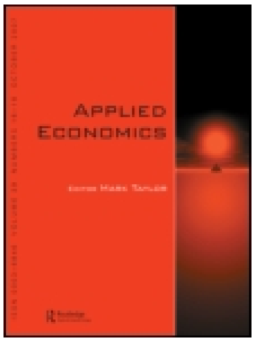

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International regulations and environmental performance

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This article employs the data envelopment analysis (DEA) approach to compute the environmental performance of all but two Organisation for Economic Co-operation and Development (OECD) countries. It is found that although the environmental performance of countries differs over time, Poland and Hungary are the two best performers for all periods while Italy, Japan, Austria and Switzerland are ranked among the worst. The effect of international regulations and some observed characteristics of countries on environmental performance are also investigated. International regulations are reported to have a positive effect on environmental performance.

I. Introduction

Increased awareness on environmental quality has prompted policy makers to adopt accurate measures and consider environmental impacts of their policy choices in the formulation of different economic policies. This not only prompts countries to measure, document and publish information about their environmental performance, but also brings proposals for a better environmental quality to international arena. OECD has a long-standing programme addressing environmental trends and their effects on economic policies. It undertakes outlooks of environmental trends, and works with its member countries to develop principles, guidelines and strategies for an effective management of the main environmental problems they face. Successful integration of environmental policies with sectoral and other economic policies is important to ensure that environmental policy goals are reached and the implications of other policy measures on the environment are addressed. Hence, as an initial step, accurate assessment of environmental trends and development of measures that will internalize negative externalities is essential for a successful environmental management in OECD.

In developing accurate environmental performance measures, an initial approach taken by international institutions such as the World Bank and OECD was based on either descriptive environmental indicators (e.g. measures of dissolved oxygen in water, suspended particular matter in air, soil salinization, etc.), or performance-based environmental indicators, which are measured against some physical threshold or normative policy goal (e.g. measures of compliance with international treaties or target levels of energy use per unit of output). However, these measures emphasize only environmental damage and losses without reconciling economic achievement with environmental goals. Owing to this fact, many recent studies propose alternative methodologies to investigate the impact of environmentally hazardous by-products using both micro and macro level data sets.

Recent literature on the measurement of environmental performance includes different methodologies

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that range from econometric estimation techniques to various optimization tools. Compared to other competing alternatives, nonparametric techniques and index number theory come up to be an attractive tool because of the advantages they possess. Obviously, the most useful and important advantage of this kind of approach is its convenience to allow one to make cross observation and over time comparisons easily. Moreover, in contrast to alternative approaches of its kind, this methodology allows for the construction of quantity indices without the need for price information on either inputs or outputs; therefore let one to proceed without constructing shadow prices.[1]

In his seminal paper, Farrell (1957), shows that how productive inefficiency and its components allocative and technical inefficiencies can be measured within a theoretically meaningful framework. Later, Färe *et al.* (1994) argue that how one can further decompose Farrell's measure of technical efficiency and extract information on the output loss due to deviations from optimal scale and congestion. This literature,[2] known as 'production frontiers', is extensively covered in Shephard (1970), Färe *et al.* (1985) and Fried *et al.* (1993). In evaluating environmental performance and constructing the efficiency indices, two competing methodologies need to be mentioned. These are stochastic frontier estimation and data envelopment analysis (DEA). Both approaches are quite favourable in the literature. For example, Reinhard *et al.* (1999) employ a stochastic frontier approach to construct an environmental efficiency index on an application to Dutch dairy farms while Ball *et al.* (1994) adapt the DEA methodology to measure environmental performance in US agriculture. Alternatively, Tyteca (1997) develops an environmental performance indicator based on the decomposition of factor productivity into a pollution index with an application to data from US fossil fuel-fired electric utilities. Later, Reinhard (1997) employs both stochastic frontier estimation and DEA to show the pros and cons of two methods.

There are also alternative approaches according to the selection of the type of the efficiency measure in the studies that employ DEA framework.[3] Färe *et al.* (1986, 1996) use radial measures of technical efficiency to compute a desirable output loss that stems from reduced disposability of undesirable outputs. In the latter work, they rely on the comparison of two input(output)-oriented radial technical efficiency scores; one accounts for the production of environmentally undesirable outputs and the other which completely ignores the production of pollutants with desirable outputs.

As opposed to the radial measure, the alternative efficiency measure is a hyperbolic measure of technical efficiency, which is suggested by Färe *et al.* (1989). Their measure of technical efficiency allows for simultaneous equiproportionate reduction in undesirable outputs (bads) with an expansion of desirable outputs (goods). The importance of this measure is to compute the opportunity cost of transforming the production process from one where all outputs are strongly disposable to the one, which is characterized by weak disposability of undesirable outputs. Later, hyperbolic measure of technical efficiency is employed in constructing environmental efficiency indices in the studies of Zaim and Taskin (1999), and Taskin and Zaim (2000). They employ this measure to construct an environmental efficiency index and measure the environmental performance of OECD countries.

In contrast to the studies cited, this article, using nonparametric techniques, employs an environmental performance index based on the well established methodology in a series of recent articles (Zaim *et al.*, 2001; Färe *et al.*, 2004; Zaim, 2004). Basically, this index is defined as the ratio of two indices, namely good (desirable) output quantity index and bad (undesirable) output quantity index. Similar to the well-known Malmquist index (Malmquist, 1953; Caves *et al.*, 1982), both indices are developed using DEA framework and distance functions approach. However, in contrast to the Malmquist index, our indices employ sub-vector distance functions since they scale the good and bad outputs separately. The indices also satisfy various properties of index numbers due to Färe and Primont (1995) as well as the theoretical underpinnings established in Diewert (1981).

The organization of this article is as follows: Section II introduces the preliminaries for the theory of joint production of desirable and undesirable outputs and then proposes the methodology to construct the environmental performance index

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[1] For the derivation of shadow prices for undesirable outputs, refer Färe *et al.* (1993).

[2] A comprehensive literature review can be found in Tyteca (1996).

[3] Data envelopment analysis approach is also employed under different contexts. Sengupta (2002), Womer (2003), and Piot-Lepetit and Vermersch (1997) are the recent examples that appeared in this journal.

employed in this study. Section III is reserved for the presentation of data and the results. Section IV investigates the country-specific factors that may affect the environmental performance and presents a discussion of the empirical results. Finally, Section V concludes.

II. Joint Production of Desirable and Undesirable Outputs

To describe the theoretical underpinnings of the model employed, let us denote desirable outputs by $y = (y_1, \ldots, y_M) \in R_+^M$ and undesirable outputs by $b = (b_1, \ldots, y_I) \in R_+^I$. Therefore, the output set (y, b) is produced by the input set $x = (x_1, \ldots, x_N) \in R_+^N$. Then, technology can be described *via* its output set:

$$T = \{(x, y, b) : x \text{ can produce } (y, b)\} \tag{1}$$

In words, for each input vector $x = (x_1, \ldots, x_N) \in R_+^N$, the technology set includes all the combinations of good and bad outputs or the output set (y, b), which can be produced by the vector of inputs. Technology set is also known as the output set $P(x)$ or can be represented by the input set $L(y, b)$ such that:

$$(x, y, b) \in T \Leftrightarrow (y, b) \in P(x) \Leftrightarrow x \in L(y, b) \tag{2}$$

The weak disposability assumption[4] of output set (y, b) can be modelled as:

$$(y, b) \in P(x) \text{ and } 0 \leq \theta \leq 1 \text{ imply } (\theta y, \theta b) \in P(x) \tag{3}$$

In words, this assumption implies that given a fixed level of inputs, a reduction in bads is feasible only when the goods are also simultaneously reduced. On the other hand, good outputs may be reduced without the reduction of the bad outputs. Free disposability of good outputs is formally:

$$(y, b) \in P(x) \text{ and } y' \leq y \text{ imply } (y', b) \in P(x) \tag{4}$$

Equations 3 and 4 together model the asymmetry between the good and bad outputs where goods are freely disposable while the bads are not. On the other hand, the assumption of null-jointness implies that no desirable outputs can be produced without producing any undesirable outputs. This idea of joint production of good and bad outputs can be modelled as:

$$\text{if } (y, b) \in P(x) \text{ and } b = 0 \text{ then } y = 0 \tag{5}$$

In addition to the assumptions on the joint production of good and bad outputs, we may also impose some restrictions over the output set $P(x)$. To model the idea that zero inputs yield zero outputs we have:

$$P(0) = \{0, 0\} \tag{6}$$

Moreover, given finite inputs, only finite outputs can be produced. Formally:

$$P(x) \text{ is compact for each } x \in R_+^N \tag{7}$$

The final assumption on output set $P(x)$ is:

$$P(x) \supseteq P(x'), \; x \geq x' \tag{8}$$

This assumption imposes free disposability of inputs, which essentially implies that if inputs are increased then outputs do not decrease.

