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A Framework for Incorporating Environmental Indicators to the Measurement of Human Well-Being

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Abstract

This study, relying on an economic-theoretical approach to index numbers, proposes a framework for incorporating environmental indicators to the measurement of human well-being. Furthermore this study also proposes an improvement index which alleviates the well-known deficiency of across-time comparison of the deprivation index. The advantage of the proposed index is that it does not require normative judgement in the selection of weights to aggregate over constituent indices. Rather, within an activity analysis framework, optimally chosen weights are determined by the data. In developing the index, due emphasis is put on production with negative externalities, and directional distance functions—a very recent analytical device—are employed as a major tool to construct quantity indexes and improvement indexes.

Keywords: well-being, environment, indexes, measurement

JEL classification: Q51, D63

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1 Introduction

The last decade has witnessed major improvements in the measurement of sustainable human development. Considerable time and research effort have been devoted to both extending the dimensions of the measurement and the methodology used to compute sustainable human development indices. Now, the measurement of human well-being is not only limited to economic indicators but also takes into account social, institutional and ecological background, thus utilizing over 130 indicators approved by the UN in April 1995 (UN 2001). Improvements in the data collection of indicators, while triggering the construction of indexes from a series of constituent indicators such as human development index (HDI) with component indicators on longevity, educational attainment and income, have also led to aggregation of indexes of different dimensions. As a typical example of the latter, one can cite Prescott-Allen's (2001) human well-being index (HWI), which is an equal weighted average of the human well-being index and ecosystem well-being index (EWI), integrating two indices with social-economical and environmental dimensions.

On the academic front, research during recent years has considerably improved our understanding of sustainable human development, but at the expense of generating a certain amount of controversy. The concerns range from not being able to construct a totally objective index of sustainable human development (because both the indicator selection and weights assigned to these reflect normative judgements of those who developed the index), to whether these indices satisfy the certain axiomatic properties required of any index (Zheng 1993; Sen 1976). Specifically, a consensus has emerged that existing indexes, such as the HDI, fail to measure performance comparisons across time, because these are designed to measure performance comparisons at a point of time rather than being a measure of over-time comparisons.[1]

The purpose of this study is to expand on earlier works by Zaim, Färe and Grosskopf (2001) and Grosskopf, Self and Zaim (2002) to provide a framework for incorporating environmental indicators to the measurement of human well-being. Although some prior studies such as Prescott-Allen (2001), Nath, Talay and Tanrivermis (1998), and Lasso de la Vega and Urrutia (2001) all had the same objective of reconciling human well-being with environmental indicators, this study with its economic-theoretical approach to index number theory is a deviation. This study proposes a useful alternative to the 'aggregate deprivation index' used to measure the well-being of individuals in different countries or geographic locations. Furthermore, an improvement index which alleviates the well-known difficulties associated with over-time comparisons of the aggregate deprivation index is also proposed. The achievement index in this study relies heavily on the theory of quantity indexes whose axiomatic properties are well established. The roots of the improvement index are well grounded in the productivity growth literature. All proposed measures depend on the computation of distance functions, which are a complete characterization of technology. The indexes introduced in this study are an improvement of the empirical literature on social indicators in several respects. First, unlike previous studies which typically produce a synthetic indicator that aggregates its constituents using artificially assigned weights, the proposed approach implicitly recognizes the underlying production process which transforms inputs (per capita income and per capita capital) into private goods (which

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[1] See Ivanova, Arcelus and Srinivasan (1999), Anand and Ravallion (1993) and McGillivray (1991).

can be proxied by per capita income), social goods (which can be proxied by longevity and knowledge) and undesired goods (such as emissions of environmentally hazardous elements) by putting sufficient emphasis on production with negative externalities. Thus, while providing an economic content to social indicators, the aggregator characteristics of distance functions (which aggregate components with optimally chosen weights determined by the data) are fully exploited. Second, the proposed improvement index, since it is measured with respect to a production technology which is allowed to change over time, can capture the improvement in performance better than alternative indexes which have less tolerance for best achievers.

