DEA-Based Green Positioning Strategy by Unified Efficiency Measure for the US Coal-fired Electricity Products

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The IAFOR International Conference on Sustainability, Energy & the Environment – Hawaii 2017
Official Conference Proceedings

Abstract
Consumers are facing a wide range of electricity products especially in a fully liberalized market. Consumers need information about their concerns such as environmental consciousness whether the energy they currently use is unsustainable since governmental regulators have paid serious attention to corporate efforts for environmental protection. Therefore, marketing efforts in enhancing green product image need not only information about operational performance but also environmental performance evaluated by unified efficiency scales indicating environmental sustainability. The purpose of this study are: (1) to propose conceptual framework of green positioning strategy to enhance product image using unified efficiency scores measured by DEA (Data Envelopment Analysis) model under natural and managerial disposability, and (2) to show the relationship between unified efficiency measures and their corresponding effective type of information which can be used by marketers. This study applied the proposed approach to discuss green-imaged positioning of the US electricity products generated by bituminous and sub-bituminous coal. This study finds that (1) the competitiveness of the market of coal electricity under managerial disposability is higher than natural disposability from positioning perspective, and (2) electricity products generated by sub-bituminous coal have limited type of information to use in marketing efforts under natural disposability. Thus, it is recommended that the US coal-fired power industry should phase out sub-bituminous electricity because it will benefit both the competition of coal electricity market and the future sustainable economic growth in the US power industry.

Keywords:DEA-based Green Positioning, Unified Efficiency Measure, Electricity Product Differentiation

Introduction

The full liberalization of Japanese electricity market has started since April 1, 2016. It is obvious that the utilization of electricity has become a major concern of households in Japan, especially after the deregulation. There are plenty of lessons to be learned from the opening of domestic electricity market in Britain (in 1999), Germany (in 1998), and the United States (in 1996), and so on. It has been generally considered that both power industry and consumers have benefited from greater competition compared with the former monopolies' power-generation market. Consumers facing a wide range of options need product information about their concerns such as environmental matters, rates/prices, available alternatives, etc. Moreover, environmental consciousness among consumers regarding the energy they currently use is not sustainable since governmental regulators have paid serious attention to corporate efforts for environmental protection. Thus, the greater competition in electricity retail market requires suppliers to offer more attractive green-imaged products differentiated by efficiency or by improvements in productivity from environmental perspective.

Therefore, marketing efforts in product positioning need not only information about operational performance but also that of environmental performance measured by unified efficiency (UE) measures indicating comparable information among competitors under a certain strategy (i.e. natural and managerial disposability). A product positioning (Kaul and Rao, 1995) is a marketing strategy. The green-imaged product positioning is a newly developed marketing strategy in enhancing green image of consumers based on their competitive advantages.

Many previous studies have discussed efficiency measures about productivities and benchmarking (targeting) to enhance economic and environmental performance by using Data Envelopment Analysis (DEA) environmental assessment. The conventional use of identifying target frontier might have been discussed with an expectation of improvements without losing the reality; however, marketing use of information based on unified efficiency measure has not yet been discussed.

The purpose of this study is (1) to propose conceptual framework of green positioning strategy for electricity products by a new use of unified efficiency scales measured by DEA model under natural and managerial disposability and (2) to show the relationship between efficiency measures and their implications of current efficiency level and characteristics of target frontier such as variable/constant return to scale (RTS) under natural disposability, variable/constant damage to scale (DTS) under managerial disposability, scale efficiencies (SE) implying environmental sustainability (i.e. Moldan, et al., 2012), and the corresponding type of information which can be used by marketers. This study also shows its application to data about the US coal power generating industry.

Literature Review

It is widely known that electricity generated from power plants using green sources (e.g. renewable) is more expensive than electricity generated from those using conventional grey sources (e.g. coal). Sundt and Rehdanz (2015) have shown that consumers' willingness to pay (WTP) for green electricity differs by energy source. Kaenzig et al., (2013) have shown that electricity consumers in full deregulated Germany market are willing to pay a premium of about 16% of average household electricity cost per a month in switching to use green power. Kristrom & Kiran (2014) have also demonstrated that a premium (WTP) increased from 4%, 2011 to 10%, 2014 (OECD, 2011, 2014). Thus, type of source is a crucial factor in enhancing their green image. Consumers' WTP also differs when their personal characteristics such as gender, age, education, and salary are accounted for (Zarnikau, 2003; Sundt and Rehdanz, 2015), which means that the role of marketing efforts in targeting became more important after the deregulation in energy market. According to Zarnikau (2003), greater information not only about energy resource options such as green energy but also about energy efficiency increase the public's WTP.

Pichert and Katsikopoulos (2008) provided empirical evidence that the reasons for consumers' choice of their electricity products: price considerations (71%), environmental considerations (62%) and both (44%) were frequently found as the reason to motivate their choice. As discussed by Woo et al., (2014), differentiated products in electricity pricing are able not only to encourage consumers' conservation actions by discouraging consumption but also to induce consumers to more effectively and efficiently satisfy their demands in an environmentally friendly way.

Wang et al., (2014) have discussed that because of a large amount of CO2 emission, the energy industry is the best investment target in developing corporate sustainability among seven industrial sectors, such as consumer discretionary, consumer staples, energy, healthcare, industrials, information technology and materials. Thus, in deregulated electricity markets, the differentiated products which induced consumers should well match with eco/green (environmental friendly) image in marketing. Therefore, it is important for marketers to appeal their green image to consumers by using information regarding their productivity, capacity management and green technology. Those performance level of production activities can be evaluated by DEA-based assessment technique (Sueyoshi and Goto, 2016). The DEA-based unified efficiency measure (operational and environmental performance) has been discussed in the industry producing marketable outputs without ignoring undesirable outputs regarding environmental protection (Yan and Pollitt, 2009). This study was newly developed and extended from the idea based on unified efficiency measures partly discussed in Sueyoshi and Goto (2016).