Following Färe *et al.* (1994), we may formulate an activity analysis or DEA. We assume that there are K observations on inputs and outputs, where k indexes each individual observation such that $\{(x^k, y^k, b^k) : k = 1, \ldots, K\}$. Using this data, we construct an output set that holds for every period and satisfies our previous assumptions. Formally, we have:

$$\begin{aligned} P(x) = \{(y, b) : \quad & \sum_{k=1}^{K} z_k y_{km} \geq y_m, \quad && m = 1, \ldots, M, \\ & \sum_{k=1}^{K} z_k b_{ki} = b_i, && i = 1, \ldots, I, \\ & \sum_{k=1}^{K} z_k x_{kn} \leq x_n, && n = 1, \ldots, N, \\ & z_k \geq 0, && k = 1, \ldots, K\} \end{aligned} \tag{9}$$

where the non-negative z_k are the intensity variables (weights) assigned to each observation when constructing the production set. The inequality constraint on the good output $y = (y_1, \ldots, y_M) \in R_+^M$ in (9) states the assumption of free disposability, which implies that desirable outputs can be disposed off without the use of any inputs. If we consider the joint production of undesirable outputs $b = (b_1, \ldots, y_I) \in R_+^I$ with desirable outputs, we should impose the weak disposability condition that satisfies the assumption introduced in (3) by choosing an equality sign for the relevant constraint. To satisfy the null-jointness introduced before, we restrict the conditions:

$$\sum_{k=1}^{K} b_{ki} > 0, \quad i = 1, \ldots, I, \tag{10}$$

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[4] For a detailed exposition on the assumptions of production frontiers, one can refer to Chung *et al.* (1997) or Shephard and Färe (1974).

and

$$\sum_{i=1}^{I} b_{ki} > 0, \quad i = 1, \ldots, K, \tag{11}$$

The inequality (10) states that each undesirable or bad output is produced by some individual sample k. On the other hand, (11) implies every k produces at least one bad output. We may further illustrate null-jointness by assuming that each $b_i = 0$, where $i = 1, \ldots, I$. Then each intensity variable z_k in (9) will be zero, implying that all the desirable good outputs y_m must be zero. Therefore, these two restrictions can be used to determine whether a particular data set satisfies null-jointness of desirable and undesirable outputs. Imposing this assumption, our application will not include the data that violate the null-jointness.

Further, the non-negativity of intensity variables in (9) implies that the production technology exhibits constant returns to scale. That is

$$P(\lambda X) = \lambda P(x), \ \lambda > 0 \tag{12}$$

Environmental performance index

Following Zaim *et al.* (2001), the environmental performance index employed in this article is the ratio of two indices, namely, good output quantity index and bad output quantity index. This index employs sub-vector distance functions since it scales the good and bad outputs separately. It also satisfies the desirable properties such as closedness and convexity due to Färe and Primont (1995). We formally define a sub-vector distance function for good outputs as:

$$D_y(x, y, b) = \inf\{\theta\colon (x, y/\theta, b) \in T\} \tag{13}$$

which holds the inputs and bad outputs fixed and expands the good outputs as much as it is feasible. Note that it is also homogeneous of degree +1 in y. Keeping this notation in mind, let x^0 and b^0 be given inputs and bad outputs, then taking the ratio of two distance functions, good output quantity index compares two output vectors y^k and y^l. Hence, quantity index for the goods is:

$$Q_y(x^0, b^0, y^k, y^l) = \frac{D_y(x^0, y^k, b^0)}{D_y(x^0, y^l, b^0)} \tag{14}$$

On the other hand, the quantity index of bad outputs is constructed using an input distance function approach. The input-based distance function for bad outputs is:

$$D_b(x, y, b) = \sup\{\lambda : (x, y, b/\lambda) \in T\} \tag{15}$$

which is homogeneous of degree +1 in bad outputs and is defined by finding the maximal contraction in undesirable outputs. Given (x^0, y^0), the quantity index of bad outputs can be computed as the ratio of two distance functions:

$$Q_b(x^0, y^0, b^k, b^l) = \frac{D_b(x^0, y^0, b^k)}{D_b(x^0, y^0, b^l)} \tag{16}$$

Finally, the environmental performance index defined is the ratio of Equations 16 and 14, i.e.:

$$P^{k,l}(x^0, y^0, b^0, y^k, y^l, b^k, b^l) = \frac{Q_b(x^0, y^0, b^k, b^l)}{Q_y(x^0, b^0, y^k, y^l)} \tag{17}$$

III. Data and Discussion of Results

The resource constraint (inputs) in constructing the environmental performance index is represented by net fixed standardized capital stock and labour (number of employed workers), whereas the outputs are GDP (PPP adjusted with 1996 prices), industrial carbon dioxide (CO_2), nitrogen oxide (NO_x) and organic water pollutant emissions. The data on capital stock, labour and GDP are compiled from a recent data set (Marquetti, 2002). World Development Indicators (World Bank, 2002) is the source for CO_2 and organic water pollutant emissions data, whereas the data for NO_x emissions[5] are compiled from the World Marketing Database (Euromonitor, 2002). Carbon dioxide and nitrogen oxide emissions from industrial processes are those arising from the burning of fossil fuels. They include contributions to CO_2 and NO_x produced during consumption of solid, liquid, gas fuels and gas flaring. Emissions of organic water pollutants are measured by biochemical oxygen demand, which refers to the amount of oxygen that bacteria in water will consume in breaking down waste. This is a standard water treatment test for the presence of organic pollutants. The annual data set includes 28 OECD countries. Slovak Republic and Czech Republic are excluded due to the unavailability of the data for these countries. The time period considered is 16 years, from 1983 to 1998.

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[5] Carbon dioxide emissions are measured in '000 kt. Nitrogen oxide emissions are measured in '000 kt. Organic water pollutant emissions are measured in '000 kg per day. Interpolation techniques are used to fill the missing values.

In constructing the environmental performance indices, previous studies[6] assign a reference country so as to construct a benchmark technology and then compute the distance of other observations from the reference observation. This technique assesses the performance of the countries relative not to average but to a particular country. Moreover, the reference country takes the value of unity for all time periods for the index computed, which means to exclude the performance of the reference country. To overcome this shortcoming, we start our analysis by creating a hypothetical country. The data for the hypothetical country is simply calculated by taking the average of each variable for all sample OECD countries. Assigning the hypothetical country as our reference, we are able to compute the environmental performance of OECD countries relative to the average performance.

Although our data set includes three undesirable outputs, we employed the pollutant data as pairs and computed environmental performance indices that incorporate NO_X and CO_2, NO_X and organic water pollutant and CO_2 and organic water pollutant emissions, respectively. The main reason for employing the pollutant data as pairs is our effort to reduce the number of infeasible solutions. As the number of time periods and variables in the linear programming problems increase, one should also expect a simultaneous increase in the number of infeasible solutions.[7] To overcome this issue as much as possible, following Färe *et al.* (2001), we assumed that each year's technology is determined by observations on inputs and outputs of current and past two periods. Moreover, the data being evaluated are also chosen to be 3-year moving averages in order to smooth the data and reduce the number of infeasible solutions.

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 $k = 1, \ldots, K$ to index the countries in our sample, for each country $k' = 1, \ldots, K$, we may compute for each sub-period (year)

$$\begin{aligned} \left(D_y\left(x^0, y^{k\prime}, b^0\right)\right)^{-1} &= \max \theta \\ \text{s.t.} & \\ \sum_{k=1}^{K} z_k y_m^k \geq \theta y_m^{k'} & \quad m = 1, \ldots, M \\ \sum_{k=1}^{K} z_k b_j^k = b_j^0 & \quad j = 1, \ldots, J \\ \sum_{k=1}^{K} z_k x_n^k \leq x_n^0 & \quad n = 1, \ldots, N \\ z_k \geq 0 & \quad k = 1, \ldots, K \end{aligned} \tag{18}$$

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 $k' = 1, \ldots, K$:

$$\begin{aligned} \left(D_b\left(x^0, y^0, b^{k\prime}\right)\right)^{-1} &= \min \lambda \\ \text{s.t.} & \\ \sum_{k=1}^{K} z_k y_m^k \geq y_m^0 & \quad m = 1, \ldots, M \\ \sum_{k=1}^{K} z_k b_j^k = \lambda b_j^{k'} & \quad j = 1, \ldots, J \\ \sum_{k=1}^{K} z_k x_n^k \leq x_n^0 & \quad n = 1, \ldots, N \\ z_k \geq 0 & \quad k = 1, \ldots, K \end{aligned} \tag{19}$$

This problem constitutes the numerator for $Q_b(x^0, b^0, y^k, y^l)$. 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.

