Chapter 9

Comparative Analysis of Endowments Effect Renewable Energy Efficiency Among OECD Countries

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Additional information is available at the end of the chapter

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1. Introduction

With the rapid development of the global economy, more people are living in urban than rural areas, thereby contributing to a significant increase in demand for energy, especially in emerging countries [1] [2] [3] [4]. The realization that fossil fuel resources required for energy generation are becoming scarce and that climate change is related to carbon emissions into the atmosphere has increased interest in energy conservation and environmental protection [5].

Among other recent issues, climate change, energy demand and fluctuations in international oil prices have become the focus of global attention. Renewable energy sources are now the fastest-growing sector of the energy mix and offer significant potential to address issues of energy security and sustainability [6]. All countries seeking to achieve the Kyoto Protocol target of reducing greenhouse gases, have renewable energy as the focus of their energy policy, and some have even become the mainstream of energy development. The energy we currently use is subject to unrestricted exploitation, not only about to run out of the global stock of face time, energy conversion process produce tangible and intangible waste, that have a significant effect on the global environment. To ensure a stable energy supply, enhance our energy supply security, reduce dependence on fossil fuels, and reduce greenhouse gas emissions, developing renewable energy sources has also become our current economic development and environmental resources for the biggest issue.

Thus, in face of the current trends, the demand for energy is rising. In addition to focusing on the power generation efficiency of power plants, we should also consider each unit of electricity efficiency to achieve an effective energy-saving effect in the pursuit of sustainable resource use. Therefore, we adopt a two-stage data envelopment analysis (DEA) [7] and incorporate two sub-processes into a DEA efficiency model to evaluate the level of management performance within renewable energy in the OECD countries. We measure managerial efficiency in two phases: operating efficiency (OE) and the energy density efficiency (DE).

This method is different from those of previous studies that focused primarily on assessing OE [8] [9]. We divide the efficiency of energy plants into two components. Management performance is no longer constrained with production efficiency but constitutes a broader dimension that covers operating activities and the efficiency of energy use. Compared to the traditional single-efficiency model, the sub-processes model is more suitable for evaluating the usage performance because of energy industry characteristics.

This evaluation model is useful for energy managers and current policy-makers. For managers, it provides a more detailed performance evaluation process including two essential operational elements in the energy generation industry; for policy- makers, it offers a complete measurement of efficiency and is based on variable combinations of these two dimensions; policy-makers can identify the most suitable policy (e.g., a subsidy) and develop the most effective strategy.

Taiwan is an island, country that is extremely lacking in energy and is more than 98% dependent on imported energy. Taiwan is also influenced by political and geographical constraints; therefore, the capacity to acquire energy is difficult compared to other countries. Thus, implementation of renewable energy and the abolition of nuclear power generation is a potential policy priority for Taiwan. Seeking the most cost-effective strategy, Taiwan's national conditions, if we can use the experience of other countries, will become Taiwan's development of a great help. OECD countries including highly and lowly developed countries, especially developing countries, is from the energy consumption, low efficiency and serious pollution to the economic development mode shift to energy efficient, less polluting economic development mode. In this study, we discuss and compare 34 OECD countries' renewable energy OE and DE by DEA. Finally, we present our conclusions and provide suggestions for renewable energy development in Taiwan. β

2. Literature review and hypothesis setting

Numerous studies related to the efficiency evaluation of renewable power plants have focused primarily on single efficiency and have assisted in the selection of input and output variables used in this study [10] [9]. First, Criswell and Thompson [11] applied DEA with a sample of large-scale commercial power systems for earth in global. They used three input and three output variables are exogenously fixed for the research. Azadeh, Ghaderi and Maghsoudi [12] used data from 25 cities in Iran with six regions within each city. Four types of input variables and two types of output variables were used in their analysis. More recently, Madlener, Antunes and Dias [13] justified the use of DEA logically and systematically in 41 agricultural biogas plants situated in Austria. They used three input and two output variables and identified that DEA offers considerable potential and advantages for seeking accurate evaluate productivity. Iglesias, Castellanos and Seijas [14] evaluated the performance of a group of 57 Spanish wind farms located in the region of Galicia by using three in-

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put and two output variables. Azadh, Ghaderi and Nasrollahi [15] measured the efficiency of wind power plants with the lowest possible costs using DEA, with data collected from 25 cities in Iran with 5 regions within each city using DEA with four input and two outputs.

