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The Human Development Index Adjusted for Efficient Resource Utilization

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Abstract

The human development index (HDI) developed by the United Nations Development Programme is computed as the average of three equally weighted outcome measures: life expectancy (LI), educational attainment (EI) and income (WI). However, this computational process is independent of the resources being devoted by each country to the achievement of the three outcome levels. Hence, it is conceivable that two different countries may consume vastly different amount of resources in achieving the same outcome, say, LI. However, this difference in the efficiency of resource utilization is not reflected in the HDI. The purpose of this paper is to address this efficiency issue.

Keywords: human development index, data envelopment analysis, efficiency, congestion and scale economics

JEL classification: C10, I31

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1 Introduction

The human development index (HDI) developed by the United Nations Development Programme (e.g., UNDP 2003) is computed as the average of three equally weighted outcome measures or indices of human development: life expectancy (LI), educational attainment (EI) and income (WI). However, this computational process is independent of the resource endowment being devoted by each country to the achievement of the three outcome levels (e.g., Raab, Kotamraju and Haag 2000). Hence, it is conceivable that two different countries consume vastly different amount of resources in achieving the same, say, LI, whereas this difference in the efficiency of resource utilization is not reflected in the HDI. The purpose of this paper is to address this efficiency issue. Here, the term *efficiency* corresponds to the concept of Pareto-Koopmans efficiency in economics (e.g., Varian 1999). Thus, it measures the ability of each country to transform the minimum possible units of its own resources into the maximum possible levels of the three outcomes. As a result, a country or decisionmaking unit (DMU) 'is fully efficient if and only if it is not possible to improve any input or output without worsening some other input or output' (Cooper, Seiford and Tone 2000: 45). This definition is operationalized through the development of a benchmarking model, where each country's three HDI outcome measures, LI, EI and WI, are evaluated relative to an efficient or 'best-practice' production frontier, formed by the benchmarking (i.e., most efficient) countries. The determination of this frontier is achieved through the use of the data envelopment analysis (or DEA) methodology (e.g., Cooper, Seiford and Tone 2000; Thanassoulis 2001; Zhu 2003).

The methodological underpinnings of the HDI are straightforward and appear as a technical note to the various *Human Development Reports* (e.g., UNDP 2003). For each country, the LI is measured by the life expectancy at birth. EI is based upon the weighted average of the adult literacy rate (2/3 weight) and the combined gross enrolment in primary, secondary and tertiary education (1/3 weight). WI uses the adjusted, per capita GDP (PPP, US$). All three are deprivations indexes. As such, LI and the two components of EI are computed as the ratio of the difference between each country's observed value and a minimum goalpost value to the difference between a maximum and the minimum goalposts. A similar procedure is followed for the computation of WI, but using the log of GDP and of the two goalposts. The use of logs is intended to account for the diminishing returns exhibited by the income component towards the enhancement of human development.

Since its inception in 1990, the HDI has spawned a wide gamut of studies that may be classified into three categories. The first deals with attempts to enhance the understanding and justification of the methodological construct. Included here are studies directed towards:

i) detailing the evolution of the construction methodology of the HDI as a measure of human well-being, its impact on policymaking and possible directions for future research (e.g., Jahan 2003);

ii) analysing the characteristics of the HDI as an index, across a variety of dimensions (e.g., Ivanova, Arcelus and Srinivasan 1999; Alkire 2002);

iii) bridging the gap between the 1990 and the 1994 methods computing the goalposts (e.g., Mazumdar 2003);

iv) extending the diminishing-returns methodology to the computation of the EI (e.g., Noorbakhsh 1998);

v) testing with a moderate amount of success the assumption of the HDI construct that per capita GDP exhibits diminishing returns to development (e.g., Cahill 2002);

vi) studying in more depth the relationship between human development and economic growth (e.g., Ranis, Stewart and Ramirez 2000), as a way of justifying the use of HDI over that of per capita GDP as 'a measure of average achievement in basic human capabilities' (Jahan 2003: 3); and

vii) stating reasons why the HDI construct may not have kept up with current global concerns (Sagar and Najam 1998).

The second category of studies explores the role of HDI in explaining specific issues related to human development in specific countries. Recent examples of this rather voluminous literature include assessing the extent of regional disparities in Iran (Noorbakhsh 2002) or the state of human development in China (Dejian 2003).

The third and final category attempts to extend the HDI's range of applicability through the incorporation of other dimensions likely to impact upon a country's human development. Examples of this literature are:

i) introducing environmental factors designed to identify the extent to which countries are willing to accept environmental degradation to obtain current income at the expense of future economic expansion (e.g., Lasso de la Vega and Urrutia 2001; Neumayer 2001);

ii) measuring cross-country divergence in the standard of living (e.g., Mazumdar 2003);

iii) assessing the advantages and disadvantages of using the HDI as a monitor of human rights worldwide (e.g., Fukuda-Parr 2001);

iv) presenting evidence of HDI dominance over per capita GDP as a measure of human welfare, on the grounds that the former is better suited to capture 'how long the economy can keep the average person alive to experience [given levels] of welfare' (Berg 2002: 193), whereas the latter 'fails to measure the lifetime welfare of the individuals' (Berg 2002: 182);

v) assessing the HDI's suitability as a measure of a nation's competitiveness (Ivanova, Arcelus and Srinivasan 1997 and 1998);

vi) evaluating the HDI's role in measuring a child's quality of life (e.g., Raab, Kotamraju and Haag 2000); and

vii) using HDI as a yardstick in the computation of alternative achievement and improvement indexes as measures of quality of life (Zaim, Färe and Grosskopf 2001).