In Table 1,[8] we report the environmental performance index that incorporates both NO_X and

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[6] See, for example, Färe *et al.* (2004) and Zaim *et al.* (2001). Färe *et al.* (2004) use a lattice approach to create a reference country. However, our approach is let us to evaluate the individual performances of our countries compared to that of an 'average country'. We thank an anonymous referee for pointing this out.

[7] For further discussion on infeasible solutions on linear programming problems, see Färe *et al.* (2001).

[8] Country codes are as follows: AUS: Australia, AUT: Austria, BEL: Belgium, CAN: Canada, DNK: Denmark, FIN: Finland, FRA: France, GER: Germany, GRC: Greece, HUN: Hungary, ISL: Iceland, IRL: Ireland, ITA: Italy, JPN: Japan, KOR: Korea, LUX: Luxembourg, MEX: Mexico, NLD: Netherlands, NZL: New Zealand, NOR: Norway, POL: Poland, PRT: Portugal, ESP: Spain, SWE: Sweden, CHE: Switzerland, TUR: Turkey, GBR: Great Britain, USA: United States.

Table 1. Environmental performance index: NO_X and CO_2

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Mean
AUS	INF	INF	INF	INF	INF	INF	INF	INF	1.2950	INF	1.2201	1.4921	1.5960	1.4560	1.5350	1.4746	1.4384
AUT	0.6001	0.6326	0.6527	0.6410	0.6419	0.6031	0.5956	0.6042	0.6025	0.5901	0.5724	0.5738	0.5458	0.5368	0.5556	0.5449	0.5933
BEL	0.7863	0.7790	0.7921	0.7944	0.8025	0.7423	0.7702	0.7758	0.7900	0.8215	0.7905	0.8044	0.7952	0.8088	0.7911	0.7832	0.7892
CAN	1.3041	1.2788	1.2142	1.2022	1.2474	1.2847	1.2975	1.3181	1.2892	1.2748	1.3015	1.3294	1.3599	1.3469	1.3531	1.3513	1.2971
DNK	0.8977	0.9156	0.9871	0.9867	1.0138	0.9304	0.8455	0.9409	1.0875	0.9074	0.9539	0.9783	0.9213	1.0013	0.9272	0.5174	0.9258
FIN	0.8848	0.9175	0.9397	1.0722	1.0930	1.0051	1.0220	1.1086	1.1639	1.0226	1.1552	1.2644	1.1689	1.2286	1.1436	1.0931	1.0802
FRA	0.6139	0.6226	0.6265	0.6044	0.5985	0.5593	0.5938	0.5784	0.5984	0.5749	0.5752	0.6000	0.6251	0.6364	0.6306	0.6241	0.6039
GER	0.8870	0.9135	0.9363	0.9512	0.9366	0.8816	0.8792	0.8317	0.8005	0.7812	0.7844	0.7071	0.6669	0.6796	0.6360	0.6325	0.8065
GRC	0.9146	0.9360	0.8890	0.8989	0.9920	1.0252	1.0579	1.1127	1.0458	1.0872	1.1386	1.2026	1.2306	1.2872	1.3001	1.3425	1.0913
HUN	1.0634	1.1081	1.1423	1.1492	1.1284	1.0798	1.0823	1.0795	1.1085	1.0661	1.0338	1.0116	1.0080	1.0745	1.0196	0.9580	1.0696
ISL	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	N/A
IRL	0.9030	0.9119	0.9964	1.1576	1.2257	1.2229	1.1700	1.0947	1.1525	1.1166	1.0990	1.0186	0.9654	0.9252	0.8801	0.8053	1.0397
ITA	0.5958	0.6119	0.6126	0.6093	0.6489	0.6583	0.6760	0.7094	0.7080	0.7072	0.7169	0.6957	0.7131	0.7214	0.7478	0.7545	0.6804
JPN	0.3173	0.3435	0.3276	0.3355	0.3641	0.3781	0.4060	INF	INF	INF	INF	INF	INF	INF	INF	INF	0.3532
KOR	1.0454	1.0300	1.0172	0.9727	0.9500	1.0108	1.0491	0.9508	0.8762	1.0089	1.0539	1.0177	0.9707	1.0141	1.0516	1.2507	1.0169
LUX	0.5473	0.5951	0.5752	0.5989	0.6304	0.6024	0.6386	0.8087	0.8262	0.8371	0.8014	0.7779	0.6648	0.6768	0.6682	0.6177	0.6792
MEX	0.9077	0.8719	0.7965	0.8259	0.8901	0.8699	0.8933	0.9313	0.9028	0.8974	0.8968	0.9158	1.0219	1.0369	1.0269	1.0040	0.9181
NLD	0.7824	0.8205	0.8350	0.8034	0.8404	0.8308	0.8545	0.8609	0.8343	0.8240	0.8081	0.7671	0.7487	0.7827	0.7292	0.7058	0.8017
NZL	0.5861	0.6378	0.6594	0.7666	0.8208	0.8376	0.8861	0.9287	0.9560	0.9396	0.9104	0.9851	1.0979	1.0751	1.1352	1.1199	0.8964
NOR	1.1265	1.2335	1.2891	1.3243	1.3220	0.8889	0.8041	0.9859	0.9860	1.0019	1.0409	1.0100	0.9844	1.0030	0.9013	0.8886	1.0494
POL	2.6417	2.6971	2.7334	2.7614	2.8054	2.6464	2.6485	INF	2.4465	2.3795	2.2934	2.1312	2.0455	2.0170	1.8086	1.7262	2.3854
PRT	0.4011	0.4276	0.4570	0.5255	0.5995	0.5431	0.7292	INF	0.5742	INF	0.5937	0.7004	0.8095	0.6160	0.7940	0.7654	0.6097
ESP	0.7852	0.7817	0.7203	0.6708	0.6803	0.6720	0.7281	0.8160	0.8151	0.8001	0.7870	0.8760	0.8992	0.8615	0.8883	0.8618	0.7896
SWE	0.6398	0.6139	0.6135	0.6441	0.6747	0.6349	0.6480	0.6438	0.6508	0.6160	0.5578	0.6479	0.6148	0.6301	0.6026	0.5659	0.6249
CHE	0.4029	0.4027	0.3975	0.4193	0.4128	0.4060	0.3891	0.4058	0.4001	0.4076	0.3858	0.3832	0.3923	0.3933	0.4373	0.3854	0.4013
TUR	0.6494	0.6398	0.6752	0.7080	0.7290	0.7088	0.7944	0.7946	0.7815	0.7528	0.7673	0.8756	0.9167	0.9180	0.9413	0.9652	0.7886
GBR	0.9658	0.9506	0.9836	0.9894	0.9904	0.9714	0.9828	1.0185	1.0250	1.0075	0.9550	0.9259	0.8803	0.8702	0.8096	0.7720	0.9436
USA	1.3616	1.3183	1.2624	1.2781	1.2829	1.3173	1.3002	1.3290	1.3292	1.3807	1.3246	1.3393	1.3474	1.3272	1.3287	1.3069	1.3164
Mean	0.8697	0.8843	0.8897	0.9112	0.9354	0.8966	0.9132	0.8969	0.9633	0.9471	0.9426	0.9627	0.9611	0.9583	0.9478	0.9160	0.9247

Notes: 'INF' denotes infeasible solutions.
Geometric means are reported.

CO_2 emissions. It should be indicated that, figures >1 (<1) represent a better (inferior) performance with respect to the hypothetical country. Note that hypothetical country takes the value of unity for all years and all indices and is not reported in the tables. Taking a quick glance at Table 1 which reveals that Poland, Australia, Canada and USA are among the best performers and have kept their position over the time period considered. On the other hand, Switzerland, Japan, Austria and France ranked among the worst for the period 1983 to 1998. It is observed that on average, environmental performance of the sample countries has decreased approximately 7% to 13% for the time span considered. It should also be stated that environmental performance index could not be computed for Iceland because of the infeasible solutions.[9]

Table 2 presents the environmental performance index that incorporates NO_X and organic water pollutant emissions. We observe that over the time period, Poland, Iceland, Portugal and Hungary are the best performers. One of the best performers in Table 1, namely Australia is among the worst performers in Table 2, along with Italy, Mexico and Switzerland. According to Table 2, OECD countries present a significant performance in environmental management (8–11% per annum on average). Finally, in contrast to Table 1, environmental performance index could not be computed for Japan.