In this section, we propose several hypotheses. Considering Sahelian countries, energy access remained relatively low until recently, despite the abundance of renewable resources such as wind and solar energy. The abundance of renewable resources assumes that access to renewable technologies could increase and improve energy access in remote rural areas [16]. They are compatible with local conditions and resource endowment. Research on regional development specifically related to China's Western Development Program by the China Energy Strategic Research Group and Fan, Sun & Ren [17] discussed sustainable development issues for economically disadvantaged areas such as the ecological deterioration and sustainable livelihoods of rural households, and suggested reasonable approaches to address energy problems in these areas, such as the use of rich natural resources (endowment), development of renewable energy, and developing a moderate centralized energy supply that considers local energy endowment conditions. Shi [18] supported a similar type of energy development because a region's unique energy endowments reflect it is energy developmental differences. Chen and Zhu [19] specifically used resource endowment, zoning separation of wind power and solar power resources, the classification results for the preliminary study on China's energy and economic regionalization. Chen and Zhu argued that there is little evidence on whether the impact of economic development on the electricity mix is affected by energy resource endowments [19]. Marcotullio and Schulz [20] provided evidence of endowment's heterogeneity in energy mix transitions across countries. Therefore, we present the following hypotheses:

H1a: Endowment and OE are positively causal related

H1b: Endowment and DE are positively causal related

British Petroleum discussed China and India's rapid increase in energy use because they represent approximately one-third of the global population, the expected depletion of oil resources in the near future, and the effect of human activities on global climate change. Bettencourt [2] indicated that as economies and populations continue to grow rapidly, energy and power consumption also increase at the same rate. The Empresa de Pesquisa Energética (EPE) indicated that because of population growth, urbanization and higher income, annual electricity consumption in the residential sector is growing steadily from 4.7% in 2003 up to 6.2% in 2009. The International Energy Agency (IEA) [6] and United Nations (UN) [4] stated that approximately 4.9 billion people (80 % of the global population) lived in developing countries as of 2001. The current annual population growth rate is approximately 1.5 % in developing countries. However, despite the lower living standards and lower per capita energy use in developing countries, total energy use in developing countries is increasing fairly rapidly. Crane and Kinzig [4] indicated that many countries in the pursuit of economic development, the population increase rapidly as the same time, but also face a requirement to increase energy. There is a growing need to implement energy efficiency. Therefore, we present the following hypotheses:

H2a: Population and OE are positively causal related

H2b: Population and DE are positively causal related

Because energy efficiency improvement relies on total-factor productivity improvement [21], the technical efficiency (TE) index is computed to analyze the energy efficiencies of economies. The TE index incorporates energy, capital, and labor as multiple inputs for production. They use DEA to find the TE of each economy. Chien and Hu [22] stated that it is possible that capital inputs may increase energy generations. From an economic production perspective, these practices imply that energy savings as well and emission reduction can be achieved by means of factor substitution between energy and capital [16] [23] [24]. This effectively mitigates the dependence of economic growth on energy input and environmental capacity; in other words, it improves the aggregated energy and environmental efficiency (AEEE). Hudson and Jorgenson [25] stated that intensity effects in the industrial sector might depend on three strong interactions. Energy and capital are both, substitutes for labor, whereas capital and energy are complements. In other words, capital and energy can be increased simultaneously. Turner [26] proposed another factor of production that is critical in determining substitution and other effects driving economy-wide responses. Specifically, rebound effects, from increased energy efficiency are capital. Therefore, we present the following hypotheses:

