Journal of Economics and Management, 2019, Vol. 15, No. 2, 171-220

A Meta Stochastic Frontier Analysis of Industry-level Energy Efficiency in OECD Countries

Jin-Li Hu*
Institute of Business and Management, National Chiao Tung University, Taiwan

Satoshi Honma
School of Political Science and Economics, Tokai University, Japan

This research follows the two-step output stochastic frontier analysis (SFA) approach of Huang *et al.* (2014), but instead applies the panel-data input SFA model proposed of Honma and Hu (2014) to estimate the total-factor energy efficiency (TFEE) of industries across countries in different years. The metafrontier TFEE denotes a product of the group TFEE and the technological gap ratio (TGR). Using four inputs (labor, capital stock, energy, and non-energy intermediate inputs) and one output (value added), we take economic data and purchasing power parity (PPP) data from EU-KLEMS (2008). The energy and economic dataset contains seven industries in 14 developed countries for the period 1995-2005. The European continental countries have a higher technical level in their energy use for the chemical and petrochemical industries, since their TGR scores are generally higher than those in other countries. These countries also have a higher average metafrontier energy efficiency for the chemical industry and perform better than the other (non-European continental) group with respect to technology gap ratios for most industries, except for the iron, steel, and non-ferrous metals industries. The European continental group performs better than the other group with respect to metafrontier energy efficiency for all seven industries.

Keywords: Two-step input stochastic frontier analysis, input metafrontier analysis, energy efficiency.
JEL classifications: D24, C51

---

* Correspondence to: Institute of Business and Management, National Chiao Tung University. Sec. 1, Chung-Hsiao W. Rd., Taipei City 10044, Taiwan. Email: jinlihu@g2.nctu.edu.tw. Fax: +886-2-23494922. URL: http://jinlihu.tripod.com. The first author thanks Taiwan's Ministry of Science and Technology for financial support (MOST104-2410-H-009-052). The second author thanks the Japan Society for the Promotion of Science for financial support (grant number 19K01659).

1 Introduction

Improving energy efficiency is one of the key issues in the world economy, but after taking into account of the progress of globalization and the Paris Agreement, more in-depth analysis is required in energy studies. In this paper, we do not use not aggregated economy-wide data, but rather utilize disaggregated industry-level data and apply a newly stochastic metafrontier. To grasp economic activity performance, aggregation and disaggregation play complementary roles in economics. The same holds for an energy efficiency study, however, due to data availability, industry-level analysis is not enough compared to country- or regional-level analyses. In this paper we target to measure industry-level energy efficiency so as to provide a beneficial cross-country comparison and to improve energy efficiency.

One of the common approaches in industry-level analyses is a case study in a specified industry. For industrial modeling, it is necessary to consolidate data availability, level of disaggregation, and modeling efforts for adequate sectoral representation (Seck *et al.*, 2013). Recent studies in this line focus on energy conservation technologies (Laurijssen *et al.*, 2012), drivers of energy efficiency (Cagno and Trianni, 2013; Thollander *et al.*, 2013), heat recovery technologies (Seck *et al.*, 2013, Ammar *et al.*, 2012), thermos-economic diagnosis system (Usón *et al.*, 2010), electricity use (Klugman *et al.*, 2007), and local learning networks (Jochem and Gruber, 2007). While the case study approach has an advantage of being able to capture industry-specific technologies and circumstances, a disadvantage is that the obtained results and implications are limited to the surveyed industry.

In contrast to a case study, an empirical approach allows us to compare industry energy efficiency across countries, by measuring industry-level energy efficiency. Miketa and Mulder (2005) examine energy productivity (EP) of 10 manufacturing sectors in 56 developed and developing countries and indicate that convergence of EP is locally limited. Mulder and de Groot (2007) analyze EPs across 14 OECD countries in 14 sectors and show that EP convergence is conditional. However, the EP approach that deems energy as the sole input overlooks the underlying production process and is likely to present misleading conclusions (Patterson, 1996).

Energy efficiency should be evaluated with other inputs, labor, and capital stock. To implement such a total-factor framework, data envelopment analysis (DEA) as a linear programming method for measuring efficiency is a suitable technique. To evaluate energy efficiency in a multiple-input model, Hu (2006) and Hu and Kao (2007) propose the total-factor energy efficiency (TFEE) index using the DEA technique. DEA applies to many cross-country and cross-regional efficiency analyses,[1] but most 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 be applied and promoted. Moreover, most existing papers applying TFEE use only the traditional CCR model (Charnes *et al.,* 1978) and the BCC model (Banker *et al.,* 1984). Thus, more advanced DEA approaches or the use of stochastic frontier to compute or estimate TFEE can be tested.

For the sake of data availability, there have been a few studies on the measurement of industry-level energy efficiency under a total-factor framework using a DEA technique. Most studies measure the efficiencies of countries, regions, or firms within a particular industry - for example, power company/plant (Sueyoshi, T. and M. Goto, 2011, 2012; Wang *et al*., 2013) and the cement industry (Oggioni *et al*., 2011). For an efficiency study across several industries, Honma and Hu (2013) evaluate 17 industries in Japan, in which all industries face the same efficient frontier for their comparison. Honma and Hu (2014a) measure TFEE for 10 industries in 14 developed countries to compare Japan's energy efficiency with that of other countries and show that chemical, machinery, non-metallic minerals, and paper industries in Japan are inefficient in some years. Other than TFEE, Mukherjee (2008) measures industry energy efficiency of the six highest energy consuming

---

[1] TFEE is applied to APEC economies (Hu and Kao, 2007), developing countries (Zhang *et al*., 2011), China (Hu and Wang 2016; Chang and Hu, 2010; Lee *et al*., 2011; Wang *et al*., 2012), Japan (Honma and Hu, 2008, 2009), and Taiwan (Hu *et al*., 2012). Other than these, Sözen and Alp (2009) and Lozano and Gutiérrez (2008) also employ DEA to compare energy efficiency across countries. For more details, please see Zhou *et al.* (2008).

2-digit sectors in U.S. manufacturing and the aggregate manufacturing sector.

DEA is flexible, but suffers from statistical noises, because it is a deterministic model. To overcome this drawback, in this study we resort to stochastic frontier analysis (SFA), which parametrically measures efficiency. Under an assumption of a production function, two error term components are divided into statistical noise and technical inefficiency. SFA has been widely used to measure energy efficiency across countries and regions. Filippini and Hunt (2011), Herrala and Goel (2012), and Stern (2012) calculate economy-wide energy efficiency using SFA, but they do not use labor and capital stock data. Unlike the above three papers, Zhou *et al.* (2012), based on the Shephard energy distance function, apply an SFA model to measure economy-wide energy efficiency of 21 OECD countries. Hu (2013) extends the model of Zhou *et al*. (2012) to a panel data model and estimates regional energy efficiency in Taiwan. Honma and Hu (2014b) measure regional TFEE in Japan, incorporating the technical inefficiency effects model proposed by Battese and Coelli (1992, 1995) into the models of Zhou *et al*. (2012) and Hu (2013), in which the determinants are estimated not only in efficiency, but also in the panel dataset.

The purpose of this study is thus to estimate the industry-level TFEE of 14 developed countries, applying metafrontier SFA to the dataset of Honma and Hu (2014a). Compared to the previous DEA results, we show that the SFA TFEE approach exhibits more discriminating power than the DEA TFEE technique.

This paper is organized as follows. Section 2 presents our two-step input-oriented meta SFA methodology and data. Section 3 shows and discusses the results. Section 4 concludes this paper.

2 Research Method and Data

2.1 Research Method

Zhou *et al.* (2012) apply the single-equation, output-oriented SFA model to estimate TFEE. They then take their cross-sectional SFA model to analyze 21 OECD countries in 2001. Combining the studies of Zhou *et al.* (2012) and Battese and

Coelli (1992), our study expands the panel data SFA model further by estimating TFEE.

Following Zhou *et al.* (2012), let us assume that the stochastic frontier distance function is included in the Cobb–Douglas function as:

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

where $D_E(\cdot)$ is the distance function, K_{it} is the amount of capital stock, L_{it} is labor employment, M_{it} is intermediate inputs, E_{it} is the energy input, Y_{it} is the real economic output, i indicates the region, t indicates the time, and v_{it} is the statistical noise, which is assumed to be normally distributed. Because the distance function is homogeneous to one degree in the energy input, we can rearrange the above equation as:

$$\begin{aligned} \ln D_E(K_{it}, L_{it}, E_{it}, Y_{it}) &= \ln (E_{it} D_E(K_{it}, L_{it}, M_{it}, 1, Y_{it})) \\ &= \ln E_{it} + \ln D_E(K_{it}, L_{it}, M_{it}, 1, Y_{it}) \\ &= \ln E_{it} + \beta_0 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_M \ln M_{it} + \beta_E \ln 1 + \beta_Y \ln Y_{it} + v_{it}, \end{aligned} \quad (2)$$

which can be rewritten as:

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

Thus, we have:

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

where u_{it} is the inefficiency term, which follows a non-negative distribution, and $v_{it} - u_{it}$ is the error component term of a stochastic production frontier. Equation (4) is consistent with the panel data stochastic frontier model proposed by Battese and Coelli (1992).

We can use the free software Frontier Version 4.1, kindly provided by Professor Coelli (1996), to estimate Eq. (4). Region i's TFEE at time t is then:

$$\mathrm{TFEE}_{it} = \mathrm{E}[\exp(-u_{it})] \quad (5)$$

Therefore, we apply the panel data stochastic production frontier approach to estimate TFEE. Moreover, if we use disaggregated energy inputs, then we can change the logged inverse energy inputs on the left-hand side of Eq. (4) and keep the other logged inputs on the right-hand side fixed, thereby obtaining the TFEE scores for different energy inputs.

Moreover, Battese and Coelli (1992) assume that the time-varying inefficiency term u_{it} follows a monotonic change as:

$$u_{it} = u_i \exp[-\eta(t-T)], \tag{6}$$

where u_i is the time-invariant inefficiency term that follows non-negative truncations of the $N(\mu, \sigma^2)$ distribution; T is the last period in time; parameter η measures the change in inefficiency over time; and a positive (negative) value of η indicates an improvement (worsening off) of efficiency over time.

Battese *et al.* (2004) propose a two-stage approach to do metafrontier analysis for the aggregate efficiency of a DMU. In the first stage, the output distance function SFA estimates the subgroup technical efficiency (TE_{it}), while in the second stage the mathematical programming approach computes the metafrontier technical efficiency (TE_{it}^*). They define the technology gap ratio (TGR) to measure the distance of a subgroup frontier and metafrontier and also derive the famous decomposition equation:

$$TE_{it}^* = TE_{it} \times TGR_{it}, \tag{7}$$

where TE_{it}^* is the metafrontier efficiency of DMU i at time t; TE_{it} is the subgroup efficiency of DMU i at time t; and TGR_{it} is the technology gap ratio of DMU i at time t. All of TE_{it}^*, TE_{it}, and TGR_{it} are left-censored at zero and right-censored at 1, fitting the usual definition of an efficiency score. If DEA is used in the two stages, then the TGR scores can be obtained by using the relation $TGR_{it} = TE_{it}^*/ TE_{it}$. However, since the error component term in an SFA model, $v_{it} - u_{it}$, contains statistical noise v_{it}, which affects the position of a stochastic frontier, in the second stage the metafronrier obatined by SFA may not be able to envelop the subgoup frontiers obatined by SFA, hence resulting in unreasonable results such as $TGR_{it} = TE_{it}^*/ TE_{it} > 1$. Therefore, Battese *et al.* (2004) instead uses DEA in the second stage.

The two-stage approach of Battese *et al.* (2004) has inconsistent assumptions about the metafrontier and subgroup frontiers, whereby the metafrontier is deterministic while the subgroup frontiers are stochastic. Huang *et al.* (2014) propose a new two-stage approach to correct the one in Battese *et al.* (2004), in order to use the SFA approach in both two stages. In the second stage, Huang *et al.* (2014) suggest that the TGR_{it} score should be estimated, instead of the metafrontier efficiency score TE_{it}^*. The metafrontier efficiency score TE_{it}^* can be obtained by multiplying TE_{it} and TGR_{it}.