Methodology

Figure 1 visually describes the structure of the approach proposed in this study. This study discuss (1) how to interpret unified efficiency measures for marketing communication, (2) how to enhance consumers' green product image by marketing efforts, and (3) the relationship between efficiency scores and type of information based on DEA.

As depicted in the top of Figure 1, in production factors regarding coal electricity, it might be easy to classify outputs into two categories, desirable and undesirable, such as electricity and its byproducts (GHG and acid gases). It is true that there are researchers who have discussed the desirability of outputs. For example, Pichert and Katsikopoulos (2008) have called gray electricity generated from conventional energy sources such as coal or atomic power, in contrast with green electricity generated from renewable sources including solar energy, biomass, geothermal and wind energy, without discussing any measurement scales. However, as discussed by Liu et al., (2015), we cannot simply classify the coal as an undesirable input just because of the production of the pollutant emissions, as long as input is able to produce desirable outputs. The environmental desirability of input also depends on many factors such as capacity, technology, and regional non-discretionary factors. Therefore, the desirability of input, needs to conduct deliberations on numerical index such as unified efficiency measures evaluated by DEA environmental assessment from various viewpoints.

From production factors to identify two types of congestions by capacity limitation or eco-technology innovation, the upper half of the Figure 1, has discussed in the previous study (Sueyoshi and Goto, 2016), so that this study newly discusses the lower area with extending their study toward marketing positioning.

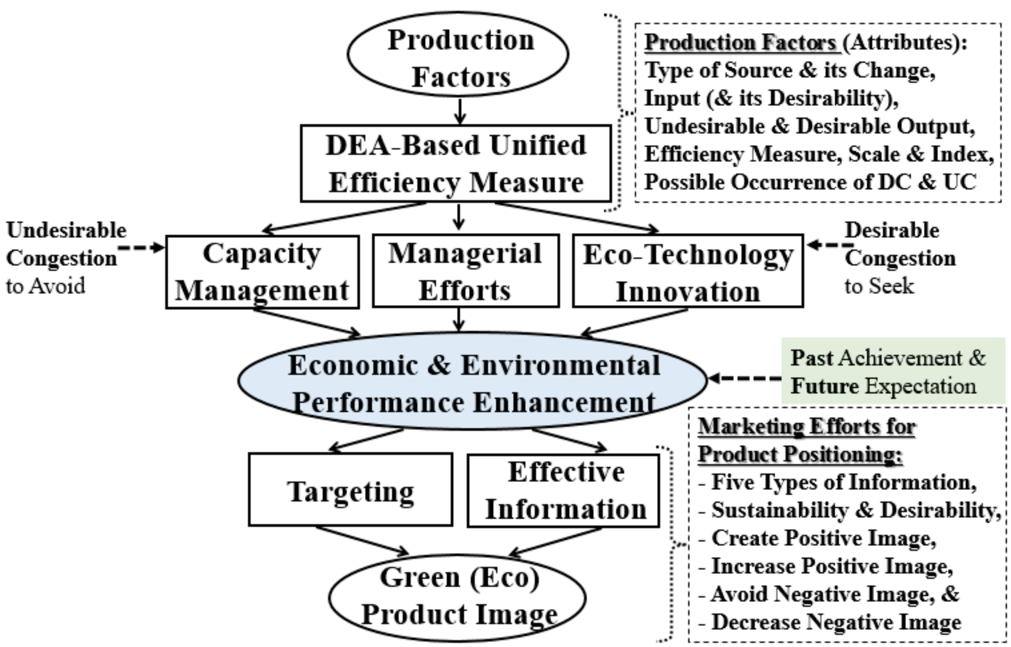

Figure 1: Conceptual Framework of Green-imaged Positioning Strategy

Assume that there are j=1,…,n decision-making units (DMUs: productivity to be evaluated). These can be electricity brands, products, electricity-generating units, companies or plants. The performance level of production activities of each DMU, which is evaluated by DEA environmental assessment, referred to as "an efficiency measure". The efficiency measure is characterized by production activities that utilize inputs to yield desirable and undesirable outputs. The efficiency measure is also characterized by a structure of the model. There are many types of efficiency measure because which performance level is measured by (1) a combination of production factors, (2) a definition of desirability of input/output and (3) a model based on a strategy/concept such as natural/managerial disposability, a radial/non-radial and an input/output orientation. Efficiency measures are conventionally used by inefficient DMUs to follow/replicate target frontier (best practice) to enhance their productivity.

Unified efficiency measures under natural and managerial disposability
UEN and UEM

Natural disposability is a concept/strategy that fits with the scope of conventional use of DEA, where an inefficient DMU decreases some components of an input vector but increases some components of a desirable output vector. The decrease of the input vector leads to a reduction on undesirable outputs, focusing upon a managerial effort to improve the operational performance of the DMU.

Managerial disposability is a concept/strategy, considering managerial performance for sustainable economic growth where an inefficient DMU increases the amount of input and increases the amount of desirable output but reduces undesirable outputs by a managerial effort such as using high quality resources, utilizing new green technology that can reduce pollution.

VRTS and VDTS

Unified (operational and environmental) production and pollution possibility sets, both of which express the concept of natural (N) and managerial (M) disposability by the two types of output vectors and an input vector, respectively, are described as follows:

$P_V^N(X) = \{(G,B): G \leq \sum_j^n G_j\lambda_j, B \geq \sum_j^n B_j\lambda_j, X \geq \sum_j^n X_j\lambda_j, \sum_j^n \lambda_j = 1 \& \lambda_j \geq 0, j = 1, \dots, n\}$ &
$P_V^M(X) = \{(G,B): G \leq \sum_j^n G_j\lambda_j, B \geq \sum_j^n B_j\lambda_j, X \leq \sum_j^n X_j\lambda_j, \sum_j^n \lambda_j = 1 \& \lambda_j \geq 0, j = 1, \dots, n\}$
…(1)

where $X \in R_+^m$ is an input vector with m components, $G \in R_+^s$ is an input vector with s components, $B \in R_+^h$ is an input vector with h components. $P_V^N(X)$ stands for production and pollution possibility set that are structured by natural disposability and $P_V^M(X)$ is for those of managerial disposability. The subscript (V) stands for variable RTS (Return to Scale) or variable DTS (Damage to Scale) because the side constraint $\left(\sum_j^n \lambda_j = 1\right)$ is incorporated into the two axiomatic expressions. The difference between the two disposability concepts is that efficiency frontier for desirable outputs locates above or on all observations, while efficiency frontier for undesirable outputs locates below or on all observations. Sueyoshi and Goto (2012) provided a detailed description on RTS and DTS in DEA environmental assessment.