The remainder of the study unfolds as follows. The next section presents the methodology for constructing a human development index that takes into account differences in the environmental conditions. Section 3 is reserved for an empirical application, while section 4 concludes.

2   Methodology

This section follows closely Zaim, Färe and Grosskopf (2001) and Grosskopf, Self and Zaim (2002) in order to summarize the methodology for constructing a human development index void of any environmental considerations, so as to prepare the background for an extension which would allow for the incorporation of environmental indicators. Let us consider a sample of K countries, each of which produces a vector of private goods denoted by $y = (y_1,...,y_M) \in R_+^M$ and a vector of social goods $s = (s_1,...,s_J) \in R_+^J$, using inputs $x = (x_1,...,x_N) \in R_+^N$ with a meta technology represented by output (or production possibilities) set as

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

which satisfy certain axioms laid out by Shephard (1970).

P.1 $P(0) = \{0,0\}$.

P.2 $P(x)$ is compact for each $x \in R_+^N$.

P.3 $P(x) \supseteq P(x'), x \geq x'$

P.4 $(y,s) \in P(x)$ and y'$\leq$ y and s'$\leq$ s imply $(y',s') \in P(x)$

Properties P.1 state that zero inputs yield zero outputs and that any nonnegative input yields at least zero output. Properties P.2 require that only finite output should be produced given finite inputs. Finally, properties P.3 and P.4 impose free disposability of inputs and outputs, respectively.

Since the ultimate goal is to construct a quantity index for private and social goods which would allow multilateral comparisons across countries, Shephard's output distance functions are a useful tool for both representing technology and also serving as

a measure of performance. Hence, given an arbitrary vector of inputs x^0, once the success of countries i and j in expanding their private and social goods with respect to a set of production possibilities (output) common to all countries is measured by means of distance functions,

$$D_o^i(x^0, y^i) = \inf\{\theta^i : x^0, (y^i, s^i)/\theta^i \in P(x)\} \text{ and}$$
$$D_o^j(x^0, y^j) = \inf\{\theta^j : x^0, (y^j, s^j)/\theta^j \in P(x)\}$$

(2)

this allows for the construction of Malmquist quantity index of (aggregated) social and private goods as

$$Q(x^0, y^i, y^j, s^i, s^j) = \frac{D_o^i(x^0, y^i, s^i)}{D_o^j(x^0, y^j, s^j)}.$$

(3)

This quantity index now compares the provision of social and private goods in country i with respect to a reference country j given an arbitrary vector of inputs x^0 common to both. Since the meta technology which serves as a basis for the computation of distance functions is unobserved, it has to be constructed from the observed inputs and outputs of the countries in our sample. For this purpose, an activity analysis or data envelopment analysis (DEA) approach, which satisfies the properties underlying the technology (see Färe, Grosskopf and Lovell 1994), is employed. The piecewise linear output set is

$$P(x) = \{(y,s): \quad \sum_{k=1}^{K} z_k y_{km} \geq y_m, \quad m = 1,...,M,$$
$$\sum_{k=1}^{K} z_k s_{kj} \geq s_j, \quad j = 1,...,J,$$
$$\sum_{k=1}^{K} z_k x_{kn} \leq x_n, \quad n = 1,...,N,$$
$$z_k \geq 0 \quad k = 1,...,K\},$$

(4)

where z_k are the intensity variables which serve to form the technology from convex combinations of the data.

This quantity index, which is essentially a Malmquist quantity index (see Färe and Primont 1995), satisfies a number of desirable properties due to Fisher (1922). These are

(1) Homogeneity: $\quad Q(x^0, \lambda y^i, y^j, \lambda s^i, s^j) = \lambda Q(x^0, y^i, y^j, s^i, s^j)$

(2) Time-reversal: $\quad Q_s(x^0, y^i, y^j, s^i, s^j) Q_s(x^0, y^j, y^i, s^j, s^i) = 1$

(3) Transitivity: $\quad Q_s(x^0, y^i, y^j, s^i, s^j) Q_s(x^0, y^j, y^t, s^j, s^t) = Q_s(x^0, y^i, y^t, s^i, s^t)$

