Operational efficiency integrating the evaluation of environmental investment: the case of Japan

Lopin Kuo
TamKang University, Taipei, Taiwan
Shihping Kevin Huang
Department of Business Administration, Shih Hsin University, Taipei, Taiwan, and
Yen-Chun Jim Wu
Department of Business Management, National Sun Yat-Sen University, Kaohsiung, Taiwan

Abstract

Purpose – The purpose of this study is to explore whether a connection exists between business operational efficiency and environmental responsibility.

Design/methodology/approach – This research adopts the DEA method through a four-step analysis to examine inter-industry differences in terms of operational efficiency with environmental consideration. The sample comprises 32 Japanese firms from three different industries listed in the Tokyo Stock Exchange between 2001 and 2006.

Findings – The results indicate a positive correlation with statistical significance in terms of a firm's environmental conservation cost, net income and economic benefit of environmental conservation for the three Japanese industries. In addition, the relationship among a firm's environmental conservation cost, CO_2 emission reduction and total CO_2 emission are positively correlated but without significance. In particular, business operational efficiency integrating social responsibility for anti-global warming initiatives (= total CO_2 emission level) could be applied to distinguish differences in terms of operational efficiency among industries.

Research limitations/implications – Japanese firms adopt a voluntary environmental disclosure; therefore this study is constrained by the availability of long-term data.

Social implications – This study enables environmentally conscious investors and fund managers to distinguish the operationally efficient industries when taking environmental performance into account.

Originality/value – The study is a novel attempt to analyze inter-industry differences in terms of operational efficiency when considering environmental conservation through the DEA method using a four-step analysis.

Keywords Environmental management, Social responsibility, Japan

Paper type Research paper

1. Introduction

In light of global warming and climate change, governments around the world have tightened environmental related laws and regulations. In addition, with increasing public awareness on environmental related issues, stakeholders from various levels are expecting firms not only have to pose outstanding financial performance but also have to engage in socially responsible management practices (Prado-Lorenzo *et al.*, 2009).

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As a part of the practice, firms are expected to make adequate environmental disclosure of all their business activities from production to distribution. Indeed, a firm's performance is measured economically and environmentally by the stakeholders (Al-Tuwaijri *et al.*, 2004).

The mandate of business has changed drastically since the time of Nobel laureate Milton Friedman who asserted that the only social responsibility of business is to use its resources to engage in activities to increase its profit (Agatiello, 2008). As Gupta (2006) revealed that "the dilemma Friedman posed was that striving for profit was inimical to chasing social causes as the latter was nothing less than unadulterated socialism … corporate philanthropy was allowed for, but only after profits were properly secured" (p. 94). Firm's environmental responsibility and profitability have been treated as tradeoffs. However, in order to make firm's social responsibility sustainable, firms have to synergize their social and business interests (Gupta, 2006). Porter and van der Linde (1995) argued that innovation is crucial in making social responsibility sustainable since reducing pollution is often coincident with improving productivity with which resources are used. According to Porter and van der Linde (1995), firm's environmental responsibility should not be treated as a cost burden but as a potential area to improve competitive advantage. Stanwick and Stanwick (2009) summarized that "by focusing on environmentally friendly strategies, firms are able to market their goods as ecofriendly, which helps differentiate their products. In addition, by focusing on the efficiency issues in the production process, firms can reduce not only the amount of waste generated by the firm, but also the costs" (p. 84). Firms can actually balance different stakeholder interests through better production process to reduce waste. Ecoefficiency stresses productivity as a critical component for firms to achieve competitive advantage. Efficient production includes saving production materials, improving manufacturing process, and utilizing by-products in the production process. Waste products are considered to be an inefficient use of resource (Stanwick and Stanwick, 2009). The more efficient production process makes firm's environmental strategy more utilitarian since such strategy serves the interests of greatest number of stakeholders.