Battese *et al.* (2004) and Huang *et al.* (2014) both use the output distance function. The subgroup maximum output level for DMU *i* at time *t* is $Y_{it}^{adj} = Y_{it}/ TE_{it}$ as an expansion-adjusted output level. The second-stage SFA regression in Huang *et al.* (2014) is hence:

$$\begin{aligned} \ln(Y_{it}^{adj}) &= \beta_0 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_M \ln M_{it} + \beta_E \ln E_{it} + v_{it}^* - u_{it}^* \\ &= \ln f^M(X_{it}) + v_{it}^* - u_{it}^* \\ &= \ln Y_{it}^* + v_{it}^* - u_{it}^*, \end{aligned} \tag{8}$$

where $f^M(\cdot)$ is the output metfafrontier for the energy input, $X_{it} = (K_{it}, L_{it}, M_{it}, E_{it})$ is a matrix of all inputs of DMU *i* at time *t*, and $Y_{it}^* = f^M(X_{it})$. The subgroup optimal output level may still be below the metafrontier optimal output level, which fits the concept of the technology gap. Equation (9) generates the technology gap ratio DMU *i* at time *t*:

$$TGR_{it} = E[\exp(-u_{it}^*)]. \tag{9}$$

In the TFEE estimation we use the input distance function such as in Eq. (4). In the second stage, we first find the optimal energy input by contracting the actual energy input such that $E_{it}^{adj} = E_{it} \times TFEE_{it}$. Our second-stage SFA regression hence becomes:

$$\begin{aligned} \ln(1/E_{it}^{adj}) &= \beta_0 + \beta_k \ln K_{it} + \beta_L \ln L_{it} + \beta_M \ln M_{it} + \beta_Y \ln Y_{it} + v_{it}^* - u_{it}^* \\ &= \ln\ g^M(\hat{X}_{it}, Y_t) + v_{it}^* - u_{it}^* \\ &= \ln (1/E_{it}^*) + v_{it}^* - u_{it}^*, \end{aligned} \tag{10}$$

where $\hat{X}_{it} = (K_{it}, L_{it}, M_{it})$ is a matrix of all inputs except energy of DMU *i* at time *t*; and $g^M(\cdot)$ is the input metafrontier for the energy input.

Equation (11) sets the total-factor enegy technology gap ratio for region *i* at time t:

$$\widehat{TGR}_{it} = \mathrm{E}[\exp(-u_{it}^{*})]. \quad (11)$$

Referring to Battese and Coelli (1992), we assume that the time-varying inefficiency term u_{it}^{*} follows a monotonic change as:

$$u_{it}^{*} = u_{i}^{*} \exp[-\eta^{M}(t-T)], \quad (12)$$

where parameter η^{M} measures the change in TGR over time, and a positive (negative) value of η^{M} indicates an improvement (worsening off) of TGR over time.

Following the new two-stage approach of Huang *et al.* (2014) by using only SFA, we obtain:

$$\mathrm{TFEE}_{it}^{*} = \mathrm{TFEE}_{it} \times \mathrm{TGR}_{it}, \quad (13)$$

where TFEE_{it}^{*} is the metfrontier TFEE score for region i at time t; TFEE_{it} is the subgroup TFEE score for region i at time t; and TGR_{it} is the technology gap ratio score for region i at time t. All of the TFEE_{it}^{*}, TFEE_{it}, and TGR_{it} scores are left-censored at 0 and right censored at 1, fitting the usual definition of an efficiency score. Huang *et al.* (2014) point out that we can also follow Battese *et al.* (1995) to simultaneously estimate the schochastic frontier and equation of ineffiency (with the environmental variables).

2.2 Data Sources

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 chemical and petrochemical industries; the construction industry; the food and tobacco industries; the machinery industry; the iron, steel, and non-ferrous metals industries; the non-metallic minerals industry; and the paper, pulp and printing industries. Table 1 lists these seven industries.

This model includes four inputs: labor, capital stock, energy, and non-energy intermediate inputs. Many international comparisons that use DEA adopt GDP as an output. In our paper, however, we calculate efficiency industry by industry. Since GDP is the total amount of value added in each industry, we employ value added as the sole output. The economic data are taken from EU-KLEMS 2008, while data on purchasing power parity (PPP) are also from EU-KLEMS. The main source is the EU-KLEMS Database (website: http://www.euklems.net). The values for the variables are in Euros with 1997 as the base year. The EU-KLEMS project, which is financed by the European Commission, has developed a revolutionary comprehensive database on European and other developed countries for use in analyzing economic growth and productivity. Using the data enables us to make international comparisons of industry-level efficiency. Data regarding energy consumption are taken from the Energy Balances of OECD Countries (International Energy Agency). Economic and energy-related data for various industries are then matched using the above data sources.

3 Empirical Findings

The fourteen countries are divided into two groups: nine European continental countries in Group 1 (Austria, the Czech Republic, Denmark, Finland, Germany, Italy, the Netherlands, Portugal, and Sweden) and five other countries in Group 2 (Australia, Japan, South Korea, the United Kingdom, and the United States). Although the United Kingdom is also in Europe, it is not on the European continent and has a relatively independent island power supply system, which is why we assign it to Group 2 (non-European-continental countries). Moreover, assigning the United Kingdom to Group 2 effectively increases the number of countries in Group 2.

3.1 Chemical and Petrochemical Industries

Tables 2(a)-(c) list the two-step estimation results for the chemical and petrochemical industries.[2] In the first step we estimate group energy efficiency and

[2] The number of the estimates for Group 2's frontier in each industry is 55. This seems a small sample,

then find the adjusted (contracted) energy input by multiplying the group energy efficiency score and actual energy input of the chemical industry in a country. We then perform the SFA estimation of Eq. (9) to find the technical gap ratio with respect to energy use. Finally, the metafrontier energy efficiency scores are realized by multiplying the group energy efficiency scores and the technical gap ratios.

Table 2(a) shows that there is no significant efficiency change in Group 1 (European continent), while Table 2(b) illustrates significant efficiency improvement over time ($\eta > 0$) in Group 2 (others). Table 2(c) presents a significantly worsening of TGR for the two groups over time ($\eta < 0$).

Table 2(d) tells us that the Czech Republic performs the best in Group 1, while the United States performs the best in Group 2. Denmark is a well-known green energy economy, while Japan is also promoting energy-saving technologies with great efforts. Table 2(e) shows that the European continental countries have a higher technical level in the energy use of the chemical and petrochemical industries, since their TGR scores (0.871) are generally higher than those in the other countries (0.542). Germany, Sweden, and Australia have the highest technology levels for using energy in these industries since their TGRs are no less than 0.950 (close to one).

Table 2(f) shows that the European continental countries have a higher average metafrontier energy efficiency for the chemical and petrochemical industries (0.309 > 0.190). Denmark, as a well-known green energy country, has the highest metafrontier energy efficiency (0.967) here, while the United States performs the worst in metafrontier energy efficiency (0.067). Lastly, the average metafrontier energy efficiency of the chemical and petrochemical industries in these countries is declining over time.

3.2 Construction Industry

Tables 3(a)-(c) list the two-step estimation results for the construction industry.

---

and one of our purposes is to illustrate our metafrontier method. A previous research close to ours, Zhou *et al.* (2012), is also a small sample covering 21 OECD countries in 2001 alone.

Table 3(a) shows that efficiency is significantly worsening off ($\eta < 0$) in Group 1 (European continent), while Table 3(b) shows significant efficiency improvement over time ($\eta > 0$) in Group 2 (others). Table 3(c) shows a significant worsening off for TGR ($\eta < 0$) of the two groups over time.

Table 3(d) tells us that the Czech Republic performs the best in Group 1, while the United States performs the best in Group 2. Table 3(e) shows that the European continental countries have a higher technical level in their energy use for the construction industry, since its TGR scores (0.683) are generally higher than those in the other countries (0.666). Germany, Sweden, and Australia have the highest technology levels in using energy here since their TGRs are no less than 0.950 (close to one).

Table 3(f) shows that the European continental countries have a higher average metafrontier energy efficiency for this industry (0.591 > 0.350). The Netherlands has the highest metafrontier energy efficiency for this industry (0.827), while Japan performs the worst in metafrontier energy efficiency (0.068). The average metafrontier energy efficiency of the construction industry in these countries is declining over time.

3.3 Food and Tobacco Industries

Tables 4(a)-(c) list the two-step estimation results for the food and tobacco industries. Table 4(a) shows that there is no significant efficiency change in Group 1 (European continent), while Table 4(b) shows a significant efficiency improvement over time ($\eta > 0$) in Group 2 (others). Table 4(c) indicates TGR significantly worsening off ($\eta < 0$) for the two groups over time.

Table 4(d) tells us that Portugal performs the best in Group 1, while the United Kingdom performs the best in Group 2. Table 4(e) shows that the European continental countries have a higher technical level in energy use for the food and tobacco industries, since their TGR scores (0.925) are generally higher than those in the other countries (0.694). Finland, Japan, the Netherlands, and Denmark have the highest technology levels in using energy since their TGRs are no less than 0.950

(close to one).

Table 4(f) shows that the European continental countries have a higher average metafrontier energy efficiency for the food and tobacco industries (0.847 > 0.562). Finland has the highest metafrontier energy efficiency (0.928), while Australia performs the worst in metafrontier energy efficiency (0.373). The average metafrontier energy efficiency for these two industries in these countries is increasing over time.

3.4 Machinery Industry

Tables 5(a)-(c) list the two-step estimation results for the machinery industry. Table 5(a) shows that there is no significant efficiency change in Group 1 (European continent), and Table 5(b) shows no significant efficiency change in Group 2 (others). Table 5(c) shows TGR significantly worsening off ($\eta < 0$) in the two groups over time.

Table 5(d) tells us that Portugal performs the best in Group 1, while Japan performs the best in Group 2. Table 5(e) shows that the European continental countries have a higher technical level in energy use for the machinery industry, since their TGR scores (0.857) are generally higher than those in the other countries (0.294). Germany has the highest technology level in using energy (0.940) here.

Table 5(f) shows that the European continental countries have a higher average metafrontier energy efficiency for this industry (0.373 > 0.214). Portugal has the highest metafrontier energy efficiency for the machinery industry (0.810), while the United States performs the worst in metafrontier energy efficiency (0.079) here. The average metafrontier energy efficiency of the machinery industry in these countries is decreasing over time.

3.5 Iron, Steel, and Non-ferrous Metals Industries

Tables 6(a)-(c) list the two-step estimation results for the iron, steel, and non-ferrous metals industries. Table 6(a) shows a significant efficiency improvement ($\eta > 0$) in

Group 1 (European continent), and Table 6(b) shows a significant efficiency improvement (η > 0) in Group 2 (others). Table 6(c) shows a significantly TGR improvement (η > 0) of the two groups over time.

Table 6(d) tells us that Denmark performs the best in Group 1, while South Korea performs the best in Group 2. Table 6(e) shows that the European continental countries have a lower technical level in energy use for these industries, since their TGR scores (0.680) are generally lower than those in other countries (0.763). Japan has the highest technology levels in using energy (0.940) here.

Table 6(f) shows that the European continental countries have a higher average metafrontier energy efficiency for these industries (0.457 > 0.424). Portugal has the highest metafrontier energy efficiency (0.873) here, while Australia performs the worst in metafrontier energy efficiency (0.079). The average metafrontier energy efficiency of the iron, steel, and non-ferrous metals industries in these countries is improving over time.

3.6 Non-metallic Minerals Industry

Tables 7(a)-(c) list the two-step estimation results for the non-metallic minerals industry. Table 8(a) shows that there is a significant efficiency improvement (η > 0) in Group 1 (European continent), and Table 7(b) shows no significant efficiency change in Group 2 (others). Table 7(c) shows no significant TGR change of the two groups over time.

Table 7(d) tells us that Austria performs the best in Group 1, while the United Kingdom performs the best in Group 2. Table 7(e) shows that the European continental countries have a higher technical level in energy use for the non-metallic minerals industry, since their TGR scores (0.864) are generally higher than those in other countries (0.742). Australia has the highest technology level in using energy (0.975) here.

Table 7(f) shows that the European continental countries have a higher average metafrontier energy efficiency for this industry (0.465 > 0.297). The Czech Republic has the highest metafrontier energy efficiency (0.691), while the United States performs the worst in metafrontier energy efficiency (0.715) here. The average metafrontier energy efficiency of the non-metallic minerals industry in these countries is improving over time.

3.7 Paper, Pulp, and Printing Industries

Tables 8(a)-(c) list the two-step estimation results for the paper, pulp, and printing industries. Table 8(a) shows that there is no significant efficiency improvement in Group 1 (European continent), and Table 7(b) shows efficiently significantly worsening off ($\eta < 0$) in Group 2 (others). Table 7(c) indicates significant TGR improvement ($\eta > 0$) of the two groups over time.

Table 8(d) tells us that Italy performs the best in Group 1, while Australia performs the best in Group 2. Table 8(e) shows that the European continental countries have a higher technical level in the energy use for these industries, since their TGR scores (0.846) are generally higher than those in other countries (0.488). The United States has the highest technology level in using energy (0.942) for the paper, pulp, and printing industries.

Table 8(f) shows that the European continental countries have a higher average metafrontier energy efficiency (0.278 > 0.219). Denmark has the highest metafrontier energy efficiency (0.601), while the United States performs the worst in metafrontier energy efficiency (0.114). The average metafrontier energy efficiency of the paper, pulp, and printing industries in these countries is improving over time.