One of the gaps that becomes apparent in this brief review of the literature is the dearth of studies on the level of effort, in terms of resources allocation, devoted by various countries in their pursuit of the three objectives embedded in the HDI and thus in the achievement of specific HDI targets. The current study attempts to bridge this gap. More specifically, the objectives of this study are (i) to assess the efficiency of each country's resource allocation policies in generating the given outcome levels of the three outcomes, LI, EI and WI; (ii) to produce an HDI for each country, adjusted for the efficiency of the resource allocation process; and (iii) to test for any statistical difference between the two.

2 Research framework

This section sets the stage for the efficiency analysis of the next section. It describes the inputs hypothesized to be affecting each output, summarizes the DEA model used in the estimation of efficiency and outlines the possible sources of efficiency.

2.1 The model's inputs and outputs

The outputs to be considered in this paper are the three components of the HDI, namely LI, EI and WI. The model also includes several inputs hypothesized to impact upon each output. Table 1 lists these inputs. Several considerations have guided the input-selection criteria. First, it should be observed that to prevent the data consistency problems common to studies of this type (e.g., Ivanova, Arcelus and Srinivasan 1997), the inputs have been selected from among those present in the website for UNDP (2003), with the two exceptions noted in Table 1. Second, in the selection of these particular sets of inputs, special care has been taken to account for the dynamic interrelationships among the inputs and outputs. For example, in the LI case, current health expenditures are obviously not the only health expenditures to impact upon LI. The pattern of past years' health policies are going to affect this year's life expectancy and thus such pattern should be included in the formulation. This is the well-known problem in economics of selecting the appropriate lag structure to each dynamic setting.

Table 1
Inputs and outputs of the model

Outputs	Inputs	
LI - Life expectancy index	PHYS	number of physicians per 100,000 population
	HEC	health expenditures per capita
	M/F LEB	male/female life expectancy at birth
EI - Educational attainment	PEDEX	public education expenditures
	A/Y LR	adult/youth literacy rate
	F/M ALR	female/male literacy rate
	F/M PST	female/male combined primary, secondary, tertiary enrolment
WI - Income index	NFDII	net foreign direct investment flows (% of GDP)
	ECPC	electricity consumption per capita
	GDPE	GDP per unit of energy use
	F/M EEI	female/male expected earned income
	GDCF	gross domestic capital formation
	IU%P	internet uses (% of population)

Sources: UNDP (2003) for all variables except for GDCF and IU%P; UN (various years) for GDCF; and Globstat for IU%P.

Given the impossibility of the task, for each output, a series of stock variables, such as PHYS, are used as proxies for the cumulative effects of past expenditure flows. Third, included here are various male/female or female/male ratios. The rationale for these ratios is that the closer they are to 1 the higher the additional expenditure flows to achieve gender equality and hence the higher the corresponding output index. As a result, these ratios are being used as proxies for stock variables, measuring how much investment has already been undertaken to achieve gender equality. A similar argument may be made in the case of A/Y LR. The closer the ratio is to one, the higher the success of the alphabetization campaigns aimed at closing the age gap in education prevalent in many countries. Fourth, the FDI variable has been normalized through its division by GDP, thus substantially palliating the problem of unusual year-to-year fluctuations.

2.2 The DEA framework

For each HDI component, the efficiency of each country or DMU (decisionmaking unit in DEA terminology) is measured by its ability to transform the appropriate inputs into the corresponding output. The starting point of the analysis is the construction of an efficient production frontier, for each of the three outputs, formed by the 'best practice' benchmarking countries. For this purpose, the DEA formulations of the paper include a set of C DMUs or countries. The outputs are denoted by y_{co}, where the index o represents a given output (o=1,2,3 for outputs LI, EI and WI, respectively). For each output o, there are I_o inputs, denoted by x_{ci}, where the index $i=1,...,I_o$ represents the appropriate inputs, as listed in Table 1 and $c=1,..., C$ represents the countries. Only 80 countries had the entire dataset and hence, for the purposes of this paper, C=80. The rationale for selecting a single-output DEA formulation, each representing a particular HDI dimension, instead of a multiple-output framework, lies on the fact that, as Table 1 indicates, some inputs are unique to a particular output and thus the policy implications differ for each HDI dimension.

