Energy Economics 45 (2014) 537–551

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

Radial and non-radial approaches for environmental assessment by Data Envelopment Analysis: Corporate sustainability and effective investment for technology innovation

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ARTICLE INFO

Article history:
Received 25 May 2014
Received in revised form 21 June 2014
Accepted 17 July 2014
Available online 19 August 2014

JEL classification:
C60
C68
M52

Keywords:
Environment
Energy
DEA
Investment
Technology innovation
Corporate sustainability

ABSTRACT

Environmental assessment and protection are important concerns in modern business. Consumers are interested in corporate effort and investment for environmental protection. It can be easily imagined that they avoid purchasing products from dirty-imaged companies even if their prices are much less than the ones produced by green-imaged companies. A green image is recently a very important concern for corporate survivability in a competitive global market. By extending previous works on environment assessment and corporate sustainability, where companies need to consider both economic prosperity and pollution prevention in their operations, this study discusses a new use of Data Envelopment Analysis (DEA) for environmental assessment by utilizing its radial and non-radial measurements. The proposed radial and non-radial approaches may guide corporate leaders, managers and policy makers by providing not only quantitative assessment on their efforts for environmental protection but also information regarding how to invest for technology innovation on abatement of undesirable outputs. The empirical investigation identifies that the green investment in U.S. energy industry is useful for improving its unified (operational and environmental) performance if operational performance is measured by ROA (Return on Assets) and an amount of CO_2 emission reduction because the industry is the largest emitter among seven industry sectors examined in this study. The green investment makes it possible that firms can increase their net incomes by a good corporate image. However, if the financial measure is replaced by a corporate value (i.e., Tobin's q ratio, mainly measured by stock price), the energy industry does not exhibit the best investment opportunity because the effect of green investment is limited on enhancing its corporate value. The energy industry is a very large process industry so that the green investment does not immediately increase its corporate value as found in the other industrial sectors such as information technology industry.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC: http://ipcc.ch/index.htm), established by United Nations environmental program, has recently reported the policy suggestion in April (2014) that it is necessary for us to reduce an amount of Greenhouse Gas (GHG) emissions, in particular CO_2, by 40–70% (compared with 2010) until 2050 and to reduce to the level of almost zero by the end of this 21st century via shifting our current systems to energy efficient ones. Otherwise, it is warned that global warming and climate change will destroy our natural and socio-economic systems. Consequently, we will have to face various risks (e.g., heat waves, droughts, floods, food crisis as well as damages to human, social and economic systems) on the earth. We will lose social sustainability whose achievement requires managing our economic developments and environmental protections like synchronized swimming.

Although it is almost impossible to establish such societies without producing any GHG emissions, global warming and climate change have been influencing corporate behaviors and operations because all firms need to change their businesses to adapt various regulation changes on preventing industrial pollution at federal, state and local governments. Furthermore, more environmentally conscious consumers refuse to purchase products and services from dirty-imaged companies even if their prices are much less than those of green-imaged companies. The conventional business philosophy and practice (e.g., less expensive price and high quality) do not function anymore in modern business because all firms belong to part of a world-wide trend toward the development of a sustainable society.

The benefits from adapting GHG technologies range from intangible ones, such as improved public images as green corporate citizen, to

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http://dx.doi.org/10.1016/j.eneco.2014.07.024
0140-9883/

measurable ones such as their lower direct and indirect emission levels. Unfortunately, acknowledging the importance of reducing GHG emissions, many companies often misunderstand a business linkage among the cost of GHG technologies, their overall performance enhancements and business opportunities. It may be true in a myopic horizon that environmental protection needs a large amount of investment for GHG reduction. The investment does not produce any direct benefit to firms.

However, such a business concern may be different in a long term horizon. As discussed by Porter and van der Linde (1995), environmental regulation does not jeopardize corporate performance, rather providing firms with an opportunity to improve efficiency and competitiveness through environmental innovations in processes and products. Such examples can be easily observed in many new products such as hybrid cars, electric vehicles and clean coal generation. In modern business reality, some companies clearly understand the trade-off between their investments for low GHG emissions, including low-carbon technologies, and enhancement in their operational performance. It is easily thought that companies with a green image become more competitive in today's environmentally conscious markets because they are more efficient in reaping benefits from their sustainability by making effective investment in GHG technologies. This clearly indicates that modern corporations in all the industrial sectors need to consider their technology investments on environmental protection and corporate performance enhancement from the perspective of corporate sustainability in short and long term horizons.

A business difficulty, associated with attaining such corporate sustainability, is that corporate leaders and academia do not have a practical methodology to assess the performance of firms in terms of their operational and environmental achievements. Moreover, there is no appropriate methodology that can assist firms in preparing their investment strategies to attain the status of corporate sustainability.