3.8 Discussion

Our results, roughly speaking, are consistent with preceding studies, Zhou *et al.* (2012) and Honma and Hu (2014a), but they do not engage in the metafrontier approach. We thus conclude that, even though there are some differences with respect to various industries, smaller countries such as the Netherlands tend to achieve higher energy efficiency, while larger countries such as Australia and former communist countries such as the Czech Republic typically have lower energy efficiency.

Due to this paper's own focus, we would like to discuss the energy efficiency scores of Japan, which are by and large lower than those in the above two studies. Table 9 summarizes the average group TFEE, TGR, and Meta TFEE scores of industries in Japan. The metafrontier energy efficiency scores of Japan are relatively low. One explanation is the off-shoring of Japan's domestic high value-added hubs (METI, 2010). Thus, keeping low value-added processes in Japan might reduce its meta TFEE scores in its manufacturing industries. For example, unlike the manufacturing industry, the construction industry in Japan has been at low efficiency due to the multi-tiered structure of subcontractors.

We finally want to elaborate upon policy suggestions from our empirical results. Since there are many DMUs (7 industries × 14 countries = 98), we simply argue two implications for inefficient DMUs. The policy suggestions for an inefficient industry depend upon which energy efficiency score for that industry is lower between the group TFEE and TGR. If an industry's group TFEE is relatively low compared to TGR (e.g., chemical and petrochemical industries in Australia), then operational inefficiency given a certain technology should be improved. For this purpose, the government may encourage firms in that industry to review manufacturing processes and perhaps introduce an energy savings program. On the other hand, if the industry's TGR is relatively low compared to the group TFEE (e.g., chemical and petrochemical industries in Japan), then the existing technology should be replaced with a more state-of-the art one. To this end, the national government may subsidize new investment and/or provide low-interest loans to that industry. If the group TFEE of an industry is low along with its TGR, then both policy suggestions can be applied.

4 Conclusions

This research follows the two-step output stochastic frontier analysis (SFA) approach by Huang *et al.* (2014), but converts it into a two-step input SFA approach. We apply the panel-data input SFA model proposed by Honma and Hu (2014b) to estimate the total-factor energy efficiency (TFEE) of industries across countries in different years. The metafrontier TFEE is defined as a product of the group TFEE and the technological gap ratio (TGR). There are 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 seven industries in fourteen 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 industries; the iron, steel and non-ferrous metals industries; the machinery industries; the non-metallic minerals industry; and the paper, pulp, and printing industries. We also separate these countries into two groups: Group 1 (European continental countries) and Group 2 (Others).

The European continental group performs better than the other group with respect to technology gap ratios for most industries, except for the iron, steel and non-ferrous metals industries. The European continental group also performs better than the other group of countries with respect to metafrontier energy efficiency for all seven industries.

Japan's metafrontier energy efficiency scores are relatively low as noted by: the chemical and petrochemical industries (0.304); the construction industry (0.068); the food and tobacco industries (0.682); the machinery industry (0.306); the iron, steel, and non-ferrous metals industries (0.314); the non-metallic minerals industry (0.334); and the paper, pulp, and printing industries (0.234). There is thus still much room for Japan to improve its energy efficiency with respect to individual industries.

References

Ammar, Y., S. Joyce, R. Norman, Y. Wang and A. P. Roskilly, (2012), "Low grade thermal energy sources and uses from the process industry in the UK," *Applied Energy*, 89, 3-20.

Banker, R. D., A. Charnes and W.W. Cooper, (1984), "Some Models for Estimating Technical and Scale Efficiencies in Data Development Analysis," *Management Science*, 30, 1078-1092.

Battese, G. E. and T. J. Coelli, (1992), "Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India," *Journal of Productive Analysis*, 3, 153-169.

Battese, G. E. and T. J. Coelli, (1995), "A model for technical inefficiency effects in a stochastic frontier production function for panel data," *Empirical Economics*, 20, 325-332.

Battese, G. E., D. P. Rao and C. J. O'Donnell, (2004), "A metafrontier production function for estimation of technical efficiencies and technology gaps for firms operating under different technologies," *Journal of Productivity Analysis*, 21, 91-103.

Cagno, E. and A. Trianni, (2013), "Exploring drivers for energy efficiency within small- and medium-sized enterprises: First evidences from Italian manufacturing enterprises," *Applied Energy*, 104, 276-85.

Chang, T. P. and J. L. Hu, (2010), "Total-factor energy productivity growth, technical progress, and efficiency change: An empirical study of China," *Applied Energy*, 87, 3262-70.

Charnes, A., W. W. Cooper and E. Rhodes, (1978), Measuring the Efficiency of Decision Making Units," *European Journal of Operational Research*, 2, 429-444.

Coelli, T. J., (1996), "A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation," *CEPA Working Paper 96/7*, University of New England, Armidale, NSW, Australia.

Filippini, M. and L. C. Hunt, (2011), "Energy demand and energy efficiency in the

OECD countries: a stochastic demand frontier approach," *Energy Journal*, 32, 59-80.

Herrala, R. and R. K. Goel, (2012), "Global CO2 efficiency: country-wise estimates using a stochastic cost frontier," *Energy Policy*, 45, 762-770.

Honma, S. and J. L. Hu, (2008), "Total-factor energy efficiency of regions in Japan," *Energy Policy*, 36, 821-33.

Honma, S. and J. L. Hu, (2009), "Total-factor energy productivity growth of regions in Japan," *Energy Policy*, 37, 3941-50.

Honma, S. and J. L. Hu, (2013), "Total-factor Energy Efficiency for Sectors in Japan," *Energy Sources Part B*, 8, 130-136.

Honma, S. and J. L. Hu, (2014a), "Industry-level total-factor energy efficiency in developed countries: A Japan-centered analysis," *Applied Energy*, 119, 67-78.

Honma, S. and J. L. Hu, (2014b), "A panel data parametric frontier technique for measuring total-factor energy efficiency: an application to Japanese regions, *Energy*, 78, 732-739.

Hu, J. L. and S. C. Wang, (2006), "Total-factor energy efficiency of regions in China," *Energy Policy,* 34, 3206-17.

Hu, J. L. and C. H. Kao, (2007), "Efficient energy-saving targets for APEC economies," *Energy Policy*, 35, 373-82.

Hu, J. L., M. C. Lio, C. H. Kao and Y. L Lin, (2012), "Total-factor energy efficiency for regions in Taiwan," *Energy Source Part B,* 7, 292-300.

Hu, J. L., (2013), "Total-factor energy efficiency for regions in Taiwan: an application of the stochastic frontier analysis," Paper Presented at the 2013 APEC Conference on Low Carbon Town and Physical Energy Storage 2013; Changsha, China.

Huang, C. J., T. H. Huang and N. H. Liu, (2014), "A new approach to estimating the metafrontier production function based on a stochastic frontier framework," *Journal of Productivity Analysis*, 42, 241-254.

Jochem, E. and E. Gruber, (2007), "Local learning-networks on energy efficiency in industry - Successful initiative in Germany," *Applied Energy,* 84, 806-16.

Klugman, S., M. Karlsson and B. Moshfegh, (2007), "A Scandinavian chemical wood pulp mill. Part 1. Energy audit aiming at efficiency measures," *Applied Energy*, 84, 326-39.

Laurijssen J., A. Faaij and E. Worrell, (2012), "Energy conversion strategies in the European paper industry - A case study in three countries," *Applied Energy*, 98, 102-13.

Lee, Y. C., J. L. Hu and C. H. Kao, (2011), "Efficient saving targets of electricity and energy for regions in China," *International Journal of Electrical Power and Energy Systems*, 33, 1211-9.

Lozano, S. and E. Gutiérrez, (2008), "Non-parametric frontier approach to modelling the relationships among population, GDP, energy consumption and CO2 emissions," *Ecological Economics*, 66, 687-99.

Miketa, A. and P. Mulder, (2005), "Energy productivity across developed and developing countries in 10 manufacturing sectors: Patterns of growth and convergence," *Energy Economics*, 27, 429-53.

Ministry of Economy, Trade and Industry, Japan. 2010. White Paper on International Economy and Trade 2010. (https://www.meti.go.jp/english/report/data/gWT2010fe.html).

Mukherjee, K., (2008), "Energy use efficiency in U.S. manufacturing: A nonparametric analysis," *Energy Economics*, 30, 76-96.

Mulder, P. and H. D. Groot, (2007), "Sectoral energy- and labor-productivity convergence," *Environmental and Resource Economics*, 36, 85-112.

Oggioni, G., R. Riccardi and R. Toninelli, (2011), "Eco-efficiency of the world cement industry: A data envelopment analysis," *Energy Policy*, 39, 2842-54.

Patterson, M. G., (1996), "What is energy efficiency? Concepts, indicators, and methodological issues," *Energy Policy*, 24, 377-90.

Seck, G. S., G. Guerassimoff and N. Maïzi, (2013), "Heat recovery with heat pumps in non-energy intensive industry: A detailed bottom-up model analysis in the French food & drink industry," *Applied Energy*, 111, 489-504.

Sözen, A. and I. Alp, (2009), "Comparison of Turkey's performance of greenhouse gas emissions and local/regional pollutants with EU countries," *Energy Policy*, 37, 5007-18.

Stern, D. I., (2012), "Modeling international trends in energy efficiency," *Ecological Economics*, 34, 2200-2208.

Sueyoshi, T. and M. Goto, (2011), "DEA approach for unified efficiency measurement: assessment of Japanese fossil fuel power generation," *Energy Economics*, 33, 292-303.

Sueyoshi, T. and M. Goto, (2012), "DEA environmental assessment of coal fired power plants: methodological comparison between radial and non-radial models," *Energy Economics*, 34, 1854-1863.

Thollander, P., S. Backlund, A. Trianni and E. Cagno, (2013), "Beyond barriers - A case study on driving forces for improved energy efficiency in the foundry industries in Finland, France, Germany, Italy, Poland, Spain, and Sweden," *Applied Energy*, 111, 636-43.

Usón, S., A. Valero and L. Correas, (2010), "Energy efficiency assessment and improvement in energy intensive systems through thermoeconomic diagnosis of the operation," *Applied Energy*, 87, 1989-95.

Wang, Z.H., H. L. Zeng, Y. M. Wei and Y. X. Zhan, (2012), "Regional total factor energy efficiency: An empirical analysis of industrial sector in China," *Applied Energy*, 97, 115-23.

Wang, Y. S., B. C. Xie, L. F. Shang and W. H. Li, (2013), "Measures to improve the performance of China's thermal power industry in view of cost efficiency," *Applied Energy*, 112, 1078-86.

Zhang, X. P., X. M. Cheng, J. H. Yuan, X. J. Gao, (2011), "Total-factor energy efficiency in developing countries," *Energy Policy*, 39, 644-650.

Zhou, P., B. W. Ang and K. L. Poh, (2008), "A Survey of Data Envelopment Analysis in Energy and Environmental Studies," *European Journal of Operational Research*, 189, 1-18.

Zhou, P., B. W. Ang and D. Q. Zhou, (2012), "Measuring economy-wide energy efficiency performance: a parametric frontier approach," *Applied Energy*, 90, 196-200.

Appendix

Table 1. List of Industries

Industry classification	Description
Chemical	Chemical and Petrochemical
Construction	Construction
Food	Food and Tobacco
Machinery	Machinery
Metal	Iron, Steel, and Non-Ferrous Metals
Non-Metallic	Non-Metallic Minerals
Paper	Paper, Pulp, and Printing

Table 2(a). Stochastic Energy Input Frontier Estimation of Group 1 in the Chemical and Petrochemical Industries

Variable	Estimated parameter	Standard error	t-value
Constant	0.717	0.987	0.726
ln(Value Added)	0.278	0.671	0.414
ln(Labor)	-0.235	0.401	-0.586
ln(Capital)	-0.755*	0.404	-1.869
ln(Intermediate Inputs)	-0.125	0.514	-0.242
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.234**	0.098	2.387
$\gamma = \sigma_u^2/\sigma^2$	0.909***	0.036	25.364
μ	0.922	0.758	1.216
η	-0.007	0.019	-0.355
Log-likelihood	11.409		
Total obs.	99		

Note: * represents 10% level of significance; ** represents 5% level of significance; *** represents 1% level of significance.

