



# The economic and environmental efficiency assessment in EU cross-country: Evidence from DEA and quantile regression approach



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## ABSTRACT

This article aims to estimate the efficiency of 26 different European Countries over 2001 and 2012 comparing their performance. Data Envelopment Analysis technique is used in a first step to evaluate the performance of each European country. The output-oriented model was used with two specifications (Variable and Constant Returns to Scale) including as inputs labour and capital productivity, the weight of fossil energy and the share of renewable energy in GDP (gross domestic product), being the output GDP per GHG (greenhouse gases) emissions. In a second step, the quantile regression technique was used, to explain different efficiency scores through variables as Environmental Taxes Revenues, Resources Productivity and Domestic Material Consumption. Results indicate that share of renewables and non-renewable energy sources are important to explain differences in emissions. They suggest a significant change in the trend of economic and environmental efficiency in European countries and put forward the high disparities existing among them. Policy recommendations point for the need of higher steps if the goal is to equal countries efficiency scores. Moreover, environmental tax revenue effects are negatively stronger in less efficient countries, whereas also exerting negative influence over those more eco-efficient. Transport taxes affect negatively more eco-efficient countries and positively less eco-efficient countries. Energy taxes only seem to positively influence the lower eco-efficient countries. There is also evidence for a negative premium of efficiency considering domestic materials consumption. Finally, resources productivity shows a positive and significant influence independently of the country technical eco-efficiency level.

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## 1. Introduction

Eco-efficiency main goals are to increase the value of a good or service, optimize resources use and to reduce environmental impacts. It was defined by OECD (1998) as “the efficiency with which ecological resources are used to meet human needs” and by Picazo-Tadeo et al. (2011) as “the ability of firms, industries or economies to produce goods and services while incurring less impact on the environment and consuming fewer natural resources”.

Robaina-Alves et al. (2015) study the eco-efficiency 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 GDP (gross domestic product) and GHG (greenhouse gases) emissions is maximized given the values of fossil fuel consumption, renewable energy consumption, capital and labour 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. This period coincides with the period after the ratification of the Kyoto protocol. Those with average growth rates between 4% and 8% are among the least efficient, from a technical and environmental perspective, and those that are more eco-efficient, are countries for which GDP grew at more moderate rates (on average between –1% and 2%).

In this article, we have two objectives: 1) to analyze the eco-efficiency of the European countries, in a comparative way, through a ranking, and the evolution of this efficiency over time; 2) to see what variables affect this eco-efficiency. We try to evaluate the eco-efficiency of 26 European countries as Robaina-Alves et al. (2015) do, but instead of using absolute values, for ranking establishment we use ratios. The use of ratios in the inputs is justified by the use of the variable output also as a ratio, to which relative variations in the inputs imply relative variations in the output, hence to guarantee this consistency in the input-output relation in the optimization problem. We also contribute to previous empirical

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findings because instead of only establishing a ranking in terms of levels of eco-efficiency differences, we try to explain through several variables the ranking differences (namely, fiscal, production and domestic material consumption variables). A final difference respects to the way estimations are to be performed.<sup>1</sup>

For environmental policymaking purposes, it is necessary to have indicators in this context. That is, indicators of economic and environmental efficiency, to compare the evolution of eco-efficiency 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 European Union (EU)). These aims justify why it is very important to consider simultaneously in the analysis the energy and non-energy resources productivity, as well as the environmental taxation revenues in every country.

With this in mind, the present article uses the non-parametric Data Envelopment Analysis (DEA), which has been extensively used in the empirical literature at the macro level operation management performance evaluation. An additional contribution to previous empirical findings is that we look at the efficiency drivers in a two-stage process, focusing directly on the causes of technical efficiency. Therefore, during the first phase we identify eco-efficiency scores and rank European countries, according to the output variable and some inputs following Kuosmanen and Kortelainen (2005), Picazo-Tadeo et al. (2011), Robaina-Alves et al. (2015) and Rashidi et al. (2015). In a second phase, we proceed with the estimation of a quantile regression to assess the impact of other determinants, such as, environmental taxes revenue (as indicated in Filipovic and Golusin, 2015), including energy taxes, transport taxes and taxes on pollution/resources. We add also resources productivity and domestic materials consumption into these determinants to understand if these explanatory variables are able to explain economic and environmental efficiency levels.

The article is composed of six sections. After this introduction, Section 2 covers the literature review and presents the tested hypothesis, while the methodology used in this article is presented in Section 3. Results and discussion are presented in Sections 4 and 5, respectively. Finally, conclusions are presented in section 6.

