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Investment strategy for sustainable society by development of regional economies and prevention of industrial pollutions in Japanese manufacturing sectors

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ABSTRACT

A balance between industrial pollution prevention and economic growth becomes a world-wide issue to develop a sustainable society in many industrial nations. To discuss the issue, this study proposes a new use of DEA environmental assessment to determine how to effectively allocate capital for developing regional industries. The amount of capital is used to invest for technology innovation for both local economic growth and environmental protection. In this study, the proposed approach separates outputs into desirable and undesirable categories. Inputs are also separated into two categories, one of which indicates an amount of investment on capital assets. The other category is used for production activities. The proposed approach unifies them by two disposability concepts. This study has evaluated the performance of manufacturing industries in 47 prefectures (local government units in Japan) by Unified Efficiency under Natural disposability (UEN), Unified Efficiency under Managerial disposability (UEM) and Unified Efficiency under Natural and Managerial disposability (UENM). The UENM is further separated into its two cases: with and without a possible occurrence on desirable congestion, or technology innovation, on undesirable outputs. This study has empirically confirmed that Japanese manufacturing industries need to make their efforts to reduce greenhouse gas emissions and air pollution substances by investing in technology innovation. Furthermore, most of economic activities are currently located at metropolitan regions (e.g., Tokyo) in Japan. To develop a sustainable society, Japan needs to allocate capital into regions with a high level of investment effectiveness by shifting the manufacturing industries from the metropolitan regions to much promising local areas identified in this study. Such a shift, along with technology innovation, makes it possible to reduce air pollutions in the entire Japan by balancing economic growth and pollution prevention. This empirical study confirms that the proposed approach is useful in both guiding regional planning and developing a sustainable society. It is easily envisioned that the proposed approach is useful for not only Japan but also the other industrial and developing nations.

1. Introduction

After the Great East Japan Earthquake and the nuclear accident at Fukushima Daiichi power plant in March 2011, Japan has been facing a major policy change on its basic energy plan, consequently directing toward more renewable resources and less dependency on nuclear power generation. Along with the policy shift toward a new energy mix after the earthquake in 2011, Japan has been paying serious attention to the climate change and global warming, as expected by the recent agreement discussed in COP 19 organized by the United Nations. See http://www.cop19.org/. Since the Kyoto Protocol came into effect in 2005, the Japanese government promoted environmental policy to reduce the amount of greenhouse gas (GHG) emissions. The policy change has influenced Japanese manufacturing industries that are major contributors to the growth of not only its whole economy but also regional economies. Meanwhile, they are the large producers of GHG emissions such as CO_2. See Greenhouse Gas Inventory Office of Japan (2013).

To develop a sustainable society in Japan, the manufacturing industries need to improve their operational efficiency and simultaneously satisfy governmental regulation on their industrial pollutions. Technology innovation, often arising from environmental constraints, is usually associated with an energy-efficient production system, as discussed by Porter and van der Linde (1995). They stated that corporate efforts for improving the productivity of an entire manufacturing process under environmental regulation resulted in both reducing an energy use and improving productivity. The assertion was often referred to as "Porter Hypothesis" among corporate strategists. The business hypothesis implies that regulation on pollutions does not jeopardize economic prosperity, rather stimulating technology innovation and producing new environment-conscious products.

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In a similar vein, Sueyoshi and Goto (2010a) have investigated 220 Japanese manufacturing firms from 2004 to 2007. The study has confirmed that the manufacturing firms look for their operational performance (so, their profits) at the first stage so that they can gradually accumulate capital to be used for future investment. Then, they invest the accumulated capital for environmental protection. That is the second stage. At the final stage, they attain a high level of operational and environmental performance. Such a business shift is often associated with their corporate sizes and growth rates. In this study, their observation is referred to as "Sueyoshi–Goto (SG) hypothesis".

This research incorporates the implication of both Porter and SG hypotheses into the framework of Data Envelopment Analysis (DEA)[1] to unify the operational and environmental performance. Then, the proposed DEA approach examines the unified performance of Japanese manufacturing industries in 47 prefectures (i.e., local government units which correspond to States in the United States) in Japan. The performance examination serves as an information basis regarding which prefecture we allocate capital assets for technology innovation to develop a sustainable society. That is the purpose of this study. This type of research has never been explored in previous DEA studies.

To attain the research purpose, this study proposes a new use of DEA environmental assessment[2] which combines desirable and undesirable outputs together under two (natural and managerial) disposability concepts which originate from corporate strategy for environmental protection. Inputs are also separated into two categories under the two disposability concepts. The structure of disposability concepts is reorganized and unified together to measure the performance of manufacturing industries in Japanese prefectures. An important feature of this study is that the proposed unification provides us with a new computational scheme for guiding effective investment strategy which stimulates technology innovation for not only enhancing economic growth but also reducing environmental pollution.

The proposed methodological development of DEA cannot be found in a series of previous studies such Goto et al. (forthcoming), Sueyoshi and Goto (2010a,b, 2011a,b,c,d, 2012a,b,c,d,e,f,g,h,i,j,k, 2013a,b,c,d,e, 2014) and Sueyoshi et al. (2009, 2010, 2013a,b) because all of them do not associate investment strategy with their efficiency measurements. Thus, this study is an extension of the previous DEA works, in particular in identifying an influence of investment on technology innovation to enhance the level of sustainability.

