The Kuznets curve and the effect of international regulations on environmental efficiency

Baris K. Yörük
Boston College

Osman Zaim
Bilkent University

Abstract

This paper extends the results of series of papers, i.e., Zaim (2004) and Yörük and Zaim (2005a, 2005b). We construct an environmental efficiency index for OECD countries and establish an environmental Kuznets curve relationship between environmental efficiency and income. We then investigate the effect of an international protocol on reducing global emissions on the environmental efficiency.

1. Introduction

The environmental Kuznets curve hypothesis claims that there exists an inverted U-type relationship between the level of pollution emissions and income. The economic intuition behind this result is that once a country reaches a certain standard of living, concerns about environment become increasingly pronounced and necessary institutional, legal, and technological regulations take place to reduce relevant emissions to desirable levels. To investigate the existence of a Kuznets curve relationship, a common methodology adopted in the literature (Grossman and Krueger, 1995; Selden and Song, 1994; Holtz-Eakin and Selden, 1995) has been a trial and error approach in which different functional forms are estimated to obtain a statistically significant fit between some measures of environmental efficiency and per capita income levels. The results of these studies support the Kuznets relationship for air pollutants, i.e., sulphur dioxide and suspended particulates, but they are mixed for water pollutants. In addition, none of these studies addresses the impact of aggregate pollution, i.e., the effect of air and water pollutants together.

This paper contributes to the previous empirical literature on the environmental Kuznets curve hypothesis in three aspects. First, following the studies that try to quantify the opportunity cost of adopting a more environmentally desirable production process, i.e., Färe *et al.* (1989), we recognize the underlying production mechanism, which converts inputs into outputs and pollutants. Second, in computing an environmental efficiency index, we assess the aggregate effect of environmental degradation that consists of both air and water pollution. Hence, we investigate the relationship between the aggregate effect of pollutants and income rather than addressing the relationship between a single pollutant and income. Third, we show the positive effect of an international protocol on reducing global emissions, the United Nations Framework Convention on Climate Change (hereafter, UNFCCC) that has been ratified by all OECD countries by 1994[1], on our environmental efficiency index.

The rest of this paper is organized as follows. Section two describes the methodology used. Section three presents the data, and the findings relating to environmental efficiency, the Kuznets curve, and the effect of the UNFCCC on environmental efficiency. Section four concludes.

2. Methodology

Following Zaim (2004), we construct an environmental efficiency index to measure the environmental performance of the OECD countries. The basic idea of this method relies on the construction of a quantity index of undesirable outputs, i.e., pollutants, and a quantity index of desirable outputs by giving due emphasis to the distinctive characteristics of production with pollutants. Consider the technology set $T = \{(x, y, b) : x \text{ can produce } (y, b)\}$, where x indexes the vector of inputs, y indexes the vector of desirable outputs, and b indexes the vector of undesirable outputs. The quantity index of desirable outputs measures the success of country i in expanding its desirable outputs while using the same level of inputs and producing the same level of pollutants compared to another country j, in a production environment in which the disposal of undesirable outputs is costly. The quantity index of undesirable outputs measures the

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[1] Belgium ratified the Convention in 1996 and Turkey in 2004.

success of country i in contracting its pollutants while holding its desirable outputs and inputs at the same level as to another country j. Our environmental efficiency index is defined as the ratio of these two indices. Formally, we define a sub-vector distance for desirable outputs as $D_y(x,y,b) = \inf\{\theta : (x,y/\theta,b) \in T\}$, which holds the inputs and undesirable outputs fixed and expands the good outputs as much as feasible, and an input based distance function as $D_b(x,y,b) = \sup\{\lambda : (x,y,b/\lambda) \in T\}$, which holds the inputs and desirable outputs fixed and contracts the undesirable outputs as much as feasible. We define the function $Q_y(x^o,b^o,y^i,y^j) = D_y(x^o,y^i,b^o)/D_y(x^o,y^j,b^o)$ as the quantity index of desirable outputs, and $Q_b(x^o,y^o,b^i,b^j) = D_b(x^o,y^o,b^i)/D_b(x^o,y^o,b^j)$ as the quantity index of undesirable outputs. Finally, we formulate our efficiency index as $E^{k,l}(x^0,y^0,b^0,y^i,y^j,b^i,b^j) = Q_y(x^0,y^0,b^i,b^j)/Q_b(x^0,b^0,y^i,y^j)$, which satisfies all the desirable properties of index numbers as documented by Fisher (1922). We present the linear programming problems in computing the distance functions mentioned in the Appendix section.