One of the objectives of this study is to re-examine the impact of firm's environmental conservation on the financial bottom line. Insofar, there is a lack of agreement in literature on the impact of environmental conservation against firm's financial performance. Through correlation analysis between variables, this study examines the relationship between environmental investment and financial performance through the case of Japan. To provide better insight into the ongoing debate, this research has expanded the scope of industry with long-term point-of-view. Furthermore, this study also added environmental variables into the business operational efficiency (such as: environmental conservation costs, economic benefit of environmental conservation, and environmental eco-variable (CO_2 emission reduction and total CO_2 emission) to measure the operational efficiency integrating social responsibility for anti-global warming initiatives. Through the method of data envelopment analysis (DEA), this study establishes hypotheses to explore whether business operational efficiency exists in significant difference among three industries with and without consideration of firm's environmental responsibilities. Such comparison provides better insight into the effect of firm's environmental conservation cost on the general ecology.

Firm's environmental conservation effort is more than just a public display. Our study shows that firm's environmental conservation initiatives helped to alleviate environmental burden. This study also has practical contribution for fund managers or investors of socially responsible investment (SRI) in choosing the appropriate industry that is environmentally friendly. In addition, through eco-efficiency, this study also corresponds to the so-called "Porter's win-win hypothesis" that firms can actually achieve operational efficiency through better environmental practices. In addition, through a cross-industry assessment, the results indicate inter-industry differences in terms of efficiency. Industry specific attributes such as production process and product life cycle might affect the outcome firm's environmental performance. In fact, Japanese electronic industry had outperformed the automobile and chemical industry through better scale efficiency. Having sufficient operational scale might be a crucial factor for firms to achieve a win-win situation between financial and environmental performance.

1.1 The case of Japan

Since the Kyoto Protocol has been signed, Japanese firms have reconfigured various levels of their supply chain from design, R&D, production, marketing to distribution under the eco-efficiency concept. The purpose of eco-efficiency is to maximize economic value of firm's business activities while minimize the adverse impact of such activities on the environment (including resource consumption and pollutant emission). The supporters of eco-efficiency believe that such practice would increase productivity and consequently lower the cost, and improve environmental performance (Bebbington, 2001; Lehman, 2002; Stone, 1995; Burnett and Hansen, 2008). Unlike the passive disclosure of pollution elimination or the calculation of the toxics release inventory (TRI) in the past, most Japanese firms have started to publicly disclose environmental reports which include emission and reduction of greenhouse gases and carbon dioxide (CO2).

The Japanese government encourages firms to reveal their environmental conservation information to the public. Firms are also required to calculate carbon footprint from raw materials extraction, manufacturing, to final disposal stage in order to avoid the transfer of pollution sources. In addition, firms also disclose the actual recovery of environmental expenses and the amount of money saved. In terms of disclosure of environmental information, Japanese firms have been one of the most transparent in the region.

2. Literature review and hypothesis

2.1 Porter's win-win hypothesis-related firm's environmental management

Firms are responding to demands from various stakeholders by increasing their environmental investments (Galdeano-Gómez, 2008). Two approaches explain the relationship between the application of environmental practices and profit. The first perspective, known as the Porter's win-win hypothesis, argues that firms can obtain competitive advantage through further investment in environmental technology, thus increase profits (e.g. Porter and van der Linde, 1995; Hart, 1997). Pollution prevention can allow firms to save control costs, reduce input and energy consumption, and also reuse materials through recycling (Hart, 1997; Shrivastava, 1995). The win-lose perspective, on the other hand, argues that environmental investments might reduce profits since such investments are usually costly in terms of facility costs and opportunity costs (Walley and Whitehead, 1994). On the other hand, the resource-based view also agues that investment in green technology may foster the development of firm's resources and capabilities which form the basis for firm's competitive advantage (Hart, 1997; Aragón-Correa and Sharma, 2003). For instance, Sharma and Vredenburg (1998) point out that investments in proactive environmental practices (e.g. pollution prevention) actually contribute to the development of valuable capabilities such as innovation, organizational learning and stakeholder integration. As the result, firms that develop these capabilities related to environmental management are able to obtain greater financial performance.