CRTS and CDTS

The unified efficiency measure of constant RTS (CRTS) and the constant DTS (CDTS) are described as follows:

$P_c^N(X) = \{(G,B): G \leq \sum_j^n G_j\lambda_j, B \geq \sum_j^n B_j\lambda_j, X \geq \sum_j^n X_j\lambda_j, \lambda_j \geq 0, j = 1, \ldots, n\}$ &
$P_c^M(X) = \{(G,B): G \leq \sum_j^n G_j\lambda_j, B \geq \sum_j^n B_j\lambda_j, X \leq \sum_j^n X_j\lambda_j, \lambda_j \geq 0, j = 1, \ldots, n\}$

…(2)

where the two equations $(\sum_j^n \lambda_j = 1)$ drop from $P_V^N(X)$ & $P_V^M(X)$ by assuming constant RTS and DTS. The subscript (c) is used to express CRTS and CDTS.

UEN Model (VRTS, CRTS and SEN)

The j-th DMU $(j = 1, \ldots, n)$ uses a column vector of inputs (X_j) in order to yield not only a column vector of desirable outputs (G_j) but also a column vector of undesirable outputs (B_j), where $X_j = (x_{1j}, x_{2j}, \ldots, x_{mj})^T$, $G_j = (g_{1j}, g_{2j}, \ldots, g_{sj})^T$ and $B_j = (b_{1j}, b_{2j}, \ldots, b_{hj})^T$, these are referred to as production factors. Here the superscript T indicates a vector transpose. It is assumed that $X_j > 0$, $G_j > 0$ and $B_j > 0$ for all $j = 1, \ldots, n$, where all components of the three vectors are strictly positive. The data ranges for adjustment are determined by the upper and lower bounds on inputs and those of production factors are as follows:

$R_i^x = (m+s+h)^{-1}\left(max\{x_{ij} | j = 1, \ldots, n\} - min\{x_{ij} | j = 1, \ldots, n\}\right)^{-1}$,
$R_r^g = (m+s+h)^{-1}\left(max\{g_{rj} | j = 1, \ldots, n\} - min\{g_{rj} | j = 1, \ldots, n\}\right)^{-1}$ and
$R_f^b = (m+s+h)^{-1}\left(max\{b_{fj} | j = 1, \ldots, n\} - min\{b_{fj} | j = 1, \ldots, n\}\right)^{-1}$.
…(3)

The following DEA model (4) measures the unified efficiency of the k-th DMU under natural disposability:

$$\begin{aligned}
&Maximize \ \xi + \varepsilon_s\left[\sum_{i=1}^m R_i^x d_i^{x-} + \sum_{r=1}^s R_r^g d_r^g + \sum_{f=1}^h R_f^b d_f^b\right] \\
&s.t. \quad \sum_{j=1}^n x_{ij}\lambda_j + d_i^{x-} = x_{ik} \quad (i = 1, \ldots, m), \\
&\qquad \sum_{j=1}^n g_{rj}\lambda_j - d_r^g - \xi g_{rk} = g_{rk} \quad (r = 1, \ldots, s), \\
&\qquad \sum_{j=1}^n b_{fj}\lambda_j + d_f^b + \xi b_{fk} = b_{fk} \quad (f = 1, \ldots, h), \\
&\qquad \sum_{j=1}^n \lambda_j = 1, \\
&\qquad \lambda_j \geq 0 \quad (j = 1, \ldots, n), \xi: \text{ URS}, \ d_i^{x-} \geq 0 \ (i = 1, \ldots, m), \\
&\qquad d_r^g \geq 0 \ (r = 1, \ldots, s), \text{ and } d_f^b \geq 0 \ (f = 1, \ldots, h)
\end{aligned}$$

…(4)

Here, d_i^{x-}, d_r^g, and d_f^b are all slack variables related to inputs, desirable and undesirable outputs, respectively. The $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_n)^T$, an unknown vector, is often referred to as structural variables. They are used for connecting all the production factors by a convex combination under variable RTS (VRTS). The above model (4) considers only single-sided input deviations $\left(d_i^{x-} = x_{ik} - \sum_{j=1}^{n} x_{ij}\lambda_j\right)$ for all inputs $(i = 1, \ldots, m)$ in order to attain the status of natural disposability. A scalar value (ξ) stands for an inefficiency score that measures a distance between an efficiency frontier and observed vectors on three production factors. The ε_s is a very small number (non-Archimedean number: 0.0001 is used) indicating the relative importance between the inefficiency score and the sum of slacks.

A unified efficiency score $(UEN_V^*{:}VRTS)$ of the k-th DMU under natural disposability becomes:

$$UEN_V^* = 1 - \left[\xi^* + \varepsilon_s\left(\sum_{i=1}^{m} R_i^x d_i^{x-*} + \sum_{r=1}^{s} R_r^g d_r^{g*} + \sum_{f=1}^{h} R_f^b d_f^{b*}\right)\right]$$
…(5)

All slacks are determined on the optimality of the model (4). The unified efficiency is obtained by radial model as follows:

$$d_i^{x-*} = x_{ik} - \sum_{j=1}^{n} x_{ij}\lambda_j^*,\ d_r^{g*} = \sum_{j=1}^{n} g_{rj}\lambda_j^* - (1+\xi^*)g_{rk}\ \&$$
$$d_f^{b*} = -\sum_{j=1}^{n} b_{fj}\lambda_j^* + (1-\xi^*)b_{fk}.$$
…(6)