In Table 3, we report the environmental performance index that incorporates CO_2 and organic water pollutant emissions. One can clearly recognize that as in Table 1, environmental performance index for Iceland could not be computed. Surprisingly, although we employed different pollutant emission pairs, Poland is the best performer for all years like in Tables 1 and 2. One can also see that Hungary, Luxembourg and Korea are among the best achievers. The worst performers in Table 3 are Mexico, Switzerland and Italy. Overall, this index reveals an approximately 2% decrease in the environmental performance for the period 1992 to 1998 while for the rest of the years it reveals an approximately 1% increase on average.

Taking relatively low-income countries into picture, the results revealed by our environmental performance index that incorporates different pollutant pairs and the ones reported by the traditional measures which attempt to assess the environmental performance by simply computing emissions per GDP, are generally in line. For example, the most recent OECD report (2004) on selected environmental indicators ranks Poland and Hungary among the best as our environmental performance indices have suggested. However, when it comes to relatively high-income countries, this fact does not hold. In contrast to our measure, the OECD report (2004) ranks USA and Australia among the worst. This result was expected since traditional measures ignore the fact that aggregate environmental degradation is a consequence of production process and hence, weak disposability assumption[10] introduced in (3) should be imposed to construct reliable measures.

To present a clear exposition, the quantity indices for undesirable outputs are also reported in appendix tables. Since the environmental performance index is the ratio of bad quantity index over good quantity index, the exact numbers can easily be computed for respective quantity indices for desirable outputs. These tables are useful as they highlight the undesirable output production of respective country. For example, when comparing Table 1 with Table A1, we observe that although USA has incredibly high CO_2 and NO_x emissions, it is still making an environmentally efficient performance because of its superior performance in the production of desirable goods.

IV. Empirical Analysis

In our empirical analysis, we investigate the country-specific variables that may affect environmental performance. Our explanatory variables are GDP per capita (GDPC), share of manufacturing in GDP (MANSHARE), population density (POPDEN) and regulation. Regulation is a dummy variable which takes the value of unity for the year that the sample country has ratified the United Nations Framework Convention on Climate Change (1992) and thereafter.[11] It should be noted that starting from 1992, all

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[9] Infeasible solutions are denoted in the tables by INF.

[10] Especially in regulated environments, where production units are required to clean up the undesirable outputs, one has to treat undesirable and desirable outputs asymmetrically in terms of their disposability characteristics. Even in the absence of regulations, the same claim may hold because of the increased environmental consciousness in the society.

[11] UNFCCC is declared to reduce global emissions. The ‘precautionary approach’ the article 3 of UNFCCC calls for a production plan that is least detrimental to environmental quality. That is among many input, output and pollution emission combinations, the production plan that maximizes the desirable outputs while simultaneously minimizing undesirable outputs is more favourable. The building blocks of our environmental performance index are in accordance with this statement.

Table 2. Environmental performance index: NO_X and organic water pollutant

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Mean
ALB	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	0.7093	0.7240	INF	INF	0.7167
AUT	0.7695	0.8203	0.8465	0.8429	0.8338	0.8343	0.8394	0.7802	0.7699	0.7830	0.7719	0.7664	0.7330	0.7353	0.8130	0.8008	0.7963
BEL	0.8558	0.8579	0.8602	0.8525	0.8730	0.8805	0.9037	0.8573	0.8599	0.8967	0.9384	0.9300	0.9177	0.9462	0.9670	0.9785	0.8985
CAN	1.1623	1.0860	1.0998	1.1025	1.1128	1.1366	1.1380	1.1792	1.1723	1.1395	1.1192	1.0727	1.0541	1.0746	1.0750	1.0376	1.1101
DNK	0.9477	0.9858	1.0636	1.1049	1.1083	1.0869	1.0738	1.2556	1.3357	1.2675	1.3078	1.2840	1.2462	1.3625	1.3365	INF	1.1845
FIN	1.2615	1.2977	1.3759	1.3983	1.4002	1.3936	1.3734	1.3904	1.4675	1.5013	1.4958	1.4597	1.3615	1.3816	1.3212	1.2226	1.3816
FRA	0.7563	0.7984	0.8088	0.8116	0.8108	0.8106	0.8523	0.7808	0.8030	0.8329	0.8565	0.8657	0.8578	0.8806	0.9183	0.9307	0.8359
GER	0.8644	0.8968	0.9168	0.9326	0.9134	0.9025	0.8817	0.8335	0.8504	0.7862	0.8037	0.7862	0.7782	0.8037	0.8388	0.8464	0.8555
GRC	0.9398	0.9634	0.9718	0.9828	1.0308	1.0232	1.0406	1.1127	1.0903	1.0888	1.1086	1.1112	1.1090	1.0968	1.08	1.0683	1.0524
HUN	1.4908	1.5742	1.6739	1.7553	1.7606	1.8874	1.6816	INF	INF	INF	INF	INF	INF	INF	INF	1.6258	1.7187
ISL	1.9500	2.0437	2.0726	2.0343	1.9832	1.9871	1.9752	1.9037	1.9201	2.0143	2.1547	2.1602	2.2345	2.0630	2.0137	1.9773	2.0317
IRL	1.0681	1.0851	1.1411	1.2455	1.3201	1.3562	1.3474	1.1837	1.2102	1.2444	1.2262	1.1377	1.0284	1.0288	0.9819	0.9228	1.1580
ITA	0.6328	0.6535	0.6482	0.6613	0.6906	0.6680	0.6613	0.6843	0.7166	0.7244	0.7550	0.7530	0.7253	0.7093	0.7234	0.7193	0.6994
JPN	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	N/A
KOR	1.3515	1.3791	1.3361	1.3597	1.3395	1.4030	1.4402	1.1663	1.0347	1.1388	1.1945	1.1309	1.0576	1.0587	1.1354	1.3370	1.2414
LUX	0.8463	0.8382	0.8463	0.8452	0.8468	0.8106	0.7907	0.8471	0.8275	0.8261	0.7856	0.7523	0.7261	0.7372	0.7250	0.7121	0.7977
MEX	INF	0.5810	0.5889	0.6118	0.5671	0.5460	0.5545	0.5589	0.5412	0.5356	0.4755	0.4331	0.4420	0.4788	0.4519	0.4351	0.5201
NLD	0.8364	0.8634	0.8940	0.9008	0.9304	0.9074	0.8871	0.8819	0.8639	0.8620	0.8431	0.8163	0.7944	0.8047	0.7853	0.7739	0.8528
NZL	1.1924	1.2215	1.2490	1.2640	1.2452	1.2905	1.3326	1.3058	1.3315	1.4603	1.4236	1.3360	1.4298	1.4580	1.4806	1.4863	1.3442
NOR	0.9616	1.0012	1.0344	1.0903	1.0918	1.0982	1.0955	1.0833	1.0235	0.9877	0.9873	0.9759	0.9735	0.9800	0.9435	0.9440	1.0170
POL	2.9010	2.9660	2.8065	2.8015	2.8137	2.8437	2.8377	INF	2.6878	2.5710	2.4468	2.4260	2.3683	2.3633	2.3447	2.1061	2.6189
PRT	INF	INF	INF	0.9578	1.0610	1.1555	1.2604	1.6181	1.6663	1.7326	1.8068	1.7982	1.7934	1.8426	1.8896	2.1296	1.5932
ESP	0.9301	0.9606	0.9000	0.8993	0.8918	0.8980	0.9433	1.0100	1.0207	1.0484	1.1660	1.1587	1.1022	1.1203	1.1594	1.1725	1.0238
SWE	1.0030	1.0326	1.0841	1.1127	1.1139	1.1265	1.1102	0.9677	1.0138	1.0299	1.0230	1.0266	0.9132	0.9399	0.9450	0.9131	1.0222
CHE	0.6612	0.6946	0.7156	0.7535	0.7796	0.8327	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	0.7395
TUR	0.7576	0.7823	0.7913	0.8099	0.8245	0.8799	0.9597	0.8981	0.8797	0.8979	0.8735	0.9592	0.9604	0.9691	0.9807	1.0059	0.8894
GBR	1.0804	1.1167	1.1416	1.1561	1.1535	1.1581	1.1829	1.1812	1.1715	1.1910	1.1300	1.0960	1.0495	1.0533	1.0392	1.0180	1.1199
USA	0.9053	0.8445	0.8227	0.7844	0.8133	0.7877	0.7769	0.8096	0.8060	0.8323	0.8372	0.8181	0.7854	0.7925	0.7991	0.7910	0.8129
Mean	1.0886	1.0938	1.1076	1.1181	1.1273	1.1425	1.1705	1.0575	1.1264	1.1445	1.1490	1.1261	1.0854	1.0978	1.1153	1.1231	1.1171

Notes: INF denotes infeasible solutions.
Geometric means are reported.