H3a: Capital and OE are positively causal related

H3b: Capital and DE are positively causal related

The renewable energy-developing indicators of an economy are obtained from Renewables Energy Information [5] and have been published by the IEA since 2002. Indicators such as household consumption, capital formation, trade balance, energy imports, and gross domestic product (GDP) are obtained from the world energy development. Anderson and Leach [27] also indicated that if renewable energy technologies supply a significant share of total energy supply, then the energy storage problem must be solved in advance. First, the manner in which GDP affects the promotion of energy policies must be studied. Bettencourt [2] indicated that there seems to be a long way to go to fully use renewable resources. Until the early 1980s, changes in the energy–GDP ratio were the subject of many studies. Questions were raised as to how the ratio would evolve over time if a country experiences different stages of economic development. Understanding such trends provides indicators for how future energy demand would evolve. A number of studies have suggested that as the process of industrialization advances, with agriculture replaced by manufacturing, energy consumption tends to increase more rapidly than GDP, creating an increasing value of the energy–GDP ratio. Among the theories on the relationship between energy consumption (or energy-related environmental indicators) and GDP, the most famous is the environmental Kuznets curve. A recent overview was provided by Ang and Liu [28]. With the GDP measured in common units, comparisons can be made between countries. Cross-country variations in the energy–GDP ratio have been studied for industrialized countries and for developing countries [27] [29].

Therefore, we present the following hypotheses:

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H4a: GDP and OE are positively causal related

H4b: GDP and DE are positively causal related

Some researchers have reached an opposing conclusion that energy subsidy reform would produce positive results. Steenblik and Coroyannakis [30] used the computable general equilibrium (CGE) model to simulate the positive effects of removing coal subsidies in Western European countries, such as promoting the industrialization of the power sector and increasing coal production and exports. United Nations [3] concluded that cutting energy subsidies could have significant impacts on residents, although this requires a more in-depth analysis in the future. Conversely, some researchers believed that fossil energy reform would increase energy use efficiency and household income levels. Choi, Roh and Yoon [9] indicated that increase in energy price could improve energy efficiency significantly. Thus, the energy price mechanism is at the core of energy reform, and energy subsidies are crucial determinant of energy prices.

Anderson and Leach [27] showed that energy subsidies in the United States would impede the use of new energy and reduce energy use efficiency. Shah and Larsen [31] showed that if the total energy subsidies worth almost $230 billion in 1990 could be removed, CO_2 emissions worldwide would decrease by 9.5%. Using the global coal model, Lam and Shiu [32] analyzed coal subsidy reform in Japan; the results showed that removing the coal subsidies in the power supply and industrial boiler sector would reduce global CO_2 emissions by 0.2%. The IEA [5] also indicated that global CO_2 emissions would decrease by more than 6% by 2010 if the fossil energy subsidies in the power sector were removed. We use these research data to test and verify these countries, and the relationship between subsidies policy and efficiency. Therefore, Hypotheses 5a and 5b are as follow:

H5a: Verify that causal relationship between subsidy and OE

H5b: Verify that causal relationship between subsidy and DE

3. Research methodology

3.1. Two-phase data envelopment analysis framework

We adopted a two-stage DEA [7] to evaluate the level of management performance in renewable energy industries in OECD countries. These two types of efficiency are based on sub-processes that detail the two essential phases of a country's renewable power plants: outputs provided and use generation. We then followed the approach by Seiford and Zhu [33], who divided the entire production activity into two sub-production processes. Fuel, labor, generating capacity, and operating expenses were the original input variables, whereas total primary renewable energy supply (TPES)/GDP ratio, TPES/population ratio, and grid were final output variables. Medial input variables included electricity-only plants (EOP), combined heat and power plants (CHP) of electricity, and CHP of heat, and heat-only plants (HOP). Figure 1 shows this process.