Firm's commitment to the environment has become an important competitive factor (Montabon *et al.*, 2007). The promotion and implementation of active environmental conservation is a tool to help organizations in obtaining better competitive advantage and performance (Hart, 1997; Shrivastava, 1995; Trung and Kumar, 2005). However, the impact of firm's investment in environmental conservation against financial performance is still inconclusive (Molina-Azorin *et al.*, 2009). Some scholars believe that good environmental performance might result in better financial performance for firms (King and Lenox, 2002; Klassen and McLaughlin, 1996; Melnyk *et al.*, 2003; Russo and Fouts, 1997; Nakao *et al.*, 2007) while others argued the inconclusive correlation between environmental performance and financial performance (Cordeiro and Sarkis, 1997; Filbeck and Gorman, 2004; Wagner, 2005; Yu *et al.*, 2009). This research hopes to contribute to the discourse about making corporate environmental responsibility sustainable through the mutually beneficial relationship between firm's financial performance and environmental performance. The struggle between firm's environmental responsibility and stockholder interests will always remain controversial without aligning the two responsibilities together. Molina-Azorin *et al.* (2009), through a thorough literature investigation of 32 studies, pointed out that most studies used US firms as sample and regression analysis is the most common method. Molina-Azorin *et al.* (2009) revealed that researches about the relationship between environmental and financial performance have mainly focused on the impact of environmental variables on financial performance but there might be a possible two-way interaction between these variables. To assess the impact of each variable, this study through a series of steps compares the impact of these variables gradually in order to examine the differences in terms of the impact of environmental variables on firm's operational efficiency in each stage.

2.2 Eco-efficiency concept

Attaining eco-efficiency is critical in corporate environmental management. Schaltegger and Sturm (1990) first proposed the concept of eco-efficiency. It is usually expressed as the ratio of product value divided by its environmental burden (Verfaillie and Bidwell, 2000). This ratio is also called environmental productivity or incremental eco-efficiency in Huppes and Ishikawa (2005). Therefore, the way to increase eco-efficiency is to reduce the environmental impact of the product or to increase its economic value (Barba-Gutiérrez *et al.*, 2007). Eco-efficiency is as a tool to improve firm's internal performance (Michelsen *et al.*, 2006). Huppes and Ishikawa (2005) also treated eco-efficiency as a tool to analyze sustainability. Thus, the essential purpose of eco-efficiency is to produce and deliver goods more economically while simultaneously reducing ecological impact and resource intensity and minimizing material as well as energy intensity (Starik and Marcus, 2000). The goal of eco-efficiency is to maximize the economic value of product while minimizing its environmental impact (use of resources and emissions). Whatever the case may be, an important problem with constructing eco-efficiency indicators is that there is a lack of agreed rules or standards for recognition, measurement, and disclosure of environmental information (UNCTAD, 2003). In the past, the concept of undesirable factors was included in the productivity performance evaluation. Although such concept has been ignored for some time, Pittman (1983) included the pollutant that generated from the process of papermaking into the measurement when he evaluated the productivity of the pulp industry in Wisconsin. Moreover, by reviewing the scope of applications for the literature which included: Pulp Industry in Canada (Hailu and Veeman, 2001); the carbon dioxide (CO2) emission in the OECD Industries (Zofio and Prieto, 2001); for US's power industry that based on coal, oil and natural gas and then emitted sulfur, nitrogen, carbon oxide (Tyteca, 1997).

2.3 Using DEA method in environmental issues

One of the limitations of Pittman's (1983) work is that it requires the pricing of pollutants which are difficult to measure, although the corresponding shadow price can be estimated by the approach of distance function (Fare *et al.*, 1993). Yet another line of research is the use of data envelopment analysis (DEA), which only requires the observed quantities of inputs and outputs. DEA is an established and well-known methodology for non-parametrically estimating the relative efficiency of a number of homogeneous units, commonly designated as decision making units (DMU) (Cooper *et al.*, 2000, 2004; Zhu, 2002). Non-parametric estimation means that it does not rely on assumptions that the data come from any specific production function. Data on the inputs and outputs of the DMUs are known. From the observed data and by making minimum assumptions, DEA determines a production possibility set which contains those operating points that are deemed feasible.

In recent years, DEA has also broadly applied to evaluate various issues that are related to industry's production efficiency, economic performance and environmental performance (Tyteca, 1996, 1997; Zaim and Taskin, 2000; Dyckhoff and Allen, 2001; Sarkis and Talluri, 2004; Korhonen and Luptacik, 2004; Zhou *et al.*, 2006, 2007; Munksgaard *et al.*, 2007; Lozano and Gutiérrez, 2008; Kortelainen, 2008). In the meantime, DEA has also been applied to the evaluation of ecological environment efficiency for procedures and products (Kuosmanen and Kortelainen, 2005, 2007; Barba-Gutiérrez *et al.*, 2007). The literature indicates that undesirable factors are the mainstream application for issues related to the environment. Environmental pollutants are the main variable for the negative output.