As mentioned previously, this study attains a unified efficiency under constant RTS $(UEN_c^*{:}CRTS)$ with the structural equation $\left(\sum_j^n \lambda_j = 1\right)$ dropped from Model (4). These two models are used in this study in order to discuss positioning strategy under the natural disposability. This study measures the level of unified efficiency under both natural disposability and CRTS by

$$UEN_c^* = 1 - \left[\xi^* + \varepsilon_s\left(\sum_{i=1}^{m} R_i^x d_i^{x-*} + \sum_{r=1}^{s} R_r^g d_r^{g*} + \sum_{f=1}^{h} R_f^b d_f^{b*}\right)\right] \quad \ldots(7)$$

The scale efficiency measures are obtained by

$$SEN^* = UEN_c^* \,/\, UEN_v^* \quad \ldots(8)$$

Scale efficiency indicates how each DMU carefully manages its operational size under natural disposability. The higher score in these efficiency measures indicates the better scale management under natural disposability.

UEM Model (VDTS, CDTS and SEM)

The strategy under managerial disposability is that a DMU considers a regulation change on industrial pollutions as a new business opportunity. To attain the status of managerial disposability, the DMU increases some components of an input vector in order to increase some components of a desirable output vector and simultaneously decrease those of an undesirable output vector without worsening the other components. The concept is not a conventional use of DEA in which DMUs enhance their operational performance by reducing input components. The concept of DEA assessment under managerial disposability provides us with an opportunity to change from the conventional production-based performance evaluation to the new environment conscious performance assessment toward the development of environmental sustainability. As mentioned previously, the difference between the models under natural and managerial disposability is that the first group of constraints, related to input components in Model (4). Therefore the unified efficiency of the k-th DMU under managerial disposability is measured by the following DEA model:

$$
\begin{aligned}
& Maximize\ \xi + \varepsilon_s\left[\sum_{i=1}^{m} R_i^x d_i^{x-} + \sum_{r=1}^{s} R_r^g d_r^g + \sum_{f=1}^{h} R_f^b d_f^b\right] \\
& s.t.\quad \sum_{j=1}^{n} x_{ij}\lambda_j - d_i^{x+} = x_{ik} \quad (i = 1, \dots, m), \\
& \qquad \sum_{j=1}^{n} g_{rj}\lambda_j - d_r^g - \xi g_{rk} = g_{rk} \quad (r = 1, \dots, s), \\
& \qquad \sum_{j=1}^{n} b_{fj}\lambda_j + d_f^b + \xi b_{fk} = b_{fk} \quad (f = 1, \dots, h), \\
& \qquad \sum_{j=1}^{n} \lambda_j = 1, \\
& \qquad \lambda_j \geq 0 \quad (j = 1, \dots, n),\ \xi:\ \text{URS},\ d_i^{x+} \geq 0\ (i = 1, \dots, m), \\
& \qquad d_r^g \geq 0\ (r = 1, \dots, s) \quad , \quad \text{and} \quad d_f^b \geq 0\ (f = 1, \dots, h)
\end{aligned}
$$

…(9)

A unified efficiency score $(UEM_V^*: VDTS)$ of the k-th DMU under managerial disposability is as follows:

$$UEM_V^* = 1 - \left[\xi^* + \varepsilon_s\left(\sum_{i=1}^{m} R_i^x d_i^{x-*} + \sum_{r=1}^{s} R_r^g d_r^{g*} + \sum_{f=1}^{h} R_f^b d_f^{b*}\right)\right] \quad \text{…(10)}$$

To attain unified efficiency under constant DTS $(UEM_c^*: CDTS)$, the equation $\left(\sum_j^n \lambda_j = 1\right)$ is dropped from Model (9). The level of unified efficiency under both managerial disposability and CDTS is measured by:

$$UEM_c^* = 1 - \left[\xi^* + \varepsilon_s\left(\sum_{i=1}^{m} R_i^x d_i^{x-*} + \sum_{r=1}^{s} R_r^g d_r^{g*} + \sum_{f=1}^{h} R_f^b d_f^{b*}\right)\right] \quad \text{…(11)}$$

Where the optimal solution is obtained from Model (9) without $\sum_j^n \lambda_j = 1$. These variable/constant DTS model are used to discuss green positioning strategy under managerial disposability.

The scale efficiency measures are obtained by

$$SEM^* = UEM_c^* \,/\, UEM_v^* \quad \text{…(12)}$$

Green-Imaged Product Positioning by UEN & UEM

Product positioning is concerned primarily with changes in consumer image of product. There are two types of product positioning from the firm's point of view: repositioning of existing products and design of a new product (Kaul and Rao, 1995). The need to reposition or redesign an existing product could arise for several reasons: (1) the firm did not make an optimal decision earlier and thus needs to revise its decision; (2) the basic characteristics of the market (i.e. consumers, regulation, region etc.) have changed and thus the firm needs to reposition/redesign its existing products to meet the changing consumer tastes; (3) the firm might want to react to the entry or changed strategy of a competitor (see Kaul and Rao, 1995).

A household mostly selects only one electricity product so that marketers should avoid creating a second best image even though their performance is inefficient. Marketers carefully create good product image by using "fact-based" information to develop their positioning strategy based on competitors' situation.

Table 1 summarizes the relationship between efficiency scores of VRTS, CRTS, SEN, VDTS, CDTS, and SEM, and a DMU's current efficiency level (location) and its target frontier, and possible types of information based on DEA environmental assessment in green positioning. As shown in Table 1, there are sixteen cases from Category (1) to (16), because the following combination does not exist:

$$\text{“}UEN_c^* = 1.0 \;\&\; SEN^* < 1.0\text{” or "}UEM_c^* = 1.0 \;\&\; SEM^* < 1.0\text{"}$$

…(13)
This study also avoids identifying "increasing RTS/DTS" and "decreasing RTS/DTS" because of meaningless in green positioning.