3. Data and Discussion of Results

Employing the methodology above, the environmental performance of OECD countries is analyzed for the 1983-1998 period. The input set is represented by the net fixed capital stock and labor, whereas GDP is used to represent desirable output set. The data on these variables are taken from Marquetti (2002)[2]. Total carbon dioxide emissions (hereafter, CO_2) and organic water pollutant emissions (hereafter, WP) are the proxies for air and water pollutants respectively, both of which are taken from World Development Indicators (World Bank, 2003). The empirical analysis in this section is presented in two steps. The first step involves the decomposition of the environmental efficiency index with GDP as the desirable output, CO_2 and WP as the undesirable outputs, and the capital stock and labor as productive inputs. In the second step, the environmental Kuznets curve hypothesis is analyzed along with the effect of UNFCCC on the environmental efficiency of OECD countries.

In computing our environmental efficiency index, rather than assigning an individual country as a reference as suggested by the previous studies, we start our analysis by creating a hypothetical country[3] to assess the performance of countries relative to the average. Table I reports the mean efficiency index relative to the hypothetical country and its decomposition into desirable and undesirable quantity indices. Notice that efficiency scores greater than 1 (less than 1) represents a better (inferior) performance with respect to the hypothetical country, which takes the value of 1 for all years and indices computed[4].

Poland, Hungary, and Luxembourg appear to be the three best performers among the OECD countries, while Italy, Mexico, and Switzerland are ranked the three worst. Notice that, most of the countries yield inferior efficiency scores relative to the hypothetical country.

Table I. Mean Environmental Efficiency Index

Country	Efficiency	Undesirables	Desirables	Rank
Australia	1.050	0.536	0.563	8
Austria	0.778	0.172	0.134	20
Belgium	0.939	0.277	0.260	15
Canada	1.048	0.947	0.993	9
Denmark	1.003	0.169	0.169	11
Finland	1.099	0.152	0.168	6
France	0.696	1.134	0.789	22
Germany	0.990	2.288	2.264	12
Greece	0.968	0.177	0.171	13
Hungary	1.504 (5)	0.234	0.352	2
Ireland	1.194	0.086	0.102	4
Italy	0.647	1.013	0.655	25
Japan	0.819	3.116	2.551	18
Korea	1.179	0.760	0.896	5
Luxembourg	1.357	0.022	0.029	3
Mexico	0.558 (8)	0.524	0.292	26
Netherlands	0.836	0.357	0.298	16
New Zealand	0.958	0.080	0.077	14
Norway	1.085	0.153	0.166	7
Poland	2.808	1.061	2.980	1
Portugal	0.688 (9)	0.116	0.080	23
Spain	0.824	0.637	0.525	17
Sweden	0.681	0.174	0.118	24
Switzerland	0.532 (13)	0.146	0.078	27
Turkey	0.794	0.401	0.319	19
United Kingdom	1.036	1.593	1.651	10
United States	0.729	7.223	5.269	21
Mean	0.993	0.872	0.813	N/A

Notes: The number of infeasible solutions is in parenthesis. Undesirables: Mean country quantity index of undesirable outputs. Desirables: Mean country quantity index of desirable outputs

In this study, our main objective is to determine if there exists an environmental Kuznets curve relationship between efficiency scores and GDP per capita, and to assess the effect of UNFCCC on the efficiency index. In Table II, we report the parametric regression results using the environmental efficiency index as dependent variable both with and without the effect of UNFCCC[5]. In the first specification that ignores the effect of UNFCCC, significant parameter estimates of GDP per capita and its quadratic term imply a U-type relationship between GDP per capita and the efficiency index. This estimate supports the environmental Kuznets curve hypothesis[6]. That is it implies that the

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[5] Yörük and Zaim (2005a) show the positive effect of the UNFCCC on productivity growth measures that incorporate negative externalities. Yörük and Zaim (2005b) show the positive effect of UNFCCC on environmental performance when share of industry is considered in the analysis. But neither of the papers tests the Kuznets curve hypothesis.