Under the DEA framework, Scheel (2001) has proposed a method that integrating undesirable output factors into the measurement of production efficiency. The hypothesis based on the adjustable positive and negative output can be divided into separating and non-separating mode. The separating mode efficiency measurement assumes the reduction of negative output is feasible in practice meaning reduction of negative output while maintaining the quantity of positive output. Scheel (2001) has also proposed a method which regarded the negative output as "input' (that is, it needs to be minimized), and shall be handled as the maximized "output"; in addition, this study has also adopted this method to dispose the undesirable factors (such as: enterprise's total CO_2 emission).

Several researches attempted to integrate technical, economic and environmental performance measures (e.g. Tyteca, 1996; or Scheel, 2001). Generally, these environmental performance measures are obtained by making adjustments to standard parametric and non-parametric efficiency analysis techniques. The majority of these studies have included an extra pollution variable into the production model. Theses pollutions variables are either treated as another input or as a weak disposable bad output (e.g. Fare *et al.*, 1989; Ball *et al.*, 1994; Piot-Lepetit and Vermersch, 1998; Reinhard *et al.*, 2000; Shaik *et al.*, 2002). Based on previous related studies, this study established a direct link between operational efficiency and environmental impacts through DEA method.

Since the relationship between firm's environmental performance and financial performance is still unclear, it is very difficult to further the promotion of environmental investment. Through correlation analysis between variables, this study investigates the relationship of environmental investment and financial performance of Japanese firms. Through the comparison of scenarios with and without environmental measures, this study hopes to uncover the impact of firm's environmental conservation on operational performance. In addition, through the integration of scenarios with and without CO_2 emission, this study is a novel attempt to apply CO_2 emission into the identification of inter-industry difference in terms of operational efficiency through DEA method using four-step analysis.

During the 1970s, two prominent views – the industry view and the firm-efficiency view – emerged as the sources of extraordinary profits. The industry view of industrial organization holds that industry structure is important in shaping the conduct of businesses, which in turn drives their profitability (Scherer, 1970). Some researches decomposed the variance of business or firm returns into components associated with industry, corporate-parent, and business-segment effects (Wernerfelt and Montgomery, 1988; Kessides, 1990; Rumelt, 1991; Roquebert *et al.*, 1996; McGahan and Porter, 1997, 2002; Bowman and Helfat, 2001; Hawawini *et al.*, 2003; Ruefli and Wiggins, 2003; Hough, 2006). Later studies have weighed the influence of industry effects only (Powell, 1996). On the other hand, some examined the influence of industry and firm effects together (Cubbin and Geroski, 1987; Mauri and Michaels, 1998), while others explored the influence of industry and organizational effects together (Hansen and Wernerfelt, 1989). According to the industry view and the firm-efficiency view of industrial organization, this study establishes *H1*.

The industrial organization literature in economics suggests that excess returns result from differences in the underlying structure of industries. According to this logic, greener industries may have higher returns than other industries because of lower compliance and regulatory costs (King and Lenox, 2002). In contrast, the resource-based view of strategic management suggests that individual firm's capabilities may lead to excess returns when they are difficult to imitate, not substitutable, rare, and valuable (Barney, 1986; Wernerfelt, 1984). According to this view, superior ability to manage environmental problems relative to others may lead to higher returns for greener firms (King and Lenox, 2002). Second, according to the view of King and Lenox (2002), this study establishes *H2*.

Furthermore, Porter's win-win hypothesis implies that firms can actually attain operational efficiency through environmental practices. This view also reflects the essence of eco-efficiency. This study is an attempt to examine the impact of environmental variables on operational efficiency through a gradual approach using DEA model. This study assumes that firms implement environmental management practices through reduction of costs and consumption of resources which leads to greater emission reduction or lower total carbon emission. According to the view of Porter's win-win hypothesis and eco-efficiency, this study establishes *H3* and *H4*. In summary, the hypotheses of this study are as follows:

H1. Without taking firm's environmental responsibilities into account, there is a significant difference in terms of business operational efficiency among different industries.