Green positioning strategy starts from identifying the level of productivity and gap from efficiency/target frontier from environmental point of view (e.g. economy, ecology, and environmental protection/regulation etc.). Marketers also try to measure differences between their current and ideal product image in the competing market. Then, they try to create green image by using information based on the current efficiency types, previous/expected improvements related to managerial efforts by investing in green technology, and information about their scale efficiency implying its potential ability for environmental sustainability (Moldan, et al., 2012). This study summarizes four types of information regarding productivity as follows:

Type I: Efficient information based on DEA environmental assessment, the DMU is located on CRTS/CDTS frontier, the marketer can use the type of information indicating the best product/production regarding quality/productivity such as efficiency scores, input/output ratio or amount and sustainability to attract consumers. However, Type I excludes expected information such as the amount/rate of emissions reduction because the DMU is on the frontier and has no target frontier. Type I, for example, 0.5kg-CO_2 /kWh (kg CO_2 emitted per kWh of electricity generation), efficiency rank/class offered by rating agencies and so on.

Type II: Efficient information based on DEA environmental assessment, the DMU is on VRTS efficient/frontier but is not located on CRTS, which indicates increasing/decreasing RTS/DTS (I/D RTS or I/D DTS), the marketer can use efficient information in a limited situation/condition. Type II indicates efficient product/production with inefficient size of capacity to the market, which indicates "not sustainable". The DMU has no expected (target-frontier-based) information because it has no target frontier.

Type III: Expected information based on DEA environmental assessment, inefficient DMU has a disadvantage in their productivity so that they need to use the other type of information to enhance their green image such as an expected amount/rate of emissions reduction (or saved resources) by investing the same/similar green technology (or replicating strategy learned from target frontier). Type III information are numerical amounts/rates related to two different terms of expected self-improved production, for example, 12% CO2 reduction, 85 million ton of annual CO2 emissions reduction. It is obvious that marketers of inefficient DMUs should use Type III excluding information about competitors to avoid customers knowing and selecting better options.

Type IV: Sustainability information, when SEN/SEM is equal to unity indicating VRTS/VDTS equals CRTS/CDTS, an efficient/inefficient DMU has appropriate/enough size of capacity to the market. This means that the DMU potentially has a capacity in terms of sustainable operation; therefore the marketers can use this information as their competitive advantage. When SEN/SEM is below unity, the target frontier is not equal to CRTS/CDTS frontier which indicates the target frontier is equal to increasing/decreasing RTS, the marketers should avoid using information about their capacity and sustainability in green positioning strategy.

Thus, use of Type III and IV along with managerial efforts indicates target-frontier-based information. It is important for DMUs to pay attention not only to their scale efficiency but also to those of their competitors in order to seek their future advantages in the market competition. If target frontier is equal to CRTS frontier, the DMU has a potential of becoming CRTS-efficient DMU without considering frontier shift (i.e. see Oh, 2010).

Table 1: Category classifications, information type, target frontier and unified efficiency scores

Categ.	Efficiency Score						Current Location or Target Frontier				Possible Type of Information			
	UEN			UEM			N		M					
	VRTS	CRTS	SEN	VDTS	CDTS	SEM		Target Frontier		Target Frontier	N		M	
1)	=1.0	=1.0	=1.0	=1.0	=1.0	=1.0	on	CRTS	on	CDTS	I	IV	I	IV
2)	=1.0	=1.0	=1.0	<1.0	<1.0	=1.0	on	CRTS		CDTS	I	IV	-	-
3)	=1.0	=1.0	=1.0	=1.0	<1.0	<1.0	on	CRTS	on	I/D DTS	I	IV	-	-
4)	=1.0	=1.0	=1.0	<1.0	<1.0	<1.0	on	CRTS		I/D DTS	I	IV	-	-
5)	<1.0	<1.0	=1.0	=1.0	=1.0	=1.0		CRTS	on	CDTS	-	-	I	IV
6)	<1.0	<1.0	=1.0	<1.0	<1.0	=1.0		CRTS		CDTS	-	III, IV	-	III, IV
7)	<1.0	<1.0	=1.0	=1.0	<1.0	<1.0		CRTS	on	I/D DTS	-	III, IV	II	-
8)	<1.0	<1.0	=1.0	<1.0	<1.0	<1.0		CRTS		I/D DTS	-	III, IV	-	III
9)	=1.0	<1.0	<1.0	=1.0	=1.0	=1.0	on	I/D RTS	on	CDTS	-	-	I	IV
10)	<1.0	<1.0	<1.0	=1.0	=1.0	=1.0		I/D RTS	on	CDTS	-	-	I	IV
11)	=1.0	<1.0	<1.0	<1.0	<1.0	=1.0	on	I/D RTS		CDTS	II	-	-	III, IV
12)	<1.0	<1.0	<1.0	<1.0	<1.0	=1.0		I/D RTS		CDTS	-	III	-	III, IV
13)	=1.0	<1.0	<1.0	=1.0	<1.0	<1.0	on	I/D RTS	on	I/D DTS	II	-	II	-
14)	<1.0	<1.0	<1.0	=1.0	<1.0	<1.0		I/D RTS	on	I/D DTS	-	III	II	-
15)	=1.0	<1.0	<1.0	<1.0	<1.0	<1.0	on	I/D RTS		I/D DTS	II	-	-	III
16)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		I/D RTS		I/D DTS	-	III	-	III

Category (1) in Table 1 shows that both performances under natural and managerial disposability are on both CRTS and CDTS frontier. Marketers can attract customers by their efficiency and recognition as the best green (the most environment-friendly) product. Marketers can also appeal their scale efficiency implying appropriate/enough size of capacity for environmental sustainability. However, they have no target frontier so they have no information about expected amount of reduction/enhancement obtained by using DEA environmental assessment. Category (2), (3) and (4) show that the level of performance under natural disposability is on CRTS frontier, but that of under managerial disposability is inefficient in terms of CDTS. The rational for green positioning should use the type of information referring to efficient information under natural disposability rather than inefficient one under managerial disposability. Because inefficient information doesn’t contribute in enhancing green image of product correspond to Category (2), (3) and (4). Category (5) indicates the opposite situation of Category (3). Category (6) shows that an inefficient DMU has an expected reduction of some components of input vector or undesirable output vector, or an expected increase in the amount of desirable output under natural disposability (Type III), if the DMU/product introduces same/similar strategy or managerial effort of its target frontier. Category (6) also shows that an inefficient DMU can use Type III regarding expected improvement by an increase of input and desirable output vector without worsening the level of undesirable outputs under managerial disposability. Moreover, the DMU can use Type IV implying its appropriate capacity for sustainable operation. Thus, the DMU corresponds to Category (6) can utilize Type III and IV under natural and managerial disposability. The other categories are almost in the same manners as Category (1) to (6).