Table 2(b). Stochastic Energy Input Frontier Estimation of Group 2 in the Chemical and Petrochemical Industries

Variable	Estimated parameter	Standard error	t-value
Constant	5.423	3.586	1.512
ln(Value Added)	0.064	0.612	0.104
ln(Labor)	0.118	0.277	0.428
ln(Capital)	-1.647	0.439	-3.748***
ln(Intermediate Inputs)	0.272	0.751	0.363
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.483	0.484	0.997
$\gamma = \sigma_u^2/\sigma^2$	0.926	0.076	12.150***
μ	0.799	0.551	1.449
η	0.027	0.087	3.103***
Log-likelihood	1.384		
Total obs.	55		

Note: * represents 10% level of significance; ** represents 5% level of significance; *** represents 1% level of significance.

Table 2(c). Stochastic Input Frontier Estimation of Groups 1 and 2 in the Chemical and Petrochemical Industries

Variable	Estimated parameter	Standard error	t-value
Constant	1.956***	0.341	5.738
ln(Value Added)	-0.012	0.097	-0.127
ln(Labor)	-0.118	0.095	-1.244
ln(Capital)	-1.057***	0.158	-6.700
ln(Intermediate Inputs)	0.279**	0.119	2.343
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	1.445**	0.669	2.161
$\gamma = \sigma_u^2/\sigma^2$	0.981***	0.009	104.686
μ	-2.382**	1.021	-2.332
η^M	-0.048***	0.011	-4.487
Log-likelihood	35.263		
Total obs.	154		

Note: ** represents 5% level of significance; *** represents 1% level of significance.

Table 2(d). Group Energy Efficiency for the Chemical and Petrochemical Industries

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.408	0.406	0.404	0.401	0.399	0.396	0.394	0.391	0.389	0.386	0.384	0.396
Czech Republic	0.297	0.295	0.292	0.290	0.287	0.285	0.283	0.280	0.278	0.276	0.273	0.285
Denmark	0.850	0.849	0.849	0.848	0.847	0.846	0.845	0.844	0.843	0.842	0.841	0.846
Finland	0.256	0.254	0.251	0.249	0.247	0.245	0.242	0.240	0.238	0.235	0.233	0.245
Germany	0.222	0.220	0.218	0.216	0.214	0.211	0.209	0.207	0.205	0.203	0.201	0.211
Italy	0.367	0.364	0.362	0.359	0.357	0.354	0.352	0.349	0.347	0.344	0.342	0.354
Netherlands	0.161	0.159	0.157	0.155	0.153	0.152	0.150	0.148	0.146	0.144	0.142	<u>0.152</u>
Portugal	0.384	0.382	0.379	0.377	0.374	0.372	0.369	0.367	0.365	0.362	0.360	0.372
Sweden	0.335	0.332	0.330	0.328	0.325	0.323	0.320	0.318	0.315	0.313	0.310	0.323
Group 1 Ave	0.364	0.362	0.360	0.358	0.356	0.354	0.352	0.349	0.347	0.345	0.343	0.354
Group 2: Others												
Australia	0.123	0.130	0.138	0.145	0.153	0.161	0.169	0.177	0.185	0.194	0.202	0.162
Japan	0.929	0.931	0.933	0.935	0.936	0.938	0.940	0.941	0.943	0.944	0.945	0.938
South Korea	0.367	0.377	0.387	0.397	0.407	0.416	0.426	0.436	0.446	0.455	0.465	0.416
United Kingdom	0.330	0.340	0.349	0.359	0.369	0.379	0.389	0.399	0.409	0.419	0.429	0.379
United States	0.148	0.156	0.163	0.172	0.180	0.188	0.197	0.205	0.214	0.223	0.232	<u>0.189</u>
Group 2 Ave	0.379	0.387	0.394	0.402	0.409	0.416	0.424	0.432	0.439	0.447	0.455	0.417

Notes: The Underlined Numbers are the Two Lowest Average Scores. The Shadowed Numbers are the Two Highest Average Scores.

Table 2(e). Technological Gap Ratios for the Chemical and Petrochemical Industries

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.905	0.901	0.896	0.892	0.887	0.881	0.876	0.870	0.865	0.858	0.852	0.880
Czech Republic	0.803	0.795	0.786	0.777	0.767	0.757	0.747	0.737	0.726	0.714	0.703	0.756
Denmark	0.927	0.924	0.920	0.916	0.912	0.908	0.904	0.900	0.895	0.890	0.885	0.907
Finland	0.875	0.869	0.863	0.857	0.851	0.844	0.837	0.830	0.822	0.815	0.807	0.843
Germany	0.974	0.973	0.971	0.970	0.969	0.967	0.966	0.964	0.962	0.960	0.959	0.967
Italy	0.953	0.950	0.948	0.946	0.943	0.940	0.938	0.935	0.932	0.928	0.925	0.940
Netherlands	0.912	0.908	0.904	0.899	0.895	0.890	0.885	0.880	0.874	0.868	0.862	0.889
Portugal	0.757	0.747	0.736	0.725	0.714	0.702	0.690	0.678	0.665	0.652	0.638	0.700
Sweden	0.964	0.963	0.961	0.959	0.957	0.955	0.953	0.951	0.948	0.946	0.943	0.955
Group 1 Ave	0.897	0.892	0.887	0.882	0.877	0.872	0.866	0.861	0.854	0.848	0.842	0.871
Group 2: Others												
Australia	0.960	0.959	0.957	0.955	0.952	0.950	0.948	0.945	0.943	0.940	0.937	0.950
Japan	0.411	0.394	0.376	0.359	0.341	0.324	0.306	0.289	0.272	0.255	0.238	0.324
South Korea	0.622	0.608	0.593	0.578	0.563	0.548	0.532	0.515	0.499	0.482	0.465	0.546
United Kingdom	0.608	0.593	0.578	0.563	0.547	0.532	0.515	0.499	0.482	0.465	0.448	0.530
United States	0.450	0.433	0.415	0.398	0.380	0.362	0.345	0.327	0.310	0.293	0.275	0.363
Group 2 Ave	0.610	0.597	0.584	0.571	0.557	0.543	0.529	0.515	0.501	0.487	0.473	0.542
All Ave.	0.794	0.787	0.779	0.771	0.763	0.754	0.746	0.737	0.728	0.719	0.710	0.753

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 2(f). Metafrontier Energy Efficiency for the Chemical and Petrochemical Industries

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.370	0.366	0.362	0.358	0.353	0.349	0.345	0.341	0.336	0.332	0.327	0.349
Czech Republic	0.239	0.234	0.230	0.225	0.221	0.216	0.211	0.206	0.202	0.197	0.192	0.216
Denmark	0.788	0.785	0.781	0.777	0.773	0.768	0.764	0.759	0.754	0.750	0.744	0.768
Finland	0.224	0.221	0.217	0.214	0.210	0.206	0.203	0.199	0.195	0.192	0.188	0.206
Germany	0.217	0.214	0.212	0.209	0.207	0.204	0.202	0.200	0.197	0.195	0.192	0.204
Italy	0.349	0.346	0.343	0.340	0.336	0.333	0.330	0.327	0.323	0.320	0.316	0.333
Netherlands	0.147	0.145	0.142	0.140	0.137	0.135	0.132	0.130	0.127	0.125	0.123	0.135
Portugal	0.291	0.285	0.279	0.273	0.267	0.261	0.255	0.249	0.242	0.236	0.230	0.261
Sweden	0.323	0.320	0.317	0.314	0.311	0.308	0.305	0.302	0.299	0.296	0.293	0.308
Group 1 Ave	0.328	0.324	0.320	0.317	0.313	0.309	0.305	0.301	0.297	0.294	0.289	0.309
Group 2: Others												
Australia	0.118	0.125	0.132	0.139	0.145	0.153	0.160	0.167	0.175	0.182	0.190	0.153
Japan	0.382	0.367	0.351	0.335	0.319	0.303	0.288	0.272	0.256	0.241	0.225	0.304
South Korea	0.228	0.229	0.230	0.229	0.229	0.228	0.227	0.225	0.222	0.220	0.216	0.226
United Kingdom	0.200	0.201	0.202	0.202	0.202	0.202	0.201	0.199	0.197	0.195	0.192	0.199
United States	0.067	0.067	0.068	0.068	0.068	0.068	0.068	0.067	0.066	0.065	0.064	0.067
Group 2 Ave	0.199	0.198	0.197	0.195	0.193	0.191	0.189	0.186	0.183	0.181	0.177	0.190
All. Ave.	0.285	0.282	0.279	0.276	0.273	0.270	0.266	0.263	0.259	0.256	0.252	0.269

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 3(a). Stochastic Energy Input Frontier Estimation of Group 1 in the Construction Industry

Variable	Estimated parameter	Standard error	t-value
Constant	-1.247	0.896	-1.391
ln(Value Added)	0.399**	0.182	2.190
ln(Labor)	-1.039***	0.233	-4.462
ln(Capital)	1.557***	0.208	7.478
ln(Intermediate Inputs)	-1.506***	0.243	-6.202
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	8.860**	3.930	2.255
$\gamma = \sigma_u^2 / \sigma^2$	0.991***	0.004	235.483
μ	-5.927***	1.828	-3.242
η	-0.137***	0.019	-7.210
Log-likelihood	-30.669		
Total obs.	99		

Note: ** represents 5% level of significance; *** represents 1% level of significance.

Table 3(b). Stochastic Energy Input Frontier Estimation of Group 2 in the Construction Industry

Variable	Estimated parameter	Standard error	t-value
Constant	-4.187***	0.957	-4.374
ln(Value Added)	2.035***	0.641	3.174
ln(Labor)	-1.679***	0.519	-3.237
ln(Capital)	0.090	0.167	0.533
ln(Intermediate Inputs)	-1.025***	0.389	-2.638
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	1.800	1.606	1.121
$\gamma = \sigma_u^2 / \sigma^2$	0.960***	0.040	24.253
μ	-2.629	2.140	-1.229
η	0.032**	0.016	2.022
Log-likelihood	-14.631		
Total obs.	55		

Note: ** represents 5% level of significance; *** represents 1% level of significance.

Table 3(c). Stochastic Input Frontier Estimation of Groups 1 and 2 in the Construction Industry

Variable	Estimated parameter	Standard error	t-value
Constant	1.956***	0.341	5.738
ln(Value Added)	-0.012	0.097	-0.127
ln(Labor)	-0.118	0.095	-1.244
ln(Capital)	-1.057***	0.158	-6.697
ln(Intermediate Inputs)	0.279**	0.119	2.343
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	1.445**	0.669	2.161
$\gamma = \sigma_u^2 / \sigma^2$	0.981***	0.009	104.686
μ	-2.382**	1.021	-2.332
η^M	-0.048***	0.011	-4.487
Log-likelihood	-40.549		
Total obs.	154		

Note: ** represents 5% level of significance; *** represents 1% level of significance.

Table 3(d). Group Energy Efficiency for the Construction Industry

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.317	0.267	0.220	0.176	0.136	0.102	0.073	0.049	0.032	0.019	0.011	0.127
Czech Republic	0.975	0.971	0.967	0.962	0.957	0.951	0.944	0.936	0.927	0.917	0.906	0.947
Denmark	0.744	0.712	0.678	0.640	0.599	0.556	0.510	0.462	0.413	0.363	0.313	0.545
Finland	0.794	0.767	0.738	0.706	0.671	0.633	0.592	0.548	0.502	0.454	0.404	0.619
Germany	0.859	0.840	0.819	0.795	0.769	0.740	0.708	0.673	0.636	0.595	0.552	0.726
Italy	0.894	0.879	0.863	0.844	0.824	0.801	0.775	0.747	0.716	0.683	0.646	0.788
Netherlands	0.966	0.962	0.956	0.950	0.943	0.935	0.926	0.916	0.904	0.891	0.877	0.930
Portugal	0.894	0.879	0.863	0.845	0.824	0.801	0.776	0.748	0.717	0.683	0.647	0.789
Sweden	0.828	0.805	0.780	0.752	0.721	0.687	0.651	0.611	0.569	0.524	0.477	0.673
Group 1 Ave	0.808	0.787	0.765	0.741	0.716	0.690	0.662	0.632	0.602	0.570	0.537	0.683
Group 2: Others												
Australia	0.348	0.360	0.371	0.383	0.395	0.406	0.418	0.430	0.441	0.452	0.464	0.406
Japan	0.165	0.175	0.184	0.194	0.205	0.215	0.226	0.236	0.247	0.258	0.269	0.216
South Korea	0.890	0.893	0.896	0.899	0.902	0.905	0.908	0.910	0.913	0.916	0.918	0.905
United Kingdom	0.881	0.885	0.888	0.891	0.894	0.897	0.900	0.903	0.906	0.909	0.912	0.897
United States	0.892	0.896	0.899	0.902	0.904	0.907	0.910	0.913	0.915	0.918	0.920	0.907
Group 2 Ave	0.635	0.642	0.648	0.654	0.660	0.666	0.672	0.678	0.684	0.691	0.697	0.666

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 3(e). Technological Gap Ratios for the Construction Industry