H2. Taking a fraction of firm's environmental measures into account, there is a significant difference in terms of business operational efficiency among different industries.

H3. Taking the return on firm's environmental investment and CO_2 emission reduction into account, there is a significant difference in terms of business operational efficiency among different industries.

H4. Taking the return on firm's environmental investment and total CO_2 emission into account, there is a significant difference in terms of business operational efficiency among different industries.

3. Research design

3.1 Research sample and data collection

This study has adopted 32 firms listed in the Nikkei 225 index from three high-pollution industries including chemical industry (ten firms), automobile industry (ten firms) and electronic industry (12 firms) as the example. The reason for the sample selection is that not only do these industries are the major industries in Japan but they also have comprehensively disclosed their environmental report during 2001-2006. The Nikkei 225 index was chosen because of the index comprises of 225 flagship companies from 35 industries in Japan that are listed in the Tokyo Stock Exchange which is the second largest stock exchange in the world by aggregate market capitalization. The Nikkei 225 is the oldest and the most well-known Asian index in the world.

3.2 Variable measurement

For the input and output variables that used in the performance measurement, assets will be measured by the total assets (i.e. business's economic resources); the number of employees (i.e. business's labor resources) will be based on the disclosed number in the annual report; enterprises' profit will be measured by the net income after tax; the environmental conservation cost will include the six major costs as stated in the Environmental Accounting Guideline published by the Japanese Ministry of Environment:

(1) costs within the business scope: the pollution prevention cost, environmental protection cost, and recycling cost;

(2) correlated costs from upstream to downstream supply chain;
(3) management activity costs;
(4) R&D costs;
(5) social activity costs; and
(6) associated costs of environmental damage.

Moreover, the economic benefit of environmental conservation and CO_2 emission are based on environmental report.

3.3 Analysis method – data envelopment analysis (DEA)

Farrell (1957) is one of the first scholars who explored the efficiency measurement method. However, the term data envelopment analysis (DEA) was formalized when Charnes *et al.* (1978) adopted the linear programming to solve the issues of multiple input and output. It can be also regarded that DEA was originated from the Charnes, Cooper, Rhodes (CCR) model that was proposed by Charnes *et al.* (1978); afterward, Banker *et al.* (1984) have overcome the limitation of the fixed constant returns and proposed the Banker, Charnes, Cooper (BCC) model. However, these two models are recognized and regarded by the academic as the most influential models in DEA field (Seiford, 1996), since these models can handle various input and output variables at the same time.

The feature of DEA model is a concept of relative efficiency which can concurrently handle with various input and output scenarios for different units and adopts the linear programming to solve the efficiency value for the decision-making unit (DMU). The DMU efficiency value will be rated between 0 and 1 with 1 indicating the DMU with efficiency, and anything less than 1 is inefficient.

Based on research *H1, H2, H3* and *H4*, this study will adopt the CCR and BCC models of DEA and gradually add more environment variable to evaluate firm's environmental performance as a part of firm's operational efficiency. The CCR model reveals efficiency in productivity. BCC model indicates technical efficiency. When dividing CCR value against BCC value, the result shows the scale efficiency. The four steps analyses are established as follows (Table I):

(1) *Step 1*: without considering any environmental negative impact of business activities, this step measures firm's actual resource commitment as input and financial performance as output. The inputs are assets and number of employees. The output is net income. The purpose of this step is to demonstrate firms utilize economic and labor resources to improve operational efficiency in terms of corporate profits. This step reveals the traditional notion of business operational efficiency measure in its simplest form while ignoring any corporate environmental responsibilities (*H1*).

(2) Based on step 1, *step 2* adds more environment variables into the analysis. The input variables include assets, the number of employees and the environmental conservation cost and the output variable consist of net income and economic benefit of environmental conservation. This step indicates that firms use economic, labor and environmental resources to create the efficiency in terms of corporate profits and economic benefit of environmental conservation. This stage measures the efficiency in terms of business performance against

Table I.
Input and output variables of four-step model using DEA analysis

Step 1 model		Step 2 model		Step 3 model		Step 4 model	
Input	Output	Input	Output	Input	Output	Input	Output
Assets/number of employees	Net income	Assets/number of employees/environmental conservation cost	Net income/economic benefit of environmental conservation	Assets/number of employees/environmental conservation cost	Net income/economic benefit of environmental conservation/CO_2 emission reduction	Assets/number of employees/environmental conservation cost/total CO_2 emission	Net income/economic benefit of environmental conservation

Note: *DMU is indicated the decision-making unit which is the enterprise in this study environmental recycling performance without taking any environmental pollution derived from business activities (*H2*).