Table 3. Environmental performance index: CO_2 and organic water pollutant

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Mean
AUS	1.1445	1.1140	1.1626	1.1387	1.1180	1.1555	1.1607	1.1344	1.1260	1.0576	1.0131	0.9533	0.8652	0.8253	0.9052	0.9209	1.0501
AUT	0.7684	0.8362	0.8111	0.7925	0.8176	0.7777	0.7734	0.8143	0.7604	0.6968	0.7251	0.7447	0.7799	0.7521	0.7948	0.8077	0.7783
BEL	0.9389	0.9702	0.9725	0.9571	0.9515	0.8891	0.8867	0.9172	0.9248	0.9024	0.8883	0.9454	0.9649	0.9757	0.9609	0.9718	0.9386
CAN	1.1253	1.0384	1.0666	1.0565	1.0542	1.0862	1.1041	1.0846	1.0620	1.0461	1.0181	0.9941	0.9955	1.0088	1.0253	1.0101	1.0485
DNK	0.8841	0.8962	0.9976	0.9806	0.9927	0.9290	0.8396	1.0061	1.0908	0.9178	1.0127	1.0752	1.0604	1.0138	1.0905	1.2594	1.0029
FIN	0.9940	1.0239	1.0803	1.1828	1.1785	1.0916	1.0646	1.0846	1.1083	1.0277	1.1031	1.1797	1.1200	1.1852	1.1067	1.0648	1.0994
FRA	0.7746	0.7897	0.7551	0.7193	0.7159	0.6477	0.6799	0.7000	0.6853	0.6138	0.6220	0.6061	0.6996	0.6875	0.7118	0.7334	0.6964
GER	0.9862	0.9918	1.0017	1.0187	1.0090	1.0033	0.9948	0.9993	0.9953	0.9718	0.9834	0.9431	0.9654	0.9902	0.9873	0.9925	0.9896
GRC	0.8326	0.8625	0.8813	0.8732	0.9356	0.9591	1.0051	1.0165	0.9264	0.9984	1.0329	1.0297	1.0327	1.0217	1.0411	1.0401	0.9681
HUN	1.7178	1.8381	1.7258	1.6315	1.6787	1.4966	1.3255	INF	1.4549	INF	INF	1.0235	1.4864	1.1662	INF	INF	1.5041
ISL	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	N/A
IRL	1.2322	1.2513	1.2175	1.3554	1.3721	1.3590	1.2422	1.2088	1.2688	1.1589	1.1663	1.1495	1.1565	1.0340	0.9876	0.9446	1.1940
ITA	0.6211	0.6404	0.6269	0.6109	0.6293	0.6178	0.6331	0.6442	0.6472	0.6678	0.6565	0.6566	0.6630	0.664S	0.6811	0.6866	0.6467
JPN	0.7866	0.8437	0.7889	0.7884	0.7850	0.8166	0.7938	0.8176	0.7736	0.7538	0.7766	0.8266	0.8660	0.8269	0.8825	0.9741	0.8188
KOR	1.1808	1.2378	1.2440	1.1755	1.1645	1.1919	1.1695	1.1568	1.0695	1.0843	1.1443	1.1610	1.1749	1.1719	1.1640	1.3685	1.1787
LUX	1.7768	1.7725	1.7633	1.6633	1.6137	1.4906	1.4586	1.4052	1.3336	1.2499	1.1323	1.1011	1.0359	1.0246	0.9651	0.9319	1.3574
MEX	INF	0.5528	0.5717	0.5899	0.5690	0.5644	0.5745	0.5373	0.5064	INF	INF	INF	INF	INF	INF	INF	0.5583
NLD	0.7790	0.8223	0.8541	0.8221	0.8484	0.8159	0.8690	0.8678	0.8568	0.8424	0.8377	0.8188	0.8057	0.8688	0.8360	0.8313	0.8360
NZL	0.7976	0.8102	0.8357	0.9033	0.9389	0.9554	1.0056	0.9964	0.9600	0.9370	0.8524	0.9501	1.0661	1.0647	1.0973	1.1348	0.9578
NOR	1.4574	1.3245	1.3425	1.3030	1.3003	0.9462	0.8238	0.9984	1.0365	1.0324	1.0590	1.0657	1.0471	1.0235	0.8162	0.7955	1.0851
POL	3.3110	3.3893	3.1918	3.1714	3.2380	3.1092	3.0140	2.8704	2.7920	2.6567	2.6012	2.5264	2.4773	2.4003	2.1908	1.9946	2.8084
PRT	0.7252	0.6629	0.6306	INF	0.6647	0.5102	0.7973	INF	INF	INF	INF	INF	0.8266	INF	INF	INF	0.6882
ESP	0.8477	0.8416	0.8306	0.7672	0.7728	0.7664	0.8094	0.8154	0.7800	0.7717	0.7784	0.8516	0.8830	0.8398	0.8962	0.9316	0.8240
SWE	0.7316	0.7371	0.7578	0.7432	0.7358	0.7236	0.7049	0.6744	0.6476	0.6149	0.5331	0.6160	0.6600	0.6623	0.6660	0.6866	0.6809
CHE	0.5954	0.4975	INF	INF	0.5039	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	0.5323
TUR	0.7137	0.7386	0.7677	0.7953	0.8057	0.7806	0.8441	0.8096	0.7704	0.7488	0.7483	0.8448	0.8549	0.8313	0.8124	0.8399	0.7941
GBR	1.0888	1.0923	1.0625	1.0727	1.0655	1.0536	1.0411	1.0532	1.0525	1.0203	0.9925	0.9914	0.9882	0.9856	0.9988	1.0033	1.0364
USA	0.8763	0.7094	0.7145	0.6966	0.7059	0.6881	0.6949	0.6744	0.6627	0.7630	0.7614	0.7575	0.7294	0.7257	0.7485	0.7613	0.7295
Mean	1.0649	1.0476	1.0644	1.0724	1.0432	1.0164	1.0119	1.0120	1.0125	0.9795	0.9756	0.9920	1.0082	0.9896	0.9724	0.9863	1.0156

Notes: INF denotes infeasible solutions.
Geometric means are reported.

the countries in our sample have ratified this convention until 1996 with an exception of Turkey which has ratified the convention in 2002. The square of GDPC and MANSHARE are also included in order to depict any quadratic relationship between environmental performance and these variables. The source for the explanatory variables except the regulation dummy is World Development Indicators (World Bank, 2002).

Under two alternative specifications (fixed effects and random effects models), Table 4 provides parameter estimates of the relevant regressions for all environmental performance indices computed. The choice between random effects and fixed effects model can be made using the Hausman test which has an asymptotic χ^2_{k-1} distribution. The parameter estimates, which are all significant at conventional levels, suggest a quadratic relationship between environmental performance and the two independent variables MANSHARE and GDPC except for the case when our dependent variable is the environmental performance index that incorporates NO_X and organic water pollutant emissions. The quadratic relationship between environmental performance and MANSHARE is inverse U type with a turning point of approximately 0.20. This suggests that, if the share of manufacturing in GDP increases beyond 20%, there would be a downward trend in environmental performance. On the other hand, positive and statistically significant coefficient of the regulation variable implies an upward pressure on environmental performance of the OECD countries that ratified the United Nations Convention on Climate Change to reduce air pollution emissions.[12] Finally, negative and highly significant coefficient of POPDEN implies that densely populated OECD countries are more likely to exhibit poor environmental performance in reducing their NO_X and water pollutant emissions.

At a more fundamental level, one would consider how the findings of this article may relate to environmental Kuznets curve hypothesis. In a short note, Yörük and Zaim (2006) use the results of this article to establish an environmental Kuznets curve relationship between environmental performance and income. They found that Kuznets curve achieves its maximum at relatively high per capita income levels ($26 973 and $33 677 under different specifications) suggesting that even most of the industrialized countries are not necessarily adhering to environmental standards and their environmental conditions are deteriorating with economic growth. However, once the stated income levels are reached, concerns about environment become increasingly pronounced and necessary regulations take place to reduce relevant emissions to desirable levels.

