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A Comparative Study of Energy Efficiency of OECD Countries: An Application of the Stochastic Frontier Analysis

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Abstract

We parametrically estimate total-factor energy efficiency (TFEE) scores for 10 industries in 14 developed countries for the period 1995-2005 using stochastic frontier analysis (SFA) technique. The model includes four inputs (labor, capital stock, energy, and non-energy intermediate inputs) and one output (value added). Unlike previous studies that use data envelopment analysis (DEA), our method can take into account statistical noises. The results show that More than half of the industries have insignificant changes in the inefficiency trend. However, construction, paper, and textile industries have significantly increasing inefficiency (decreasing efficiency). The metal industry is the only industry which has decreasing inefficiency (increasing efficiency). As a result, most of the OECD industries have much room in improving their total-factor energy efficiency. Moreover, more than half of the industries have insignificant changes in the inefficiency trend. However, construction, paper, and textile industries have significantly increasing inefficiency. The metal industry is the only industry which has decreasing inefficiency. As a result, most of the OECD industries have much room in improving their total-factor energy efficiency.

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Keywords: Industry Energy Efficiency, Stochastic frontier analysis (SFA), Total-factor energy efficiency (TFEE), International comparison

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1. Introduction

Since Hu and Wang [1] and Hu and Kao [2] construct the total-factor energy efficiency (TFEE) index, it has been widely applied and improved by the following literature [3]. However, most of the existing literature applies the TFEE index to analyze regional or economy-wide energy efficiency. The application of TFEE to industry-wide energy efficiency still remains to apply and promote. Moreover, most of the existing papers applying TFEE use only the traditional CCR [4] and BCC [5] models. More advanced DEA approaches or the use of stochastic frontier to compute or estimate TFEE can still be further tried, as this two-year project will do. We apply and extend the SFA model proposed by Zhou, Ang and Zhou [6] to estimate the industry energy efficiency across countries in different years. This paper is a companion paper of our previous work, Honma and Hu [7] in which we resorted to the DEA technique measure the industry-level TFEE.

Nomenclature

$D(\cdot)$	distance function
K_{it}	capital stock
L_{it}	labor employment
I_{it}	non-energy intermediate inputs
E_{it}	energy input
Y_{it}	real economic output
i	region
t	time
v_{it}	statistical noise
u_{it}	inefficiency term

2. Methodology and Data

Following Zhou, Ang and Zhou [6], we assume that the stochastic frontier distance function is included in the Cobb–Douglas function as

$$\ln D\,(K_{it}, L_{it}, E_{it}, Y_{it}) = \beta_0 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_I \ln I_{it} + \beta_E \ln E_{it} + \beta_Y \ln Y_{it} + v_{it} \quad (1)$$

Because the distance function is homogeneous to degree one in the energy input, the above equation can be rearranged as:

$$\ln D_E\,(K_{it}, L_{it}, E_{it}, Y_{it}) = \ln E_{it} + \beta_0 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_I \ln I_{it} + \beta_E \ln 1 + \beta_Y \ln Y_{it} + v_{it} \quad (2)$$

which can be also be arranged as

$$-\ln E_{it} = \beta_0 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_I \ln I_{it} + \beta_E \ln 1 + \beta_Y \ln Y_{it} + v_{it} - \ln D_E\,(K_{it}, L_{it}, E_{it}, Y_{it}) \quad (3)$$

That is,

$$\ln(1/E_{it}) = \beta_0 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_I \ln I_{it} + \beta_Y \ln Y_{it} + v_{it} - u_{it} \quad (4)$$

The TFEE of region i at time t is then

$$\mathrm{TFEE}_{it} = \exp(-u_{it}) \tag{5}$$

The above model can be estimated by using the panel data SFA model proposed by Basttese and Coelli [8]. This model includes four inputs (labor, capital stock, energy, and non-energy intermediate inputs) and one output (value added). The economic data are taken from EU-KLEMS 2008, while data on purchasing power parity (PPP) are also from EU-KLEMS. The values for the variables are in Euros with 1997 as the base year. The energy and economic dataset contains 10 industries in 14 developed countries for the period 1995-2005. The countries include Australia, Austria, the Czech Republic, Denmark, Finland, Germany, Italy, Japan, South Korea, the Netherlands, Portugal, Sweden, the United Kingdom, and the United States. The industries include the construction industry; the chemical and petrochemical industry; the food and tobacco industry; the iron, steel, and non-ferrous metals industries; the machinery industry; the non-metallic minerals industry; the paper, pulp and printing industry; the textile and leather industry; the transport equipment industry; and the wood and wood products industry.

