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Optimizing the new formulation of the United Nations' human development index: An empirical view from data envelopment analysis.

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Abstract

In this paper, we propose a new way to simulate an optimal Human Development Index [HDI]. Indeed, the formulation of the original HDI established by the United Nations Development Programme [UNDP] relies on a major methodological shortcoming, namely the contestable assumption that all component indices have the same weights. So, we implement a new approach to determine the optimal weights of each sub-indicator in the light of Data Envelopment Analysis [DEA]. Accordingly, we follow the multiplicative optimization approach introduced by Zhou et al. (2010), to assess robustly the relative performance of a set of 169 economies around the world in terms of human development. Finally, the new world ranking is close to and highly correlated with the standard HDI one, giving then some support to the equal weighting method adopted by the UNDP.

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1. Introduction

Since the beginning of nineties, composite indicators [CI] have gained momentum in the field of development economics. These later increasingly influence performance comparisons, benchmarking, academic researches and economic policy decisions across the world (Hicks and Streeten 1979, Hezri and Dovers 2006 and Nourry 2008). Among the vast set of the existing CIs, the Human Development Index [HDI] is undoubtedly the most popular one. The HDI was introduced by the first Human Development Report [HDR] of the United Nations Development Programme [UNDP] released in 1990 (UNDP 1990). As mentioned by the UNDP, the HDI is "a summary measure of human development. It measures the average achievements in a country in three basic dimensions of human development: a long and healthy life, access to knowledge and a decent standard of living" (UNDP 2010, p. 216).

However, in spite of a real success based on a simple and transparent computational methodology, this indicator has met considerable criticism at least in three dimensions: *(i)* those relative to the ability of the HDI to give a suitable measure of development due to the quality and limitation of raw data (Murray 1993, Srinivasan 1994, Noorbakhsh 1998 and Stiglitz *et al.* 2009), *(ii)* those highlighting the urgent need to take into account more information and other variables into the global index (UNDP 1995, Hicks 1997, Sagar and Najam 1998, Lasso de La Vega 2001, Costantini et Monni 2004 and Nourry 2008), and *(iii)* those concerning the technical limits of the HDI, the so-called "weighting and aggregation problem" (McGillivray 1991, Gormely 1995, Sagar and Najam 1998 and Mazumbar 2003).

In 2010, for the twentieth anniversary of the HDR, the UNDP decided to revise deeply the methodology of its indicator in order to integrate numbers of these claims[1]. On the one hand, some sub-indicators have changed to better characterize the three components of human development[2]. On the other hand, the HDI is now calculated by the geometric mean of the normalized dimension indices instead of the earlier arithmetic average method[3]. Thus, the undesirable feature of the full compensability between the dimensions of a CI implied by the additive aggregation is avoided. Unfortunately, a crucial methodological problem remains namely the fact that equal weights are given to its component indices. And yet the inconsistency of this assumption has been recognized since a long time ago (Desai 1991 and Kelly 1991).

Actually, the ideal approach would probably determinate the weights of each component according to its contribution to human development. As long as HDI is concerned, the literature focused on this aspect took two main directions[4]. Firstly, a weighting system can be obtained from an opinion survey conducted among a set of experts in development economics around the world (Chowdhury and Squire 2006). However, even if a fixed set of weights is derived, it still might be difficult to reach an agreement on such weights among the interviewed persons (Cherchye *et al.* 2008). Secondly, an optimal weighting scheme can be

[1] See UNDP (2010) for conceptual and technical details about the determination of the HDI.
[2] In the knowledge dimension, mean years of schooling replaces literacy, and gross enrollment is reformulated as expected years of schooling. To measure the standard of living, gross domestic product per capita is substituted by gross national income per capita.
[3] Note that the normalization process has been also modified. The new methodology has shifted the maximum values in each dimension to the observed maximum rather than a predefined cut-off beyond which achievements are ignored (UNDP 2010).
[4] More generally, there are numeral weighting methods (Principal components/Factor analysis, DEA, unobserved components model, budget allocation process, public opinion, analytic hierarchy process and conjoint analysis) when determining a composite indicator (OECD 2008).

simulated from the implementation of the Data Envelopment Analysis [DEA] approach (Charnes *et al.* 1978 and Charnes *et al.* 1983). Re-estimating HDI via DEA-like models results in two decisive advantages in the extent that they endogenously construct a set of best practice countries and that the weights of each sub-indicator is endogenously determined based on optimization calculus, i.e. no prior knowledge of the weights for sub-indicators is required. Several studies have already applied this method to the HDI setting (Mahlberg and Obersteiner 2001, Despotis 2005a 2005b, Zhou *et al.* 2007, Cherchye *et al.* 2008 and Hatefi and Torabi 2010). Besides these decisive assets, DEA as the other methods has additional advantages but also disadvantages namely *(i)* the presence of several best performers, *(ii)* the fact that the best performers cannot see their progress or *(iii)* that the *status quo* is promoted (OECD 2008). The methodologies proposed by Despotis (2005a, 2005b), Zhou *et al.* (2007) or Hatefi and Torabi (2010) allow us to solve most of these limits.