To reply such inquiries, this study proposes a holistic methodology, or Data Envelopment Analysis (DEA), to evaluate the performance of firms from corporate sustainability. See Glover and Sueyoshi (2009) and Ijiri and Sueyoshi (2010) for a description on its historical development. The proposed use of DEA,[1] often referred to as "DEA environmental assessment", has four research tasks to be explored in this study. First, it incorporates three disposability concepts such as natural disposability, managerial disposability and natural & managerial disposability. Outputs and inputs, characterizing their operational and environmental performance, are separated under the three types of disposability. Second, this study investigates the concept of congestion on undesirable outputs in order to identify effective investment for preventing industrial pollution. Third, this study applies the proposed DEA approach for performance evaluation of U.S. firms so that we compare computational results obtained by DEA radial and non-radial approaches. This type of comparison is important in avoiding a methodological bias, often existing in many empirical studies. The methodological bias simply indicates that different methods produce different results. It is necessary for us to examine different methods to prepare policy and/or business suggestions regarding large policy issues such as global warming and climate change. Finally, this study describes implications on investment strategy obtained from the proposed DEA application.

[1] DEA has been extensively used for environmental assessment. Such DEA application can be found in a series of studies (Sueyoshi and Goto, 2009, 2010a, 2010b, 2011a, 2011b, 2011c; Sueyoshi et al., 2009, 2010). An important feature of these studies is that they have developed a computational framework, but lacking a conceptual framework for DEA environmental assessment. The first article, which has discussed the conceptual framework such as natural and managerial disposability, can be found in Sueyoshi and Goto (2012a). Then, the concept of natural and managerial disposability has served a concept basis for proceeding research efforts. See, for example, Sueyoshi and Goto (2012b, 2012d, 2012e, 2012f, 2012g, 2012h, 2012i, 2012j, 2012k, 2013a, 2013c, 2013d, 2014a, 2014b) and Sueyoshi et al. (2013a, 2013b). Moreover, a conventional use of DEA was applied to renewable energy assessment (Sueyoshi and Goto, 2014c) and its combination with other methodology (Sueyoshi and Goto, 2012c).

The remainder of this study is organized as follows. Section 2 provides a literature review on corporate sustainability. Section 3 discusses underlying concepts incorporated into the proposed radial and non-radial approaches. Section 4 describes non-radial DEA models under natural, managerial and natural & managerial disposability. Section 5 describes radial DEA models under the three types of disposability. Section 6 characterizes the shape of a supporting hyperplane in multiple production factors and documents the investment rule for technology innovation on GHG emission reduction. Section 7 applies the proposed DEA models to evaluate the environmental and operational performance of S&P 500 companies and summarizes our empirical results. Section 8 concludes this research along with future extensions.

2. Literature review

According to Sarkis et al. (2010), green supply chain management is classified into eight research groups. Although this study is concerned with corporate sustainability, their classifications are useful in specifying the position of this research by comparing it with the other previous efforts. The eight research groups, reorganized for this study, include (a) business complexity, (b) ecological modernization, (c) information utilization, (d) institutional externality, (e) resource-based view, (f) resource dependency, (g) social network and (h) stakeholder involvement.

Business complexity: First, the concept implies that business complexity is defined through heterogeneity or diversity in environmental factors such as consumers, governmental regulations and technological advancements. Along with an increase in a corporate size, firms have had a difficulty in planning and predicting their business actions, including product return, recycling, product inspection and quality check (Chakravarthy, 1997; Vachon and Klassen, 2006). The concern was also discussed by Sueyoshi and Goto (2010a). Utilizing a data set on 220 Japanese manufacturing firms from 2004 to 2007, so being the total of 853 observations, their study concluded that Japanese firms tried to accumulate capital at the initial stage and then invested the capital for preventing industrial pollution. As a result of their study, the size of firms is very important in understanding their corporate behaviors toward environmental protection. Acknowledging the influence of regulation on firms, their study has also discussed that they cannot precede any strategic step toward corporate sustainability without capital accumulation even under regulation.

Ecological modernization: As an eco-innovation, firms are geared toward achieving industrial development and environmental protection via technology innovation. Regulation has influenced corporate efforts on environmental innovation (Murphy and Gouldson, 2000). Their study has also suggested that manufacturing firms can overcome barriers to innovation and gain operational opportunities for performance improvement. However, as reported by Revell (2007), their corporate efforts have not yielded a major financial benefit. Therefore, it is necessary for an industrial sector to develop a diffusion mechanism in which core large firms motivate first toward environmental innovation and then diffuse their innovation technology to small and medium ones (Hall, 2001).

Information utilization: Firms need to report their environmental performance to outside stakeholders (e.g., customers and equity holders), but they lack full knowledge on products, processes and material flows. Consequently, information imbalance has occurred between firms and outside stakeholders (Simpson, 2010). Information sharing is critical for coordinating between firms and stakeholders in terms of enhancing a corporate image and satisfying regulation requirements (Wong et al., 2009). A difficulty associated with information symmetry and sharing is that all stakeholders need a brief summary which they can easily understand, not detailed and complicated information to indicate the unified (operational and environmental) performance of firms.

Institution externality: It examines how external pressures influence firms to adapt business practice (Lai et al., 2006). The theory can be used