(4) Dimensionality: $\quad Q_s(x^0, \lambda y^i, \lambda y^j, \lambda s^i, \lambda s^j) = Q_s(x^0, y^i, y^j, s^i, s^j)$

As for the improvement index, we measure the success of a particular country in expanding its social goods from year t to year $t+1$ with respect to a common (world) benchmark technology constructed for the period t. Our improvement index

$$IMP^{t,t+1} = \frac{D_o^{k,t}(x^{k,t}, y^{k,t+1}, s^{k,t+1})}{D_o^{k,t}(x^{k,t}, y^{k,t}, s^{k,t})} \tag{5}$$

is the ratio of two distance functions where

$$D_o^{k,t}(x^{k,t}, y^{k,t+1}, s^{k,t+1}) = \inf\{\theta^{k,t+1} : (x^{k,t}, (y^{k,t+1}, s^{k,t+1})/\theta^{k,t+1}) \in P^t(x^t)\}$$

and $\tag{6}$

$$D_o^{k,t}(x^{k,t}, y^{k,t}, s^{k',t}) = \inf\{\theta^{k,t} : (x^{k,t}, (y^{k,t}, s^{k,t})/\theta^{k,t}) \in P^t(x^t)\}.$$

The first-distance function shows the success of an observation, say k, in expanding its private and social goods in year $t+1$ (with respect to a common frontier which represents the technology at t) while using the same level as in year t (i.e., $x^{k,t}$). Similarly, the second-distance function measures the success of the same observation in expanding its private and social goods in period t with respect to a common frontier representing the technology at t. Note that, since the distances are measured against the same benchmark (while holding resources and private goods at their year t levels), the ratio indicates the improvement in the provision of private and social goods for observation k.

To incorporate the joint production of bad outputs $b = (b_1,...,b_I) \in R_+^I$ (i.e., emissions of environmentally hazardous elements, which would ultimately affect human well-being negatively), this requires modifications both in our definition of performance measure and also in axiomatic properties of the meta technology. Note that while the Shephard output distance function allows one to construct a human well-being index by aggregating the social and private goods without any normative judgements, it still fails to account for the joint production of goods and bads. The generalization of this index to include bad outputs would not be meaningful (by redefining the output distance function as $D_o(x,y,s,b) = \inf\{\theta : x, (y,s,b)/\theta \in P(x)\}$) since it would mean proportionate expansion of bads together with private and social goods as much as feasible without crediting the reduction of bads. Nevertheless, the directional distance function proposed by Chung, Färe and Grosskopf (1997) which suggests asymmetric treatment of good and bad outputs provides a solution by crediting the expansion of good outputs and the contraction of bad outputs. Letting $g = (g_y, g_s, -g_b)$ be a direction vector, the directional distance function is expressed as

$$\vec{D}_o(x,y,s,b;g_y,g_s,-g_b) = \sup[\beta : (y + \beta g_y, s + \beta g_s, b - \beta g_b) \in P(x)]. \tag{7}$$

A nice feature of this directional distance function is that, as shown by Chung, Färe and Grosskopf (1997), it embodies Shephard's output distance function as a special case. Letting $g = (y,s,b)$ and following Chung, Färe and Grosskopf (1997)

$$\vec{D}_0(x,y,s,b;y,s,b) = \sup\{\beta : D_0(x,(y,s,b) + \beta(y,s,b)) \le 1\}$$
$$= \sup\{\beta : (1+\beta)D_0(x,y,s,b) \le 1\}$$
$$= \sup\{\beta : \beta \le \frac{1}{D_0(x,y,s,b)} - 1\} \tag{8}$$
$$= \frac{1}{D_0(x,y,s,b)} - 1$$

or equivalently

$$D_0(x,y,s,b) = 1/(1 + \vec{D}_0(x,y,s,b;y,s,b)).$$

Then, letting $g = (y,s,-b)$, the bads-incorporating human well-being index can be expressed as

$$Q(x^0,y^i,y^j,s^i,s^j,b^i,b^j) = \frac{1 + \vec{D}_0^j(x^0,y^j,s^j,b^j;y^j,s^j,-b^j)}{1 + \vec{D}_0^i(x^0,y^i,s^i,b^i;y^i,s^i,-b^i)}. \tag{9}$$