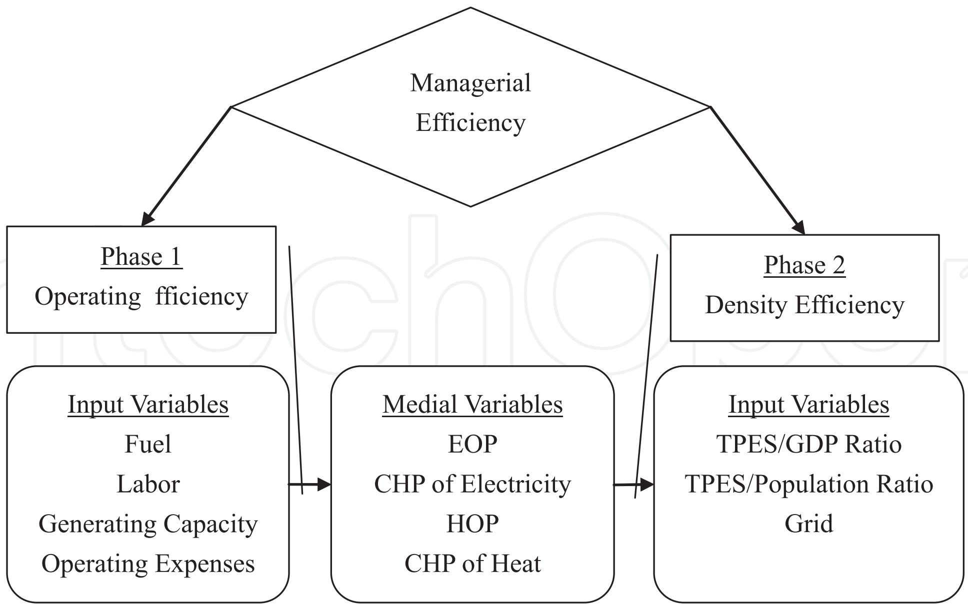

Figure 1. Two Phases DEA Model

3.2. Input and output variables

Donthu, Hershberger, and Osmonbekok [10] emphasized the significance of variable selection because the research outcome is heavily dependent on the input and output variables used in the model. Their arguments led researchers to believe that there should be a more rigorous method than those of previous studies for selecting input and output variables for efficiency assessment.

Phase I Input Variables: Selection of input variables is critical task for performance analysis, and the choice of variables depends on the selected methodology and technical requirements, the availability and quality of data, and on countries' individual socio-economic structures [34]. In this study, we use fuel, labor, generating capacity and operation expenses as our input:

1. *Fuel:* According to the IEA, renewable energy is divided into three categories of: (1) hydro fuel; (2) geothermal, solar, tidal, and wind fuel; and (3) combustible renewable energy and waste. The three categories of energy are all different in nature and cost [35]. On this basis, we discuss four renewable power sources: (1) Solar radiation: Glaser [36] provided a critical insight for a new source of solar energy. He proposed that large satellites be placed in geosynchronous orbit around Earth. These solar power satellites (SPS) would continually face the sun. Each SPS would convert a steady stream of sunlight to electric power, transform the electric power to microwave energy, and then transmit the microwaves in a tight beam to a receiver (rectenna) on Earth; (2) Wind speed: Boud and Thorpe [37] and, Bedard et al. [38] suggested that progress ratios from the wind and offshore engineering industries may be expected within the renewable energy industry; (3) Wave energy: Reviews of wave energy technologies are presented by

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Thorpe [39], among others. Wave energy conversion devices have been classified according to numerous features including their relative location to the shore, the wave mode that energy is captured from, or the device operational type; and (4) Bio-energy: Many studies have stated that the substitution of conventional fossil fuels with biomass for energy production results in a net reduction of greenhouse gas emissions and in the replacement of non-renewable energy sources [40] [41] [42].

2. *Labor:* Adjaye [43] and Ghosh [44] indicated that the relationship among output, energy use, and labor employment are built on an econometric framework. From a policy viewpoint, the direction of causality between these variables has important implications. Bettencourt [2] proposed the primary reason for the continued use of labor as an input was because labor cost is a significant cost in many industries. Dugan and Autor [45] and Morey [46] indicated that electric power production is a comprehensive process that includes generation, transmission, distribution, and retailing, involving large amounts of capital, labor, and financial resources.

3. *Generating Capacity:* Electric power production is a comprehensive process that includes generation, transmission, distribution, and retailing, involving large amounts of capital, labor, and financial resources [45] [46]. Furthermore, major infrastructure facilities, such as electric power and transport systems, have been improved [21].

4. *Operation Expenses:* Many studies on operational processes have been produced within the energy industry [47] a greater energy density of renewable at the design sites schemes increases the importance of efficient operations and maintenance (O&M) planning. Marcotullio and Schulz [20] indicated that controlling the operating costs results in achieving specific renovation and maintenance (R&M) program, adopting better maintenance practices and promoting greater plant utilization.