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.905	0.901	0.896	0.892	0.887	0.881	0.876	0.870	0.865	0.858	0.852	0.880
Czech Republic	0.803	0.795	0.786	0.777	0.767	0.757	0.747	0.737	0.726	0.714	0.703	0.756
Denmark	0.927	0.924	0.920	0.916	0.912	0.908	0.904	0.900	0.895	0.890	0.885	0.907
Finland	0.875	0.869	0.863	0.857	0.851	0.844	0.837	0.830	0.822	0.815	0.807	0.843
Germany	0.974	0.973	0.971	0.970	0.969	0.967	0.966	0.964	0.962	0.960	0.959	0.967
Italy	0.953	0.950	0.948	0.946	0.943	0.940	0.938	0.935	0.932	0.928	0.925	0.940
Netherlands	0.912	0.908	0.904	0.899	0.895	0.890	0.885	0.880	0.874	0.868	0.862	0.889
Portugal	0.757	0.747	0.736	0.725	0.714	0.702	0.690	0.678	0.665	0.652	0.638	0.700
Sweden	0.964	0.963	0.961	0.959	0.957	0.955	0.953	0.951	0.948	0.946	0.943	0.955
Group 1 Ave	0.897	0.892	0.887	0.882	0.877	0.872	0.866	0.861	0.854	0.848	0.842	0.871
Group 2: Others												
Australia	0.960	0.959	0.957	0.955	0.952	0.950	0.948	0.945	0.943	0.940	0.937	0.950
Japan	0.411	0.394	0.376	0.359	0.341	0.324	0.306	0.289	0.272	0.255	0.238	0.324
South Korea	0.622	0.608	0.593	0.578	0.563	0.548	0.532	0.515	0.499	0.482	0.465	0.546
United Kingdom	0.608	0.593	0.578	0.563	0.547	0.532	0.515	0.499	0.482	0.465	0.448	0.530
United States	0.450	0.433	0.415	0.398	0.380	0.362	0.345	0.327	0.310	0.293	0.275	0.363
Group 2 Ave	0.610	0.597	0.584	0.571	0.557	0.543	0.529	0.515	0.501	0.487	0.473	0.542
All Ave.	0.794	0.787	0.779	0.771	0.763	0.754	0.746	0.737	0.728	0.719	0.710	0.753

Table 3(f). Metafrontier Energy Efficiency for the Construction Industry

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.287	0.241	0.197	0.157	0.121	0.090	0.064	0.043	0.027	0.016	0.009	0.114
Czech Republic	0.783	0.772	0.760	0.747	0.734	0.720	0.705	0.689	0.673	0.655	0.636	0.716
Denmark	0.690	0.658	0.623	0.586	0.547	0.505	0.461	0.416	0.370	0.323	0.277	0.496
Finland	0.695	0.667	0.637	0.605	0.571	0.534	0.495	0.455	0.413	0.370	0.326	0.524
Germany	0.837	0.817	0.795	0.771	0.745	0.716	0.684	0.649	0.612	0.572	0.529	0.702
Italy	0.851	0.836	0.818	0.798	0.777	0.753	0.727	0.698	0.667	0.634	0.598	0.742
Netherlands	0.882	0.873	0.864	0.854	0.844	0.832	0.819	0.805	0.790	0.774	0.756	0.827
Portugal	0.677	0.657	0.635	0.613	0.588	0.563	0.535	0.507	0.477	0.445	0.413	0.555
Sweden	0.798	0.775	0.749	0.721	0.690	0.656	0.620	0.581	0.539	0.495	0.450	0.643
Group 1 Ave	0.722	0.700	0.675	0.650	0.624	0.597	0.568	0.538	0.508	0.476	0.444	0.591
Group 2: Others												
Australia	0.334	0.345	0.355	0.366	0.376	0.386	0.396	0.406	0.416	0.425	0.435	0.385
Japan	0.068	0.069	0.069	0.070	0.070	0.070	0.069	0.068	0.067	0.066	0.064	0.068
South Korea	0.554	0.543	0.532	0.520	0.508	0.495	0.482	0.469	0.455	0.441	0.427	0.493
United Kingdom	0.536	0.525	0.514	0.502	0.490	0.477	0.464	0.451	0.437	0.423	0.408	0.475
United States	0.402	0.387	0.373	0.359	0.344	0.329	0.314	0.299	0.284	0.268	0.253	0.328
Group 2 Ave	0.379	0.374	0.369	0.363	0.358	0.351	0.345	0.339	0.332	0.325	0.317	0.350
All Ave.	0.600	0.583	0.566	0.548	0.529	0.509	0.488	0.467	0.445	0.422	0.399	0.505

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 4(a). Stochastic Energy Input Frontier Estimation of Group 1 in the Food and Tobacco Industries

Variable	Estimated parameter	Standard error	t-value
Constant	1.722***	0.350	4.928
ln(Value Added)	-0.066	0.107	-0.616
ln(Labor)	-0.077	0.084	-0.915
ln(Capital)	-0.044	0.156	-0.280
ln(Intermediate Inputs)	-0.736***	0.139	-5.280
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.053	0.116	0.456
$\gamma = \sigma_u^2 / \sigma^2$	0.635	0.803	0.791
μ	-0.229	1.367	-0.167
η	0.009	0.050	0.181
Log-likelihood	48.419629		
Total obs.	99		

Note: *** represents 1% level of significance.

Table 4(b). Stochastic Energy Input Frontier Estimation of Group 2 in the Food and Tobacco Industries

Variable	Estimated parameter	Standard error	t-value
Constant	4.701***	0.943	4.988
ln(Value Added)	0.244	0.340	0.718
ln(Labor)	0.741***	0.149	4.987
ln(Capital)	-0.664	0.446	-1.488
ln(Intermediate Inputs)	-1.266***	0.152	-8.329
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.038***	0.010	3.781
$\gamma = \sigma_u^2 / \sigma^2$	0.128	0.218	0.590
μ	0.044	0.099	0.449
η	0.165***	0.058	2.848
Log-likelihood	9.865		
Total obs.	55		

Note: ** represents 1% level of significance.

Table 4(c). Stochastic Input Frontier Estimation of Groups 1 and 2 in the food and Tobacco Industries

Variable	Estimated parameter	Standard error	t-value
Constant	2.057***	0.302	6.808
ln(Value Added)	0.005	0.097	0.050
ln(Labor)	-0.008	0.041	-0.196
ln(Capital)	-0.049	0.148	-0.331
ln(Intermediate Inputs)	-0.861***	0.112	-7.698
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.513**	0.235	2.186
$\gamma = \sigma_u^2 / \sigma^2$	0.953***	0.024	40.480
μ	-1.398***	0.498	-2.806
η^M	-0.037	0.011	-3.298
Log-likelihood	50.384		
Total obs.	154		

Note: ** represents 5% level of significance; *** represents 1% level of significance.

Table 4(d). Group energy Efficiency for the Food and Tobacco Industries

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.950	0.950	0.950	0.951	0.951	0.952	0.952	0.952	0.953	0.953	0.954	0.952
Czech Republic	0.789	0.790	0.792	0.794	0.795	0.797	0.798	0.800	0.802	0.803	0.805	0.797
Denmark	0.824	0.825	0.827	0.828	0.829	0.831	0.832	0.834	0.835	0.836	0.838	0.831
Finland	0.963	0.964	0.964	0.964	0.965	0.965	0.965	0.966	0.966	0.966	0.967	0.965
Germany	0.964	0.965	0.965	0.965	0.965	0.966	0.966	0.966	0.967	0.967	0.967	0.966
Italy	0.947	0.947	0.948	0.948	0.949	0.949	0.950	0.950	0.950	0.951	0.951	0.949
Netherlands	0.847	0.849	0.850	0.851	0.852	0.854	0.855	0.856	0.857	0.858	0.860	0.854
Portugal	0.970	0.970	0.970	0.970	0.971	0.971	0.971	0.971	0.972	0.972	0.972	0.971
Sweden	0.949	0.950	0.950	0.950	0.951	0.951	0.952	0.952	0.953	0.953	0.953	0.951
Group 1 Ave	0.911	0.912	0.913	0.913	0.914	0.915	0.916	0.916	0.917	0.918	0.919	0.915
Group 2: Others												
Australia	0.615	0.662	0.704	0.743	0.777	0.807	0.834	0.857	0.878	0.895	0.910	0.789
Japan	0.490	0.546	0.599	0.647	0.691	0.731	0.767	0.798	0.826	0.851	0.872	0.711
South Korea	0.570	0.621	0.667	0.709	0.747	0.781	0.811	0.837	0.860	0.880	0.897	0.762
United Kingdom	0.911	0.924	0.935	0.944	0.953	0.960	0.966	0.971	0.975	0.979	0.982	0.955
United States	0.902	0.916	0.928	0.938	0.947	0.955	0.962	0.967	0.972	0.976	0.980	0.949
Group 2 Ave	0.698	0.734	0.767	0.796	0.823	0.847	0.868	0.886	0.902	0.916	0.928	0.833

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 4(e). Technological Gap Ratios for the Food and Tobacco Industries

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.892	0.889	0.885	0.881	0.877	0.872	0.868	0.863	0.859	0.854	0.849	0.872
Czech Republic	0.886	0.882	0.877	0.873	0.869	0.864	0.860	0.855	0.850	0.845	0.839	0.864
Denmark	0.959	0.958	0.956	0.954	0.953	0.951	0.949	0.948	0.946	0.944	0.942	0.951
Finland	0.968	0.966	0.965	0.964	0.963	0.961	0.960	0.958	0.957	0.955	0.954	0.961
Germany	0.938	0.936	0.934	0.932	0.929	0.927	0.924	0.921	0.919	0.916	0.913	0.926
Italy	0.937	0.935	0.933	0.930	0.928	0.925	0.923	0.920	0.917	0.914	0.911	0.925
Netherlands	0.959	0.958	0.956	0.955	0.953	0.951	0.950	0.948	0.946	0.944	0.942	0.951
Portugal	0.951	0.949	0.947	0.946	0.944	0.942	0.939	0.937	0.935	0.933	0.930	0.941
Sweden	0.946	0.944	0.942	0.940	0.938	0.936	0.934	0.931	0.929	0.926	0.924	0.935
Group 1 Ave	0.937	0.935	0.933	0.931	0.928	0.925	0.923	0.920	0.918	0.915	0.912	0.925
Group 2: Others												
Australia	0.541	0.529	0.517	0.504	0.491	0.478	0.465	0.452	0.439	0.426	0.412	0.478
Japan	0.967	0.966	0.964	0.963	0.962	0.960	0.959	0.957	0.956	0.954	0.953	0.960
South Korea	0.949	0.947	0.945	0.943	0.941	0.939	0.937	0.934	0.932	0.930	0.927	0.939
United Kingdom	0.673	0.663	0.653	0.642	0.632	0.621	0.610	0.599	0.587	0.576	0.564	0.620
United States	0.537	0.525	0.512	0.500	0.487	0.474	0.461	0.448	0.435	0.421	0.408	0.473
Group 2 Ave	0.733	0.726	0.718	0.710	0.703	0.694	0.686	0.678	0.670	0.661	0.653	0.694
All Ave.	0.865	0.861	0.856	0.852	0.848	0.843	0.839	0.834	0.829	0.824	0.819	0.843

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 4(f). Metafrontier Energy Efficiency for the Food and Tobacco Industries

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.847	0.844	0.841	0.837	0.834	0.830	0.826	0.822	0.818	0.814	0.809	0.829
Czech Republic	0.698	0.697	0.695	0.693	0.691	0.689	0.686	0.684	0.681	0.678	0.675	0.688
Denmark	0.790	0.790	0.790	0.790	0.790	0.790	0.790	0.790	0.790	0.789	0.789	0.790
Finland	0.932	0.931	0.931	0.930	0.929	0.928	0.927	0.926	0.924	0.923	0.922	0.928
Germany	0.905	0.903	0.901	0.899	0.897	0.895	0.893	0.890	0.888	0.885	0.883	0.894
Italy	0.888	0.886	0.884	0.882	0.880	0.878	0.876	0.874	0.872	0.869	0.867	0.878
Netherlands	0.813	0.813	0.813	0.813	0.812	0.812	0.812	0.811	0.811	0.810	0.810	0.812
Portugal	0.922	0.921	0.919	0.917	0.916	0.914	0.912	0.910	0.908	0.906	0.904	0.914
Sweden	0.898	0.897	0.895	0.894	0.892	0.890	0.889	0.887	0.885	0.883	0.881	0.890
Group 1 Ave	0.855	0.854	0.852	0.851	0.849	0.847	0.846	0.844	0.842	0.840	0.838	0.847
Group 2: Others												
Australia	0.333	0.350	0.364	0.374	0.382	0.386	0.388	0.388	0.385	0.381	0.375	0.373
Japan	0.474	0.527	0.577	0.623	0.665	0.702	0.735	0.764	0.790	0.812	0.831	0.682
South Korea	0.541	0.588	0.631	0.669	0.703	0.733	0.760	0.782	0.802	0.818	0.832	0.714
United Kingdom	0.613	0.612	0.610	0.607	0.602	0.596	0.589	0.581	0.573	0.564	0.554	0.591
United States	0.484	0.481	0.476	0.469	0.461	0.453	0.443	0.433	0.423	0.411	0.400	0.449
Group 2 Ave	0.489	0.512	0.532	0.548	0.563	0.574	0.583	0.590	0.595	0.597	0.598	0.562
Ave.	0.724	0.731	0.738	0.743	0.747	0.750	0.752	0.753	0.754	0.753	0.752	0.745

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 5(a). Stochastic Energy Input Frontier Estimation of Group 1 in the Machinery Industry

Variable	Estimated parameter	Standard error	t-value
Constant	1.621	1.134	1.430
ln(Value Added)	0.342***	0.119	2.884
ln(Labor)	-0.132	0.392	-0.338
ln(Capital)	-0.888***	0.306	-2.897
ln(Intermediate Inputs)	-0.0975	0.220	-0.443
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.226**	0.088	2.574
$\gamma = \sigma_u^2 / \sigma^2$	0.786***	0.067	11.684
μ	0.842**	0.328	2.570
η	0.006	0.016	0.391
Log-likelihood	-7.433		
Total obs.	99		

Note: * represents 10% level of significance; ** represents 5% level of significance; *** represents 1% level of significance.