This quantity index now shows the success of country *i* in equiproportionate expansion and contraction of good (social and private) and bad outputs respectively, relative to a reference country *j*. Similarly the bads-incorporating improvement index can be written as

$$IMP^{t,t+1} = \frac{1 + \vec{D}_o^{k,t}(x^{k,t},y^{k,t},s^{k,t},b^{k,t};y^{k,t},s^{k,t},-b^{k,t})}{1 + \vec{D}_o^{k,t}(x^{k,t},y^{k,t+1},s^{k,t+1},b^{k,t+1};y^{k,t+1},s^{k,t+1},-b^{k,t+1})} \tag{10}$$

Now we turn our attention to the axiomatic properties of the output set when some outputs are undesired or associated with negative externalities. In the production theory, it is common to assume that outputs are strongly disposable, which implies that the disposal of any output can be achieved without incurring any costs in terms of reduced production of other outputs. This is, in fact, the case for desired outputs, private and social goods in P.4. However, the symmetric treatment of outputs in terms of their disposability characteristics loses its justification if one or some of the outputs, along with the desired outputs, are undesired goods such as carbon dioxide production (as a byproduct). Especially in regulated environments, where the productive unit is forced to clean up its undesired output or to reduce its levels of undesired output production, undesired and desired outputs have to be treated asymmetrically in terms of their disposability characteristics. Even in the absence of regulations, increased environmental consciousness in the society still requires the treatment of undesired goods as weakly disposable, that is, their disposal is achieved by reducing the desired outputs proportionately. The following property

P.5 $(y,s,b) \in P(x)$ and $0 \le \theta \le 1$ imply $(\theta y, \theta s, \theta b) \in P(x)$ [2]

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[2] Shephard (1970) introduced the notion of weak disposability of outputs.

imposes weak disposability of good and bad outputs. It states that for a given input vector, only a proportional contraction of good and bad outputs is feasible. Finally one should also recognize the joint product nature of bad outputs. The following property, P.6, is referred to as null-jointness.[3]

P.6 $(y,b) \in P(x)$ and $b = 0$ then $y = 0$.

This implies that for a given output vector, if bad output is zero, then so too must be good output. In other words, if one wishes to produce good output, some bad output will also be produced.

The piecewise linear output set associated with properties P.1-P.6 is (see Färe, Grosskopf and Lovell 1994)

$$P(x) = \{(y,s,b): \sum_{k=1}^{K} z_k y_{km} \geq y_m, \quad m = 1,...,M,$$
$$\sum_{k=1}^{K} z_k s_{kj} \geq s_j, \quad j = 1,...,J,$$
$$\sum_{k=1}^{K} z_k b_{ki} = b_i, \quad i = 1,...,I, \quad (11)$$
$$\sum_{k=1}^{K} z_k x_{kn} \leq x_n, \quad n = 1,...,N,$$
$$z_k \geq 0 \quad k = 1,...,K\},$$

where the z_k are intensity variables which serve to form the technology from convex combinations of the data. The technology represented in (11) also satisfies constant returns to scale; that is

$$P(\lambda x) = \lambda P(x), \lambda > 0. \quad (12)$$

The first two inequalities in (11) imply that private and social goods are freely disposable. Since the intensity variables $z_k, k = 1,...,K$, are nonnegative and the bad output constraint is a strict equality, one can show that (12) satisfies weak disposability.

Null-jointness requires that

i) $\quad \sum_{k=1}^{K} b_{ki} > 0, \ i = 1,...,I,$

ii) $\quad \sum_{i=1}^{I} b_{ki} > 0, \ i = 1,...,K.$

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[3] Shephard and Färe (1974) introduced this property.

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The first inequality requires that each bad output is produced by some firm k, while the second inequality states that each firm k produces some bad output.