3.3. Medial input/output variables: The medial outputs of phase I and also the medial inputs of phase II

1. *Electricity-Only Plants (EOP):* EOP refers to plants that are designed to produce electricity only [48]. The electric power business is separated into the following four functions: generation, transmission, distribution and retailing. Numerous previous have studies applied DEA to evaluate the performance of electricity generation facilities in many industrialized nations [32] [49] [50] [51].

2. *Heat-only Plants (HOP):* HOP refers to plants designed to produce heat only [48]. The names used below for each model originate from the study by Agrell and Bogetoft [52]. The heat output used by Agrell and Bogetoft is the production at the plant and not the quantity sold to heat customers.

3. *Combined Heat and Power Plants (CHP):* CHP refers to plants designed to produce heat and electricity, occasionally referred to as co-generation power stations [48]. If possible, fuel inputs and electricity/heat outputs are on a unit basis rather than on a plant basis. However, if data are unavailable on a unit basis, the convention for defining a CHP plant is adopted [5].

3.4. Output variables

Phase II Output Variables in: The results of recent studies have contributed to energy efficiency or environment efficiency evaluation problems that consider total production activity factors. Ramanathan [53] proposed an overall efficiency index that combined energy inputs, desirable outputs and undesirable outputs using DEA to study the relationships among global GDP, energy consumption, and carbon dioxide emissions. The final outputs used in this research, are as follows:

1. *TEPS/GDP ratio:* TPES per US. $1000 of GDP. The ratios are calculated by dividing each country's annual TPES by their annual GDP expressed in constant prices and converted to US. dollars using purchasing power parities (PPPs) (www.OECD-iLibrary.org). TPES consists of primary energy production adjusted for net trade, bunkers and stock changes.

2. *TPES/Population ratio:* TPES includes the sum of the unexplained statistical differences for individual fuels, as they appear in basic energy statistics [48]. TPES per population, ratios are calculated by dividing each country's TPES by unit people (www.OECD-iLibrary.org). This ratio can be used to obtain the electricity consumption of residents for each country.

3. *Grid:* The energy's transport length of line required to moor multiple devices is dependent on the spacing between devices and the array configuration. The length of cable required depends on the array configuration, although groups of devices are typically interconnected in series and each group is connected to a hub [38].

We used the intermediation approach to view the energy industry as intermediaries, and summarized the major input and output variables in Table 1.

3.5. Research resource and sample

This research is based on DEA of operating procedures. Though data collection and literature review on performance measurement of renewable power, we can understand the differences in renewable energy efficiency among 34 OECD countries (Table 2) and provide suggestions for Taiwan. The data obtained for this analysis were gathered from many relevant data resources, including the IEA, Renewable Information, World Bank, and other energy indices of a representative sample from 2007 to 2009. However, the data obtained from Renewable Energy Information [48] are used account for the full range of statistics collected from the Annual Renewables and Waste Questionnaire. This database of annual statistics for OECD countries covers hydroelectricity, solid biofuels, geothermal, renewable municipal waste, wind, gas from biomass, liquid biofuels, solar photovoltaic, solar thermal, tide/wave/ocean, non-renewable municipal waste and industrial waste. It includes EOP and HOP from renewable sources and supply/demand balances of renewable and waste products. The primary data from this system are from IEA annual publications.

Input Variables (Phase I)	
1. Fuel	IEA; Glaser, 1977; Thorpe, 1999; Boud and Thorpe, 2003; Schneider and McCarl, 2003;Owen, 2004; Bedard et al., 2005; Previsic et al., 2005; Dowaki and Mori, 2005; Caputo et al., 2005
2. Labor	Buonafina, 1992; Adjaye, 2000; Morey, 2001; Ghosh, 2002; Dugan et al., 2002;
3. Generating Capacity	Dorian, 1998; Morey, 2001; Dugan et al., 2002
4. Operation Expenses	Kannan and Pillai, 2000; Herman, 2002; AMEC, 2004
Medial Input/Output Variables (Output Phase I and Input Phase II)	
1. EOP	Olatubi and Dismukes, 2000; Lam and Shiu, 2001; Nag, 2006; Pombo and Taborda, 2006; Sueyoshi and Goto, 2010; Renewables Information, 2011
2. HOP	Agrell and Bogetoft, 2004; Renewables Information, 2011
3. CHP	IEA; Renewable Information, 2011
Output Variables (Phase II)	
1. TEPS/GDP ratio	PPPs (www.OECD-iLibrary.org)
2. TEPS/Population ratio	Renewable Information, 2011; PPPs
3. Grid	Halcrow, 2005; Bedard et al., 2005