(3) To further the evaluation on step 2, *step 3* incorporates the impact of environmental pollution derived from business process. The input variables are assets, the number of employees and the environmental conservation cost and the output variables net income, economic benefit of environmental conservation and CO_2 emission reduction (environmental eco-variables). This step shows that firms use economic, labor and environmental resources to create the efficiency in terms of corporate profits, economic benefit of environmental conservation and CO_2 emission reduction. The objective of step 3 is to measure business operational performance as a part of CO_2 emission reduction (*H3*).

(4) Finally, in *step 4*, environmental eco-variable is changed to the total CO_2 emission. The input variables are assets, the number of employees, environmental conservation cost and total carbon emission. The output variables are net income and economic benefit of environmental conservation. This step reveals that firms use economic resources, labor resources, environmental expenditure and total CO_2 emission to create the efficiency of corporate profits and economic benefit of environmental conservation. Since the emission of carbon dioxide (CO2) is a type of negative output, thus according to the method that is proposed by Scheel (2001), the negative output is treated as the input (*H4*).

4. Empirical result and analysis

4.1 Analysis

From Table II, we found that the result has indicated a positive correlation with significance among firm's environmental conservation cost, net income and economic benefit of environmental conservation, which revealed that enterprises' long-term implementation of the environmental protection activities during the period between 2001 and 2006 has a positive influence on firm's profits. In addition, the relationship between firm's environmental conservation cost and CO_2 emission reduction is positive correlation but without significance which means that firm's environmental spending made impact on CO_2 emission reduction but the effort is still not enough. Moreover, the result also shows a positive correlation between environmental conservation cost and total CO_2 emission. Although the result did not yield statistical significance it is still imperative that firms should continue their effort in making environmental commitment in order to further reduce total CO_2 emission. Based on Table III, the average spending on environmental conservation cost for the 3 industries is around 2.8 billion Yen between 2001 and 2006.

Table IV shows that the ratio of average environmental conservation cost divided by the average revenue is less than 2 percent: 1.83 percent for the chemical industry, 1.25 percent for the automobile industry, and 1.41 percent for the electronic industry. The results implied that the long-term implementation of environmental conservational activities had only a limited impact on Japanese firm's financial bottom line. When considering economic benefit of environmental conservation against assets, electronic industry had the best performance (0.72 percent). In addition,

Table II.
Pearson correlation coefficient matrix of variables measured

	Assets	Number of employee	Environmental conservation cost	Total CO_2 emission	Net income	Economic benefit of environmental conservation	CO_2 emission reduction
Assets	–						
Number of employees	0.798**	–					
Environmental conservation cost	0.592**	0.308	–				
Total CO_2 emission	0.21	0.442*	0.015	–			
Net income	0.810**	0.504**	0.658**	−0.049	–		
Economic benefit of environmental conservation	0.037	−0.001	0.728**	0.066	0.072	–	
CO_2 emission reduction	0.155	0.218	0.164	0.001	0.318	0.275	–

Notes: $n = 32$

Table III.
Descriptive statistics

	Number	Min.	Max.	Average	Standard deviation
Assets (Million Yen)	32	177,731	24,620,587	2,660,880	4,689,958
Number of employees (person)	32	2,682	347,193	55,237	87,684
Environmental conservation cost (Million Yen)	32	580	231,923	28,524	54,285
Total CO_2 emission (thousand tons)	32	9	15,755	1,977	3,570
Net income (Million Yen)	32	16,965	1,312,551	197,497	226,842
Economic benefit of environmental conservation (Million Yen)	32	23	167,696	10,781	29,979
CO_2 emission reduction (thousand tons)	32	58	3,490	1,264	1,300

Table IV. The average information related to environmental protection for three Japanese industries during 2001-2006

	Environmental conservation cost/ revenue (1) (%)	Environmental conservation cost/ operational expense (2) (%)	Economic benefit of environmental conservation (3) (million Yen)	Economic benefit of environmental conservation/assets (4) (%)	CO_2 emission reduction (thousand tons) (5)	Total CO_2 emission (thousand tons) (6)	Total CO_2 emission/ assets (7) (%)
Chemical	1.83	6.74	33,630	0.43	160	2,151	0.16
Automobile	1.25	2.92	17,748	0.08	121	542	0.01
Electronic	1.41	5.34	129,674	0.72	2,744	3,029	0.10

automobile industry had the best result (0.01 percent) when total CO_2 emission against assets.