Having formed the output set for each of the countries in our dataset $k'= 1,\ldots K$, the solution to the following linear programming problem computes the directional distance

$$\vec{D}_0(x^0, y^{k'}, s^{k'}, b^{k'}; g) = \max \beta$$
such that

$$\sum_{k=1}^{K} z_k y_m^k \geq y_m^{k'} + \beta y_m^{k'} \qquad m = 1,\ldots, M$$

$$\sum_{k=1}^{K} z_k s_j^k \geq s_j^{k'} + \beta s_j^{k'} \qquad j = 1,\ldots, J \qquad (13)$$

$$\sum_{k=1}^{K} z_k b_i^k = b_i^{k'} - \beta b_i^{k'} \qquad i = 1,\ldots, I$$

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

which is in the denominator of (9). The directional distance of the reference country in the numerator is computed by replacing the right-hand sides of the first three constraints above with the associated quantities of the country chosen as the reference country, that is, country j.

As for the computation of the improvement index, for each k' the following linear programming problem

$$\vec{D}^{k't}(x^{k'}, s^{k',t+1}, b^{k'',t+1}, y^{k't+1}) = \max \theta^{k',t+1}$$
such that
$$\sum_{k=1}^{K} z_k s_{kj}^t - \theta^{k',t+1} s_{k'j}^{k',t+1} \geq s_{k'j}^{t+1} \qquad j = 1,\ldots, J$$

$$\sum_{k=1}^{K} z_k y_{km}^t - \theta^{k',t+1} y_{k'm}^{t+1} \geq y_{k'm}^{t+1} \qquad m = 1,\ldots, M \qquad (14)$$

$$\sum_{k=1}^{K} z_k b_{ki}^t + \theta^{k',t+1} b_{k'i}^{t+1} = b_{k'i}^{t+1} \qquad i = 1,\ldots, I$$

$$\sum_{k=1}^{K} z_k x_{kn}^t \leq x_{k'n}^t \qquad n = 1,\ldots, N$$

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

solves for the directional distance function in the denominator of $IMP^{t,t+1}$. The numerator can be computed in a similar fashion as

$$\vec{D}^{k't}(x^{k'}, s^{k',t}, b^{k',t}, y^{k',t}) = \max \theta^{k'}$$

such that

$$\sum_{k=1}^{K} z_k s_{kj}^t - \theta^{k',t} s_{k'j}^{k'} \geq s_{k'j}^t \qquad j = 1,....,J$$

$$\sum_{k=1}^{K} z_k y_{km}^t - \theta^{k',t} y_{k'm}^t \geq y_{k'm}^t \qquad m = 1,....,M \tag{15}$$

$$\sum_{k=1}^{K} z_k b_{ki}^t + \theta^{k',t} b_{k'i}^t = b_{k'i}^t \qquad i = 1,....,I$$

$$\sum_{k=1}^{K} z_k x_{kn}^t \leq x_{k'n}^t \qquad n = 1,....,N$$

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

3 A numerical example

In constructing the numerical exercise for the human well-being and improvement indexes proposed in this study, data for 22 high-income OECD countries are selected for the years 1977, 1980, 1982, 1987, 1990. The reason for restricting the sample to high-income countries is twofold. First, since a meta technology that is common to all countries exists, it is desirable that the weak disposability of undesired outputs assumption holds for each country. Otherwise there is always a danger of over-crediting the comparatively lower emissions of lower-income countries who are treating undesired outputs as strongly disposable. In such instances it may be better to relax the weak disposability assumption in favour of strongly disposable outputs but still crediting expansion of desired outputs and contraction of undesired. Second, this allows the demonstration of a couple of stylized facts on informational validity of HDI. Various studies, specifically Ivanova, Arcelus and Srinivasan (1999), in their assessment of the measurement properties of HDI find very high correlations between the HDI index and per capita GDP of countries. Furthermore, they show that this high correlation is independent of the weights assigned to constituent indices. Therefore, one would expect this to be amplified within a group of high-income countries, resulting in a HDI, which is indistinguishable from per capita income, since all other constituent indices except income are very close to each other. If this is in fact the case, it will provide further justification to search for alternative constituent indices or aggregation of indexes of different dimensions.