Note. Source from this study

Table 1. Input and Output Variables

3.6. DEA model

Data Envelopment Analysis (DEA) is a method for measuring the performance efficiency of decision units, characterizing by multiple input and output variables [8]. The DEA technique uses linear programming to estimate the maximum potential efficiency for various levels of inputs based on each firm's actual inputs and output. DEA includes two major models, the CCR model, and the BCC model. Charnes, Cooper and Rhodes [54] proposed a model under the assumption of constant return to scale (CRS), called the CCR model. This model is only appropriate when all DMUs are operating at an optimal scale. Banker, Charnes and Cooper [55] extended the CCR model to include the variable returns to scale named the BCC model, which can further decompose the TE into two components: pure technical efficiency (PTE) and scale efficiency (SE). The problem of calculating efficiency can be formulated as a fractional linear programming problem as below:

$$\begin{aligned} &Max\ \mathrm{E}_j = \sum_{n=1}^{N} U_n Y_{jn} - u_0 \,/\, \sum_{m=1}^{M} V_m X_{jm} \\ &s.t.\ \sum_{n=1}^{N} U_n Y_{jn} - u_0 \,/\, \sum_{m=1}^{M} V_m X_{jm} \le 1;\ \forall \mathrm{r} \\ &\mathrm{U}_n,\ \mathrm{V}_m \ge 0\ \ \mathrm{m=1,2,\ldots,M;\ n=1,2,\ldots N;} \\ &r = 1, 2, \ldots, j, \ldots R \end{aligned} \tag{1}$$

We utilized the BCC input-oriented model to measure phase I and II to find a maximum output with certain medial output.

DMUs	Country Name	DMUs	Country Name
D1	Australia	D18	Japan
D2	Austria	D19	Korea
D3	Belgium	D20	Luxembourg
D4	Canada	D21	Mexico
D5	Chile	D22	Netherlands
D6	Czech Republic	D23	New Zealand
D7	Denmark	D24	Norway
D8	Estonia	D25	Poland
D9	Finland	D26	Portugal
D10	France	D27	Slovak Republic
D11	Germany	D28	Slovenia
D12	Greece	D29	Spain
D13	Hungary	D30	Sweden
D14	Iceland	D31	Switzerland
D15	Ireland	D32	Turkey
D16	Israel	D33	United Kingdom
D17	Italy	D34	United States

Note. Source from this study

Table 2. Country Names of each DMU

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4. Empirical analysis

First, multi-collinearity analysis was employed to examine the correlation coefficient between input and input variables, and then between output and output variables [56]. We used isotonicity diagnosis to examine positive correlation coefficients between input and output variables [57]. We then used sensitivity analysis to sequentially increase or reduce the input or output variables to examine variation of efficiency [8]. The obtained sensitivity analysis result does not consider the operating expenses because of their highly correlation. Additionally, we also test the rule of thumb issued by Golany and Roll [58]. The four tests are all hold.

Tables 3 and 4 report the BCC efficiency scores of OE and DE for the 34 OECD countries from 2007 to 2009. Table 3 shows the comparison of the main goal in phase I to evaluate how efficiently countries use their resources; in other words, to identify any inefficiency result from PTE or SE. The resource inefficiency 2007, 2008, and 2009 is primarily pure technical efficiency (0.729, 0.704, and 0.727, respectively). In other words, the inefficiency is a result of inappropriate input and output configuration, rather than inappropriate scale. Table 4 shows a comparison of the main goal in Phase II to evaluate how efficiency energy is used to identify inefficiency resulting from PTE or SE. The resource inefficiency during 2007, 2008, and 2009 is primarily scale efficiency (0.439, 0.431, and 0.45, respectively). In other words, the inefficiency is result of inappropriate scale.