To achieve this paper's objectives, several characteristics of the input/output relationship need to be described first. These are based upon standard notions of production economics (e.g., Coelli, Rao and Battese 1998; Cooper, Seiford and Tone 2000; Thanassoulis 2001). The first deals with how efficiency should be measured. For this purpose, observe that a DEA formulation may adopt an output or an input orientation. With the former, the efficiency of an economic unit is measured in terms of the output levels produced with a given level of inputs and of its ability to increase those output levels up to those of the benchmark. This is in contrast to an input orientation, where the efficiency of an economic unit is assessed in terms of the levels of the various inputs utilized to produce given levels of output and of its ability to reduce those input levels down to those of the benchmark. This paper uses the input orientation, as being closer to the stated purpose of this paper of developing a resource-adjusted HDI estimates. Further, an input orientation appears more desirable since countries have a greater ability to control their inputs than their outputs. The second characteristic deals with returns to scale. If the underlying system is characterized by a constant-returns-to-scale (CRS) technology, with inputs and outputs increasing or decreasing at the same rate, both orientations ought to yield the same efficiency level. Otherwise, when the rates of change differ for the inputs and the output, variable returns to scale (VRS) are manifestations of scale, which should be purged before the appropriate measure of inefficiency can be obtained. Of particular importance for this paper are the cases of non-increasing (NRS), decreasing (DR) and increasing (IR) returns to scale.

Another important characteristic of these formulations is the presence or absence of congestion. ‘Evidence of congestion is present when reductions in one or more inputs can be associated with increases in one or more outputs—or, proceeding in reverse, when increases in one or more inputs can be associated with decreases in one or more outputs—without worsening any other input or output’ (Cooper, Seiford and Tone 2000: 2). Coelli, Rao and Battese (1998: section 7.5) gives some examples of input congestion in cases of government or union-based controls on the use of certain inputs. Output congestion is not relevant for this paper, since the outputs, LI, EI and WI, are being evaluated separately. The problem with congestion is that it is not costless to dispose of unwanted inputs. Hence, resources that would otherwise be used towards the production of the desired outputs must be devoted for such disposal. In the language of production economics, the terms weak disposability (WD) and strong disposability (SD) are used to denote the presence or absence, respectively, of congestion.

The DEA formulations exhibiting various combinations of characteristics are listed in Table 2. Each model is identified by two criteria: (i) WD or SD, in terms of congestion; and (ii) CRS, NRS or VRS for scale. The references listed earlier (e.g., Coelli, Rao and Battese 1998; Cooper, Seiford and Tone 2000; Thanassoulis 2001) provide theoretical justification for their use. For the purpose of this paper, the information of interest

Table 2
DEA formulations and efficiency decompositions

For all formulations	$Min\ k_n$ $\sum_{c=1}^{C} \lambda_c y_c \geq y_n$ $\lambda_c \geq 0,\ c = 1,...,C$
For SD, add	$\sum_{c=1}^{C} \lambda_c x_{ci} \leq k_n x_{in} \quad i = 1,...,I$
For WD, add	$\sum_{c=1}^{C} \lambda_c x_{ci} = k_n x_{in} \quad i = 1,...,I$
For VRS, add	$\sum_{c=1}^{C} \lambda_c = 1$
For NRS, add	$\sum_{c=1}^{C} \lambda_c \geq 1$
Efficiency decompositions	k_n (CRS, SD) = (Congestion)(Scale)(PTE) Scale = k_n (CRS, SD) / k_n (VRS, SD) Congestion = k_n (VRS, SD) / k_n (VRS, WD) PTE= k_n (VRS, WD)
DR if	Scale <1 and k_n (NRS, SD) > k_n (CRS, SD)
IR if	Scale <1 and k_n (NRS, SD) = k_n (CRS, SD)
CRS if	Scale =1

consists of the optimum values of the efficiency index, k_n, as well as an assessment of the effect of congestion and scale on efficiency. The subscript 'n' identifies the country/nation that is going to be evaluated in terms of its ability to generate more output or use fewer inputs than a composite of Sall countries. All models have two constrains in common. One is the non-negativity constraint for the weights, i.e. for λ_c, c=1,...,C. The other indicates that the level of output of the composite country, computed as the weighted average of all the countries' output, has to be at least as large as that of the country being evaluated. The other four rows provide the additional constraint(s) to be added, depending upon the congestion and scale characteristics desired. Observe that the above decomposition is performed for each output separately. Joint effects of the inputs on the outputs are left for future research.

2.3 Decomposing the efficiency indexes

The decomposition used in this study follows the methodology in Färe, Grosskopf and Lovell (1994). A summary appears in Färe and Grosskopf (1998a) and an application in Nasierowski and Arcelus (2003). The starting point is to decompose the optimal efficiency of the model in Charnes, Cooper and Rhodes (1981), with constant-returns-to scale, strong disposability (SD, CRS) into three factors. These factors are also listed in Table 2. The first two control for scale and for congestion. The last is the pure technical efficiency (PTE), a residual unexplained by the other two factors and thus perhaps a better measure of resource utilization than the VRS or CRS formulations. It should be observed that the NRS case does not play a role in the decomposition process. Its usefulness lies in the role it plays when determining whether the scale factor, if it exists, is due to increasing (IR) or decreasing (DR) returns to scale. Table 2 also sets the conditions for this dichotomy.

3 Analysis of results

This section describes the two-part numerical analysis undertaken in support of the efficiency-related model of the manuscript. The first part evaluates the implications of the efficiency decomposition listed in Table 2. The second uses this information to derive the various efficiency-related HDI estimates and the corresponding country ranks and discusses the statistical evidence for and against the usefulness of the various estimates.

