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Efficient energy-saving targets for APEC economies

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Abstract

Energy-saving target ratios (ESTR) for 17 APEC economies during 1991–2000 are computed in a total-factor framework. All nominal variables are transformed into real variables by the purchasing power parity (PPP) 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 gross domestic productions (GDPs) in each year. Energy, labor, and capital are the three inputs, while GDP is the single output. Our major findings are as follows: (1) China has the largest EST up to almost half of its current usage. (2) Hong Kong, the Philippines, and the United States have the highest energy efficiency. (3) The energy efficiency generally increases for APEC economies except for Canada and New Zealand. (4) Chile, Mexico, and Taiwan have significantly improved their energy efficiency in the last 5 years. (5) An inverted U-shape relation exists between per capita EST and per capita GDP. (6) ESTR has a positive relation with the value-added percentage of GDP of the industry sector and a negative relation with that of the service sector.

Keywords: Energy-saving target (EST); Energy-saving target ratio (ESTR); Industrial structure

1. Introduction

Energy saving has been a crucial issue for sustainable development. During the past 300 years, economic development all over the world has relied on depletable petro-fossil fuels. Therefore, before new and substitute fuels become available, energy saving is a must in order to make economic growth possible. Asia-Pacific Economic Cooperation (APEC) economies include the fastest economies in the world and have attracted the most foreign capital, technology, as well as managerial know-how during the past 20 years. Fast-developing economies and fast-growing energy consumption definitely add pressure to petro-fossil fuels' depletion. However, many people worry that drastic savings in energy will hamper economic growth. Therefore, finding efficient ESTs for APEC economies without reducing the potential maximum economic growth has become a very important issue.

Ever 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 energy system plays a central role in the interrelated economic, social, and environmental aims of sustainable human development (WCED, 1987). Energy issues must be integrated with environmental management to achieve sustainable development, especially for fast-developing economies. Energy efficiency improvement is the key to sustainable energy management. For example, European Union estimates that realizing 10–20% of efficiency potential in the European use of electricity would save 10–20 billion ECU annually in terms of fossil fuels use. In Malaysia, it is expected that aggressive deployment of energy efficiency could save about US$1.38 billion by 2015 (Keong, 2005). The economic energy efficiency potentials of various industries range from 2% to 18% in the United States in 2010, 5% to 40% in China in 2010, and 2.2% to 28.5% in Thailand 2005 (WEC et al., 2000). Hu and Wang (2006) also indicate that China can improve its energy efficiency in various regions without reducing its potential economic

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growth. These studies also show that developing economies have more energy efficiency potentials than developed ones.

The Joint Economic Committee of the Congress of the United States (1981) proposed a commonly used indicator of energy inefficiency—the energy intensity as a direct ratio of the energy input to GDP. However, there has been widespread criticism of using energy intensity for measuring energy efficiency (Patterson, 1996). The main problem with energy/GDP, as pointed out by Wilson et al. (1994), is that it does not measure the underlying technical energy efficiency, which can lead to misleading conclusions. For example, the energy intensity may decrease solely because energy is substituted for labor, rather than any underlying deterioration in the technical energy efficiency (Patterson, 1996). 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). The use of the energy efficiency indicator in conjunction with labor and capital can provide useful insights into whether or not energy inputs act as complements or substitutes to other inputs (Patterson, 1996).

Given the limited availability of economically viable alternative energy sources, reducing total domestic energy use without sacrificing economic growth is an important issue for economies all over the world (de Nooij et al., 2003). ESTs are hence important for all economies. In the same way, energy efficiency improvement should rely on total factor productivity improvement (Boyd and Pang, 2000). Therefore, a multiple input–output model should be applied for evaluating an EST with a total-factor model.

Data envelopment analysis (DEA) finds 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 the '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 on the frontier. By comparing the relative practice of various inputs and output in different economies, we can identify the main amount (target) of energy saving 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. A similar approach to construct abatement ratios from the total-factor framework can be found in Hu (2006) and Hu and Wang (2006).

Few studies apply DEA to compare productivity and efficiency by considering energy use across countries: Färe et al. (2004) used DEA to construct an environmental performance index focusing on pollution. In their study, energy is just one part of the inputs that are taken into account. Since their major objective is 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 the electricity industry in Europe and Northern Europe at the plant level. A special feature of this across economies study herein is that the data (for 1990s) are based on a sample of APEC economies at the 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 and Huang, 1997; Krüger et al., 2000; Chang and Luh, 2000). Many economies have adopted energy efficiency policies and measures, but systematic information is only available for OECD economies. There is hence a significant need to improve energy efficiency policy collaboration among APEC economies and disseminate successful practices (APERC, 2002). As such, the energy efficiency among APEC economies is worth further studying. Focusing on the international association as a partnership in sharing technology and resources, we apply the DEA approach using multiple inputs containing capital, labor, and energy consumption in order to analyze the total-factor energy efficiency of APEC economies. This analysis computes the possible energy savings without reducing the maximum potential economic outputs for 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 they calculate the energy-saving amount and ratio by comparing with the actual energy input in an individual economy. Section 3 includes 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

This paper uses DEA to find out the input targets for each APEC economy by comparing with the annual efficiency frontier constituted by all the APEC economies in each year. There is an efficiency frontier for each APEC economy in each year constituted by data of all APEC economies in that year. 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 nonparametric techniques (Färe et al., 1994). Let us first define some mathematical notations: There are K inputs and M outputs for each of N objects. For the ith object these are represented by the column vectors x_i and y_i, respectively. The $K \times N$ input matrix X and the $M \times N$ output matrix Y represent the data for all N objects. The input set $L(y_i)$ for the ith object is defined as $L(y_i) = \{x_i : y_i \geqslant f(x_i)\}$. The