Phase 1									
	2007			**2008**			**2009**		
DMUs	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE
Ave.	0.666	0.729	0.917	0.5	0.704	0.848	0.597	0.727	0.812
SD	0.26	0.247	0.148	0.266	0.255	0.176	0.274	0.247	0.183
No. of Efficient DMUs Efficient DMUs	9	11	11	6	10	7	7	13	7
Phase 2									
	2007			**2008**			**2009**		
DMUs	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE
Ave.	0.387	0.735	0.439	0.373	0.726	0.431	0.367	0.718	0.45
SD	0.445	0.293	0.474	0.441	0.291	0.48	0.407	0.285	0.431
No. of Efficient DMUs Efficient DMUs	9	15	12	8	14	12	7	12	11

Note. Source from this study

Table 3. BCC-efficiency Scores for operating efficiency for each year

We employed the Mann-Whitney U-Test, a non-parameter statistical method, to test the same mean between two groups. The results in Table 4 show that the OE and DE for all cases do not achieve a level of significance (p >.05) for all compared years. Therefore, these 3-years are suitable for the DEA model using 102 DMUs to determine if there is a significant difference between OE and DE (Table 5).

Phase 1				
Case	**Test Value**	**TE**	**PTE**	**SE**
Between 2008 and 2007	Z Test	-0.21	-0.372	-0.501
	p-vale	0.834	0.71	0.617
Between 20.50.58 and 20.50.57	Z Test	-1.349	-0.604	-1.571
	p-vale	0.177	0.546	0.077
Phase 2				
Case	**Test Value**	**TE**	**PTE**	**SE**
Between 2008 and 2007	Z Test	-0.98	-0.234	-0.5.057
	p-vale	0.327	0.815	0.29
Between 20.50.58 and 20.50.57	Z Test	-0.433	-0.179	-0.345
	p-vale	0.665	0.858	0.73

Note. Source from this study

Table 4. Results of Mann – Whitney U Test

	2007		2008		2009	
DMUs	**0E**	**DE**	**OE**	**DE**	**OE**	**DE**
Ave.	0.666	0.387	0.5	0.373	0.597	0.367
SD	0.26	0.445	0.266	0.441	0.274	0.407
No. of Efficient DMUs	9	9	6	8	7	7

Note. Source from this study

Table 5. Bcc-efficiency score for OE and DE for each year

The Mann-Whitney U-Test is also used to determine if there is a significant difference between OE and DE before and after 2008 (Table 6). The results show that the global financial crisis did not influence OE and DE. Because OE and DE are non-significant, we can assert that the data are consistent and that renewable energy capital investments in each country have a certain proportion; thus, 2008 financial crisis did not have s significant influence on renewable energy development. This implies that the development of renewable energy is crucial. Furthermore, we want to determine if there is a significant difference between OE and DE.

Case	Test Value	OE	DE	OEvsDE
Between 2008 and 2007	Z Test	-0.006	-0.98	-2.812
	p-vale	0.995	0.327	0.005**
Between 20.50.58 and 20.50.57	Z Test	-1.258	-0.5.433	-2.819
	p-vale	0.208	0.665	0.005**

Note. Source from this study

Table 6. Results of Mann – Whitney U Test of OE and DE

Tobit regression analysis was conducted to determine whether the efficiency scores are related to characteristics such as GDP, population, capital, endowment and subsidy (Table 7). Furthermore, a dummy variable was included to evaluate the renewable energy subsidies in OECD countries. The function of a regression model can be expressed as: $Y = a + bX$, where Y represents the dependent variable and X represents regression form to a logistic probability function because the efficiency ranges from zero to one. The transformed regression function is expressed as:

$$\ln(\frac{Y}{1-Y}) = a + bX, \tag{2}$$

derived from:

$$Y = F(a+bX) = \frac{1}{1+\exp(-a-bx)}. \tag{3}$$

The Tobit regression analysis result shows that endowment, population, and capital all have high positive significance with OE and DE. Thus, H1a, H1b, H2a, H2b, H3a, and H3b are supported. However, GDP has a non-significant negative correlation with OE and DE. Thus, H4a and H4B are rejected. GDP, capital, trade balance, household consumption, and energy imports are critical factors for measuring renewable energy indicators [5]. Our finding in H4a and H4b is that the GDP and OE are negatively correlated, and GDP and DE are also negative correlated. This is potentially because countries did not allocate the use of renewable energy in accordance with GDP degree. For example, compared to poorer countries, wealthy countries must improve the relatively large number of renewable energy use to achieve the target.