V. Conclusion

This article is aimed to measure the environmental performance of all but two OECD countries. Using nonparametric techniques, we proposed an environmental performance index by adopting a well-established methodology in a series of recent papers (Zaim *et al*., 2001; Färe *et al*., 2004; Zaim, 2004). This index relies on the computation of the distance functions within a DEA framework and allows one to evaluate how much good output is produced per bad output.

We computed three different environmental performance indices that employ different pollutant emission pairs. Although the ranking and environmental performances of countries differ over time and according to the pollutants considered, it is found that Poland and Hungary are the best performers for all indices, while Italy, Japan, Austria and Switzerland are among the worst. It should also be noted that environmental performance index that incorporates NO_X and organic water pollutant emissions reveals significantly higher environmental performance figures than other indices. The results showed that some industrialized and well-developed countries are ranked among the worst in terms of their environmental efficiency. We also noted that when we consider relatively low-income countries, the results revealed by our environmental performance index that incorporates different pollutant pairs and the ones reported by the traditional measures which attempt to assess the environmental performance by computing emissions per GDP are generally in line. However, when it comes to relatively high-income countries, this result does not hold.

We also investigated a set of country-specific variables that may possibly affect environmental performance. We found that as the share of manufacturing in GDP increases beyond 20%, there is a downward trend in environmental performance. On the other hand, positive and statistically significant coefficient of the regulation variable implies an

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[12] Yörük and Zaim (2005) and Yörük (2006) show the positive effect of UNFCCC on productivity growth measures that incorporate negative externalities. However, they do not address the effect of UNFCCC on environmental performance.

Table 4. Parameter estimates for alternative models

	Environmental performance index (CO_2/NO_X)				Environmental performance index (CO_2/WP)				Environmental performance index (CO_2/WP)			
	Without regulation		With regulation		Without regulation		With regulation		Without regulation		With regulation	
Dependent variable:	Fixed effects	Random effects	Fixed effects	Random effects	Fixed effects	Random effects	Fixed effects	Random effects	Fixed effects	Random effects	Fixed effects	Random effects
Constant	0.289	0.505	0.350	0.545	0.266	0.602	0.318	0.668	1.919	1.548	1.932	1.545
	(0.332)	(0.311)	(0.332)	(0.308)	(0.326)	(0.309)	(0.330)	(0.307)	(0.352)	(0.350)	(0.354)	(0.351)
	[0.364]	[0.293]	[0.407]	[0.331]	[0.285]	[0.249]	[0.300]	[0.254]	[0.439]	[0.365]	[0.508]	[0.342]
GDPPC	2.66E-05**	2.61 E-05***	2.72E-05**	2.38E-05***	−3.37E-05***	−1.59E*	−3.23E-05***	−1.58E-10*	3.34E-05***	2.53E-06	3.38E-05***	2.49E-06
	(1.12E-05)	(8.27E-06)	(1.12E-05)	(8.26E-06)	(1.09E-05)	(8.19E-06)	(1.10E-05)	(8.14E-06)	(1.22E-05)	(9.44E-06)	(1.23E-05)	(9.48E-06)
	[1.15E-05]	[7.78E-06]	[1.49E-05]	[9.48E-06]	[3.37E-05]	[8.73E-06]	[1.42E-05]	[8.64E-06]	[1.79E-05]	[1.14E-05]	[1.98E-05]	[9.38E-06]
$GDPPC^2$	−8.00E-10***	−8.02E-10***	−9.14E-10***	−8.57E-10***	7.40E-10**	2.92E-10	6.53E-10**	1.84E-10	−8.42E-10*	−8.24E-11	−8.77E-10*	−7.41 E-11
	(2.99E-10)	(2.33E-10)	(3.03E-10)	(2.33E-10)	(2.89E-10)	(2.29E-10)	(3.40E-10)	(2.34E-10)	(3.52E-10)	(2.64E-10)	(3.36E-10)	(2.68E-10)
	[3.21 E-10]	[2.30e-10]	[4.20E-10]	[2.70E-06]	[7.40E-10]	[2.60E-10]	[4.00E-10]	[2.64E-10]	[4.71 E-10]	[2.86E-10]	[5.51 E-10]	[2.74E-10]
MANSHARE	5.102*	3.728	5.183*	3.686	5.013*	4.581*	4.917*	4.268*	−1.870	−1.650	−1.833	−1.652
	(2.719)	(2.620)	(2.703)	(2.610)	(2.618)	(2.557)	(2.622)	(2.555)	(2.884)	(2.896)	(2.891)	(2.904)
	[3.141]	[2.511]	[3.611]	[3.059]	[2.610]	[2.265]	[2.912]	[2.3520]	[3.356]	[3.485]	[3.523]	[3.164]
$MANSHARE^2$	−12.487**	−9.755*	−12.55*	−9.555*	−11.988**	−11.188**	−11.72**	−10.44*	1.730	1.461	1.691	1.457
	(5.819)	(5.654)	(5.785)	(5.624)	(5.535)	(5.434)	(5.545)	(5.440)	(6.180)	(6.226)	(6.192)	(6.243)
	[6.525]	[5.363]	[7.489]	[6.793]	[5.672]	[5.009]	[6.645]	[5.313]	[7.541]	[7.877]	[7.629]	[7.229]
POPDEN	−1.50E-04	−4.20E-04	−7.18E-04	−5.10E-04	4.00E-03	6.60E-04	3.60E-03**	4.90E-04	−6.91 E-03*	−1.35E-03**	−7.08E-03***	−1.35 E-03**
	(1.47E-03])	(4.70E-04)	(1.40E-03)	(4.50E-04)	(1.40E-03)	(5.00E-04)	(1.45E-03)	(4.60E-03)	(1.58E-03)	(6.60E-04)	(1.63E-03)	(6.60E-04)
	[1.98e-03]	[2.24E-04]	[2.02E-03]	[2.23E-04]	[2.10E-03]	[2.93E-04]	[1.93E-03]	[2.71E-04]	[2.54E-03]	[3.71 E-04]	[3.00E-03]	[3.58E-04]
Regulation	–	–	0.035*	0.038**	–	–	0.0174	0.0344*	–	–	0.0085	−0.0026
	–	–	(0.0183)	(0.0179)	–	–	(0.0191)	(0.0186)	–	–	(0.1997)	(0.0198)
	–	–	[0.0129]	[0.0163]	–	–	[0.0189]	[0.0224]	–	–	[0.0245]	[0.0023]
Hausman test	–	11.47	–	8.59	–	15.01	–	7.63	–	14.90	–	40.09
Turning point (MANSHARE)	0.20	0.19	0.21	0.19	0.21	0.20	0.21	0.20	0.54	0.56	0.54	0.56
R2	0.0913	0.0898	0.1059	0.1040	0.0930	0.0965	0.0760	0.1005	0.05	0.0602	0.1012	0.0598
Number of observations	255	255	255	255	248	248	248	248	251	251	251	251

Notes: The values in parentheses are SE. The values in brackets are bootstrap errors after 50 replications.

#Indicates the model is favourable according to the Hausman test.

*Indicates a variable is significant at the 10% level of significance.

**Indicates a variable is significant at the 5% level of significance.

***Indicates a variable is significant at the 1% level of significance.

upward pressure on environmental performance of the OECD countries, which ratified the United Nations convention on climate change to reduce the air pollution emissions.

