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Measuring the efficiency of the investment for renewable energy in Korea using data envelopment analysis

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ABSTRACT

New and renewable energy (NRE) has been paid much attention as a core alternative energy that can respond to the depletion of fossil fuel, the global movement to address climate change, and recent high oil prices because it is more environment-friendly and sustainable than fossil fuel. As the scale of investment in NRE has increased, an intriguing issue of the *efficiency* of the investment has been raised since strategic selection and focused investment allows policy goals to be achieved with limited resources and budget. Particularly, since there are various kinds of renewable energy sources, the efficiency of each NRE technology must be examined to find suitable technologies for the environments of each target country and to eventually realize efficient investments in NRE. The purpose of this paper is to evaluate the investment efficiency of three NRE technologies – wind power, photovoltaic, and fuel cells – with the DEA (data envelopment analysis) method considering the two policy objectives of public investment, technological development and wider dissemination of NRE in Korea. The results indicate that wind power is the most efficient renewable energy in Korea from the perspective of government investment.

Contents

1. Introduction

New and renewable energy (NRE) is a core alternative energy that can respond to the depletion of fossil fuel, the global movement of climate change, and recent high oil prices because it is more environment-friendly and sustainable than fossil fuel. Despite economic depression after financial crisis in 2008, the global scale of investment in NRE reached an all-time high of $279 billion in 2011 then slightly decreased in 2012 to $244 billion, which is nonetheless the second highest NRE investment to date. Regionally, the largest investor country in the world is China, having invested $66.6 billion in 2012; the US followed with $36 billion, while the EU as a whole invested $79.9 billion [1].

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This indicates that most advanced countries increase their investments in NRE based on the long-term perspectives of not only energy securities, but also sustainable economic development. In particular, for countries who have been highly dependent upon energy imports, such as Korea, it is imperative to promote the development and the utilization of NRE in order to strengthen energy self-reliance.

Many countries, including Korea, have presented their own national strategic plans for the development and dissemination of NRE technology. The Korean government has been establishing national plans for NRE with a 10-year planning term, and the third plan is now in progress. The first such basic plan (1997–2006) focused on the technological development of NRE, and the second basic plan for NRE technology development, utilization, and dissemination (2003–2012) covered an efficient dissemination strategy as well as technology development. In the third plan (2009–2030), the Korean government established the target penetration rate of NRE among primary energy sources as 11% by 2030. The third plan emphasizes policy integration between technological development and dissemination of NRE in order to resolve the problems that arose in the execution of prior plans such as budget deficiency and the overemphasis on dissemination-related policy. Public investment in NRE of Korea was 854.6 billion KRW[1] in 2010, 7.5 times larger than in 2003, and NRE-related investments are expected to increase continuously.

As the scale of investment is increasing, an intriguing issue of the *efficient allocation* of the public funds in NRE has been raised [2] since strategic selection and focused investment allows the policy goals of NRE to be achieved with limited resources and budget. In the case of NRE, since there are various kinds of energy sources such as wind, solar, biomass, fuel cells, etc., the efficiency of each NRE technology must be examined to choose suitable technology for the particular environments of each target country and to eventually realize efficient investment. The efficiency analysis should be performed in both systematic and scientific manners in order to produce meaningful results which provide policy makers with critical decision-making information regarding efficient resource allocation for NRE. However, there is no previous study in which a national NRE investment system is systematically defined and the investment efficiency analyzed using a quantitative methodology like multiple criteria decision analysis (MCDA) or data envelopment analysis (DEA).

In general, NRE policy is composed of technology development and market dissemination; therefore, investments are also divided into those two areas. Hence, whether or not a country's NRE policy is successful should be judged on the basis of both aspects. This implies that, when the efficiency of NRE-related investment is evaluated, the NRE technology development and their dissemination in energy market should be considered together in a single investment system model [3]. However, the studies conducted thus far on the efficiency of NRE-related investments dealt with the technology development and market dissemination as two separate entities [4–10].

The purpose of this paper is to evaluate (with the DEA method) the investment efficiency of three NRE technologies – wind power, photovoltaic, and fuel cells – considering the two policy objectives of public investment, technological development and wider dissemination of NRE in Korea. We present a system model of public investments in NRE that includes relevant elements of both technology development and dissemination policies. Based on this system model, this paper analyzes the efficiencies of public investments for NRE technologies by using DEA to measure the efficiencies of each NRE technology using the available empirical data of Korea. The remainder of paper is organized as follows: Section 2 provides a brief review of relevant literature. Section 3 explains the investment system model on which the subsequent efficiency analysis is based, and introduces the DEA model used in this paper. Section 4 presents the data and the results of the analysis. Finally, Section 5 concludes this study with a discussion of policy implications.

[1] Monetary unit of Korea. The exchange rate for $1 is about 1100 KRW in 2014.

2. Literature review

DEA is a non-parametric methodology for quantitatively analyzing efficiency, particularly the relative efficiencies of a set of comparable entities, often called decision-making units (DMUs). In general, each DMU performs the same function by transforming multiple inputs into multiple outputs, which are characterized by a system model. DEA has been extensively applied to empirical studies of efficiency analysis due to its advantages; it does not require any prior assumptions about the underlying functional relationships between inputs and outputs, and it is applicable to systems with various kinds of input or output variables of different units. Since the late 1980s, DEA has been accepted as a major frontier technique for benchmarking energy sectors in many countries [11], and a considerable set of literature has been produced.

Beginning in the middle of 2000, studies have applied DEA to the efficiency analysis of NRE areas. Those studies can be categorized into two themes: efficiency analysis of NRE power generation companies (or facilities), and efficiency analysis of alternative NRE sources or technologies. Among the former category, Barros [12] estimated the changes in total productivity for the period 2001–2004, breaking this down into technically efficient change and technological change by applying DEA to one of the renewable energy sources in Portugal, the hydroelectric energy generating plants of Energias de Portugal (EDP; an electricity company). Barros [12] concluded that the hydroelectric plants exhibited average improvement in technical efficiency and technological change. The increase in technological change was higher than the increase in technical efficiency. In addition, his results indicated that EDP should adopt an internal benchmarking procedure to upgrade the efficiency of the ineffective units. Jha and Shrestha [13] evaluated the performance of hydropower plants owned by Nepal Electricity Authority (NEA) during the financial year 2001–2004 period using DEA with three inputs (the installed capacity of the plant, total operations and maintenance (O&M] expenditure, and the number of employees) and three outputs (energy generated by the plant, winter peaking capacity, and summer peaking capacity). Madlener et al. [14] performed an assessment of 41 agricultural biogas plants located in Austria to determine their relative performance in terms of economic, environmental, and social criteria and corresponding indicators. DEA and MCDA techniques were used to measure the performance of biogas plants with two inputs (labor and organic dry substance) and three outputs (electricity, heat, and greenhouse gas emissions).

The previously mentioned papers analyzed the efficiency at a plant or facility level, but Chien and Hu [15] applied DEA to compare the efficiencies of NRE technology at the country level. They analyzed the effects of renewable energy on the macroeconomic technical efficiency of 45 countries during the 2001–2002 period using DEA with three inputs (labor, capital stock, and energy consumption) and a single output (real GDP). Furthermore, dividing 45 DMUs into OECD member-countries and non-member countries, Chien and Hu [15] concluded that OECD countries have higher technical efficiency in renewable energy than non-OECD countries. Furthermore they found that OECD countries have a higher share of geothermal, solar, tide, and wind fuels within their