Nevertheless, all of them used some versions of an additive linear programming approach to build the optimal HDI. So they are not adapted to the geometric aggregation feature of the new United Nations' HDI postulated by the HDR (2010). To this regard, in this article we propose to recalculate this one by implementing the new multiplicative optimization approach recently developed by Zhou *et al.* (2010). This latter method generates the optimal weights by solving a series of multiplicative DEA type models that can be transformed into equivalent linear programs. Moreover, even if no special knowledge about the weights is needed, this approach is enough flexible to allow the integration of additional relevant information on them into the models considered. Then, we apply this new computational methodology to the 2010 data of 169 economies mentioned in the HDR (2010). Finally, we do not observe fundamental changes in the world HDI ranking but our DEA-like measurement of human development becomes scientifically more robust.

The rest of this article is organized as follows. Section 2 presents the multiplicative optimization method of Zhou *et al.* (2010) for constructing an optimal HDI. Section 3 gives the results and some comments when this method is applied to the 2010 world data. Section 4 concludes by highlighting some potential methodological improvements for on-going researches in the field.

2. The multiplicative optimization approach of Zhou *et al.* (2010)

In order to capitalize on the new developments in CI construction from Data Envelopment Analysis (Charnes *et al.* 1978 and Charnes *et al.* 1983) and to better coincide with the last HDI proposed by the UNDP (2010), we use the multiplicative optimization approach recently proposed by Zhou *et al.* (2010).

Assume that we have information for m countries about n sub-indicators which allows the calculation of a CI. Let I_{ij} denote the value of country i with respect to sub-indicator j. Consider w_j as the weight for sub-indicator j. We seek to aggregate $I_{ij}\left(j=1,2,\ldots,n\right)$ into a CI for country i. In the manner of Zhou *et al.* (2010), we construct our CI (i.e. HDI) from the weighted product method to take advantage of these desirable properties (see eg. Ebert and Welsch (2004) for details). CI is determined as follows:

$$\mathrm{CI}_i = \prod_{j=1}^{n} I_{ij}^{w_j}, \quad i=1,2,\ldots,m \tag{1}$$

According to Zhou *et al.* (2007), Zhou *et al.* (2010) propose a series of multiplicative models to determine CI. These models noted (2) and (3) respectively seek the best and the worst sets of weights which are used to aggregate the sub-indicators into a performance score. They are similar to multiplicative DEA models output- and input-oriented, respectively (Charnes *et al.* 1983). Thus, we avoid the subjective assignment of weights and provide an objective performance score for performance comparison. By combining these two models, we are also assured that only one country will have a composite indicator score equal to 1. We can write (2) and (3) respectively as follows:

$$\begin{aligned} gI_i &= \max_w \prod_{j=1}^{n} I_{ij}^{w_j} \\ \text{s.t. } & \prod_{j=1}^{n} I_{ij}^{w_j} \le e, \quad i = 1, 2, \dots, m \\ & w_j \ge 0, \quad j = 1, 2, \dots, n \end{aligned} \qquad (2)$$

$$\begin{aligned} bI_i &= \min_w \prod_{j=1}^{n} I_{ij}^{w_j} \\ \text{s.t. } & \prod_{j=1}^{n} I_{ij}^{w_j} \ge e \quad i = 1, 2, \dots, m \\ & w_j \ge 0, \quad j = 1, 2, \dots, n \end{aligned} \qquad (3)$$

where e is the natural number and $\ln(e) = 1$.

These two DEA-like models provide an aggregated performance score for country i in terms of all sub-indicators j. Finally, Zhou *et al.* (2010) combine the two indexes gI_i and bI_i into an overall index as follows:

$$\text{CI}_i(\lambda) = \lambda . \frac{\ln(gI_i) - \ln(gI_{\min})}{\ln(gI_{\max}) - \ln(gI_{\min})} + (1-\lambda) . \frac{\ln(bI_i) - \ln(bI_{\min})}{\ln(bI_{\max}) - \ln(bI_{\min})} \qquad (4)$$

where $gI_{\max} = \max\{gI_i, i = 1, \dots, m\}$, $gI_{\min} = \min\{gI_i, i = 1, \dots, m\}$, $bI_{\max} = \max\{bI_i, i = 1, \dots, m\}$ and $bI_{\min} = \min\{bI_i, i = 1, \dots, m\}$. $0 \le \lambda \le 1$ is an adjusting parameter used to combine gI and bI. For example, if $\lambda = 0.5$, the decision makers are neutral between the two measurements. Moreover, CI is a standardized index which is included in the interval $[0,1]$. The larger the value of CI_i, the better the country i performs. If a country has the largest value for both gI_i and bI_i, then CI=1, whatever λ. If a country has the smallest value for both gI_i and bI_i, then CI=0, whatever λ.

Unfortunately, the two programs above are nonlinear and then it may not be easy to solve directly. In order to get linear programming models, Zhou *et al.* (2010) propose to take the logarithms with base e of programs (2) and (3). Thus, we obtain the programs (5) and (6):

$$\begin{aligned} gI_i^{'} &= \max_w \sum w_j I_{ij}^{'} \\ \text{s.t. } & \sum w_j I_{ij}^{'} \le 1 \quad i = 1, 2, \dots, m \\ & w_j \ge 0, \quad j = 1, 2, \dots, n \end{aligned} \qquad (5)$$

$$\begin{aligned} bI_i^{'} &= \min_w \sum w_j I_{ij}^{'} \\ \text{s.t. } & \sum w_j I_{ij}^{'} \ge 1 \quad i = 1, 2, \dots, m \\ & w_j \ge 0, \quad j = 1, 2, \dots, n \end{aligned} \qquad (6)$$

where $I'_{ij} = \ln I_{ij}, gI'_i = \ln(gI_i)$ and $bI'_i = \ln(bI_i)$.