[6] Taskin and Zaim (2000) find a similar result employing a non-parametric index of environmental performance and Kernel estimation to a group of high and low income countries.

environmental efficiency in OECD countries declines in the initial stages of development up until a threshold income level of $26,963 and then once this threshold level of income is reached, it starts increasing. In the second specification that incorporates the effect of UNFCCC, the same relationship is observed with a threshold income level of $33,677. In addition, the coefficient of the dummy variable capturing the effect of UNFCCC is posive and statistically significant, supporting the positive effect of UNFCCC on environmental efficiency in OECD countries that have ratified the convention.

Table II. Relationship between Environmental Efficiency and Income per Capita

Variable	Without Protocol		With Protocol	
	Coefficient	t-stat	Coefficient	t-stat
Constant	1.297	(17.02)	1.309	(17.34)
GDP per capita	-3.09×10^{-5}	(-3.33)	-3.26×10^{-5}	(-3.55)
(GDP per capita)^2	5.73×10^{-10}	(2.11)	4.84×10^{-10}	(1.79)
UNFCCC	-	-	0.125	(3.11)
R^2	0.062		0.085	
Turning Point	26,963		33,677	

Notes: UNFCCC is a dummy variable that takes the value of one for the year, in which the sample country ratified the UNFCCC and all subsequent years.

4. Conclusion

In this paper, we first construct an environmental efficiency index for the OECD countries and investigate an environmental Kuznets curve relationship between GDP per capita and envonmental efficiency. We find evidence of the existence of such a relationship. We then show the positive effect of international regulations, i.e., the UNFCCC, on environmental performance.

Appendix

In order to compute the environmental performance index, we need to solve two linear programming problems by employing DEA methodology. Assuming that $j = 0$ refers to the associated quantities of hypothetical country and letting $k = 1,...K$ to index the countries in our sample, for each country $k' = 1,...,K$, we may compute for each sub-period (year)

$$(D_y(x^0, y^{k'}, b^0))^{-1} = \max \theta$$

$$s.t.$$

$$\sum_{k=1}^{K} z_k y_m^k \geq \theta y_m^{k'} \qquad m = 1,...,M$$

$$\sum_{k=1}^{K} z_k b_j^k = b_j^0 \qquad j = 1,...,J \qquad (1)$$

$$\sum_{k=1}^{K} z_k x_n^k \leq x_n^0 \qquad n = 1,...,N$$

$$z_k \geq 0 \qquad k = 1,...,K$$

which constitutes the numerator for $Q_y(x^0, b^0, y^k, y^l)$. The denominator is computed by replacing $y^{k'}$ on the right hand side of the good output constraint with the observed output for the hypothetical country (y^0). This problem constructs the best practice frontier for each sub-period and computes the scaling factor on good outputs required for each observation to attain best practice.

On the other hand, the quantity index of bads can be computed by solving the following problem for each country $k' = 1,...,K$:

$$(D_y(x^0, y^0, b^{k'}))^{-1} = \min \lambda$$

$$s.t.$$

$$\sum_{k=1}^{K} z_k y_m^k \geq y_m^0 \qquad m = 1,...,M$$

$$\sum_{k=1}^{K} z_k b_j^k = \lambda b_j^{k'} \qquad j = 1,...,J \qquad\qquad (2)$$

$$\sum_{k=1}^{K} z_k x_n^k \leq x_n^0 \qquad n = 1,...,N$$

$$z_k \geq 0 \qquad k = 1,...,K$$

This problem constitutes the numerator for $Q_b(x^0, y^0, b^k, b^l)$. The denominator is computed by replacing $b^{k'}$ on the right hand side of the bad output constraint with the observed bad outputs for the hypothetical country (b^0). Similar to the quantity index of goods, this problem constructs the best practice frontier and computes the scaling factor on bad outputs required for each observation to attain the best practice.

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