3.1 The efficiency decomposition

Table 3 presents the numerical results of the efficiency decomposition of Table 2. The results were obtained with the *OnFront* package (Färe and Grosskopf 1998b). For each output, be it LI, EI or WI, and each country, the table presents the efficiency measure (EFF) under CRS and SD, and its decomposition, in terms of scale (SC), congestion (CON) and pure technical efficiency (PTE). The last column for each output indicates whether the country in question exhibits the type of returns to scale (RS) that can be classified as increasing (IR), constant (CRS) or decreasing (DR), in accordance to the criteria listed at the end of Table 2. The results indicate that congestion is not much of a problem for any country. Even for those with CON below 1, the actual value is over 0.9 and even higher for LI and EI. A few exceptions exist in the WI case (New Zealand, Latvia, Bulgaria and Philippines), but even then the CON values are all in the high 0.80s. Most of the inefficiency, when in existence, appears to be scale related. This is true even in highly inefficient countries for one or more outputs, as is the case, for example, with South Africa, Zimbabwe, Nigeria and Zambia for LI, or Senegal for EI. Once congestion and scale are controlled for, the high values in the PTE columns indicate scant evidence of inefficiency left to be explained by exogenous factors. Further, with a few exceptions, the evidence indicates that any further resource investment and/or reallocation in most inefficient countries should be directed towards health and education, to judge by the overwhelming majority of IR in the LI and EI columns and the mostly DR in WI. These results are also consistent with key tenets of human capital theory (e.g., Schultz 1993).

Table 3
Efficiency decompositions

	LI					EI					WI				
Country	EFF	SC	CON	PTE	RS	EFF	SC	CON	PTE	RS	EFF	SC	CON	PTE	RS
Norway	0.95	0.97	0.97	1	IR	0.99	1	0.99	1	CR	1	1	1	1	CR
Sweden	0.96	0.99	0.99	0.98	IR	1	1	1	1	CR	0.93	0.93	1	1	DR
Canada	0.97	0.99	1	0.98	IR	0.99	1	1	0.99	CR	0.85	0.85	1	1	DR
Belgium	0.96	0.98	0.99	0.99	IR	1	1	1	1	CR	0.94	0.94	1	1	DR
Australia	0.98	1	1	0.98	CR	1	1	1	1	CR	0.81	0.83	0.98	1	DR
United States	0.93	0.96	0.96	1	IR	0.99	1	1	0.99	CR	0.97	0.97	1	1	DR
Iceland	0.95	0.98	0.99	0.97	IR	0.97	1	1	0.97	CR	1	1	1	1	CR
Netherlands	0.95	0.98	1	0.97	IR	0.99	0.99	1	1	DR	0.86	0.86	1	1	DR
Japan	1	1	1	1	CR	0.94	0.99	1	0.95	IR	1	1	1	1	CR
Finland	0.97	0.98	1	0.99	IR	1	1	1	1	CR	0.88	0.92	0.96	1	DR
Switzerland	0.97	0.98	0.99	1	IR	0.94	1	1	0.95	CR	0.9	0.9	1	1	DR
France	0.97	0.97	0.99	1	IR	0.98	1	1	0.98	CR	0.93	0.93	1	1	DR
United Kingdom	0.96	0.99	1	0.97	IR	1	1	1	1	CR	0.88	0.88	1	1	DR
Denmark	0.89	0.95	0.98	0.96	IR	0.99	1	1	0.99	CR	0.77	0.77	1	1	DR
Austria	0.96	0.98	1	0.99	IR	0.97	1	1	0.97	CR	0.85	0.85	1	1	DR
Germany	0.95	0.97	0.99	0.99	IR	0.98	1	1	0.98	CR	0.88	0.88	1	0.99	DR
Ireland	0.94	0.98	1	0.97	IR	0.97	1	1	0.97	CR	0.98	0.98	1	1	DR
New Zealand	0.98	1	1	0.98	CR	1	1	1	1	CR	0.83	0.95	0.87	1	DR
Italy	0.97	0.99	0.98	1	IR	0.96	0.98	1	0.98	IR	1	1	1	1	CR
Spain	1	1	1	1	CR	1	1	1	1	CR	0.9	0.9	1	1	DR
Israel	0.95	1	1	0.96	CR	0.96	0.99	1	0.97	IR	0.92	0.96	0.99	0.97	DR
Greece	0.99	0.99	1	1	DR	0.96	0.98	1	0.98	IR	0.94	0.94	1	1	DR
Singapore	1	1	1	1	CR	0.95	0.98	1	0.98	IR	0.86	0.86	1	1	DR
Korea, Rep. of	0.99	0.99	1	1	IR	0.98	1	0.98	1	CR	0.92	0.92	1	1	DR
Portugal	0.96	0.99	1	0.98	IR	1	1	1	1	CR	0.79	0.79	1	1	DR
Slovenia	0.97	0.99	1	0.99	IR	0.95	0.98	1	0.97	IR	0.83	0.83	1	1	DR
Argentina	0.94	0.98	1	0.96	IR	0.95	0.96	1	0.99	IR	1	1	1	1	CR
Hungary	0.94	0.98	1	0.96	IR	0.94	0.97	1	0.97	IR	0.81	0.81	1	1	DR
Poland	0.99	0.99	1	1	IR	0.95	0.99	1	0.95	IR	0.76	0.76	1	1	DR
Chile	1	1	1	1	CR	0.93	0.98	0.98	0.97	IR	0.93	0.95	0.98	1	DR
Uruguay	0.96	0.99	1	0.98	IR	0.96	0.96	1	1	IR	1	1	1	1	CR
Costa Rica	1	1	1	1	CR	0.87	0.94	1	0.93	IR	0.95	0.95	1	1	DR
Lithuania	1	1	1	1	CR	0.94	0.97	1	0.97	IR	0.85	0.85	1	1	DR
Trinidad and Tobago	0.98	0.98	1	1	DR	0.88	0.94	1	0.94	IR	1	1	1	1	CR