Marketers in Category (1), (6), (7), (8), (11), (12), (13), (14), (15), or (16) can select from two types of disposability in developing their green positioning. However, it is recommended that marketers in Category (2), (3), or (4) should develop their green positioning under natural disposability, and positioning strategy in Category (5), (9), or (10) should be under managerial disposability.

Table 2: Type of DEA-based information and characteristics in green positioning

Type of Information	Characteristics/Attributes			
	Target-frontier -based	Past Achievement	Future Expectation	Sustainability
I		✔		✔
II		✔		
III	✔		✔	
IV	✔	✔	✔	✔

Thus, green product positioning in attracting consumers mostly depends upon marketing efforts by using such limited type of information (I-IV) based on DEA measurement, focusing on their advantages related to past/future environmental and operational enhancement/improvement. Table 2 summarizes DEA-based information and characteristics.

Data

According to the EIA's forecast (TODAY IN ENERGY by U.S. Energy Information Administration (EIA), released March 16, 2016:
http://www.eia.gov/todayinenergy/detail.cfm?id=25392), coal's share falls 32% of generation in the United States under the share of natural gas. The recent decline in the generation share of coal and the rise in the share of natural gas appears to have been primarily because of their prices (Electricity Monthly Update by EIA, released June 24, 2016:
http://www.eia.gov/electricity/monthly/update/archive/june2016/).

There are two types of coal called bituminous and subbituminous are mainly used by coal-fired power plants in the United Sates. Almost 48% of the coal produced in the United States is bituminous, while about 44% is subbituminous. The coal conversion produces undesirable outputs, such as Green-House Gases (GHG) and acid rain gases, which cause the climate change and damages on the environment. The GHG emissions include CO2 (carbon dioxide), CH4 (methane), N2O (nitrous oxide), HFCs (hydrofluorocarbons), PFCs (perfluorocarbons) and SF6 (sulfur hexafluoride). SO2 (sulfur dioxide) and NOx (various oxides of nitrogen) are also emissions produced by coal-fired power plants, which belong to the acid rain gases.

This study uses data set on 68 PJM's coal-fired power plants in 2010, which source is the database of Environmental Protection Agency (EPA) "eGRID year 2010" (http://www.epa.gov/energy/egrid). This study assumes 68 different electricity products (see Sueyoshi and Goto, 2016). In this study, each product is characterized by the following production factors:

Inputs
X1: the nameplate capacity (MW: Megawatt)
X2: the amount of annual heat input (MM Btu)

Desirable Output
G1: the amount of annual net generation (MWh: Megawatt hours)

Undesirable Outputs
B1: the annual amount of NOx emissions (tons)
B2: the annual amount of SO_2 emissions (tons)
B3: the annual amount of CO_2 emissions (tons)

As mentioned previously, "unit-less" data calculated by the equation (3) are used to avoid the situation where a large production factor dominates the others in the computational process of the DEA.

Results

Table 3 exhibits unified efficiency scores of 68 electricity products under natural and managerial disposability, and the corresponding type of category in Table 1. The number from 1b to 57b corresponds to products/DMUs with bituminous coal, and 58s to 68s are with sub-bituminous coal (the scores are partly discussed in Sueyoshi and Goto, 2016). Model (3), (4), (7) and (8) under natural disposability and Model (12), (13), (15) and (16) under managerial disposability are used to measure unified efficiency scores, VRTS, CRTS, SEN and VDTS, CRTS, SEM of each product. For example, product number b50 in Table 1, indicates Category (9), which indicates inefficient in terms of both CRTS and SEN under natural disposability but efficient in terms of VDTS, CDTS and SEM under managerial disposability, that the marketer should use information Type I and IV under managerial disposability to enhance its green image.

In order to discuss characteristics of the US coal electricity market, this study compared mean values of both under natural disposability and that of under managerial disposability.

(a) The mean (standard deviation) of VRTS and VDTS are 0.9518 (0.04922) and 0.9934 (0.011345). The mean of VDTS is higher than that of VRTS ($t(67)=7.511$, $p<.001$).
(b) The mean (standard deviation) of CRTS and CDTS are 0.9238 (0.092951) and 0.9901 (0.012459). The mean of CDTS is higher than that of CRTS ($t(67)=6.548$, $p<.001$).

The difference between unified efficiency measures under natural and managerial disposability is confirmed at the level of 1% significance of the paired t-test.