Assume that $gI'_{\max} = \max\{gI'_i, i = 1,\dots,m\}$, $gI'_{\min} = \min\{gI'_i, i = 1,\dots,m\}$, $bI'_{\max} = \max\{bI'_i, i = 1, \dots, m\}$ and $bI'_{\min} = \min\{bI'_i, i = 1,\dots,m\}$. Then, we have $gI'_{\max} = \ln(gI_{\max})$ and $gI'_{\min} = \ln(gI_{\min})$. By substituting $gI, gI_{\max}$ and $gI_{\min}$ by $gI', gI'_{\max}$ and $gI'_{\min}$ in equation (4), we can re-write CI as follows:

$$\mathrm{CI}_i(\lambda) = \lambda.\frac{gI'_i - gI'_{\min}}{gI'_{\max} - gI'_{\min}} + (1-\lambda).\frac{bI'_i - bI'_{\min}}{bI'_{\max} - bI'_{\min}} \qquad (7)$$

Moreover, note that this method is enough general to allow us to incorporate weight restriction constraints when additional information about the weight is available. Following Zhou *et al.* (2010), we use for each sub-indicator the "proportion constraints" in multiplicative form as follows:

$$\left(\prod_{j=1}^{n} I_{ij}^{wj}\right)^{L_j} \le I_{ij}^{wj} \le \left(\prod_{j=1}^{n} I_{ij}^{wj}\right)^{U_j} \qquad j = 1, 2, \dots, n \qquad (8)$$

where L_j and U_j, respectively, denote the lower and upper limits for the contribution of the j-th sub-indicator in CI and satisfy $0 \le L_j < U_j \le 1$. Then, by transformation we can obtain the following constraints in the additive form as:

$$L_j \le \frac{w_j I'_{ij}}{\sum_{j=1}^{n} w_j I'_{ij}} \le U_j \qquad j = 1, 2, \dots, n \qquad (9)$$

and incorporate them into models (5) and (6) before calculating gI'_i and bI'_i.

3. Results and comments

Our empirical analysis focuses on the HDI sample of the 169 world economies studied by the HDR (2010). The data relative to the United Nations' HDI (scores and ranks) are presented in Table 1. Note that we have normalized the HDI (the m-score), in the spirit of Mahlberg and Obersteiner (2001), to ensure the comparability with the DEA values resulting from our simulations. So a value of 1 is assigned to the highest developed country and a value of less than 1 to all relatively less developed countries. Table 1 puts forward a major shortcoming linked to the standard HDI. Along with the arbitrary determination of equal weight, the UNDP indicator does not discriminate completely and thus some countries are ranked equally. For instance, this is the case for Sweden and Germany, France and Israel, Portugal and Poland, amongst others. Therefore, the HDI does not discriminate enough to give a fair assessment of the relative performance of the countries in terms of human development.

So in order to cancel out this limit, we compute endogenous weights by implementing two versions of DEA-type models in the spirit of Zhou *et al.* (2010)[5]. We propose first a basic model without special constraints on the weights (Model 1). Then, we consider a model where the flexibility of the weights is restricted so as to integrate possible additional information

[5] Following Zhou *et al.* (2010), all the three sub-indicators are rescaled by multiplying them by 100 before calculation. We also set the control parameter λ to 0.5.

from “the experts” (Model 2). Accordingly, we arbitrarily fix $L_1 = L_2 = L_3 = 0.1$ and $U_1 = U_2 = U_3 = 0.5$, indicating that the contribution of each component indicator can only be between 10 and 50% of the simulated HDI. The experts’ viewpoint found in the empirical literature generally supports this latter hypothesis (Chowdhury and Squire 2006).

