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Economic and Environmental assessment: EU cross-country efficiency ranking analysis

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Abstract

This article aims to estimate and compare the efficiency of 26 different European Countries over 2001 and 2012, using Data Envelopment Analysis (DEA) technique. Both output-and input-oriented models were used in order to see if efficiency rankings change. In the input oriented model the inputs used were capital (K), labor (L), renewable energy (R) and fossil fuel (F). In the output oriented model the inputs considered were GDP/L, GDP/K, F/GDP and R/GDP (share of renewable energy in Gross Domestic Product (GDP)), and for both the output considered is GDP per greenhouse gases (GHG) emissions. Our results show that economic and environmental estimates for these European countries change if we propose different input or output-oriented models. It changes mainly in terms of years and technical efficiency versions. While some countries succeeded in terms of National Renewable Energy Action Plans, others observed a ranking decrease through time, thus suggesting that a higher emphasis should be provided in the accomplishment of European Environmental Policies.

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1. Introduction

Eco-efficiency (EE) is synonymous of increasing the value of a good or service, optimizing resources use and reducing environmental impacts. OECD [1] defines it as “the efficiency with which ecological resources are used to meet human needs” and for Picazo-Tadeo et al. [2] it is “the ability of firms, industries or economies to produce goods and services while incurring less impact on the environment and consuming fewer natural resources”. More recently, Robaina-Alves et al. [3] study the problem of 27 European countries in two distinct periods (2000-2004 and 2005-2011) to account for the Kyoto Protocol in 2005. The authors specified a new stochastic frontier model where the ratio between Gross Domestic Product (GDP) and Greenhouse gases (GHG) emissions is maximized given the

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values of fossil fuel consumption, renewable energy consumption, capital and labor as inputs. Their empirical results show the most efficient countries (Portugal, Slovakia, Hungary and Ireland) and the least efficient ones (Bulgaria, Italy, Romania and Denmark) and they noticed that there has been a great effort by some countries in the second period of the analysis to converge to the efficiency frontier. Countries that are more eco-efficient, like Sweden, Cyprus, Latvia and UK are countries for which GDP grew at more moderate rates (on average between -1% and 2%). However the authors only account for the output maximization.

To support the environmental policymaking in Europe it is necessary to have indicators of economic and environmental efficiency, to compare the evolution of EE among countries, set goals and to simultaneously implement effective environmental taxation policies (whose aim is to justify the level of differences in goal commitment harmonization of environmental taxation policy in the EU). These propose justify why it is very important to consider simultaneously in the analysis both energy and non-energy resources in energy and environmental efficiency.

In the present study, we try to evaluate the resource and environment efficiency or EE of 26 European countries using Data Envelopment Analysis (DEA) both by minimizing inputs (input-oriented model) and maximizing outputs (output-oriented model). The input orientation keeps the output fixed and explores the possible average proportional reduction in the use of inputs. On the other hand, the output oriented model keeps the input constant and measures the possible proportional growth over outputs.

Considering these two options of economic and environmental performance valuation in Europe we want to confirm if both options drive to different or similar performance results and of positioning in the ranking at the level of European eco-efficiency. Similar to Robaina-Alves et al. [3] technical efficiency was estimated and the output is the GDP/GHG ratio. Thus, the estimation of technical efficiency is also a measure of eco-efficiency, just by replacing CO2 by a composite good of environmental pressures (GHG as do Schmidheiny and Zorraquin, 1996).

The non-parametric DEA has been extensively used in the empirical literature at the macro level operation management performance evaluation as well as a solution to solve and evaluate the level of productivity in panel European countries. So, we will use the solutions of the linear programming problem in order to identify efficiency scores and ranking the countries evaluation position. First,, we evaluate resource and environment efficiency (Eco-efficiency) problem of European countries according to the output variable and some inputs following Robaina-Alves et al. [3], and then we analyze the period 2001-2012 (before and after Kyoto commitment). This can be useful to verify if GDP, GHG emissions, fossil fuel consumption, renewable energy consumption, capital and labor act as key determinants of different efficiency levels among European countries, and contribute to a best design of environmental policies.

The article is composed of five sections. After this introduction, section 2 covers the literature review, while the methodology used is presented in section 3. Results and their respective discussion are presented in section 4 and finally, conclusions are presented in section 5.

2. Literature Review

DEA techniques have already been used to study EE of countries and/or economic sectors. Chang [4] argues that energy is an essential and crucial input factor in the production process, which had also been assessed by Stern [5], Oh and Lee [6], [7], Ghali and El-Sakka [8], Beaudreau [9] and Wei et al. [10]. Wei et al. [10] used DEA to analyze the energy efficiency of China's iron and steel sector, and all the inputs considered were energy factors (fuel oil, natural gas, electricity, coal, and coke). Later, Shi et al. [11] argued that only the energy input in a production process is unable to produce any output. As such, other input factors should be considered together with energy inputs in the process of estimating energy efficiency in the production process. Patterson [12] introduced the conventional energy efficiency index, which is viewed as the partial-factor energy productivity index that disregards the substitutability between the energy inputs and the non-energy inputs, such as labor employment and capital stock. Other works, like Hu and Wang [13], Hu and Kao [14], Han et al. [15], Honma and Hu [16], [17], Shi et al. [11], Zhang et al. [18] and Chang [19], [4], emphasized total-factor energy productivity.

Chang [4] considers the concept of maximized energy reduction to model the energy productivity index by decomposing it into energy technical change and energy efficiency change. The author uses data from the eight SADC (Southern Africa Development Community) to estimate their energy efficiency, energy productivity change,

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