Table 3 continues

Table 3 (con't)
Efficiency decompositions

	LI					EI					WI				
Country	EFF	SC	CON	PTE	RS	EFF	SC	CON	PTE	RS	EFF	SC	CON	PTE	RS
Latvia	1	1	1	1	CR	0.94	0.98	1	0.95	IR	0.72	0.81	0.88	1	DR
Mexico	0.94	0.98	1	0.96	IR	0.88	0.94	1	0.95	IR	0.96	0.96	1	1	DR
Belarus	0.99	0.99	1	1	IR	0.93	0.97	1	0.96	IR	1	1	1	1	CR
Panama	0.96	0.99	1	0.96	IR	0.89	0.92	1	0.97	IR	0.67	0.91	0.97	0.75	DR
Malaysia	0.98	0.99	1	0.98	IR	0.89	0.9	1	0.99	IR	0.86	0.87	1	0.99	DR
Bulgaria	0.97	1	0.98	1	CR	0.95	0.95	1	1	IR	0.8	0.94	0.85	1	DR
Romania	0.94	0.97	1	0.97	IR	0.91	0.95	1	0.95	IR	0.91	0.91	1	1	DR
Colombia	0.93	0.95	1	0.99	IR	0.89	0.94	0.99	0.95	IR	0.84	0.84	1	1	DR
Venezuela	0.97	1	1	0.97	CR	0.87	0.9	1	0.97	IR	1	1	1	1	CR
Thailand	1	1	1	1	CR	0.87	0.92	1	0.95	IR	0.79	0.88	0.9	1	DR
Brazil	0.87	0.87	1	1	IR	0.89	0.92	0.98	0.98	IR	0.87	1	0.98	0.89	CR
Lebanon	0.9	0.97	1	0.92	IR	0.98	0.98	1	1	IR	0.94	0.99	0.95	1	DR
Philippines	0.91	0.96	1	0.96	IR	0.94	0.96	0.99	0.99	IR	0.81	0.92	0.88	1	DR
Ukraine	0.99	0.99	1	1	IR	0.93	0.99	1	0.94	IR	1	1	1	1	CR
Peru	0.89	0.91	1	0.97	IR	0.97	0.99	1	0.98	IR	1	1	1	1	CR
Turkey	0.91	0.94	1	0.96	IR	0.98	0.99	0.98	1	IR	1	1	1	1	CR
Jamaica	0.99	0.99	1	1	DR	0.84	0.89	0.94	1	IR	0.72	0.91	0.93	0.84	DR
Sri Lanka	1	1	1	1	CR	0.9	0.93	1	0.97	IR	0.97	0.97	1	1	DR
Paraguay	0.91	0.95	1	0.96	IR	0.86	0.92	1	0.94	IR	0.94	0.94	1	1	DR
Ecuador	0.93	0.98	1	0.95	IR	0.93	0.97	0.98	0.98	IR	1	1	1	1	CR
Dominican Republic	0.86	0.92	1	0.94	IR	0.95	0.95	1	1	IR	1	1	1	1	CR
Uzbekistan	0.92	0.98	0.94	1	IR	0.92	1	0.97	0.95	CR	1	1	1	1	CR
China	0.94	0.99	1	0.95	IR	1	1	1	1	CR	0.69	0.74	0.94	1	DR
Tunisia	0.88	0.94	1	0.94	IR	0.97	0.97	1	1	IR	0.86	0.92	0.93	1	DR
Jordan	0.89	0.97	1	0.92	IR	0.89	0.89	1	1	IR	0.94	1	0.94	1	CR
El Salvador	0.92	0.94	1	0.98	IR	0.86	0.87	0.99	1	IR	1	1	1	1	CR
South Africa	0.55	0.56	0.98	1	IR	0.93	0.94	1	1	IR	1	1	1	1	CR
Syrian Arab Republic	0.9	0.98	1	0.92	IR	0.98	0.98	1	1	IR	1	1	1	1	CR
Viet Nam	0.97	0.97	1	0.99	IR	0.88	0.96	0.99	0.93	IR	0.75	0.81	0.93	1	DR
Indonesia	1	1	1	1	CR	1	1	1	1	CR	0.94	0.94	1	1	DR
Tajikistan	1	1	1	1	CR	0.95	0.97	0.98	1	DR	1	1	1	1	CR
Bolivia	0.75	0.8	1	0.94	IR	0.92	0.98	1	0.95	IR	0.87	0.95	0.91	1	DR
Honduras	0.85	0.86	1	0.98	IR	0.79	0.79	1	1	IR	0.91	0.99	0.92	1	IR
Nicaragua	0.9	0.92	1	0.97	IR	0.7	0.71	0.98	1	IR	0.95	0.95	1	1	DR
Guatemala	0.83	0.84	1	0.99	IR	0.84	0.88	0.95	1	IR	1	1	1	1	CR
Zimbabwe	0.43	0.47	0.92	0.98	IR	0.89	0.96	1	0.93	IR	0.92	1	0.93	1	CR
Ghana	0.94	0.94	1	1	IR	0.8	0.82	0.99	0.97	IR	0.83	0.83	1	1	DR
Kenya	0.65	0.68	0.98	0.97	IR	0.84	0.88	0.99	0.97	IR	1	1	1	1	CR
Congo	0.6	0.6	1	1	IR	0.89	0.93	0.96	1	IR	1	1	1	1	CR
Pakistan	0.73	0.79	1	0.91	IR	0.78	0.8	0.98	1	IR	1	1	1	1	CR
Nepal	1	1	1	1	CR	1	1	1	1	CR	1	1	1	1	CR
Bangladesh	0.83	0.83	1	1	IR	0.69	0.69	1	1	IR	1	1	1	1	CR
Nigeria	0.59	0.63	0.99	0.94	IR	1	1	1	1	CR	1	1	1	1	CR
Zambia	0.45	0.48	0.92	1	IR	0.85	0.9	0.99	0.94	IR	0.8	0.82	0.98	1	IR
Senegal	0.82	0.82	1	1	IR	0.59	0.62	0.96	1	IR	0.87	0.96	0.91	1	DR
Benin	0.87	0.87	1	1	IR	0.77	0.78	0.99	1	IR	1	1	1	1	CR