Table 1. The HDI and Optimization results for the 169 world economies, year 2010

	HDI			Model with constraint (model 2)					Model without constraint (model 1)				
COUNTRIES	**score**	**m-score**	**rank**	**score**	**rank**	**diff**	gI'	bI'	**score**	**rank**	**diff**	gI'	bI'
VERY HIGH HUMAN DEVELOPMENT													
Norway	0,9376	1,0000	1	0,9919	2	-1	1,0000	1,3432	0,9815	6	-5	1,0000	1,2475
Australia	0,9373	0,9997	2	1,0000	1	1	1,0000	1,3489	0,9889	2	0	1,0000	1,2513
New Zealand	0,9068	0,9672	3	0,9891	3	0	0,9965	1,3430	0,9778	7	-4	1,0000	1,2456
United States	0,9016	0,9617	4	0,9718	6	-2	0,9928	1,3328	0,9539	22	-18	0,9938	1,2411
Ireland	0,8946	0,9542	5	0,9746	4	1	0,9912	1,3356	0,9596	17	-12	0,9935	1,2444
Liechtenstein	0,8914	0,9507	6	0,9637	16	-10	0,9996	1,3237	0,9692	13	-7	1,0000	1,2411
Netherlands	0,8902	0,9495	7	0,9691	10	-3	0,9912	1,3317	0,9618	16	-9	0,9943	1,2445
Canada	0,8883	0,9475	8	0,9705	7	1	0,9915	1,3326	0,9713	10	-2	0,9957	1,2476
Sweden	0,8849	0,9438	9	0,9696	8	1	0,9910	1,3322	0,9737	9	0	0,9958	1,2487
Germany	0,8849	0,9438	9	0,9676	11	-1	0,9895	1,3315	0,9575	19	-9	0,9930	1,2439
Japan	0,8840	0,9429	11	0,9745	5	6	0,9927	1,3348	1,0000	1	10	1,0000	1,2570
Korea (Republic of)	0,8772	0,9356	12	0,9649	14	-2	0,9875	1,3307	0,9483	25	-13	0,9908	1,2420
Switzerland	0,8745	0,9327	13	0,9659	13	0	0,9924	1,3289	0,9883	3	10	0,9985	1,2528
France	0,8724	0,9305	14	0,9646	15	-1	0,9896	1,3294	0,9770	8	6	0,9959	1,2503
Israel	0,8724	0,9305	14	0,9661	12	3	0,9878	1,3314	0,9692	12	3	0,9945	1,2481
Finland	0,8709	0,9289	16	0,9598	18	-2	0,9871	1,3273	0,9534	23	-7	0,9918	1,2433
Iceland	0,8686	0,9264	17	0,9692	9	8	0,9875	1,3337	0,9839	5	12	0,9976	1,2517
Belgium	0,8668	0,9245	18	0,9579	20	-2	0,9875	1,3258	0,9568	20	-2	0,9924	1,2443
Denmark	0,8658	0,9234	19	0,9527	22	-3	0,9857	1,3231	0,9334	30	-11	0,9887	1,2370
Spain	0,8634	0,9209	20	0,9600	17	3	0,9865	1,3278	0,9688	14	6	0,9938	1,2487
Hong Kong	0,8620	0,9194	21	0,9588	19	2	0,9932	1,3235	0,9871	4	17	1,0000	1,2503
Greece	0,8549	0,9118	22	0,9522	23	-1	0,9833	1,3240	0,9430	28	-6	0,9890	1,2415
Italy	0,8543	0,9112	23	0,9554	21	2	0,9860	1,3249	0,9706	11	12	0,9940	1,2494
Luxembourg	0,8521	0,9088	24	0,9457	26	-2	0,9903	1,3159	0,9562	21	3	0,9953	1,2404

Austria	0,8510	0,9077	25	0,9490	24	1	0,9871	1,3198	0,9587	18	7	0,9928	1,2447
United Kingdom	0,8490	0,9055	26	0,9467	25	1	0,9854	1,3191	0,9480	26	0	0,9907	1,2419
Singapore	0,8461	0,9025	27	0,9448	27	0	0,9904	1,3152	0,9620	15	12	0,9967	1,2416
Czech Republic	0,8415	0,8975	28	0,9404	28	0	0,9778	1,3186	0,8975	40	-12	0,9806	1,2286
Slovenia	0,8280	0,8831	29	0,9350	29	0	0,9784	1,3145	0,9255	31	-2	0,9851	1,2374
Andorra	0,8243	0,8792	30	0,9347	30	0	0,9857	1,3105	0,9517	24	6	0,9939	1,2398
Slovakia	0,8184	0,8730	31	0,9221	33	-2	0,9716	1,3089	0,8639	50	-19	0,9739	1,2198
United Arab Emirates	0,8153	0,8696	32	0,9186	35	-3	0,9864	1,2990	0,9168	34	-2	0,9913	1,2252
Malta	0,8146	0,8688	33	0,9324	31	2	0,9761	1,3138	0,9442	27	6	0,9890	1,2422
Estonia	0,8119	0,8660	34	0,9194	34	0	0,9700	1,3078	0,8451	56	-22	0,9718	1,2129
Cyprus	0,8103	0,8643	35	0,9293	32	3	0,9762	1,3115	0,9408	29	6	0,9887	1,2408
Hungary	0,8049	0,8586	36	0,9139	38	-2	0,9673	1,3053	0,8405	58	-22	0,9693	1,2136
Brunei Darussalam	0,8046	0,8582	37	0,9125	39	-2	0,9829	1,2965	0,9075	36	1	0,9887	1,2236
Qatar	0,8028	0,8562	38	0,9051	43	-5	0,9875	1,2890	0,9154	35	3	0,9993	1,2144
Bahrain	0,8009	0,8542	39	0,9115	41	-2	0,9724	1,3011	0,8806	43	-4	0,9772	1,2243
Portugal	0,7949	0,8478	40	0,9178	36	4	0,9738	1,3048	0,9220	32	8	0,9855	1,2351
Poland	0,7948	0,8478	40	0,9124	40	1	0,9676	1,3042	0,8748	46	-5	0,9750	1,2240
Barbados	0,7881	0,8406	42	0,9104	42	0	0,9710	1,3010	0,9000	38	4	0,9804	1,2302
HIGH HUMAN DEVELOPMENT													
Bahamas	0,7840	0,8362	43	0,8972	49	-6	0,9676	1,2935	0,8508	52	-9	0,9716	1,2160
Lithuania	0,7833	0,8354	44	0,8984	46	-2	0,9618	1,2973	0,8057	72	-28	0,9625	1,2043
Chile	0,7828	0,8349	45	0,9159	37	8	0,9672	1,3068	0,9216	33	12	0,9844	1,2363
Argentina	0,7754	0,8271	46	0,9023	44	2	0,9630	1,2994	0,8673	49	-3	0,9734	1,2223
Kuwait	0,7708	0,8221	47	0,8917	52	-5	0,9816	1,2826	0,8984	39	8	0,9913	1,2157
Latvia	0,7690	0,8202	48	0,8937	50	-2	0,9593	1,2953	0,8208	68	-20	0,9649	1,2089
Montenegro	0,7687	0,8199	49	0,8979	47	2	0,9603	1,2978	0,8481	53	-4	0,9701	1,2166
Romania	0,7672	0,8183	50	0,8930	51	-1	0,9589	1,2950	0,8239	65	-15	0,9654	1,2099
Croatia	0,7672	0,8183	50	0,8975	48	3	0,9636	1,2958	0,8817	42	9	0,9765	1,2257
Uruguay	0,7654	0,8164	52	0,8987	45	7	0,9618	1,2976	0,8838	41	11	0,9765	1,2268
Libyan Arab Jam.	0,7550	0,8052	53	0,8834	55	-2	0,9598	1,2879	0,8428	57	-4	0,9679	1,2166