Table 5(b). Stochastic Energy Input Frontier Estimation of Group 2 in the Machinery Industry

Variable	Estimated parameter	Standard error	t-value
Constant	1.187***	0.440	2.695
***ln(Value Added)	-0.178	0.168	-1.063
ln(Labor)	-0.310	0.224	-1.386
ln(Capital)	-0.265	0.184	-1.438
ln(Intermediate Inputs)	-0.127	0.150	-0.850
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.565	1.794	0.315
$\gamma = \sigma_u^2 / \sigma^2$	0.952***	0.153	6.207
μ	-0.754	4.678	-0.161
η	0.022	0.024	0.937
Log-likelihood	11.864		
Total obs.	55		

Note: *** represents 1% level of significance.

Table 5(c). Stochastic Input Frontier Estimation of Groups 1 and 2 in the Machinery Industry

Variable	Estimated parameter	Standard error	t-value
Constant	1.590	0.424	3.749***
ln(Value Added)	0.228	0.092	2.473**
ln(Labor)	-0.387	0.153	-2.532**
ln(Capital)	-0.597	0.185	-3.225***
ln(Intermediate Inputs)	-0.084	0.113	-0.755
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	2.914	1.452	2.006**
$\gamma = \sigma_u^2 / \sigma^2$	0.986	0.008	130.605***
μ	-3.389	1.031	-3.287***
η^M	-0.025	0.008	-3.305***
Log-likelihood	-0.306		
Total obs.	154		

Note: ** represents 5% level of significance; *** represents 1% level of significance.

Table 5(d). Group Energy Efficiency for the Machinery Industry

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.509	0.511	0.514	0.516	0.518	0.520	0.522	0.524	0.526	0.528	0.530	0.520
Czech Republic	0.332	0.334	0.337	0.339	0.341	0.344	0.346	0.348	0.350	0.353	0.355	0.344
Denmark	0.334	0.336	0.339	0.341	0.343	0.345	0.348	0.350	0.352	0.355	0.357	0.345
Finland	0.339	0.342	0.344	0.346	0.349	0.351	0.353	0.355	0.358	0.360	0.362	0.351
Germany	0.291	0.293	0.295	0.298	0.300	0.302	0.304	0.307	0.309	0.311	0.313	0.302
Italy	0.438	0.440	0.442	0.444	0.447	0.449	0.451	0.453	0.456	0.458	0.460	0.449
Netherlands	0.222	0.224	0.226	0.228	0.230	0.233	0.235	0.237	0.239	0.241	0.243	0.233
Portugal	0.905	0.905	0.906	0.907	0.907	0.908	0.908	0.909	0.909	0.910	0.910	0.908
Sweden	0.446	0.448	0.451	0.453	0.455	0.457	0.460	0.462	0.464	0.466	0.469	0.457
Group 1 Ave	0.424	0.426	0.428	0.430	0.432	0.434	0.436	0.438	0.440	0.442	0.444	0.434
Group 2: Others												
Australia	0.930	0.932	0.933	0.934	0.936	0.937	0.938	0.940	0.941	0.942	0.943	0.937
Japan	0.931	0.932	0.934	0.935	0.937	0.938	0.939	0.940	0.942	0.943	0.944	0.938
South Korea	0.675	0.681	0.686	0.692	0.698	0.703	0.709	0.714	0.719	0.725	0.730	0.703
United Kingdom	0.490	0.498	0.506	0.513	0.521	0.528	0.536	0.543	0.550	0.558	0.565	0.528
United States	0.325	0.334	0.342	0.350	0.358	0.366	0.374	0.383	0.391	0.399	0.407	0.366
Group 2 Ave	0.670	0.675	0.680	0.685	0.690	0.694	0.699	0.704	0.709	0.713	0.718	0.694

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 5(e). Technological Gap Ratios for the Machinery Industry

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.862	0.859	0.856	0.852	0.849	0.845	0.842	0.838	0.834	0.830	0.826	0.845
Czech Republic	0.946	0.945	0.944	0.942	0.941	0.939	0.938	0.936	0.935	0.933	0.932	0.939
Denmark	0.820	0.816	0.812	0.808	0.803	0.799	0.794	0.790	0.785	0.780	0.775	0.798
Finland	0.917	0.915	0.913	0.911	0.909	0.907	0.905	0.902	0.900	0.898	0.895	0.907
Germany	0.947	0.945	0.944	0.943	0.941	0.940	0.938	0.937	0.935	0.934	0.932	0.940
Italy	0.725	0.719	0.713	0.707	0.701	0.695	0.688	0.682	0.675	0.668	0.661	0.694
Netherlands	0.826	0.822	0.817	0.813	0.809	0.805	0.800	0.796	0.791	0.786	0.782	0.804
Portugal	0.904	0.902	0.900	0.897	0.895	0.892	0.890	0.887	0.884	0.882	0.879	0.892
Sweden	0.906	0.903	0.901	0.899	0.896	0.894	0.891	0.889	0.886	0.883	0.880	0.893
Group 1 Ave	0.873	0.870	0.867	0.864	0.860	0.857	0.854	0.851	0.847	0.844	0.840	0.857
Group 2: Others												
Australia	0.422	0.413	0.404	0.394	0.385	0.376	0.366	0.357	0.348	0.339	0.329	0.376
Japan	0.373	0.364	0.354	0.345	0.336	0.326	0.317	0.308	0.299	0.290	0.281	0.327
South Korea	0.306	0.297	0.288	0.279	0.270	0.261	0.252	0.243	0.234	0.226	0.217	0.261
United Kingdom	0.332	0.323	0.313	0.304	0.295	0.286	0.277	0.268	0.259	0.250	0.241	0.286
United States	0.262	0.253	0.244	0.235	0.227	0.218	0.210	0.202	0.194	0.186	0.178	0.219
Group 2 Ave	0.339	0.330	0.321	0.311	0.303	0.293	0.284	0.276	0.267	0.258	0.249	0.294
All Ave.	0.682	0.677	0.672	0.666	0.661	0.656	0.651	0.645	0.640	0.635	0.629	0.656

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 5(f). Metafrontier Energy Efficiency for the Machinery Industry

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.439	0.439	0.439	0.439	0.439	0.439	0.439	0.439	0.439	0.439	0.438	0.439
Czech Republic	0.314	0.316	0.318	0.319	0.321	0.323	0.324	0.326	0.328	0.329	0.331	0.323
Denmark	0.274	0.275	0.275	0.275	0.276	0.276	0.276	0.276	0.277	0.277	0.277	0.276
Finland	0.311	0.313	0.314	0.315	0.317	0.318	0.319	0.321	0.322	0.323	0.324	0.318
Germany	0.275	0.277	0.279	0.280	0.282	0.284	0.285	0.287	0.289	0.290	0.292	0.284
Italy	0.317	0.316	0.315	0.314	0.313	0.312	0.310	0.309	0.308	0.306	0.304	0.311
Netherlands	0.183	0.184	0.185	0.186	0.186	0.187	0.188	0.188	0.189	0.190	0.190	0.187
Portugal	0.818	0.817	0.815	0.813	0.812	0.810	0.808	0.806	0.804	0.802	0.800	0.810
Sweden	0.404	0.405	0.406	0.407	0.408	0.409	0.410	0.410	0.411	0.412	0.412	0.409
Group 1 Ave.	0.371	0.371	0.372	0.372	0.373	0.373	0.373	0.374	0.374	0.374	0.374	0.373
Group 2: Others												
Australia	0.393	0.385	0.377	0.369	0.360	0.352	0.344	0.336	0.327	0.319	0.311	0.352
Japan	0.347	0.339	0.331	0.323	0.314	0.306	0.298	0.290	0.281	0.273	0.265	0.306
South Korea	0.207	0.202	0.198	0.193	0.188	0.183	0.179	0.174	0.169	0.164	0.159	0.183
United Kingdom	0.163	0.161	0.158	0.156	0.154	0.151	0.148	0.145	0.143	0.139	0.136	0.150
United States	0.085	0.084	0.083	0.082	0.081	0.080	0.079	0.077	0.076	0.074	0.072	0.079
Group 2 Ave.	0.239	0.234	0.229	0.225	0.219	0.214	0.210	0.204	0.199	0.194	0.189	0.214
Ave.	0.324	0.322	0.321	0.319	0.318	0.316	0.315	0.313	0.312	0.310	0.308	0.316

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 6(a). Stochastic energy input frontier estimation of Group 1 in the iron, steel, and non-ferrous metals industries

Variable	Estimated parameter	Standard error	t-value
Constant	0.399	0.337	1.187
ln(Value Added)	0.169	0.109	1.550
ln(Labor)	-0.762***	0.124	-6.125
ln(Capital)	-0.557***	0.170	-3.281
ln(Intermediate Inputs)	-0.079	0.154	-0.512
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	1.347	0.940	1.433
$\gamma = \sigma_u^2/\sigma^2$	0.986***	0.011	93.458
μ	-2.305	1.561	-1.476
η	0.032***	0.009	3.585
Log-likelihood	35.782		
Total obs.	99		

Note: *** represents 1% level of significance.

Table 6(b). Stochastic Energy Input Frontier Estimation of Group 2 in the Iron, Steel, and Non-ferrous Metals Industry

Variable	Estimated parameter	Standard error	t-value
Constant	-1.80482	2.67644	-0.67434
ln(Value Added)	-0.42733	0.32520	-1.31405
ln(Labor)	-0.93137	0.17694	-5.26391***
ln(Capital)	0.40302	0.36289	1.11061
ln(Intermediate Inputs)	-0.12484	0.50788	-0.24581
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.72625	1.42171	0.51083
$\gamma = \sigma_u^2/\sigma^2$	0.96319	0.07245	13.29448***
μ	-0.02269	2.01911	-0.01124
η	0.01545	0.00902	1.71310*
Log-likelihood	10.247565		
Total obs.	55		

Note: * represents 10% level of significance; ** represents 5% level of significance; *** represents 1% level of significance.

Table 6(c). Stochastic Input Frontier Estimation of Groups 1 and 2 in the Iron, Steel, and Non-ferrous Metals Industries

Variable	Estimated parameter	Standard error	t-value
Constant	-1.80482	2.67644	-0.67434
ln(Value Added)	-0.42733	0.32520	-1.31405
ln(Labor)	-0.93137	0.17694	-5.26391***
ln(Capital)	0.40302	0.36289	1.11061
ln(Intermediate Inputs)	-0.12484	0.50788	-0.24581
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.72625	1.42171	0.51083
$\gamma = \sigma_u^2/\sigma^2$	0.96319	0.07245	13.29448***
μ	-0.02269	2.01911	-0.01124
η^M	0.01545	0.00902	1.71310*
Log-likelihood	52.385274		
Total obs.	154		

Note: * represents 10% level of significance; ** represents 5% level of significance; *** represents 1% level of significance.