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Appendix

Table A1. Quantity index for bads: NO_X and CO_2

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Mean
AUS	INF	INF	INF	INF	INF	INF	INF	INF	0.6298	INF	0.6221	0.7751	0.8617	0.7848	0.8159	0.7843	0.7534
AUT	0.1418	0.1430	0.1457	0.1422	0.1398	0.1298	0.1290	0.1335	0.1367	0.1327	0.1275	0.1267	0.1205	0.1169	0.1184	0.1170	0.1313
BEL	0.2489	0.2415	0.2391	0.2363	0.2365	0.2204	0.2293	0.2326	0.2383	0.2462	0.2299	0.2326	0.2291	0.2270	0.2223	0.2209	0.2332
CAN	1.1679	1.1612	1.1269	1.1132	1.1681	1.2114	1.2135	1.1953	1.1307	1.1026	1.1408	1.1805	1.2114	1.1825	1.2066	1.2131	1.1704
DNK	0.1607	0.1637	0.1778	0.1785	0.1781	0.1590	0.1401	0.1546	0.1802	0.1489	0.1554	0.1630	0.1520	0.1643	0.1519	0.0800	0.1568
FIN	0.1338	0.1361	0.1382	0.1559	0.1591	0.1467	0.1525	0.1606	0.1537	0.1276	0.1420	0.1583	0.1527	0.1609	0.1553	0.1530	0.1492
FRA	1.0740	1.0502	1.0403	1.0004	0.9796	0.9179	0.9838	0.9591	0.9912	0.9408	0.9124	0.9603	0.9903	0.9872	0.9653	0.9652	0.9818
GER	2.2027	2.2233	2.2505	2.2821	2.2021	2.0666	2.0535	1.9343	1.8557	1.8071	1.7664	1.5860	1.5030	1.4933	1.3752	1.3643	1.8733
GRC	0.1816	0.1810	0.1720	0.1712	0.1824	0.1884	0.1955	0.2019	0.1943	0.1983	0.2018	0.2103	0.2156	0.2235	0.2259	0.2361	0.1987
HUN	0.1916	0.1941	0.1936	0.1929	0.1898	0.1728	0.1682	0.1584	0.1445	0.1324	0.1309	0.1258	0.1268	0.1310	0.1250	0.1211	0.1562
ISL	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	N/A
IRL	0.0594	0.0595	0.0643	0.0720	0.0767	0.0770	0.0754	0.0752	0.0802	0.0791	0.0787	0.0770	0.0797	0.0794	0.0814	0.0794	0.0747
ITA	0.9975	1.0013	0.9952	0.9881	1.0479	1.0571	1.0788	1.1290	1.1297	1.1101	1.0954	1.0531	1.0896	1.0744	1.0940	1.0938	1.0647
JPN	1.1767	1.2635	1.2181	1.2435	1.3569	1.4322	1.5553	INF	INF	INF	INF	INF	INF	INF	INF	INF	1.3209
KOR	0.4484	0.4592	0.4654	0.4792	0.5047	0.5736	0.6200	0.6062	0.6092	0.7188	0.7782	0.7918	0.7975	0.8619	0.8905	0.9310	0.6585
LUX	0.0072	0.0081	0.0078	0.0085	0.088	0.0090	0.0101	0.0127	0.0137	0.0143	0.0147	0.0145	0.0126	0.0127	0.0131	0.0125	0.0113
MEX	0.9174	0.8726	0.7941	0.7669	0.8097	0.7733	0.8018	0.8618	0.8685	0.8823	0.8838	0.9146	0.9174	0.9274	0.9346	0.9386	0.8666
NLD	0.3416	0.3530	0.3578	0.3434	0.3515	0.3416	0.3553	0.3638	0.3577	0.3527	0.3439	0.3265	0.3234	0.3374	0.3154	0.3088	0.3421
NZL	0.0561	0.0612	0.0615	0.0707	0.0735	0.0714	0.0741	0.0750	0.0751	0.0733	0.0747	0.0827	0.0866	0.0840	0.0874	0.0855	0.0746
NOR	0.1576	0.1751	0.1849	0.1907	0.1885	0.1215	0.1071	0.1307	0.1341	0.1378	0.1451	0.1446	0.1420	0.1472	0.1328	0.1293	0.1481
POL	1.0287	1.0493	1.0877	1.1167	1.1167	1.0437	1.0065	INF	0.8197	0.7979	0.7997	0.7547	0.7548	0.7766	0.7257	0.7142	0.9062
PRT	0.0688	0.0680	0.0721	0.0846	0.0996	0.0936	0.1269	INF	0.1053	INF	0.1077	0.1260	0.1451	0.1100	0.1422	0.1380	0.1063
ESP	0.6067	0.5805	0.5263	0.4937	0.5142	0.5141	0.5675	0.6452	0.6551	0.6344	0.6037	0.6656	0.7146	0.6698	0.7012	0.6916	0.6115
SWE	0.1773	0.1692	0.1661	0.1729	0.1803	0.1659	0.1670	0.1641	0.1624	0.1482	0.1302	0.1519	0.1531	0.1535	0.1459	0.1388	0.1592
CHE	0.1130	0.1113	0.1106	0.1139	0.1087	0.1058	0.1024	0.1080	0.1043	0.1048	0.0976	0.0937	0.0901	0.0907	0.0855	0.0834	0.1015
TUR	0.2909	0.2893	0.3077	0.3410	0.3622	0.3385	0.3672	0.4006	0.3941	0.3911	0.4335	0.4379	0.4817	0.5003	0.5352	0.5436	0.4009
GBR	1.5358	1.4770	1.5288	1.5590	1.5806	1.5607	1.5574	1.5786	1.5431	1.4768	1.4094	1.3801	1.3345	1.3088	1.2201	1.1628	1.4508
USA	13.0606	13.0096	12.4837	12.6733	12.7127	13.0154	12.8156	12.9788	12.8005	12.7759	13.0959	13.3890	13.4324	13.2952	13.4754	13.5379	13.0345
Mean	1.0210	1.0193	0.9968	1.0073	1.0206	1.0195	1.0251	1.0548	0.9811	1.0223	0.9816	0.9966	1.0045	0.9962	0.9978	0.9940	1.0087

Table A2. Quantity index for bads: NO_X and organic water pollutant

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Mean
AUS	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	0.3829	0.3903	INF	INF	0.3866
AUT	0.1818	0.1854	0.1890	0.1870	0.1861	0.1795	0.1817	0.1724	0.1746	0.1760	0.1720	0.1692	0.1618	0.1601	0.1732	0.1720	0.1761
BEL	0.2709	0.2660	0.2596	0.2535	0.2573	0.2614	0.2690	0.2571	0.2594	0.2687	0.2730	0.2689	0.2643	0.2656	0.2717	0.2760	0.2652
CAN	1.0409	0.9861	1.0207	1.0210	1.0420	1.0718	1.0643	1.0693	1.0283	0.9855	0.9810	0.9526	0.9390	0.9434	0.9585	0.9314	1.0022
DNK	0.1696	0.1762	0.1916	0.1998	0.1947	0.1857	0.1779	0.2063	0.2214	0.2079	0.2131	0.2140	0.2056	0.2236	0.2189	INF	0.2004
FIN	0.1907	0.1925	0.2023	0.2033	0.2038	0.2035	0.2049	0.2014	0.1937	0.1874	0.1838	0.1828	0.1779	0.1814	0.1794	0.1711	0.1912
FRA	1.3231	1.3468	1.3430	1.3435	1.3270	1.3304	1.4120	1.2948	1.3300	1.3630	1.3586	1.3710	1.3588	1.3661	1.4057	1.4394	1.3571
GER	2.1466	2.1826	2.2038	2.2375	2.1557	2.1156	2.0591	1.9384	1.8811	1.9205	1.9150	1.7636	1.7540	1.7661	1.8136	1.8259	1.9799
GRC	0.1866	0.1863	0.1880	0.1870	0.1896	0.1880	0.1923	0.2020	0.2026	0.1986	0.1965	0.1943	0.1943	0.1910	0.1906	0.1879	0.1922
HUN	0.2686	0.2758	0.2837	0.2946	0.2961	0.3021	0.3079	INF	INF	INF	INF	INF	INF	INF	INF	0.2056	0.2793
ISL	0.0158	0.0165	0.0166	0.0168	0.0169	0.0163	0.0158	0.0151	0.0151	0.0150	0.0162	0.0163	0.0165	0.0156	0.0153	0.0151	0.0159
IRL	0.0703	0.0707	0.0736	0.0774	0.0826	0.0854	0.0868	0.0813	0.0843	0.0882	0.0886	0.0860	0.0849	0.O883	0.0909	0.0910	0.0831
ITA	1.0594	1.0694	1.0531	1.0724	1.1152	1.0728	1.0920	1.1404	1.1559	1.1851	1.1505	1.0978	1.0839	1.0775	1.0602	1.0429	1.0955
JPN	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	N/A
KOR	0.5797	0.6148	0.6113	0.6699	0.7116	0.7961	0.8511	0.7436	0.7194	0.8114	0.8820	0.8799	0.8689	0.8999	0.9615	0.9952	0.7873
LUX	0.0112	0.0113	0.0115	0.0120	0.0118	0.0121	0.0125	0.0133	0.0137	0.0141	0.0144	0.0140	0.0137	0.0138	0.0142	0.0144	0.0130
MEX	INF	0.5815	0.5871	0.5681	0.5159	0.4854	0.4978	0.5172	0.5207	0.5266	0.4686	0.4326	0.3968	0.4282	0.4112	0.4068	0.4896
NLD	0.3652	0.3714	0.3831	0.3850	0.3892	0.3731	0.3639	0.3762	0.3704	0.3689	0.3588	0.3475	0.3432	0.3468	0.3397	0.3386	0.3639
NZL	0.1141	0.1172	0.1165	0.1166	0.1114	0.1100	0.1114	0.1054	0.1047	0.1140	0.1167	0.1122	0.1127	0.1139	0.1140	0.1135	0.1128
NOR	0.1345	0.1421	0.1484	0.1570	0.1556	0.1501	0.1460	0.1436	0.1391	0.1359	0.1377	0.1397	0.1404	0.1439	0.1390	0.1374	0.1432
POL	1.1297	1.1539	1.1168	1.1330	1.1200	1.1216	1.0784	INF	0.9006	0.8621	0.8532	0.8590	0.8743	0.9099	0.9409	0.8713	0.9950
PRT	INF	INF	INF	0.1541	0.1763	0.1991	0.2194	0.2886	0.3057	0.3209	0.3276	0.3235	0.3215	0.3289	0.3384	0.3840	0.2837
ESP	0.7187	0.7133	0.6575	0.6618	0.6741	0.6870	0.7351	0.7985	0.8205	0.8313	0.8944	0.8805	0.8759	0.8812	0.9153	0.9410	0.7929
SWE	0.2780	0.2847	0.2935	0.2986	0.2976	0.2942	0.2861	0.2467	0.2529	0.2478	0.2387	0.2407	0.2274	0.2290	0.2289	0.2239	0.2605
CHE	0.1855	0.1920	0.1991	0.2047	0.2053	0.2171	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	0.2006
TUR	0.3394	0.3537	0.3606	0.3901	0.4096	0.4202	0.4436	0.4529	0.4436	0.4665	0.4935	0.4797	0.5047	0.5281	0.5576	0.5665	0.4506
GBR	1.7180	1.7351	1.7744	1.8216	1.8409	1.8608	1.8746	1.8309	1.7635	1.7457	1.6676	1.6336	1.5911	1.5842	1.5657	1.5334	1.7213
USA	8.6842	8.3339	8.1356	7.7779	8.0630	7.7823	7.6574	7.9016	7.7621	8.1253	8.2770	8.1792	7.8295	7.9387	8.1043	8.1944	8.0467
Mean	0.8826	0.8624	0.8568	0.8248	0.8363	0.8278	0.8538	0.8693	0.8610	0.8819	0.8866	0.8683	0.8290	0.8406	0.8754	0.8783	0.8584