Panama	0,7546	0,8049	54	0,8901	53	1	0,9588	1,2930	0,8694	48	6	0,9737	1,2229
Saudi Arabia	0,7518	0,8019	55	0,8745	61	-6	0,9628	1,2802	0,8266	63	-8	0,9683	1,2077
Mexico	0,7505	0,8004	56	0,8885	54	2	0,9596	1,2915	0,8776	44	12	0,9765	1,2236
Malaysia	0,7439	0,7934	57	0,8791	58	-1	0,9561	1,2867	0,8456	54	3	0,9689	1,2168
Bulgaria	0,7432	0,7927	58	0,8802	56	2	0,9538	1,2886	0,8293	62	-4	0,9657	1,2123
Trinidad & Tobago	0,7356	0,7846	59	0,8546	72	-13	0,9562	1,2696	0,7731	90	-31	0,9583	1,1928
Serbia	0,7352	0,7842	60	0,8772	59	1	0,9526	1,2872	0,8394	59	1	0,9675	1,2153
Belarus	0,7320	0,7808	61	0,8580	68	-7	0,9474	1,2764	0,7505	95	-34	0,9504	1,1911
Costa Rica	0,7250	0,7732	62	0,8801	57	5	0,9564	1,2873	0,9062	37	25	0,9855	1,2269
Peru	0,7227	0,7708	63	0,8716	62	1	0,9497	1,2848	0,8261	64	-1	0,9651	1,2115
Albania	0,7187	0,7666	64	0,8764	60	4	0,9505	1,2877	0,8774	45	19	0,9772	1,2226
Russian Federation	0,7186	0,7665	65	0,8384	84	-19	0,9427	1,2652	0,7068	107	-42	0,9433	1,1775
Kazakhstan	0,7139	0,7614	66	0,8401	83	-17	0,9433	1,2660	0,7025	108	-42	0,9503	1,1666
Azerbaijan	0,7129	0,7604	67	0,8561	70	-3	0,9445	1,2765	0,7727	91	-24	0,9547	1,1971
Bosnia & Herzegovina	0,7104	0,7577	68	0,8663	65	3	0,9475	1,2822	0,8527	51	17	0,9719	1,2166
Ukraine	0,7099	0,7572	69	0,8594	67	2	0,9482	1,2770	0,7527	94	-25	0,9564	1,1847
Iran	0,7022	0,7490	70	0,8453	77	-7	0,9451	1,2688	0,7865	82	-12	0,9574	1,2008
Macedonia	0,7012	0,7479	71	0,8542	73	-2	0,9454	1,2748	0,8314	61	10	0,9681	1,2104
Mauritius	0,7007	0,7473	72	0,8435	80	-8	0,9472	1,2664	0,7855	84	-12	0,9582	1,1993
Brazil	0,6986	0,7451	73	0,8468	75	-2	0,9446	1,2700	0,8030	73	0	0,9616	1,2040
Georgia	0,6977	0,7442	74	0,8674	63	11	0,9493	1,2821	0,7975	77	-3	0,9608	1,2022
Venezuela	0,6964	0,7428	75	0,8475	74	1	0,9481	1,2688	0,8195	69	6	0,9668	1,2059
Armenia	0,6950	0,7413	76	0,8648	66	10	0,9468	1,2814	0,8342	60	16	0,9669	1,2134
Ecuador	0,6950	0,7413	76	0,8548	71	6	0,9438	1,2761	0,8452	55	22	0,9715	1,2132
Belize	0,6944	0,7406	78	0,8671	64	14	0,9464	1,2833	0,8735	47	31	0,9772	1,2207
Colombia	0,6888	0,7347	79	0,8437	79	0	0,9408	1,2698	0,8102	70	9	0,9636	1,2053
Jamaica	0,6884	0,7342	80	0,8448	78	2	0,9392	1,2714	0,7965	78	2	0,9591	1,2037
Tunisia	0,6825	0,7280	81	0,8424	81	0	0,9401	1,2693	0,8231	67	14	0,9673	1,2072
Jordan	0,6809	0,7262	82	0,8465	76	6	0,9395	1,2725	0,8094	71	11	0,9623	1,2064
Turkey	0,6787	0,7239	83	0,8282	87	-4	0,9451	1,2569	0,7760	88	-5	0,9587	1,1937