[1] Glover and Sueyoshi (2009) discussed the contributions of Professor W. W. Cooper who invented DEA from the linkage of L1 regression proposed in 18th century. Both DEA and L1 regression have a close linkage in these developments. See also Ijiri and Sueyoshi (2010) that discussed the contributions of Professor Cooper from the perspective of social economics and social accounting, both provided DEA development with a conceptual backbone. The use of DEA has various extensions such as methodological comparisons (Sueyoshi and Goto, 2011b,c, 2012h,j,k). A guideline on the use of DEA can be found in Sueyoshi and Sekitani (2009), Sueyoshi and Goto (2013b) and Sueyoshi et al. (2013a). Unfortunately, DEA is one of the methodologies which many researchers, in particular production economists, have been misusing in guiding various policy issues including the current energy problems.

[2] Dyckhoff and Allen (2001) discussed that a non-radial model was useful as an ecological efficiency measure. All production factors are classified by good, natural and bad inputs/outputs. Korhonen and Luptacik (2004) started from a conventional radial model, so-called CCR-ratio form and then discussed how to measure ecological efficiency. Kumar (2006) discussed a radial model to measure a Malmquist–Luenberger index in a time horizon. The study compared a frontier shift of efficiency frontiers from 1972 to 1992. Liang et al. (2004) used a conventional radial model to identify differences in solving an industrial pollution problem in Anhui province of China. Oude Lansink and Bezlepkin (2003) used DEA to measure the efficiency of greenhouse firms in the Netherlands over the period 1991–1995, based upon the concept of weak and strong disposability. Picazo-Tadeo et al. (2005) applied the conventional DEA approach to measure the performance of Spanish producers of ceramic pavements by using the concept of weak and strong disposability. Ramanathan (2002) investigated the amount of CO_2 emission in developing nations. The study found that Luxembourg, Norway, Sudan, Switzerland and Tanzania were efficient countries, followed by India and Nigeria. Central European countries such as Poland, Romania, Czech Republic, and South Africa belonged to the least efficient group according their study. Zaim (2004) measured the environmental performance of manufacturing in American states, examining their Malmquist quantity indexes. Zhou et al. (2008) summarized previous articles related to DEA environmental studies in the area of energy.

The remainder of this research is structured as follows: Section 2 summarizes underlying concepts used in this study. Section 3 discusses formulations for unified efficiency measures. Section 4 extends these concepts by considering an occurrence of desirable congestion. Section 5 applies the proposed approach to examine the performance of Japanese manufacturing industries in 47 prefectures. Section 6 summarizes this study along with future research extensions.

2. Underlying concepts

2.1. Nomenclatures

First of all, this study summarizes all abbreviations and nomenclatures in the following manner: DMU: Decision Making Unit, DEA: Data Envelopment Analysis, URS: Unrestricted, UE: Unified Efficiency, UEN: Unified Efficiency under Natural disposability, UEM: Unified Efficiency under Managerial disposability, UENM: Unified Efficiency under Natural and Managerial disposability, RTS: Returns to Scale, DTS: Damages to Scale, DTR: Damages to Return, DC: Desirable Congestion, UC: Undesirable Congestion, GPP: Gross Prefecture Product, L: Labor index, E: Energy consumption, K: Capital index, X: A column vector of m inputs, G: A column vector of s desirable outputs, B: A column vector of h undesirable outputs, d_i^x: An unknown slack variable of the ith input, d_r^g: An unknown slack variable of the rth desirable output, d_f^b: An unknown slack variable of the fth undesirable output, λ: An unknown column vector of intensity (or structural) variables, R_i^x: A data range related to the ith input, R_r^g: A data range related to the rth desirable output, and R_f^b: A data range related to the fth undesirable output.

2.2. Natural and managerial disposability

To discuss DEA environmental assessment, this study needs to describe two strategic concepts related to environmental protection. As discussed by Sueyoshi and Goto (2012a,b, 2013c) and Sueyoshi et al. (2013a,b), one of the two strategic concepts, referred to as "natural disposability", indicates that a DMU decreases the directional vector of inputs to decrease the directional vector of undesirable outputs. Given the reduced vector of inputs, the DMU increases the directional vector of desirable outputs as much as possible. This study considers the natural disposability as limited adaptation to a change on environmental regulation. This type of disposability belongs to conventional efficiency enhancement where the DMU attempts to attain an efficiency frontier.

The other strategic concept, referred to as "managerial disposability", indicates an opposite case of the natural disposability in terms of the direction of an input vector. In the disposability concept, a DMU increases the directional vector of inputs to decrease the directional vector of undesirable outputs by technology innovation (e.g., clean coal technology in an electricity industry) and/or a managerial change (e.g., a use of coal combustion with less CO_2 emission). Given the increased input vector, the DMU increases the directional vector of desirable outputs as much as possible under new technology and/or management. This study considers the managerial disposability as positive adaptation to a change on environmental regulation. The managerial disposability is often accomplished by investment into facilities for production and environmental protection. Although this study does not address the production cost minimization in an explicit manner, the technological innovation and environmental protection are associated with long-term cost saving through increased competitiveness and successful adaptation to environment-oriented business conditions.

It is important to note that the research of Porter and van der Linde (1995) has conceptually discussed the importance of managerial disposability. Meanwhile, this study analytically discusses the concept and its related measurement by incorporating it into DEA. Thus, the two studies have a major difference in the methodology development.

Fig. 1 visually describes the relationship between desirable and undesirable outputs under the two types of adaptation to regulation. The