Table A3. Quantity index for bads: CO_2 and organic water pollutant

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Mean
AUS	0.5794	0.5633	0.5922	0.5735	0.5706	0.5911	0.5909	0.5552	0.5476	0.5211	0.5166	0.4983	0.4671	0.4450	0.4812	0.4898	0.5364
AUT	0.1816	0.1890	0.1811	0.1758	0.1781	0.1673	0.1674	0.1800	0.1725	0.1566	0.1615	0.1644	0.1722	0.1637	0.1693	0.1735	0.1721
BEL	0.2972	0.3008	0.2935	0.2846	0.2804	0.2640	0.2640	0.2750	0.2790	0.2704	0.2584	0.2734	0.2779	0.2738	0.2700	0.2741	0.2773
CAN	1.0078	0.9429	0.9900	0.9783	0.9871	1.0242	1.0326	0.9835	0.9315	0.9047	0.8923	0.8828	0.8869	0.8857	0.9142	0.9068	0.9470
DNK	0.1583	0.1602	0.1797	0.1773	0.1744	0.1587	0.1391	0.1653	0.1808	0.1506	0.1650	0.1792	0.1749	0.1663	0.1786	0.1947	0.1689
FIN	0.1503	0.1519	0.1588	0.1720	0.1715	0.1594	0.1588	0.1571	0.1463	0.1276	0.1356	0.1477	0.1463	0.1552	0.1503	0.1490	0.1524
FRA	1.3551	1.3321	1.2537	1.1906	1.1717	1.0630	1.1264	1.1608	1.1351	1.0045	0.9866	0.9599	1.1083	1.0664	1.0896	1.1343	1.1336
GER	2.4489	2.4139	2.4076	2.4440	2.3812	2.3520	2.3234	2.3242	2.3072	2.2479	2.2146	2.1154	2.1758	2.1758	2.1347	2.1410	2.2880
GRC	0.1653	0.1668	0.1705	0.1663	0.1721	0.1762	0.1857	0.1845	0.1721	0.1821	0.1831	0.1801	0.1809	0.1774	0.1809	0.1829	0.1767
HUN	0.3095	0.3220	0.2924	0.2738	0.2823	0.2396	0.2059	INF	0.1896	INF	INF	0.1273	0.1870	0.1422	INF	INF	0.2338
ISL	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	N/A
IRL	0.0811	0.0816	0.0786	0.0843	0.0859	0.0856	0.0801	0.0830	0.0883	0.0821	0.0843	0.869	0.0955	0.0887	0.0914	0.0932	0.0857
ITA	1.0398	1.0479	1.0185	0.9906	1.0162	0.9922	1.0103	1.0251	1.0328	1.0482	1.0030	0.9939	1.0132	0.9902	0.9965	0.9954	1.0134
JPN	2.9176	3.1037	2.9335	2.9222	2.9252	3.0931	3.0413	3.2144	3.1382	3.0224	3.0792	3.1895	3.2752	3.1860	3.3293	3.4790	3.1156
KOR	0.5065	0.5518	0.5692	0.5792	0.6186	0.6744	0.6912	0.7376	0.7436	0.7725	0.8449	0.9033	0.9653	0.9961	0.9857	1.0186	0.7600
LUX	0.0235	0.0240	0.0239	0.0236	0.0225	0.0222	0.0201	0.0221	0.0220	0.0214	0.0207	0.0205	0.0196	0.0192	0.0189	0.0188	0.0216
MEX	INF	0.5533	0.5700	0.5477	0.5176	0.5018	0.515	0.4972	0.4872	INF	INF	INF	INF	INF	INF	INF	0.5238
NLD	0.3401	0.3538	0.3660	0.3514	0.3549	0.3354	0.3614	0.3667	0.3673	0.3606	0.3565	0.3485	0.3480	0.3745	0.3616	0.3637	0.3569
NZL	0.0763	0.0777	0.0779	0.0833	0.0840	0.0814	0.0841	0.0804	0.0770	0.0731	0.0699	0.0798	0.0840	0.0832	0.0845	0.0867	0.0802
NOR	0.2039	0.1880	0.1926	0.1876	0.1854	0.1293	0.1098	0.1324	0.1409	0.1420	0.1477	0.1511	0.1510	0.1502	0.1202	0.1158	0.1530
POL	1.2894	1.3186	1.2701	1.2826	1.2889	1.2263	1.1454	0.9870	0.9355	0.8908	0.9070	0.8946	0.9146	0.9241	0.8791	0.8252	1.0612
PRT	0.1244	0.1054	0.0995	INF	0.1104	0.0879	0.1388	INF	INF	INF	INF	INF	0.1482	INF	INF	INF	0.1164
ESP	0.6550	0.6250	0.6068	0.5646	0.5841	0.5863	0.6308	0.6447	0.6270	0.6119	0.5972	0.6471	0.7017	0.6606	0.7075	0.7477	0.6374
SWE	0.2027	0.2032	0.2051	0.1995	0.1966	0.1890	0.1817	0.1719	0.1616	0.1479	0.1244	0.1444	0.1644	0.1614	0.1613	0.1684	0.1740
CHE	0.1670	0.1375	INF	INF	0.1327	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	0.1457
TUR	0.3197	0.3339	0.3498	0.3830	0.4003	0.3728	0.3901	0.4082	0.3885	0.3890	0.4227	0.4225	0.4493	0.4530	0.4620	0.4730	0.4011
GBR	1.7314	1.6972	1.6825	1.6902	1.7005	1.6927	1.6498	1.6324	1.5845	1.4956	1.4627	1.4777	1.4982	1.4824	1.5049	1.5112	1.5935
USA	8.4059	7.0011	7.0661	6.9268	6.9958	6.7983	6.8493	6.5815	6.3824	7.4488	7.5272	7.5730	7.2718	7.2693	7.5914	7.8860	7.2234
Mean	0.9515	0.8869	0.9088	0.9301	0.8737	0.8872	0.8884	0.9404	0.8895	0.9596	0.9636	0.9359	0.9151	0.9371	0.9940	1.0186	0.9300