We proxy the vector of social goods with infant survival rate, life expectancy at birth (total years) primary school enrolment rate (per cent gross) and secondary school enrolment rate (per cent gross). The environmental indicator is chosen as per capita carbon dioxide emission. Our proxy for private goods is real gross domestic product per labour. The resource constraint is represented with an aggregate input, capital stock per labour. The source for the variables representing social goods, and the environmental indicator is the World Bank Social Indicators Database. Other variables, real gross domestic product, capital stock and employment are retrieved from the Penn World Tables which limits extending our data to 1990 only since revised capital stock estimates are not yet available for later years.

Table 1
Alternative indexes of human well-being in OECD countries

	$Q(x^0,y^i,y^j,s^0,s^0,b^0,b^0)$		$Q(x^0,y^0,y^0,s^i,s^j,b^0,b^0)$		$Q(x^0,y^i,y^j,s^i,s^j,b^0,b^0)$		$Q(x^0,y^i,y^j,s^i,s^j,b^i,b^j)$	
Australia	1.1303	(7)	1.023	(8)	1.1303	(7)	1.0137	(19)
Austria	0.9702	(13)	0.9934	(22)	0.9702	(13)	1.1195	(11)
Belgium	1.1315	(6)	0.9967	(18)	1.1315	(6)	1.03	(15)
Canada	1.2309	(3)	1.0111	(13)	1.2309	(3)	1.025	(16)
Denmark	0.935	(14)	1.005	(15)	0.9432	(16)	0.95	(21)
Finland	0.831	(19)	1.0379	(2)	0.9574	(14)	1.0235	(17)
France	1.1069	(8)	1.0418	(1)	1.1069	(8)	1.1111	(12)
Greece	0.6278	(22)	0.9951	(20)	0.9069	(21)	1.3146	(1)
Ireland	0.7303	(20)	1.0268	(7)	0.936	(19)	1.2294	(7)
Iceland	0.8707	(17)	1.0284	(6)	0.9372	(18)	1.0605	(13)
Israel	0.8362	(18)	0.9944	(21)	0.9063	(22)	1.2548	(4)
Italy	1.0159	(11)	0.9953	(19)	1.0159	(12)	1.2422	(5)
Japan	0.6286	(21)	1.0379	(2)	0.9459	(15)	1.1253	(10)
Luxembourg	1.1729	(5)	0.9998	(16)	1.1729	(5)	0.891	(22)
Netherlands	1.2532	(2)	1.0341	(4)	1.2532	(2)	1.144	(9)
New Zealand	1.0627	(9)	1.0136	(10)	1.0627	(9)	1.2352	(6)
Norway	1.0142	(12)	1.0308	(5)	1.0229	(11)	1.1684	(8)
Spain	0.933	(15)	1.023	(8)	0.9432	(16)	1.3146	(1)
Sweden	1.0407	(10)	1.0117	(11)	1.0407	(10)	1.0139	(18)
Switzerland	1.1911	(4)	1.0116	(12)	1.1911	(4)	1.3142	(3)
UK	0.8994	(16)	0.9968	(17)	0.9268	(20)	0.9846	(20)
USA	1.3877	(1)	1.0081	(14)	1.3877	(1)	1.055	(14)
Average	1		1		1		1	

In this particular application, a hypothetical 'average country' (in all variables for every year) is chosen as a reference country. Thus, it is assumed that $j = 0$ which then refers to the associated quantities for the 'average country'.