3.2 The HDI estimates

With the efficiency coefficients listed in Table 3, three different HDI estimates are computed. The first adds up the values of LI, EI and WI, weighted by the corresponding EFF (model CRS, SD) estimates of Table 3 and divides the resulting sum by three. The equal weight given to each output follows the original HDI computational procedure. This process yields the values of the HCRS column of Table 4. A similar procedure is used with the EFF estimates for the (VRS, SD) model, to yield the values of the HVRS column. Similarly, the use of the PTE weights results in the estimates of the HPTE column. Table 4 includes the necessary information together with the original HDI and the gender-related HDI values and the country ranks resulting from each set of estimates.

Table 4 provides a wide assortment of index values and of ranks, but no hint as to whether there are any statistically significant differences among them. The issue here is whether the various indexes exhibit any information content over and above that provided by the original HDI. The statistical analysis is summarized in Table 5. The data in Tables 4 are used in the computation of the Pearson correlation coefficients between the values of any two indexes (the pair comparison t-test was also used, with similar conclusions and hence are not reported) and the nonparametric Spearman correlation coefficients for the corresponding ranks. These and other statistical tests appear in most textbooks on the subject (e.g., Lind *et al.* 2003). The null hypothesis tests for the existence of pairwise correlation. Low p-values indicate presence of such correlation.

Several implications of the results in Table 5 deserve special consideration. First, GHDI and HDI yield almost identical values and ranks. Hence, GHDI does not exhibit much discriminating power, independent of HDI, in explaining gender-related issues. Second, each component of the decomposition in Table 2 may be evaluated in terms of its information content over and above that provided by HDI. This can be readily seen by comparing, both for the values and for the ranks. As a result,

i) HDI/GHD vs HCRS can be used for the effect of accounting or not for efficiency;

ii) HCRS vs HVRS, for the effect of scale;

iii) HVRS vs HPTE, for the effect of congestion; and

iv) HDI/GHDI vs HPTE for the effect of controlling for both congestion and scale.

The last comparison is of particular importance, since the comparison is made between the first and last indexes, i.e. without any efficiency considerations and after both effects have been accounted for. The results suggest the robustness of the original HDI estimates. All correlations are above 0.9 and highly significant. This indicates that HDI does manage to capture most of the inefficiency of countries in the utilization of their resources. Finally, these interpretations should be tempered by the observation that this stability is certainly due to the behaviour of the countries ranked in approximately the bottom two-thirds of the table. The top, say, 20 ranked countries (approximately) do exhibit sufficient variations across the various HDI estimates, to suggest substantial differences in ranking. Thus, the resource-adjusted HDI adds an additional explanatory dimension without distorting the information content of the original HDI. The reasons for this dichotomy are left as avenue for further research.

