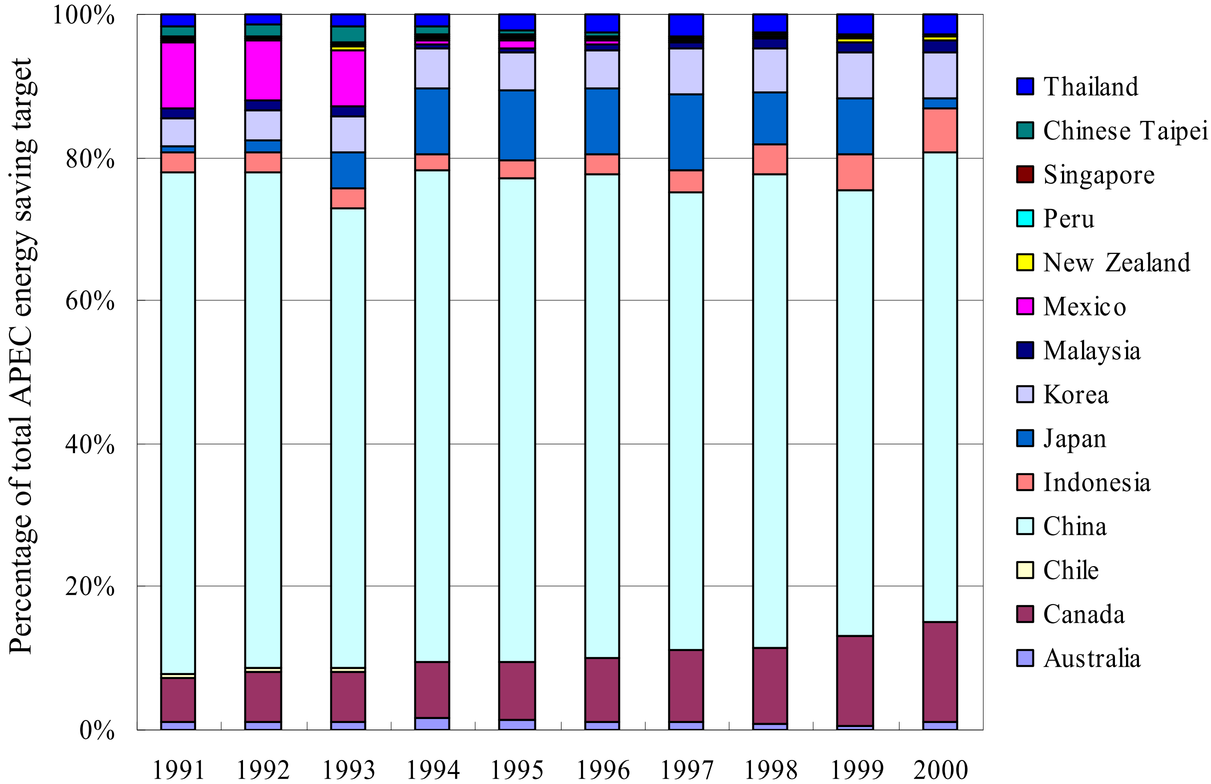

Figure 2
Percentage of total energy saving amount of each APEC economies (1991-2000)