To provide a means of comparison among indexes with different component indices, a step-by-step approach is followed for the year 1977. First, by holding all variables other than income constant at 'average country' levels, an income index is generated for the year 1977. This index (with associated ranks) is shown in column 1 of Table 1. Note that income is almost equally dispersed around the average country with the highest income (USA) and the lowest income (Greece) being approximately 38 per cent above and low average, respectively. Then, the same exercise is repeated for the vector of social goods only, holding income, undesired output and resources at the average country levels. A close examination of column 2 reveals that, with respect to the provision of social goods, high-income countries are very similar to each other, the difference between the best and the worst provision only 5 per cent. Column 3 is reserved for the traditional HDI, a composite index of social goods and income, but with the weights being determined optimally by the data. The comparison of columns 3 and 4 confirms our prior expectation that, with similar provision of social goods, HDI becomes almost identical to per capita labour income and provides justification to Ivanova, Arcelus and Srinivasan's assessment of the measurement properties of the HDI. Note that while the HDI index value for half of the countries is the same as per

labour GDP, considerable differences still exist between the two indexes for Finland, Greece, Ireland, Iceland and Japan. Armed with sufficient justification for an alternative index, in the last column in Table 1, the quantity index in (9)—which shows the success of country *i* in equiproportionate expansion and contraction of good (social and private) and bad outputs relative to a reference country *j*—is listed. Note that while this index rewards relatively low polluters such as Greece, Spain, Italy, New Zealand and Ireland, it punishes severely high polluters such as Luxembourg, USA, Sweden, Denmark and Canada.

Since this index is transitive, it allows for bilateral comparisons among all country pairs. To facilitate an easier exposition, the bads-incorporating quantity index (9) is normalized for each year by the value of the best performer, so as to assign a value of 100 for the best achiever. These are given in Table 2, where although the ranking of individual countries differs from year to year, Switzerland, Spain, and Italy have always maintained their position within the best five performers. As for the worst performers, our bads-incorporating quantity index consistently places UK, Luxembourg, Norway, Australia and Denmark among the last seven. Although the quantity index in (9) is not designed to measure performance over time, examination of the ranks pertaining to each year reveals the spectacular performance of France and Sweden, which raised their

Table 2
Quantity indexes

	1977		1980		1982		1987		1990		IMP 1977-90
Australia	77.11	(19)	78.45	(16)	74.28	(18)	75.40	(18)	77.75	(22)	1.01
Austria	85.16	(11)	92.29	(7)	89.83	(11)	84.20	(11)	87.12	(10)	1.12
Belgium	78.35	(15)	80.62	(14)	81.22	(15)	81.60	(13)	88.21	(8)	1.19
Canada	77.97	(16)	76.09	(19)	74.23	(19)	79.20	(14)	85.51	(12)	1.13
Denmark	72.27	(21)	79.19	(15)	78.30	(16)	72.74	(20)	79.63	(20)	1.14
Finland	77.86	(17)	77.98	(17)	82.97	(14)	73.96	(19)	82.73	(16)	1.10
France	84.52	(12)	87.33	(9)	92.72	(8)	94.71	(2)	100.00	(1)	1.25
Greece	100.00	(1)	99.53	(3)	99.06	(4)	86.98	(6)	88.45	(7)	0.92
Iceland	80.67	(13)	84.16	(13)	91.12	(9)	85.16	(10)	84.96	(13)	Infeasible
Ireland	93.52	(7)	87.32	(10)	87.49	(12)	77.33	(15)	82.00	(18)	1.01
Israel	95.45	(4)	98.95	(4)	94.92	(6)	85.81	(9)	86.59	(11)	0.95
Italy	94.49	(5)	100.00	(1)	99.18	(3)	94.44	(3)	95.12	(3)	1.12
Japan	85.60	(10)	86.33	(11)	86.42	(13)	82.29	(12)	82.30	(17)	0.99
Luxembourg	67.78	(22)	66.79	(22)	67.39	(21)	71.00	(21)	84.26	(14)	1.24
Netherlands	87.02	(9)	87.41	(8)	94.50	(7)	86.17	(8)	88.07	(9)	1.11
New Zealand	93.96	(6)	95.93	(6)	100.00	(1)	86.27	(7)	89.64	(6)	1.01
Norway	88.88	(8)	67.60	(21)	65.84	(22)	67.44	(22)	81.04	(19)	0.89
Spain	100.00	(1)	100.00	(1)	100.00	(1)	100.00	(1)	100.00	(1)	1.28
Sweden	77.13	(18)	85.89	(12)	90.64	(10)	90.16	(5)	92.38	(5)	1.28
Switzerland	99.97	(3)	98.70	(5)	95.61	(5)	91.04	(4)	94.43	(4)	0.99
UK	74.90	(20)	75.73	(20)	77.16	(17)	75.74	(16)	78.24	(21)	Infeasible
USA	80.25	(14)	76.39	(18)	74.00	(20)	75.67	(17)	83.64	(15)	1.14
Geometric mean	84.62		84.97		85.55		82.19		86.70		1.09