Specially, subsidies are significant with OE but not with DE. In other words, the subsidy is positively correlated with OE but negatively correlated with DE. Thus, H5a is supported and H5b is rejected. Some researchers have reached an opposing conclusion that subsidies and OE are positively correlated and that energy subsidy reform would produce positive results. Promoting “subsidy” policies can reduce industrial production costs. However, if they are implemented inefficiently without carefully assessing the cost-efficiency and associated financial risks, a "free rider" phenomenon is created with consequent disadvantages; thus, the subsidies do not have a positive benefit. Therefore, renewable energy subsidies and DE may be negatively correlated [59].

Model	**Phase 1**			**Phase 2**		
Dependent Variables	**OE**			**DE**		
	β-value coe.	t-value	p-value	β-value	t-value	p-value
Independent Variables						
Endowment	3.131	-4.7	0.013**	-14.294	2.54	0.000**
Population	-0.004	4.43	0.006**	0.13	-2.83	0.000**
Capital	0.001	-3.3	0.018**	-0.007	2.4	0.001**
GDP	-2.3	0.39	0.961	0.001	-0.05	0.695
Subsidy	0.17	-0.26	0.017**	-0.029	2.42	0.797
r^2	0.337			0.264		
F-value	4.04			8.69		
P-value	0.000**			0.000**		

Note. Here is the efficiency scores derived from operating efficiency (OE) and density efficiency (DE). The observation is 102. ** represents significant at 0.05 level and * represents significant at 0.1 level.

Table 7. Estimated Results of the Tobit Regression Analysis

5. Conclusion

Numerous DEA studies have incorporated the concept of production activities with multiple phases. They subsequently divided the DEA model into several sub-processes [60] [55] [33] [61] [62] [19]. Our first finding in this research is that there is a significant difference between OE and DE. In other words, sub-process DEA model is suitable for measuring management performance because of the characteristic of production activities in renewable energy industries [61].

OECD countries in response to United Nations climate Change Framework Convention and the relevant provisions of the Kyoto Protocol, In addition to adjusting the energy supply and demand side policies, and with the greenhouse gas performance of fiscal policy (subsidy) to promote energy conservation and reduce dioxide emissions [63]. Our second finding is that subsidies are positively correlated with OE and negatively correlated with DE. Promoting subsidy policies can reduce industrial production cost. However, if they are implemented inefficiently without carefully assessing the cost-efficiency and associated financial risks, a "free rider" phenomenon is created with consequent disadvantages; thus, the subsidies do not have a positive benefit. Therefore, renewable energy subsidies and DE may be negatively correlated [59].

In our study, we attempted to measure OECD countries' renewable OE and DE simultaneously, to examine the OECD renewable energy's promote, employ, and the relevance to the development of research, and provide feasible suggestions for a renewable energy development strategy in Taiwan. For example, because Taiwan is an island country, and resources are difficult to obtain, efforts should be made to actively develop renewable energy technology to replace traditional energy sources. In addition, policy-makers should assess renewable energy subsidy programs, promote renewable energy industry research and development, assist the industry in developing cost-efficient production technologies, and develop a new energy market. Furthermore, strengthen the use of renewable energy demonstration and propaganda work, and to enhance the efficiency of the client to use.

Finally, this study has several limitations that require discussion. First, only 34 OECD samples were selected that could provide the data required to conduct this study. Future research could include more countries, especially developing countries, such as Taiwan, China, and India to achieve more precise results. Second, non-financial data such as output quality and investment of renewable land were not included in our model. These variables are also critical factors for the evaluation of energy industry performance. Future research could include this as an additional evaluation variable. Finally, in this study, we independently tested and verified the two phases of efficiency. However, future research could use a supply chain model that assumes that the two phases of efficiency are dependent and further evaluate the real scores of management efficiency.

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