Table 4
HDI values and associated country ranks

Country	HDI		HCRS		HVRS		HPTE		GHDI	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
Norway	0.9420	1	0.9219	1	0.9278	4	0.9400	1	0.9410	1
Sweden	0.9410	2	0.9064	6	0.9309	2	0.9339	5	0.9360	5
Canada	0.9400	3	0.8807	12	0.9307	3	0.9307	6	0.9380	2
Belgium	0.9390	4	0.9093	4	0.9341	1	0.9370	2	0.9330	7
Australia	0.9390	4	0.8751	15	0.9278	5	0.9340	4	0.9380	2
United States	0.9390	4	0.9067	5	0.9251	7	0.9367	3	0.9370	4
Iceland	0.9360	7	0.9121	2	0.9181	8	0.9181	10	0.9340	6
Netherlands	0.9350	8	0.8751	14	0.9278	6	0.9278	7	0.9300	8
Japan	0.9330	9	0.9114	3	0.9145	12	0.9145	12	0.9270	10
Finland	0.9300	10	0.8844	10	0.9148	11	0.9271	8	0.9280	9
Switzerland	0.9280	11	0.8675	16	0.9080	15	0.9110	15	0.9230	14
France	0.9280	11	0.8898	9	0.9172	10	0.9202	9	0.9260	11
UK	0.9280	11	0.8785	13	0.9179	9	0.9179	11	0.9250	12
Denmark	0.9260	14	0.8168	24	0.9031	17	0.9087	18	0.9240	13
Austria	0.9260	14	0.8587	19	0.9111	14	0.9141	13	0.9210	15
Germany	0.9250	16	0.8654	17	0.9079	16	0.9109	16	0.9200	16
Ireland	0.9250	16	0.8902	8	0.9023	18	0.9051	20	0.9170	17
New Zealand	0.9170	18	0.8609	18	0.8727	24	0.9108	17	0.9140	18
Italy	0.9130	19	0.8919	7	0.9011	19	0.9071	19	0.9070	19
Spain	0.9130	19	0.8840	11	0.9133	13	0.9133	14	0.9060	20
Israel	0.8960	21	0.8491	21	0.8670	26	0.8700	25	0.8910	21
Greece	0.8850	22	0.8544	20	0.8805	20	0.8805	22	0.8790	23
Singapore	0.8850	22	0.8297	23	0.8780	21	0.8809	21	0.8800	22
Korea, Rep.	0.8820	24	0.8480	22	0.8737	23	0.8800	23	0.8750	26
Portugal	0.8800	25	0.8086	26	0.8744	22	0.8744	24	0.8760	25
Slovenia	0.8790	26	0.8072	27	0.8678	25	0.8678	26	0.8770	24
Argentina	0.8440	27	0.8118	25	0.8295	27	0.8295	27	0.8360	27
Hungary	0.8350	28	0.7487	35	0.8107	31	0.8138	31	0.8330	28
Poland	0.8330	29	0.7550	33	0.8177	29	0.8177	30	0.8310	29
Chile	0.8310	30	0.7946	29	0.8163	30	0.8243	29	0.8240	31
Uruguay	0.8310	30	0.8068	28	0.8218	28	0.8245	28	0.8280	30
Costa Rica	0.8200	32	0.7704	30	0.7999	32	0.7999	32	0.8140	32
Lithuania	0.8080	33	0.7526	34	0.7974	33	0.7974	33	0.8060	33
Trinidad and Tobago	0.8050	34	0.7643	32	0.7865	34	0.7865	34	0.7980	34
Latvia	0.8000	35	0.7151	40	0.7561	38	0.7845	35	0.7980	34
Mexico	0.7960	36	0.7339	36	0.7660	37	0.7688	39	0.7890	36
Belarus	0.7880	37	0.7661	31	0.7777	35	0.7777	37	0.7860	37
Panama	0.7870	38	0.6694	54	0.7059	54	0.7105	55	0.7840	38
Malaysia	0.7820	39	0.7104	44	0.7696	36	0.7696	38	0.7760	40
Bulgaria	0.7790	40	0.7121	42	0.7409	42	0.7800	36	0.7780	39