Table IV only displayed the information of single ratio. To further the analysis, this research adopts DEA method through four-step model.

Table V shows the Kruskal-Wallis test (K-W test) of four-step model for the three Japanese industries. KW test is a tool to distinguish inter-industry difference in terms of operational efficiency (CCR efficiency value). At $\alpha = 0.05$, step 1 to 4 modes, described in Table I, all displayed significant difference (p value is less than 0.05) which indicates that regardless of environment variable, there is a significant difference in terms of business operational efficiency among three industries. However, under more strict significance level $\alpha = 0.01$ with only environmental consideration (namely, models of steps 2, 3 and 4) the results display significant difference among three industries. Thus, at $\alpha = 0.05$, *H1, H2, H3* and *H4* can be accepted, but at $\alpha = 0.01$ level only *H2, H3* and *H4* are accepted. Furthermore, using the Mann-Whitney U test to compare inter-industry efficiency value, the results indicate step 4 model has less p-value than steps 2 and 3 models (see Table VI).

Since it is under different significant levels, step 1 model accepts either the null or the opposite hypotheses; thus, the empirical conclusions are inconsistent. However, according to the result in Table V, at the more strict significant level ($\alpha = 0.01$), step 2, 3 and 4 models will not be yielded any inconsistency based on the empirical evidence. Based on Table VI, the Mann-Whitney U test, at $\alpha = 0.01$, step 2, 3 and 4 models are all consistently pointing to the indifference in business operational efficiency between chemical industry and automobile industry. But results also indicate significant operational efficiency differences between chemical and electronic industry. One of this study's contributions is that the inclusion of environment variables in the evaluation of business operational efficiency has yielded significant inter-industrial difference. In fact according to Table VII, electronic industry actually outperforms both chemical and automobile industry in terms of business operational efficiency value with environmental variables.

This study has further explored on the reason as to why the electronic industry had outperformed the chemical and automobile industry. Following the input and output variables of the proceeding steps 2, 3, and 4 using BCC model, we obtained the BCC

Table V. K-W test of four-step model for three Japanese industries

K-W TEST	Step 1 model	Step 2 model	Step 3 model	Step 4 model
Chi-square	7.367	12.503	12.95	14.497
p-value	0.025	0.002	0.002	0.001

Table VI. Mann-Whitney U test for three Japanese industries

Mann-Whitney U test		Step 2 model	Step 3 model	Step 4 model
Z-test	Chemical vs automobile	−0.378 (0.705)	−0.608 (0.496)	−0.680 (0.496)
(p-value)	Automobile vs electronic	−3.249 (0.001)*	−3.249 (0.001)*	−3.484 (0.000)*
	Chemical vs electronic	−2.719 (0.007)*	−2.785 (0.005)*	−2.948 (0.003)*

Note: *It is significant when the significant level is 0.01 (two-tailed) value as an indicator for technical efficiency. For measurement of scale efficiency, we divided CCR value against BCC value. Operational efficiency was calculated based on the earlier result on technical and scale efficiency. For firms with a rate of 0.85 (inclusive) are classified as operational efficient; on the other hand, firms below 0.3 (including) were treated as operational inefficient. Based on such a scale, we tried to distinguish the proportion of efficient performers in each industry for each year. For industry consists more than 50 percent of efficient performers for the year was indicated as "V", on the contrary, industry with more than 50 percent of inefficient performers for the year was indicated as "X". Based on Table VIII, the technical efficiency for electronic industry did not consistently outperformed the other two industries. However, on Table IX in terms of scale efficiency, electronic industry

Table VII.
Average operational efficiency value for three Japanese industries during 2001-2006