Table 3: Product number and category classifications

no.	UEN			UEM			Cat eg.	no.	UEN			UEM			Cat eg.
	VRTS	CRTS	SEN	VDTS	CDTS	SEM			VRTS	CRTS	SEN	VDTS	CDTS	SEM	
b1	0.9564	0.9555	0.9991	1.0000	0.9982	0.9982	14	b36	0.9076	0.9025	0.9944	0.9974	0.9964	0.9991	16
b2	0.9526	0.9522	0.9996	0.9811	0.9772	0.9960	16	b37	0.9676	0.9663	0.9987	1.0000	0.9992	0.9992	14
b3	0.9543	0.8256	0.8651	0.9969	0.9964	0.9995	16	b38	0.9820	0.9819	0.9999	0.9997	0.9994	0.9997	16
b4	0.9779	0.9761	0.9982	0.9782	0.9782	1.0000	12	b39	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1
b5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1	b40	0.9488	0.9477	0.9988	0.9976	0.9976	0.9999	16
b6	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1	b41	0.8056	0.8034	0.9973	0.9971	0.9965	0.9994	16
b7	0.9852	0.9832	0.9981	1.0000	1.0000	1.0000	10	b42	0.9226	0.9145	0.9912	0.9965	0.9965	0.9999	16
b8	0.9990	0.9983	0.9993	1.0000	1.0000	1.0000	10	b43	0.9469	0.9389	0.9916	0.9974	0.9972	0.9998	16
b9	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1	b44	0.9142	0.9119	0.9975	1.0000	0.9762	0.9762	14
b10	0.9234	0.9233	0.9999	1.0000	0.9768	0.9768	14	b45	1.0000	1.0000	1.0000	0.9997	0.9995	0.9997	4
b11	1.0000	0.7374	0.7374	0.9951	0.9947	0.9995	15	b46	0.8760	0.8678	0.9907	0.9964	0.9964	1.0000	12
b12	0.8441	0.8393	0.9943	0.9794	0.9754	0.9960	16	b47	0.9483	0.9478	0.9994	0.9946	0.9943	0.9997	16
b13	0.9647	0.9646	0.9999	0.9779	0.9777	0.9997	12	b48	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1
b14	0.8779	0.8759	0.9977	0.9866	0.9748	0.9881	16	b49	0.9778	0.9775	0.9997	0.9996	0.9996	1.0000	12
b15	0.9555	0.9545	0.9990	1.0000	0.9775	0.9775	14	b50	1.0000	0.4177	0.4177	1.0000	1.0000	1.0000	9
b16	1.0000	1.0000	1.0000	1.0000	0.9959	0.9959	3	b51	1.0000	0.9758	0.9758	1.0000	0.9933	0.9933	13
b17	1.0000	0.9523	0.9523	1.0000	0.9994	0.9994	13	b52	0.9786	0.9771	0.9984	1.0000	0.9890	0.9890	14
b18	0.9373	0.9317	0.9940	0.9992	0.9990	0.9998	16	b53	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1
b19	0.9652	0.9646	0.9993	0.9995	0.9991	0.9996	16	b54	1.0000	1.0000	1.0000	1.0000	0.9998	0.9998	3
b20	0.9757	0.9755	0.9999	0.9972	0.9782	0.9809	16	b55	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1
b21	0.9001	0.8881	0.9866	1.0000	0.9965	0.9965	14	b56	1.0000	0.9970	0.9970	1.0000	1.0000	1.0000	9
b22	0.8442	0.7757	0.9189	0.9948	0.9947	0.9999	16	b57	0.9585	0.9577	0.9992	1.0000	0.9780	0.9780	14
b23	0.9868	0.7867	0.7972	0.9967	0.9962	0.9995	16	s58	0.9069	0.9042	0.9971	0.9632	0.9631	1.0000	12
b24	0.9362	0.8021	0.8568	0.9755	0.9753	0.9998	16	s59	0.8997	0.8949	0.9947	1.0000	0.9637	0.9637	14
b25	1.0000	0.7331	0.7331	0.9961	0.9954	0.9994	15	s60	0.8741	0.8687	0.9938	0.9621	0.9620	0.9998	16
b26	1.0000	1.0000	1.0000	1.0000	0.9999	0.9999	3	s61	0.8965	0.8962	0.9996	0.9773	0.9761	0.9988	16
b27	0.9024	0.9021	0.9996	1.0000	0.9964	0.9964	14	s62	0.8884	0.8874	0.9989	0.9626	0.9612	0.9986	16
b28	0.9248	0.9237	0.9987	1.0000	1.0000	1.0000	10	s63	0.9035	0.9023	0.9986	0.9681	0.9681	1.0000	12
b29	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1	s64	0.8922	0.8918	0.9996	0.9601	0.9596	0.9994	16
b30	0.9581	0.9506	0.9922	0.9977	0.9977	0.9999	16	s65	0.9709	0.9621	0.9909	0.9784	0.9771	0.9987	16
b31	1.0000	0.9872	0.9872	1.0000	0.9999	0.9999	13	s66	0.9493	0.9469	0.9975	0.9770	0.9770	1.0000	12
b32	0.9404	0.9324	0.9915	1.0000	1.0000	1.0000	10	s67	0.9463	0.9382	0.9914	0.9768	0.9768	0.9999	16
b33	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1	s68	0.8358	0.7919	0.9475	1.0000	0.9818	0.9818	14
b34	0.9667	0.9597	0.9928	0.9999	0.9987	0.9989	16	Avg.	0.9518	0.9238	0.9712	0.9934	0.9901	0.9966	
b35	0.9958	0.9944	0.9986	1.0000	1.0000	1.0000	10	S.D.	0.0492	0.0930	0.0878	0.0113	0.0125	0.0075	