Table 3
Improvement in human well-being over sub-periods

	1977-80	1980-82	1982-87	1987-90	1977-90
Australia	1.00	0.97	1.05	0.99	1.01
Austria	1.09	0.98	1.03	1.02	1.12
Belgium	1.01	1.02	1.08	1.07	1.19
Canada	1.00	1.01	1.10	1.02	1.13
Denmark	1.08	1.02	1.00	1.03	1.14
Finland	0.99	1.11	0.95	1.05	1.10
France	1.01	1.07	1.11	1.04	1.25
Greece	0.99	1.00	0.96	0.97	0.92
Iceland		1.09		1.25	Infeasible
Ireland	0.98	1.03	0.99	1.01	1.01
Israel	1.01	0.96	1.01	0.97	0.95
Italy	1.03	1.02	1.04	1.02	1.12
Japan	1.01	1.02	1.02	0.94	0.99
Luxembourg	1.03	1.04	1.07	1.08	1.24
Netherlands	1.00	1.10	0.99	1.02	1.11
New Zealand	0.99	1.08	0.94	1.01	1.01
Norway	0.72	1.00	1.03	1.20	0.89
Spain	1.04	1.04	1.15	1.04	1.28
Sweden	1.09	1.07	1.08	1.01	1.28
Switzerland	0.96	0.97	1.02	1.03	0.99
UK	1.01	1.01			Infeasible
USA	1.00	1.01	1.04	1.08	1.14
Geometric mean	0.98	1.03	1.02	1.04	1.09

ranks from 12th to 1st position and from 18th to 5th, respectively. Greece, Israel, Norway, Ireland and Japan, on the other hand, seem to have lost their comparative advantage in the provision of healthy standard of living. The last column in Table 2 is reserved for the overall improvement in the human well-being index computed using (10). A breakdown of human improvement index for subperiods is also provided in Table 3.

An analysis of the overall improvement rate combined with observations on a year-to-year variation of the relative rankings of countries reveals fairly consistent results. For example, France and Sweden owe their quite spectacular climb with regard to their rank among the 22 countries to their rather high improvement rates (25 per cent and 28 per cent, respectively). Spain, on the other hand, maintains its top position among the countries because of its high overall improvement rate, an achievement shared with Sweden.

We also observe that countries showing deterioration in performance (like Greece, Japan, Switzerland and Norway) have also experienced a fall in their relative ranking. It is also useful note that a comparison of quantity indexes across time will not reveal much about overall improvement. With such a comparison, one would incorrectly conclude, for example, that Spain shows no improvement, whereas with its highest

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growth performance, it is, in fact, the country that boosts the distribution of human well-being index over time.[4]

4   Conclusions

This study, relying on an economic-theoretical approach to index numbers, proposes a framework for incorporating environmental indicators to the measurement of human well-being. Furthermore, this study also introduces an improvement index which alleviates the well-known deficiency of across-time comparison of deprivation index. The benefit of the proposed index is that it does not require normative judgements in the selection of weights to aggregate over constituent indices. Instead, optimally chosen weights, within an activity analysis framework, are determined by the data. In developing the index which incorporates environmental indicators, due emphasis is put on production with negative externalities and directional distance functions—a very recent analytical device—are employed as a major tool to construct quantity indexes and improvement indexes. The improvement index is well grounded in the theory of productivity growth. The paper also provides a numerical example of computations over 22 high-income OECD countries to show that the indexes proposed are capable of differentiating differences in human well-being where more traditional indexes fail.

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[4]   See Zaim, Färe and Grosskopf (2001) for details on the superiority of the improvement index in this study versus across-time comparison of deprivation indexes.

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