CCR efficiency value	Step 2 model	Step 3 model	Step 4 model
Chemical industry	0.288552	0.369525	0.314579
Automobile industry	0.327685	0.33076	0.353629
Electronic industry	0.656197	0.677356	0.678489

Table VIII.
Comparison with BBC efficiency (technical efficiency) value during 2001-2006

BCC efficiency value	Industry	2001	2002	2003	2004	2005	2006
Step 2 model	Chemical industry						
	Automobile industry	X	X		V	X	X
	Electronic industry	V	V	X	X	V	V
Step 3 model	Chemical industry			X			
	Automobile industry	X	X			X	X
	Electronic industry	V	V			V	V
Step 4 model	Chemical industry						
	Automobile industry	X	X			X	X
	Electronic industry	V	V	X	X	V	V

Notes: V means more than 50 percent of companies possessed better performance; X means more than 50 percent of companies possessed poor performance

Table IX.
Comparison with scale efficiency value during 2001-2006

Scale efficiency value	Industry	2001	2002	2003	2004	2005	2006
Step 2 model	Chemical	X		X	X	X	X
	Automobile						
	Electronic	V	V	V	V	V	V
Step 3 model	Chemical			X	X	X	
	Automobile	X					
	Electronic	V	V	V	V	V	V
Step 4 model	Chemical	X		X	X	X	X
	Automobile						
	Electronic	V	V	V	V	V	V

Notes: V means more than 50 percent of companies possessed better performance; X means more than 50 percent of companies possessed poor performance consistently outperformed the other two industries. As result, electronic industry was able to attain operational efficiency through scale efficiency.

5. Conclusions and suggestions

In light of the ongoing debate between firm's investment on environmental conservation and operational efficiency, this study tries to provide further empirical evidence on the debate through the case of Japan. Based on our analysis, we find a positive correlation with statistical significance among firm's environmental conservation cost, net income and economic benefit of environmental conservation, which revealed that firm' long-term implementation of environmental conservation has a positive influence on firm's profits in the case of Japan between 2001 and 2006. In addition, the relationship between firm's environmental conservation cost and CO_2 emission reduction is positively correlated but without significance which means that firm's environmental spending made impact on CO_2 emission reduction but the effort is still not enough. Moreover, the result also shows a positive correlation between environmental conservation cost and total CO_2 emission. Although the result did not yield statistical significance it is still imperative that firms should continue their effort in making environmental commitment in order to further reduce total CO_2 emission.

During 2001-2006, for the three selected Japanese industries (chemical, automobile and electronic), the ratio of average environmental conservation cost divided by the average revenue was less than 2 percent. The results indicate that the impact of long-term environmental conservation activities on profit is limited for the selected Japanese firms.

Finally, one of the objectives of this study is to examine the impact of firm's spending on environmental conservation on firm's operational efficiency. At $\alpha = 0.05$, *H1, H2, H3* and *H4* can be accepted, but at $\alpha = 0.01$ only *H2, H3* and *H4* are accepted. When we take industry's environmental responsibilities into account, especially when we refined our operational efficiency requirement at $\alpha = 0.01$, we observed significant inter-industry differences in terms of environmental spending, recycling, and CO_2 emission reduction. Furthermore, when applying the Mann-Whitney U test to compare inter-industry efficiency value, the results indicate step 4 model has less *p*-value than steps 2 and 3 models.

This result suggests that firm's operational efficiency differs among industries with responsible consideration of environmental conservation under the more strict significant level. Furthermore, using the Mann-Whitney U test to compare inter-industry efficiency value, the results indicate step 4 model has less *p*-value than steps 2 and 3 models indicating step 4 model is more effective in distinguishing inter-industry difference in terms of operational efficiency.

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About the authors

Lopin Kuo is an Associate Professor of Accounting at TamKang University in Taiwan. Kuo's research interests involve: activity-based costing, corporate governance, performance evaluation to environmental management, environmental disclosure and legitimacy, sustainability education.

Shihping Kevin Huang is an Assistant Professor of Management at National Sun Yat-sen University. Huang's current research involves environmental disclosure, corporate social responsibility, and education for sustainability.

Yen-Chun Jim Wu is based in the Department of Business Management, National Sun Yat-Sen University, Kaohsiung, Taiwan. Yen-Chun Jim Wu is the corresponding author and can be contacted at ycwu@faculty.nsysu.edu.tw