Algeria	0,6771	0,7222	84	0,8343	86	-2	0,9382	1,2646	0,7976	76	8	0,9615	1,2013
Tonga	0,6766	0,7217	85	0,8569	69	16	0,9449	1,2770	0,7957	79	6	0,9602	1,2020
MEDIUM HUMAN DEVELOPMENT													
Fiji	0,6694	0,7139	86	0,8412	82	4	0,9397	1,2686	0,7399	96	-10	0,9492	1,1871
Turkmenistan	0,6694	0,7139	86	0,8124	93	-6	0,9293	1,2538	0,6568	113	-26	0,9319	1,1662
Dominican Republic	0,6634	0,7076	88	0,8241	89	-1	0,9365	1,2583	0,7897	81	7	0,9611	1,1978
China	0,6634	0,7076	88	0,8274	88	1	0,9351	1,2613	0,8030	74	15	0,9638	1,2012
El Salvador	0,6594	0,7033	90	0,8228	90	0	0,9317	1,2598	0,7793	87	3	0,9576	1,1969
Sri Lanka	0,6582	0,7020	91	0,8354	85	6	0,9341	1,2674	0,8235	66	25	0,9676	1,2070
Thailand	0,6541	0,6977	92	0,8079	96	-4	0,9294	1,2506	0,7288	100	-8	0,9462	1,1852
Gabon	0,6480	0,6912	93	0,7717	109	-16	0,9233	1,2284	0,5975	120	-27	0,9276	1,1412
Suriname	0,6459	0,6890	94	0,8034	98	-4	0,9265	1,2490	0,7285	101	-7	0,9465	1,1847
Bolivia	0,6426	0,6854	95	0,8093	95	0	0,9277	1,2524	0,6762	112	-17	0,9360	1,1710
Paraguay	0,6398	0,6824	96	0,8165	92	4	0,9272	1,2577	0,7827	86	10	0,9589	1,1970
Philippines	0,6381	0,6806	97	0,8210	91	6	0,9293	1,2598	0,7862	83	14	0,9592	1,1984
Botswana	0,6334	0,6756	98	0,7457	114	-16	0,9252	1,2094	0,5298	128	-30	0,9327	1,0999
Moldova	0,6234	0,6649	99	0,8109	94	5	0,9271	1,2539	0,7258	102	-3	0,9455	1,1846
Mongolia	0,6220	0,6634	100	0,7996	101	-1	0,9231	1,2480	0,6919	110	-10	0,9385	1,1760
Egypt	0,6198	0,6611	101	0,7887	104	-3	0,9218	1,2411	0,7392	97	4	0,9516	1,1838
Uzbekistan	0,6175	0,6586	102	0,8045	97	5	0,9248	1,2506	0,7107	106	-4	0,9425	1,1806
Micronesia	0,6144	0,6553	103	0,8003	100	3	0,9225	1,2488	0,7243	103	0	0,9448	1,1846
Guyana	0,6111	0,6518	104	0,7942	102	2	0,9205	1,2456	0,7020	109	-5	0,9401	1,1791
Namibia	0,6062	0,6466	105	0,7507	112	-7	0,9074	1,2218	0,5711	123	-18	0,9129	1,1461
Honduras	0,6042	0,6444	106	0,7896	103	3	0,9162	1,2445	0,7752	89	17	0,9603	1,1913
Maldives	0,6021	0,6422	107	0,7797	107	0	0,9205	1,2354	0,7610	92	15	0,9591	1,1855
Indonesia	0,5999	0,6399	108	0,7817	106	2	0,9142	1,2400	0,7537	93	15	0,9556	1,1862
Kyrgyzstan	0,5984	0,6382	109	0,8004	99	10	0,9231	1,2486	0,7144	105	4	0,9436	1,1811
South Africa	0,5974	0,6372	110	0,7088	117	-7	0,9155	1,1886	0,4484	135	-25	0,9223	1,0711
Syrian Arab Republic	0,5890	0,6282	111	0,7751	108	3	0,9193	1,2329	0,7932	80	31	0,9685	1,1903
Tajikistan	0,5797	0,6184	112	0,7852	105	7	0,9174	1,2409	0,6894	111	1	0,9385	1,1746