Table 6(d). Group Energy Efficiency for the Iron, Steel, and Non-ferrous Metals Industries

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.464	0.475	0.486	0.497	0.508	0.519	0.529	0.540	0.550	0.560	0.571	0.518
Czech Republic	0.770	0.776	0.782	0.788	0.794	0.800	0.805	0.811	0.816	0.821	0.826	0.799
Denmark	0.932	0.934	0.936	0.938	0.940	0.942	0.943	0.945	0.947	0.948	0.950	0.941
Finland	0.259	0.270	0.281	0.293	0.304	0.315	0.327	0.338	0.350	0.362	0.373	0.316
Germany	0.757	0.764	0.770	0.777	0.783	0.789	0.794	0.800	0.806	0.811	0.816	0.788
Italy	0.918	0.920	0.923	0.925	0.927	0.929	0.931	0.933	0.935	0.937	0.939	0.929
Netherlands	0.194	0.204	0.214	0.225	0.236	0.246	0.257	0.268	0.280	0.291	0.302	0.247
Portugal	0.928	0.930	0.932	0.934	0.936	0.938	0.940	0.942	0.943	0.945	0.947	0.938
Sweden	0.486	0.497	0.508	0.519	0.530	0.540	0.550	0.561	0.571	0.581	0.591	0.539
Group 1 Ave	0.634	0.641	0.648	0.655	0.662	0.669	0.675	0.682	0.689	0.695	0.702	0.668
Group 2: Others												
Australia	0.178	0.183	0.188	0.193	0.198	0.203	0.208	0.213	0.218	0.223	0.228	0.203
Japan	0.332	0.338	0.344	0.349	0.355	0.361	0.366	0.372	0.378	0.383	0.389	0.361
South Korea	0.930	0.931	0.932	0.933	0.934	0.935	0.936	0.937	0.938	0.939	0.940	0.935
United Kingdom	0.646	0.651	0.655	0.659	0.663	0.668	0.672	0.676	0.680	0.684	0.688	0.667
United States	0.604	0.609	0.613	0.618	0.623	0.627	0.632	0.636	0.640	0.645	0.649	0.627
Group 2 Ave	0.602	0.608	0.614	0.620	0.626	0.632	0.638	0.644	0.649	0.655	0.661	0.632

Table 6(e). Technological Gap Ratios for the Iron, Steel, and Non-ferrous Metals Industries

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.656	0.654	0.653	0.652	0.650	0.649	0.648	0.646	0.645	0.644	0.642	0.649
Czech Republic	0.599	0.597	0.596	0.594	0.593	0.591	0.590	0.588	0.587	0.585	0.584	0.591
Denmark	0.876	0.876	0.875	0.875	0.874	0.874	0.873	0.872	0.872	0.871	0.871	0.874
Finland	0.684	0.683	0.682	0.681	0.679	0.678	0.677	0.676	0.674	0.673	0.672	0.678
Germany	0.557	0.555	0.553	0.552	0.550	0.549	0.547	0.546	0.544	0.542	0.541	0.549
Italy	0.462	0.460	0.458	0.457	0.455	0.453	0.451	0.450	0.448	0.446	0.445	0.453
Netherlands	0.722	0.721	0.720	0.718	0.717	0.716	0.715	0.714	0.713	0.712	0.710	0.716
Portugal	0.933	0.933	0.932	0.932	0.932	0.931	0.931	0.931	0.931	0.930	0.930	0.931
Sweden	0.686	0.685	0.684	0.682	0.681	0.680	0.678	0.677	0.676	0.675	0.673	0.680
Group 1 Ave.	0.686	0.685	0.684	0.683	0.681	0.680	0.679	0.678	0.677	0.675	0.674	0.680
Group 2: Others												
Australia	0.720	0.719	0.718	0.717	0.716	0.715	0.713	0.712	0.711	0.710	0.709	0.715
Japan	0.947	0.946	0.946	0.946	0.946	0.945	0.945	0.945	0.945	0.944	0.944	0.945
South Korea	0.836	0.835	0.834	0.833	0.833	0.832	0.831	0.831	0.830	0.829	0.828	0.832
United Kingdom	0.663	0.662	0.660	0.659	0.658	0.656	0.655	0.654	0.652	0.651	0.650	0.656
United States	0.674	0.673	0.672	0.670	0.669	0.668	0.666	0.665	0.664	0.662	0.661	0.668
Group 2 Ave.	0.768	0.767	0.766	0.765	0.764	0.763	0.762	0.761	0.760	0.759	0.758	0.763
All Ave.	0.715	0.714	0.713	0.712	0.711	0.710	0.709	0.708	0.707	0.705	0.704	0.710

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 6(f). Metafrontier Energy Efficiency for the Iron, Steel, and Non-ferrous Metals Industries

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.304	0.311	0.317	0.324	0.330	0.337	0.343	0.349	0.355	0.361	0.366	0.336
Czech Republic	0.461	0.464	0.466	0.468	0.471	0.473	0.475	0.477	0.479	0.481	0.482	0.472
Denmark	0.817	0.818	0.819	0.821	0.822	0.823	0.824	0.825	0.825	0.826	0.827	0.822
Finland	0.177	0.184	0.192	0.199	0.206	0.214	0.221	0.229	0.236	0.243	0.251	0.214
Germany	0.422	0.424	0.426	0.429	0.431	0.433	0.435	0.437	0.438	0.440	0.441	0.432
Italy	0.424	0.423	0.423	0.422	0.422	0.421	0.420	0.420	0.419	0.418	0.418	0.421
Netherlands	0.140	0.147	0.154	0.162	0.169	0.176	0.184	0.192	0.199	0.207	0.215	0.177
Portugal	0.866	0.867	0.869	0.871	0.872	0.874	0.875	0.876	0.878	0.879	0.880	0.873
Sweden	0.334	0.340	0.347	0.354	0.361	0.367	0.373	0.380	0.386	0.392	0.398	0.367
Group 1 Ave.	0.438	0.442	0.446	0.450	0.454	0.458	0.461	0.465	0.468	0.472	0.475	0.457
Group 2: Others												
Australia	0.128	0.132	0.135	0.138	0.141	0.145	0.148	0.152	0.155	0.158	0.162	0.145
Japan	0.315	0.320	0.325	0.330	0.336	0.341	0.346	0.351	0.357	0.362	0.367	0.341
South Korea	0.777	0.777	0.777	0.778	0.778	0.778	0.778	0.778	0.778	0.778	0.778	0.778
United Kingdom	0.428	0.430	0.432	0.434	0.436	0.438	0.440	0.442	0.443	0.445	0.447	0.438
United States	0.407	0.410	0.412	0.414	0.416	0.419	0.421	0.423	0.425	0.427	0.429	0.418
Group 2 Ave.	0.411	0.414	0.416	0.419	0.421	0.424	0.427	0.429	0.432	0.434	0.437	0.424
All Ave.	0.429	0.432	0.435	0.439	0.442	0.446	0.449	0.452	0.455	0.458	0.462	0.445

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 7(a). Stochastic Energy Input Frontier Estimation of Group 1 in the Non-metallic Minerals Industry

Variable	Estimated parameter	Standard error	t-value
Constant	1.146	0.793	1.445
ln(Value Added)	-0.404*	0.229	-1.762
ln(Labor)	0.321	0.205	1.564
ln(Capital)	-1.272***	0.184	-6.923
ln(Intermediate Inputs)	0.599***	0.154	3.891
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.098*	0.053	1.853
$\gamma = \sigma_u^2 / \sigma^2$	0.866***	0.066	13.143
μ	0.583***	0.204	2.851
η	0.014	0.009	1.655
Log-likelihood	54.308		
Total obs.	99		

Note: * represents 10% level of significance; *** represents 1% level of significance.

Table 7(b). Stochastic Energy Input Frontier Estimation of Group 2 in the Non-metallic Minerals Industry

Variable	Estimated parameter	Standard error	t-value
Constant	2.200**	1.022	2.153
ln(Value Added)	-0.871**	0.366	-2.379
ln(Labor)	-0.126	0.168	-0.750
ln(Capital)	-0.214	0.247	-0.863
ln(Intermediate Inputs)	0.084	0.343	0.244
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.094**	0.046	2.057
$\gamma = \sigma_u^2 / \sigma^2$	0.921***	0.024	37.928
μ	0.589	0.409	1.441
η	0.013	0.017	0.773
Log-likelihood	46.484		
Total obs.	55		

Note: ** represents 5% level of significance; *** represents 1% level of significance.

Table 7(c). Stochastic Input Frontier Estimation of Groups 1 and 2 in the Non-metallic Minerals Industry

Variable	Estimated parameter	Standard error	t-value
Constant	0.744**	0.230	2.483
ln(Value Added)	-0.279**	0.132	-2.104
ln(Labor)	-0.091	0.090	-1.015
ln(Capital)	-0.677***	0.107	-6.339
ln(Intermediate Inputs)	0.154	0.116	1.329
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.341	0.287	1.187
$\gamma = \sigma_u^2 / \sigma^2$	0.959***	0.036	26.621
μ	-1.144	1.004	-1.139
η^M	0.006	0.014	0.455
Log-likelihood	40.682		
Total obs.	154		

Note: ** represents 5% level of significance; *** represents 1% level of significance.

Table 7(d). Group Energy Efficiency for the Non-metallic Minerals Industry

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.917	0.919	0.920	0.921	0.922	0.923	0.924	0.925	0.926	0.927	0.928	0.923
Czech Republic	0.768	0.770	0.773	0.776	0.779	0.782	0.784	0.787	0.790	0.792	0.795	0.781
Denmark	0.423	0.428	0.433	0.438	0.443	0.448	0.454	0.459	0.464	0.469	0.474	0.448
Finland	0.504	0.509	0.513	0.518	0.523	0.528	0.533	0.537	0.542	0.547	0.551	0.528
Germany	0.390	0.396	0.401	0.406	0.411	0.416	0.421	0.427	0.432	0.437	0.442	0.416
Italy	0.450	0.455	0.460	0.465	0.470	0.475	0.480	0.485	0.490	0.495	0.500	0.475
Netherlands	0.520	0.524	0.529	0.534	0.539	0.543	0.548	0.553	0.557	0.562	0.567	0.543
Portugal	0.319	0.324	0.329	0.334	0.339	0.345	0.350	0.355	0.360	0.365	0.371	0.345
Sweden	0.431	0.437	0.442	0.447	0.452	0.457	0.462	0.467	0.472	0.477	0.482	0.457
Group 1 Ave.	0.525	0.529	0.533	0.538	0.542	0.546	0.551	0.555	0.559	0.563	0.568	0.546
Group 2: Others												
Australia	0.228	0.232	0.237	0.241	0.246	0.251	0.255	0.260	0.265	0.270	0.274	0.251
Japan	0.470	0.474	0.479	0.484	0.489	0.493	0.498	0.503	0.507	0.512	0.517	0.493
South Korea	0.320	0.325	0.330	0.335	0.340	0.345	0.350	0.355	0.360	0.365	0.370	0.345
United Kingdom	0.588	0.593	0.597	0.601	0.605	0.609	0.613	0.617	0.621	0.625	0.629	0.609
United States	0.360	0.365	0.370	0.375	0.380	0.385	0.390	0.395	0.399	0.404	0.409	0.385
Group 2 Ave.	0.393	0.398	0.403	0.407	0.412	0.417	0.421	0.426	0.430	0.435	0.440	0.417

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 7(e). Technological Gap Ratios for the Non-metallic Minerals Industry

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.728	0.730	0.731	0.733	0.734	0.735	0.737	0.738	0.740	0.741	0.742	0.735
Czech Republic	0.881	0.881	0.882	0.883	0.883	0.884	0.885	0.885	0.886	0.887	0.887	0.884
Denmark	0.728	0.730	0.731	0.733	0.734	0.736	0.737	0.738	0.740	0.741	0.743	0.736
Finland	0.803	0.804	0.805	0.806	0.807	0.808	0.809	0.810	0.811	0.813	0.814	0.808
Germany	0.962	0.962	0.962	0.963	0.963	0.963	0.963	0.963	0.964	0.964	0.964	0.963
Italy	0.919	0.920	0.920	0.921	0.921	0.921	0.922	0.922	0.923	0.923	0.924	0.921
Netherlands	0.958	0.958	0.958	0.958	0.959	0.959	0.959	0.959	0.960	0.960	0.960	0.959
Portugal	0.942	0.942	0.943	0.943	0.943	0.944	0.944	0.944	0.945	0.945	0.945	0.944
Sweden	0.819	0.821	0.822	0.823	0.824	0.825	0.826	0.827	0.828	0.828	0.829	0.825
Group 1 Ave.	0.860	0.861	0.862	0.863	0.863	0.864	0.865	0.865	0.866	0.867	0.868	0.864
Group 2: Others												
Australia	0.974	0.974	0.974	0.975	0.975	0.975	0.975	0.975	0.975	0.976	0.976	0.975
Japan	0.670	0.671	0.673	0.675	0.676	0.678	0.680	0.681	0.683	0.684	0.686	0.678
South Korea	0.935	0.935	0.935	0.936	0.936	0.937	0.937	0.937	0.938	0.938	0.938	0.937
United Kingdom	0.658	0.660	0.662	0.663	0.665	0.667	0.668	0.670	0.672	0.673	0.675	0.667
United States	0.444	0.447	0.449	0.451	0.453	0.456	0.458	0.460	0.462	0.465	0.467	0.456
Group 2 Ave	0.736	0.737	0.739	0.740	0.741	0.743	0.744	0.745	0.746	0.747	0.748	0.742
All Ave.	0.816	0.817	0.818	0.819	0.820	0.821	0.821	0.822	0.823	0.824	0.825	0.820