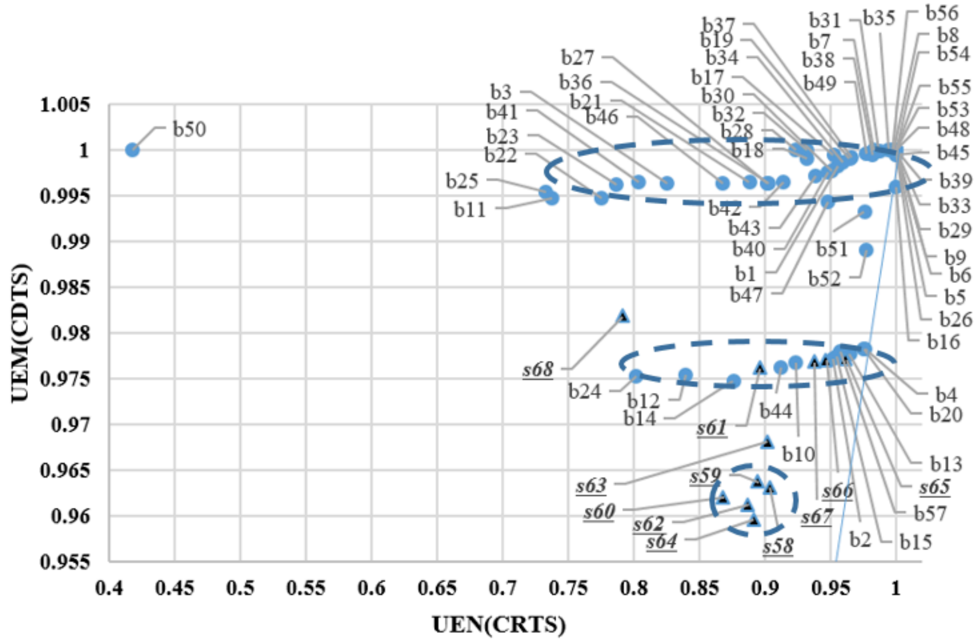

Figure 2: Visual description on two unified efficiency scores, CRTS and CDTS

Figure 2 visually describes the electricity products plotted by unified efficiency measures under managerial disposability (UEM) on the vertical axis and unified efficiency measures under natural disposability (UEN) on the horizontal axis. The plotted dot is a symbol for a product generated with bituminous coal, while a triangle symbolizes a product with sub-bituminous coal. The 68 products are roughly classified into three groups encircled with dotted line vertically as depicted in Figure 2.

As shown in Table 3 and Figure 2, this study found (1) the value of UEM are mostly larger than that of UEN, (2) the standard deviations of UEM are smaller than those of UEN, and (3) the group in the upper part of the graph encircled with dotted line, composed of products with bituminous, however, the group in the lowest part of the graph consists of products with sub-bituminous. It is also found that the competition of US electricity market is high and well homogenized under managerial disposability compared with natural disposability.

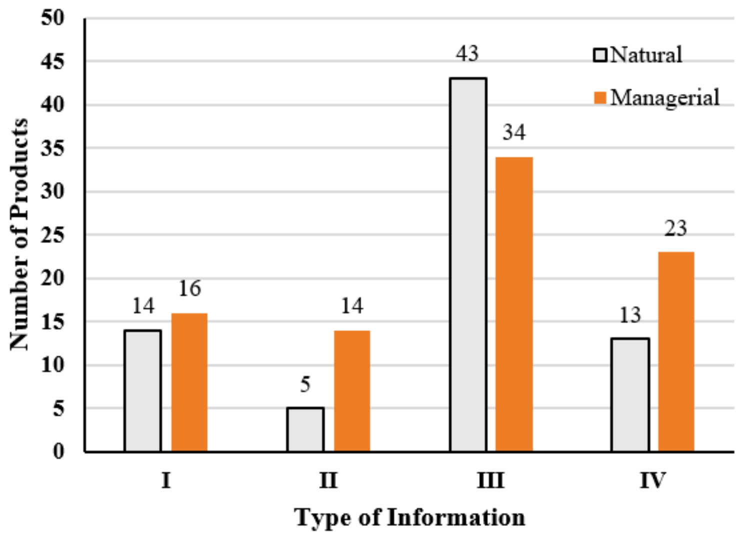

Figure 3: Type of Information and disposability

Figure 3 depicts the possible type of information in green positioning strategy under natural and managerial disposability in the US coal electricity market. In terms of under natural disposability, 13 of 68 products/marketers can use Type IV, whereas, 23 of 68 products under managerial disposability can use Type IV. This means that a limited number of DMUs/products has appropriate size of capacity under natural disposability. The comparison the situation between both natural and managerial disposability provides us with an important strategic implication that which type of disposability is better for a DMU/product to select in green positioning strategy.

Table 4: Type of coal and information

Type of Information	Bituminous		Sub-bituminous	
	N	M	N	M
I	24.6%	28.1%	0.0%	0.0%
II	8.8%	21.1%	0.0%	18.2%
III	56.1%	43.9%	100.0%	81.8%
IV	22.8%	35.1%	0.0%	27.3%

Table 4 summarizes the type of information by coal type under natural and managerial disposability. For example, a green positioning for a product generated by Sub-bituminous under natural disposability is not able to use Type I, II, IV but Type III.

Discussion

In discussing green positioning, it is important for marketers to recognize the current situation of electricity market and their productivity evaluated with unified efficiency measures. The comparison between two green positioning strategies under natural and managerial disposability is also important because marketers should recognize their advantages and weaknesses among competitors and they should develop effective strategy under a competitive market.

The US electricity products generated by coal were examined in terms of green-imaged positioning proposed in this study. The results of paired t-test between UEN and UEM imply that (1) the competitiveness of productivity is higher under managerial disposability than that under natural disposability, (2) a product differentiation by an efficient company under managerial disposability is considered to need more efforts to sustain current position than that under natural disposability.

This study finds that electricity products generated by coal-fired power plant operated with sub-bituminous have limited type of information (only Type III) to use in green positioning strategy under natural disposability. It is recommended that the sub-bituminous electricity should be phased out under natural disposability because it will benefit both the competition of coal electricity market and the future sustainable economic growth.

Conclusions

This study discussed the importance of green positioning strategy in a fully liberalized electricity market. This study proposed conceptual framework of green-imaged positioning using unified efficiency measure under natural and managerial disposability. Our approach is partly based on and newly extended from the research by Sueyoshi and Goto (2016). This study also discusses four types of information based on VRTS, CRTS, SEN, VDTS, CDTS, and SEM measured by DEA model to create a distinct product impression in consumers' mind by identifying and communicating its uniqueness. In order to develop effective positioning strategy, marketers can identify their strength of electricity products and competitors' situation by the proposed approach in this study, and their availability type of information under natural and managerial disposability in the market. This study has examined the US coal electricity market by the proposed approach. It is possible for us to consider various applications including an idea of frontier shift (or future frontier without replicating the current target frontiers), a desirable congestion to be identified for new technology, an undesirable congestion to be avoided caused by capacity limitation, and so on in the proposed green positioning strategy. For future research, it is also possible for us to expand our green-imaged positioning approach to pricing strategy including other production factors such as other natural resources and costs.

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