Viet Nam	0,5720	0,6101	113	0,7685	110	3	0,9077	1,2341	0,7997	75	38	0,9696	1,1923
Morocco	0,5667	0,6044	114	0,7494	113	1	0,9119	1,2187	0,7379	98	16	0,9571	1,1762
Nicaragua	0,5652	0,6028	115	0,7653	111	4	0,9051	1,2333	0,7827	85	30	0,9650	1,1893
Guatemala	0,5600	0,5973	116	0,7407	115	1	0,9098	1,2137	0,7159	104	12	0,9526	1,1706
Equatorial Guinea	0,5381	0,5739	117	0,6353	130	-13	0,8993	1,1454	0,4975	133	-16	0,9488	1,0631
Cape Verde	0,5338	0,5694	118	0,7234	116	2	0,8997	1,2067	0,7293	99	19	0,9575	1,1713
India	0,5191	0,5537	119	0,6910	118	1	0,8865	1,1908	0,5884	122	-3	0,9232	1,1420
Timor-Leste	0,5017	0,5351	120	0,6593	125	-5	0,8893	1,1673	0,5161	130	-10	0,9117	1,1193
Swaziland	0,4979	0,5311	121	0,6026	137	-16	0,8743	1,1353	0,2569	152	-31	0,8810	1,0247
Lao People's Dem. Rep.	0,4968	0,5299	122	0,6785	120	2	0,8763	1,1872	0,6130	119	3	0,9306	1,1454
Solomon Islands	0,4942	0,5271	123	0,6796	119	4	0,8757	1,1883	0,6344	114	9	0,9360	1,1495
Cambodia	0,4937	0,5266	124	0,6772	121	3	0,8745	1,1873	0,5472	125	-1	0,9122	1,1345
Pakistan	0,4903	0,5229	125	0,6717	123	2	0,8810	1,1801	0,6279	115	10	0,9366	1,1455
Congo	0,4889	0,5215	126	0,6243	132	-6	0,8605	1,1574	0,3422	146	-20	0,8660	1,0874
Sao Tome & Principe	0,4876	0,5201	127	0,6744	122	5	0,8718	1,1867	0,6167	118	9	0,9315	1,1460
LOW HUMAN DEVELOPMENT													
Kenya	0,4701	0,5014	128	0,6387	129	-1	0,8629	1,1663	0,3900	140	-12	0,8770	1,0980
Bangladesh	0,4693	0,5005	129	0,6604	124	5	0,8648	1,1805	0,6264	116	13	0,9355	1,1460
Ghana	0,4672	0,4983	130	0,6494	126	4	0,8664	1,1719	0,4317	136	-6	0,8856	1,1087
Cameroon	0,4598	0,4904	131	0,5955	138	-7	0,8472	1,1441	0,2742	151	-20	0,8531	1,0686
Myanmar	0,4510	0,4810	132	0,6288	131	1	0,8546	1,1636	0,5357	126	6	0,9152	1,1249
Yemen	0,4395	0,4687	133	0,6071	136	-3	0,8639	1,1437	0,5343	127	6	0,9207	1,1173
Benin	0,4353	0,4643	134	0,6093	135	-1	0,8477	1,1535	0,5184	129	5	0,9130	1,1188
Madagascar	0,4347	0,4637	135	0,6396	128	7	0,8598	1,1684	0,5142	131	4	0,9074	1,1236
Mauritania	0,4335	0,4624	136	0,5855	141	-5	0,8484	1,1365	0,4001	139	-3	0,8855	1,0926
Papua New Guinea	0,4314	0,4602	137	0,5936	139	-2	0,8570	1,1378	0,4870	134	3	0,9093	1,1074
Nepal	0,4285	0,4570	138	0,6175	133	5	0,8472	1,1594	0,6175	117	21	0,9379	1,1384
Togo	0,4281	0,4567	139	0,6430	127	12	0,8602	1,1707	0,5551	124	15	0,9179	1,1316
Comoros	0,4276	0,4561	140	0,6161	134	6	0,8466	1,1588	0,5948	121	19	0,9320	1,1342
Lesotho	0,4271	0,4556	141	0,5363	149	-8	0,8335	1,1098	0,1480	159	-18	0,8451	1,0138

Nigeria	0,4227	0,4508	142	0,5350	150	-8	0,8264	1,1125	0,1583	157	-15	0,8293	1,0390
Uganda	0,4216	0,4497	143	0,5853	142	1	0,8415	1,1399	0,3364	148	-5	0,8664	1,0839
Senegal	0,4111	0,4385	144	0,5578	143	1	0,8379	1,1225	0,3646	145	-1	0,8793	1,0821
Haiti	0,4040	0,4310	145	0,5906	140	5	0,8389	1,1449	0,5005	132	13	0,9097	1,1137
Angola	0,4031	0,4299	146	0,4957	155	-9	0,8425	1,0769	0,2149	154	-8	0,8688	1,0184
Djibouti	0,4020	0,4288	147	0,5381	147	0	0,8438	1,1058	0,3408	147	0	0,8788	1,0705
Tanzania	0,3983	0,4248	148	0,5499	145	3	0,8270	1,1225	0,3813	141	7	0,8835	1,0854
Côte d'Ivoire	0,3968	0,4233	149	0,5473	146	3	0,8356	1,1163	0,4051	138	11	0,8917	1,0873
Zambia	0,3949	0,4212	150	0,5144	153	-3	0,8173	1,1027	0,1164	161	-11	0,8215	1,0272
Gambia	0,3901	0,4161	151	0,5377	148	3	0,8251	1,1150	0,3664	144	7	0,8814	1,0804
Rwanda	0,3854	0,4111	152	0,5218	152	0	0,8169	1,1080	0,2322	153	-1	0,8463	1,0556
Malawi	0,3847	0,4103	153	0,5503	144	9	0,8266	1,1230	0,3318	149	4	0,8694	1,0777
Sudan	0,3787	0,4040	154	0,5129	154	0	0,8386	1,0908	0,3772	143	11	0,8945	1,0695
Afghanistan	0,3492	0,3725	155	0,4303	158	-3	0,7886	1,0585	0,0000	169	-14	0,7956	1,0000
Guinea	0,3402	0,3628	156	0,4758	156	0	0,8036	1,0827	0,3787	142	14	0,8945	1,0702
Ethiopia	0,3282	0,3501	157	0,4489	157	0	0,7979	1,0668	0,3068	150	7	0,8787	1,0532
Sierra Leone	0,3175	0,3386	158	0,4192	161	-3	0,7762	1,0571	0,1080	164	-6	0,8252	1,0182
Central African Rep.	0,3151	0,3361	159	0,4192	160	-1	0,7769	1,0567	0,0927	165	-6	0,8210	1,0156
Mali	0,3094	0,3300	160	0,3933	163	-3	0,7855	1,0343	0,1090	163	-3	0,8326	1,0094
Burkina Faso	0,3051	0,3254	161	0,3888	164	-3	0,7939	1,0269	0,1959	156	5	0,8636	1,0152
Liberia	0,2999	0,3199	162	0,5290	151	11	0,8078	1,1177	0,4292	137	25	0,8959	1,0944
Chad	0,2948	0,3144	163	0,3679	166	-3	0,7778	1,0205	0,0915	166	-3	0,8326	1,0005
Guinea-Bissau	0,2887	0,3080	164	0,4000	162	2	0,7687	1,0475	0,1111	162	2	0,8278	1,0166
Mozambique	0,2843	0,3033	165	0,3537	167	-2	0,7641	1,0175	0,0749	168	-3	0,8262	1,0000
Burundi	0,2815	0,3003	166	0,4288	159	7	0,7780	1,0629	0,2027	155	11	0,8480	1,0383
Niger	0,2614	0,2788	167	0,3203	168	-1	0,7527	1,0000	0,1469	160	7	0,8556	1,0000
Dem. Rep. of Congo	0,2391	0,2550	168	0,3826	165	3	0,7535	1,0431	0,0913	167	1	0,8234	1,0120
Zimbabwe	0,1401	0,1494	169	0,0000	169	0	0,3119	1,0000	0,1538	158	11	0,8584	1,0000