Table 4 continues

Table 4 (con't)
HDI values and associated country ranks

	HDI		HCRS		HVRS		HPTE		GHDI	
Country	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
Romania	0.7750	41	0.7112	43	0.7512	40	0.7512	42	0.7730	41
Colombia	0.7720	42	0.6841	48	0.7533	39	0.7533	41	0.7670	42
Venezuela	0.7700	43	0.7260	38	0.7509	41	0.7537	40	0.7640	43
Thailand	0.7620	44	0.6753	51	0.7230	47	0.7460	43	0.7600	44
Brazil	0.7570	45	0.6609	57	0.7135	49	0.7214	50	0.7510	45
Lebanon	0.7550	46	0.7085	45	0.7215	48	0.7320	47	0.7390	48
Philippines	0.7540	47	0.6743	52	0.7130	50	0.7404	44	0.7510	45
Ukraine	0.7480	48	0.7261	37	0.7316	44	0.7316	48	0.7440	47
Peru	0.7470	49	0.7145	41	0.7369	43	0.7369	45	0.7290	52
Turkey	0.7420	50	0.7157	39	0.7282	46	0.7333	46	0.7340	51
Jamaica	0.7420	50	0.6424	63	0.6855	59	0.7113	53	0.7390	48
Sri Lanka	0.7410	52	0.7061	46	0.7316	44	0.7316	48	0.7370	50
Paraguay	0.7400	53	0.6628	56	0.7101	52	0.7101	56	0.7270	53
Ecuador	0.7320	54	0.6955	47	0.7092	53	0.7150	51	0.7180	56
Dominican Republic	0.7270	55	0.6807	49	0.7127	51	0.7127	52	0.7180	56
Uzbekistan	0.7270	55	0.6796	50	0.6845	60	0.7082	57	0.7250	54
China	0.7260	57	0.6451	62	0.6985	56	0.7107	54	0.7240	55
Tunisia	0.7220	58	0.6506	60	0.6889	58	0.7050	58	0.7090	58
Jordan	0.7170	59	0.6480	61	0.6842	61	0.6964	61	0.7010	59
El Salvador	0.7060	60	0.6555	58	0.7025	55	0.7050	58	0.6960	60
South Africa	0.6950	61	0.6086	64	0.6937	57	0.6967	60	0.6890	61
Syrian Arab Republic	0.6910	62	0.6629	55	0.6728	63	0.6728	63	0.6690	64
Viet Nam	0.6880	63	0.6042	65	0.6502	65	0.6647	65	0.6870	62
Indonesia	0.6840	64	0.6719	53	0.6833	62	0.6833	62	0.6780	63
Tajikistan	0.6670	65	0.6520	59	0.6608	64	0.6667	64	0.6640	65
Bolivia	0.6530	66	0.5540	67	0.6084	69	0.6243	69	0.6450	66
Honduras	0.6380	67	0.5378	68	0.6180	67	0.6321	66	0.6280	68
Nicaragua	0.6350	68	0.5355	69	0.6218	66	0.6261	68	0.6290	67
Guatemala	0.6310	69	0.5595	66	0.6175	68	0.6278	67	0.6170	69
Zimbabwe	0.5510	70	0.4520	72	0.5126	71	0.5324	71	0.5450	70
Ghana	0.5480	71	0.4697	71	0.5417	70	0.5438	70	0.5440	71
Kenya	0.5130	72	0.4248	74	0.4980	73	0.5018	73	0.5110	72
Congo	0.5120	73	0.4272	73	0.5033	72	0.5133	72	0.5060	73
Pakistan	0.4990	74	0.4137	75	0.4765	76	0.4793	75	0.4680	75
Nepal	0.4900	75	0.4900	70	0.4900	74	0.4900	74	0.4700	74
Bangladesh	0.4780	76	0.4030	77	0.4767	75	0.4767	76	0.4680	75
Nigeria	0.4620	77	0.4032	76	0.4531	77	0.4545	77	0.4490	77
Zambia	0.4330	78	0.3238	80	0.4069	80	0.4164	80	0.4240	78
Senegal	0.4310	79	0.3317	79	0.4116	79	0.4300	78	0.4210	79
Benin	0.4200	80	0.3685	78	0.4187	78	0.4200	79	0.4040	80

Table 5
Statistical tests (correlation coefficients in upper triangle; p-values in lower triangle)

	Pearson correlation				
	HDI	GHDI	HCRS	HVRS	HPTE
HDI	—	0.999	0.987	0.995	0.980
GHDI	0	—	0.984	0.994	0.988
HCRS	0	0	—	0.991	0.997
HVRS	0	0	0	—	0.986
HPTE	0	0	0	0	—
	Spearman correlation				
	HDI	GHDI	HCRS	HVRS	HPTE
HDI	—	0.999	0.972	0.990	0.980
GHDI	0	—	0.969	0.988	0.977
HCRS	0	0	—	0.997	0.991
HVRS	0	0	0	—	0.971
HPTE	0	0	0	0	—

4 Some concluding comments

HDI as an alternative measure of progress of nations has opened up new prospects for analysing socioeconomic development in a cross-country comparative context. However, it is still in need of refinement since development is a complex, dynamic and multidimensional concept. In fact, as noted earlier in this paper, there is a growing body of literature devoted to this objective. However, this literature appears to have focussed mainly on distributional or equity aspect of development, without any recognition to changes in the resource base. But equity without efficiency is not sustainable over time. It is thus important to analyse whether a given level of human development of a nation is achieved using available resources optimally. The DEA methodology addresses this problem by recognizing and analysing the output levels and resource commitments in the estimation of efficiency-adjusted HDIs. Further, such analysis has been undertaken relative to the performance of other countries, rather than on the basis of some predetermined objective. In this way, the modern benchmarking methodology may be brought to the fore for a large cross-section of countries. One of the policy implications of this study, then, is that countries can find their human development achievements relative to resource utilization, and take a more pro-active approach to improve efficiency in such events where inefficient use of resources is discernible. As a result, to increase the HDI, an efficient country may need more resources, whereas an inefficient one may start by considering the need for structural change. Further, from the RS results of Table 3, the resource allocation should be directed towards health and education, the two dimension where the overwhelming majority of inefficient countries exhibit increasing returns of their investment.

This study also calls for an extension of the debate on HDI by bringing in the efficiency dimension to it. In essence, it has attempted to integrate welfare economics and production economics to study the globally significant issue of development. Within these two branches of economics, there exist many facets of human development issues that remain unexplored. More research along this integrative line may open up possibilities for important theoretical and practical developments. For example, it may lead to the calculation of HDI that may be more in tune to new concerns, such as the environment or as in this paper, gender equality. The advantage of this development is that comparing across a variety of these HDIs leads to the identification of the countries that may rank higher in the achievement of a particular objective than in another. In this way, the selection of inputs and outputs can provide a better match to society's values. Such an approach is also more in tune to Sen's (1990, 1992) concept of development as an expansion of the capabilities of a country and of its citizens.

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