## 2. Literature review and hypotheses

Eco-efficiency of countries and/or economic sectors have already been assessed through DEA techniques. For example, Haynes et al. (1993) measure technical efficiency in pollution prevention activities, using chemical as input and chemical waste as output, among other traditional inputs and outputs. Picazo-Tadeo and Prior (2009) use DEA and directional distance functions to conclude that intensive technology economic activities can diminish environmental damages without compromising output maximization.

Literature suggests the existence of a relationship between economic growth and environmental degradation (or inversely with the level of eco-efficiency). This relationship could be positive before economies cross a certain level of income (Kuznets, 1955). Reaching a 'sustainable development' is possible, thus turning economic growth compatible with environmental quality, after that certain level of income (Hu et al., 2011). The ecological modernization theory suggests that through time the economic impact

on the environment should decrease, with higher probabilities of occurrence in economically developed countries, thus increasing eco-efficiency. But recently, Jorgenson (2016) concluded that economic development might decrease the environmental degradation even with higher levels of economic growth. The author argues that the economy development or GDP growth might continue harming the environment.

In this framework, DEA has been used for cross-country or cross-regions and over time comparisons of eco-efficiency like in Taskin and Zaim (2000). The authors measure eco-efficiency for 52 countries to conclude that high-income countries are more efficient than low and middle-income countries but they have not noticed major changes through time in none of the groups. Other studies using DEA for eco-efficiency evaluation can be pointed as follows. Yang et al. (2015) measure the efficiency of China regions using DEA. In addition, Chen et al. (2015) use DEA to evaluate the environmental efficiency of Chinese provinces. Yin et al. (2014) use eco-efficiency as an indicator to measure urban sustainable development cities using DEA, showing that the inefficient cities are located in the Southwest and Northwest of China. Zhang et al. (2015) measure ecological total factor efficiency incorporating environmental technology effects and including heterogeneity into Chinese regions. Results point for a significant evidence that provinces are not performing at high ecological energy efficiency level. Allowing for dynamic effects and using panel data (DEA window analysis – Charnes and Cooper, 1985), Halkos and Tzeremes (2009) calculate the eco-efficiency for 17 OECD countries constructing an efficiency ratio<sup>2</sup> also used by Zaim et al. (2001) and Zaim (2004).

Wang et al. (2012) estimate the environmental efficiency, economic efficiency, economic environmental efficiency and two-stage efficiency of different provinces in China by considering carbon dioxide (CO<sub>2</sub>) emissions. Empirical results show that the environmental and economic efficiency of China are generally low and there are comparatively large differences in different areas. The authors notice that when desirable outputs are adjusted to the optimal level, some provinces have still the possibility to further reduce CO<sub>2</sub> emissions. They conclude that about half of the provinces are found to be in the status of high incoordination between environment and economy. Chen et al. (2015) investigate the horizontal and vertical difference of environmental efficiency in six Chinese regions and among years using the DEA technique. Results show a high statistical and significantly evidence to support the environmental policies adjustment into different regions.

Eco-efficiency has been studied not only at the country or regional level, but also at the sectoral level. Picazo-Tadeo et al. (2011, 2012) analyze eco-efficiency in the agricultural sector. Previously, Mandal and Madheswaran (2010) studied eco-efficiency in the cement industry of India. Moreover, Kuosmanen and Kortelainen (2005) analyzed the eco-efficiency of road transport in Finland through four different types of environmental pressures. More recently, Egilmez et al. (2013) use economic input-output life cycle assessment (Joshi, 1999) and DEA to measure eco-efficiency in US manufacturing sectors. Rashidi et al. (2015) use as energy inputs coal and petroleum consumption, non-energy inputs, labour force and precipitation average, and as outputs, a desirable output and undesirable CO<sub>2</sub> emissions. They construct two informative indices (energy saving potential and undesirable output abatement potential) to study the relationship between energy inputs consumption and undesirable outputs production. Empirical results allowed them to conclude that countries producing high undesirable outputs may not operate in an eco-efficient way turning them able to have extreme potential to save energy resources. They also

<sup>1</sup> As in Robaina-Alves et al. (2015), technical efficiency was estimated and the maximized output is the GDP/GHG ratio. It should be noticed that the estimation of technical efficiency is a measure of eco-efficiency, just by replacing CO<sub>2</sub> by a composite good of environmental pressures (GHG as do Schmidheiny and Zorraquin, 1996).

<sup>2</sup> Good efficiency through good output, due to a poor measure of efficiency using a bad output.

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