Table 1 Mean total-factor energy efficiencies for 10 industries during 1995-2005

Country	Chemical	Construc-tion	Food	Machinery	Metal	Non-Metallic	Paper	Textile	Transport	Wood
Australia	0.211	0.540	0.424	0.414	0.176	0.358	0.363	0.589	na	0.050
Austria	0.466	0.104	0.836	0.516	0.388	0.934	0.187	0.616	0.339	0.089
Czech Republic	0.290	0.929	0.804	0.425	0.537	0.939	0.439	0.665	0.439	0.074
Denmark	0.913	0.405	0.765	0.302	0.903	0.452	0.939	0.951	0.364	0.075
Finland	0.260	0.473	0.940	0.375	0.255	0.575	0.078	0.708	0.842	0.075
Germany	0.426	0.526	0.964	0.486	0.503	0.625	0.453	0.549	0.377	0.119
Italy	0.698	0.835	0.914	0.470	0.540	0.623	0.450	0.736	0.909	0.227
Japan	0.669	0.177	0.937	0.546	0.501	0.545	0.355	na	na	na
South Korea	0.409	0.398	0.934	0.309	0.940	0.468	0.335	0.352	0.518	0.073
Netherlands	0.244	0.723	0.835	0.228	0.205	0.732	0.515	0.680	0.546	0.093
Portugal	0.323	0.690	0.965	0.900	0.922	0.475	0.254	0.952	0.596	0.092
Sweden	0.406	0.660	0.944	0.503	0.426	0.502	0.090	0.600	0.476	0.059
United Kingdom	0.366	0.953	0.714	0.230	0.479	0.671	0.607	0.466	0.507	0.603
United States	0.153	0.887	0.575	0.158	0.486	0.313	0.176	0.325	0.381	0.022
Average	0.417	0.593	0.825	0.419	0.519	0.587	0.374	0.630	0.525	0.127

3. Results

3.1 total-factor energy efficiency

More than half of the industries have insignificant changes in the inefficiency trend. However, construction, paper, and textile industries have significantly increasing inefficiency (decreasing efficiency). The metal industry is the only industry which has decreasing inefficiency (increasing efficiency). As a result, most of the OECD industries have much room in improving their total-factor energy efficiency.

Countries perform quite differently in different industries. The best performers in different industries are: chemical (Denmark), construction (United Kingdom), food (Portugal), machinery (Portugal), metal (South Korea), non-metallic (Czech Republic), paper (Denmark), textile (Portugal), transport (Italy), and wood (United Kingdom).

Table 1 presents the mean total- factor energy efficiencies for 10 industries during 1995-2005. c The average total-factor energy efficiency scores are: chemical (0.417), construction (0.593), food (0.825), machinery (0.419), metal (0.519), non-metallic (0.587), paper (0.374), textile (0.630), transport (0.525), and wood (0.127).

3.2 Comparison of DEA and SFA TFEE

We compare the SFA TFEEs obtained in this study with the DEA TFEEs in our earlier work [7] for each industry. Due to the space limitation, figures for the comparison are omitted in this proceedings paper. We can observe that, if the number of DMUs is small like this study, the SFA TFEE approach has a higher discriminating power than DEA.

4. Concluding Remarks

In this paper, we parametrically measure industry-level TFEEs of 10 industries of 14 developed countries using the SFA technique with consideration for statistical noises. Using a panel data set, even when the total number of DMUs are small like this study, one can measure the total-factor energy efficiency by SFA. We believe that this SFA approach provides an alternative measure of the total-factor energy efficiency.

The next step would be to introduce developed stochastic models in the SFA literature. Our model does not include any environmental variables. Using the technical inefficiency effects model provided by Batttese and Coelli [9] can lead to explore determinants of the inefficiency.

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