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 7(f). Metafrontier Energy Efficiency for the Non-metallic Minerals Industry

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.668	0.670	0.672	0.674	0.677	0.679	0.681	0.683	0.685	0.687	0.689	0.679
Czech Republic	0.676	0.679	0.682	0.685	0.688	0.691	0.694	0.697	0.700	0.703	0.705	0.691
Denmark	0.308	0.312	0.317	0.321	0.325	0.330	0.334	0.339	0.343	0.347	0.352	0.330
Finland	0.404	0.409	0.413	0.418	0.422	0.427	0.431	0.436	0.440	0.444	0.449	0.427
Germany	0.375	0.381	0.386	0.391	0.396	0.401	0.406	0.411	0.416	0.421	0.426	0.401
Italy	0.414	0.419	0.424	0.428	0.433	0.438	0.443	0.448	0.453	0.457	0.462	0.438
Netherlands	0.498	0.502	0.507	0.512	0.516	0.521	0.526	0.530	0.535	0.539	0.544	0.521
Portugal	0.300	0.305	0.310	0.315	0.320	0.325	0.330	0.335	0.340	0.345	0.350	0.325
Sweden	0.354	0.358	0.363	0.368	0.372	0.377	0.381	0.386	0.391	0.395	0.400	0.377
Group 1 Ave	0.444	0.448	0.453	0.457	0.461	0.465	0.470	0.474	0.478	0.482	0.486	0.465
Group 2: Others												
Australia	0.222	0.226	0.231	0.235	0.240	0.244	0.249	0.254	0.258	0.263	0.268	0.245
Japan	0.315	0.318	0.322	0.326	0.330	0.334	0.338	0.342	0.346	0.350	0.354	0.334
South Korea	0.299	0.304	0.309	0.314	0.318	0.323	0.328	0.333	0.338	0.342	0.347	0.323
United Kingdom	0.387	0.391	0.395	0.399	0.402	0.406	0.410	0.414	0.417	0.421	0.425	0.406
United States	0.160	0.163	0.166	0.169	0.172	0.175	0.178	0.182	0.185	0.188	0.191	0.175
Group 2 Ave	0.277	0.280	0.285	0.289	0.292	0.296	0.301	0.305	0.309	0.313	0.317	0.297
All Ave.	0.384	0.388	0.393	0.397	0.401	0.405	0.409	0.414	0.418	0.422	0.426	0.405

Table 8(a). Stochastic Energy Input Frontier Estimation of Group 1 in the Paper, Pulp, and Printing Industries

Variable	Estimated parameter	Standard error	t-value
Constant	5.012***	1.019	4.918
ln(Value Added)	0.0870	0.258	0.337
ln(Labor)	0.101	0.247	0.408
ln(Capital)	-0.705***	0.194	-3.637
ln(Intermediate Inputs)	-0.640*	0.372	-1.720
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.226***	0.069	3.258
$\gamma = \sigma_u^2 / \sigma^2$	0.932***	0.018	52.710
μ	0.917	0.607	1.511
η	-0.002	0.008	-0.196
Log-likelihood	16.657		
Total obs.	99		

Note: *** represents 1% level of significance.

Table 8(b). Stochastic Energy Input Frontier Estimation of Group 2 in the Paper, Pulp, and Printing Industries

Variable	Estimated parameter	Standard error	t-value
Constant	-3.400***	0.880	-3.864
ln(Value Added)	0.097	0.290	0.336
ln(Labor)	-0.394*	0.207	-1.902
ln(Capital)	0.290	0.239	1.213
ln(Intermediate Inputs)	-0.537	0.363	-1.482
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	4.998	4.114	1.215
$\gamma = \sigma_u^2 / \sigma^2$	0.997***	0.003	373.596
μ	-4.464**	2.109	-2.116
η	-0.026***	0.006	-4.175
Log-likelihood	23.771		
Total obs.	55		

Note: * represents 10% level of significance; ** represents 5% level of significance; *** represents 1% level of significance.

Table 8(c). Stochastic Input Frontier Estimation of Groups 1 and 2 in the Paper, Pulp, and Printing Industries

Variable	Estimated parameter	Standard error	t-value
Constant	4.305***	0.305	14.117
ln(Value Added)	0.153	0.118	1.290
ln(Labor)	0.277***	0.057	4.986
ln(Capital)	-0.282**	0.119	-2.363
ln(Intermediate Inputs)	-1.130***	0.165	-6.864
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	1.086**	0.500	2.173
$\gamma = \sigma_u^2 / \sigma^2$	0.983***	0.009	115.474
μ	-2.066***	0.653	-3.163
η^M	0.038***	0.006	6.834
Log-likelihood	58.590		
Total obs.	154		

Note: * represents 10% level of significance; ** represents 5% level of significance; *** represents 1% level of significance.

Table 8(d). Group Energy Efficiency for the Paper, Pulp, and Printing Industries

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.166	0.166	0.165	0.165	0.164	0.164	0.163	0.163	0.162	0.162	0.161	0.164
Czech Republic	0.321	0.321	0.320	0.320	0.319	0.319	0.318	0.317	0.317	0.316	0.316	0.319
Denmark	0.662	0.661	0.661	0.661	0.660	0.660	0.659	0.659	0.659	0.658	0.658	0.660
Finland	0.106	0.106	0.105	0.105	0.104	0.104	0.104	0.103	0.103	0.103	0.102	0.104
Germany	0.577	0.576	0.576	0.575	0.575	0.574	0.574	0.573	0.573	0.572	0.572	0.574
Italy	0.614	0.613	0.613	0.612	0.612	0.611	0.611	0.610	0.610	0.609	0.609	0.611
Netherlands	0.399	0.398	0.398	0.397	0.397	0.396	0.396	0.395	0.394	0.394	0.393	0.396
Portugal	0.162	0.161	0.161	0.160	0.160	0.159	0.159	0.158	0.158	0.157	0.157	0.159
Sweden	0.121	0.121	0.120	0.120	0.119	0.119	0.119	0.118	0.118	0.118	0.117	0.119
Group 1 Ave.	0.348	0.347	0.347	0.346	0.346	0.345	0.345	0.344	0.344	0.343	0.343	0.345
Group 2: Others												
Australia	0.954	0.952	0.951	0.950	0.949	0.947	0.946	0.944	0.943	0.942	0.940	0.947
Japan	0.386	0.376	0.367	0.357	0.347	0.338	0.328	0.318	0.309	0.299	0.290	0.338
South Korea	0.913	0.910	0.908	0.906	0.903	0.901	0.898	0.896	0.893	0.891	0.888	0.901
United Kingdom	0.950	0.948	0.947	0.946	0.944	0.943	0.941	0.940	0.938	0.937	0.935	0.943
United States	0.156	0.149	0.141	0.134	0.127	0.120	0.114	0.107	0.101	0.095	0.089	0.121
Group 2 Ave.	0.672	0.667	0.663	0.659	0.654	0.650	0.645	0.641	0.637	0.633	0.628	0.650

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 8(e). Technological Gap Ratios for the Paper, Pulp, and Printing Industries

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.935	0.937	0.939	0.941	0.944	0.946	0.948	0.950	0.951	0.953	0.955	0.945
Czech Republic	0.860	0.865	0.870	0.874	0.879	0.883	0.887	0.891	0.895	0.899	0.902	0.882
Denmark	0.895	0.899	0.902	0.906	0.909	0.912	0.916	0.919	0.921	0.924	0.927	0.912
Finland	0.901	0.905	0.908	0.911	0.914	0.917	0.920	0.923	0.926	0.929	0.931	0.917
Germany	0.557	0.570	0.582	0.594	0.606	0.617	0.629	0.640	0.650	0.661	0.671	0.616
Italy	0.631	0.642	0.653	0.664	0.674	0.684	0.694	0.703	0.713	0.722	0.731	0.683
Netherlands	0.865	0.870	0.874	0.879	0.883	0.887	0.891	0.895	0.899	0.902	0.906	0.886
Portugal	0.957	0.959	0.960	0.962	0.963	0.965	0.966	0.967	0.968	0.970	0.971	0.964
Sweden	0.771	0.778	0.786	0.793	0.800	0.806	0.813	0.819	0.825	0.831	0.837	0.805
Group 1 Ave.	0.819	0.825	0.830	0.836	0.841	0.846	0.852	0.856	0.861	0.866	0.870	0.846
Group 2: Others												
Australia	0.159	0.171	0.183	0.195	0.207	0.220	0.233	0.246	0.259	0.272	0.286	0.221
Japan	0.646	0.657	0.667	0.677	0.687	0.697	0.707	0.716	0.725	0.734	0.742	0.696
South Korea	0.146	0.157	0.168	0.180	0.192	0.204	0.216	0.229	0.242	0.256	0.269	0.205
United Kingdom	0.304	0.318	0.332	0.346	0.360	0.374	0.388	0.402	0.416	0.430	0.444	0.374
United States	0.931	0.934	0.936	0.938	0.941	0.943	0.945	0.947	0.949	0.951	0.952	0.942
Group 2 Ave.	0.437	0.447	0.457	0.467	0.477	0.488	0.498	0.508	0.518	0.529	0.539	0.488
All Ave.	0.683	0.690	0.697	0.704	0.711	0.718	0.725	0.732	0.739	0.745	0.752	0.718

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 8(f). Metafrontier Energy Efficiency for the Paper, Pulp, and Printing Industries

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Ave.
Group 1: Euro-continent												
Austria	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.154	0.154	0.154	0.155
Czech Republic	0.276	0.277	0.279	0.279	0.280	0.281	0.282	0.283	0.284	0.284	0.285	0.281
Denmark	0.592	0.594	0.596	0.598	0.600	0.602	0.604	0.605	0.607	0.608	0.610	0.601
Finland	0.095	0.095	0.096	0.096	0.096	0.096	0.095	0.095	0.095	0.095	0.095	0.095
Germany	0.321	0.328	0.335	0.342	0.348	0.354	0.361	0.367	0.372	0.378	0.384	0.354
Italy	0.387	0.394	0.400	0.406	0.412	0.418	0.424	0.429	0.435	0.440	0.445	0.417
Netherlands	0.345	0.347	0.348	0.349	0.350	0.351	0.353	0.354	0.354	0.355	0.356	0.351
Portugal	0.155	0.154	0.154	0.154	0.154	0.154	0.153	0.153	0.153	0.153	0.152	0.154
Sweden	0.093	0.094	0.094	0.095	0.096	0.096	0.097	0.097	0.097	0.098	0.098	0.096
Group 1 Ave.	0.269	0.271	0.273	0.275	0.277	0.279	0.280	0.282	0.283	0.285	0.287	0.278
Group 2: Others												
Australia	0.152	0.163	0.174	0.185	0.196	0.208	0.220	0.232	0.244	0.257	0.269	0.209
Japan	0.249	0.247	0.245	0.242	0.239	0.236	0.232	0.228	0.224	0.219	0.215	0.234
South Korea	0.133	0.143	0.153	0.163	0.173	0.184	0.194	0.205	0.216	0.228	0.239	0.185
United Kingdom	0.289	0.301	0.314	0.327	0.340	0.353	0.365	0.378	0.390	0.403	0.415	0.352
United States	0.145	0.139	0.132	0.126	0.119	0.113	0.108	0.101	0.096	0.090	0.085	0.114
Group 2 Ave.	0.194	0.199	0.204	0.209	0.213	0.219	0.224	0.229	0.234	0.239	0.245	0.219
All Ave.	0.242	0.245	0.248	0.251	0.254	0.257	0.260	0.263	0.266	0.269	0.272	0.257

Notes: The underlined numbers are the two lowest average scores. The shadowed numbers are the two highest average scores.

Table 9. Average Group TFEE, TGR, and Meta TFEE of Japanese Industries during 1995-2005

Industry	Group TFEE	TGR	Meta TFEE
Chemical and Petrochemical	0.938	0.324	0.304
Construction	0.216	0.324	0.068
Food and Tobacco	0.711	0.960	0.682
Machinery	0.938	0.327	0.306
Iron, Steel, and Non-Ferrous Metals	0.361	0.945	0.341
Non-Metallic Minerals	0.493	0.678	0.334
Paper, Pulp, and Printing	0.338	0.696	0.234