Note: Total sample size is 169. Diff corresponds to the difference in rankings between standard HDI and HDI based on DEA.
Source: HDR, UNDP (2010) and authors' calculations.

Finally, three sets of findings emerge from this study (see Table 1).
In first place, the used approach has good discriminating properties in the extent that we have just one efficient entity, namely Japan for the model 1 and Australia for the model 2. In addition, contrary to the standard HDI no country is ranked equally.
In second place, the Spearman's rank correlation test[6] shows that our results are globally robust. Indeed, in accordance with Table 2, the Spearman's rank correlation coefficient regarding the classic HDI values obtained from the two models are 0.958 and 0.994, respectively. Moreover, the P-value of this test is zero and thus the null hypothesis is rejected at $\alpha = 0.001$. Hence, we can conclude that the design of the United Nations' HDI is quite good. Table 2 also presents the correlation between the different CIs and the three sub-indicators. A striking difference appears. Both models 1 and 2 are more highly correlated with Life expectancy whereas the standard HDI is more correlated with Income per capita.

Table 2. The Spearman's rank correlation test

	Life expectancy	Education	Income	HDI	Model 1	Model 2
HDI	0.923	0.924	0.953	1		
Model 1	0.991	0.846	0.895	0.958	1	
Model 2	0.946	0.927	0.925	0.994	0.975	1

Source: Authors' calculations.

In last place, we do not observe major modifications between the rankings resulting from the standard HDI and the model with constraint. The largest positive and negative differences between the two methods are +16 (for Tonga) and -19 (for Russian Federation), respectively. Moreover, most of economies remain into their human development category defined by the HDI. The distinction between the rankings of the HDI and the model without constraint is more important. Indeed, many and large positive and negative variations are present, particularly in the middle of the sample. Note the surprising outcome of United States of America. Although this country keeps its status of "very high human development", it displays a decline of 18 places to be ranked only 22th. In addition, several countries are associated with very important gains or losses $(\geq \mp 25)$: Lithuania (-28), Trinidad & Tobago (-31), Belarus (-34), Costa-Rica (+25), Russian Federation (-42), Kazakhstan (-42), Ukraine (-25), Belize (31), Turkmenistan (-26), Sri Lanka (+25), Gabon (-27), Botswana (-30), South Africa (-25), Syria (+31), Viet Nam (+38), Nicaragua (+30), Swaziland (-31) and Liberia (+25). These results are explained by the fact that, contrary to the HDI, the income component is no longer the most significant contribution factor for the new CI. However, the results associated with this latter model must be taken with caution. The nature of the chosen optimization procedure could lead to extreme weights which are often unrealistic and impractical because of ignoring the impact of sub-indicators with extremely small weight values in HDI calculation. So we recommend using rather the model 2 that is the DEA type model with constraints on the weights.

4. Conclusion

To conclude, this study revisited the United Nations' HDI within a DEA setting. Our main concern was to circumvent the equal weights assumption retained in the construction of this indicator. So following the recent work of Zhou *et al.* (2010), we applied multiplicative DEA type models in order to generate an optimal weighting scheme for all economies considered in

[6] We also computed the Kendall's coefficient of concordance but the results have not really changed. These ones are of course available upon request from the authors.

the HDR (2010). The new measure of human development results in a world ranking close to and highly correlated with the world ranking based on the standard HDI. Moreover, this new measure relies on the fact that the weights assumed for each component are less arbitrary and contestable, as a result of an optimization process. Thus, our finding gives finally a robustly statistical support to the ad hoc equal weighting system adopted by the UNDP.

However, our results must be taken with caution. Indeed, Hatefi and Torabi (2010) pointed out one main drawback of Zhou *et al.* (2010)'s method. Choosing subjectively an appropriate value for the parameter λ can be problematic for the analyst. Furthermore, different values of λ might conduce to misleading results for the global index, then making difficulty in reaching a final decision.

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