HUMAN DEVELOPMENT INDEX: A NON-COMPENSATORY ASSESSMENT

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INTRODUCTION

In 1990, the United Nations Development Programme (UNDP) introduced the Human Development Index (HDI) as a summary measure of Human Development (HD) on three basic dimensions, namely longevity, knowledge and standard of living. An index is computed for each of these three dimensions and a simple average computed. Since its conception, the HDI has been the focus of a public debate. Apart from other criticism (e.g. Srinivasan 1994), some scholars have called it redundant in the sense that HDI is generally highly correlated with its component indexes (see e.g. McGillivray 1991, Srinivasan 1994 and Cahill 2005). Other researchers (e.g. Trabold-Nübler 1991, Lüchters and Menkhoff 1996) have shown so-

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me undesirable consequences of the way some components are derived, thus leading $UNDP$ to refine the HDI along the years to correct those flaws. Morse (2003) presents a summary of the evolution in the calculation of the HDI. It is not the aim of this paper to discuss the choice of capabilities included in the HDI.

An important issue is that the aggregation of the component indices forces the specification of tradeoffs between the various HDI dimensions (Kelley 1991). The index allows attainments in any one of the three dimensions to be traded off against another (Ravallion 1997). In fact, the equal weighting of the component indexes suggests a perfect substitution between them and therefore implicit trade-offs between the corresponding dimensions (Desai 1991). He suggests the use of a log additive formula as a way of restricting substitutability. Along the same lines, Sagar and Najam (1998) propose a Reformed HDI that, instead of averaging the component indexes, multiplies them so that a high value of the HDI would require high values of the three component indexes simultaneously.

However, as recognized in Hopkins (1991) there is no a priori rationale that allows one to add life expectancy to literacy. Most researchers have however maintained the additivity of the component indices, including those such as the Modified HDI (Noorbakhsh 1998a) and the Rescaled New HDI (Mazumdar 2003) that use Euclidean vector distance. Not all approaches, however, have maintained the equal weighting of the components. Thus, Noorbakhsh (1998b) use weights derived from the data using Principal Component Analysis, while the Data Envelopment Analysis approach in Despotis (2005a, 2005b) and more recently Lozano and Gutiérrez (2008) determine different weights for each country so that it appears under the best possible light.

In this paper, we propose an explicit Non-Compensatory (NC) criterion that is based on the assumption that the achievements in one dimension cannot compensate an underachievement in another. In this way the simplicity of HDI of providing a single figure from a reduced number of component indicators is maintained. However, "the task of specification must relate to the underlying motivation of the exercise as well as dealing with the social values involved" (Sen 1989). Thus, the philosophical principle emphasized in $NCHDI$ is that of the inalienability of the inherent rights to human development in all its different dimensions. This concept is especially important since the measures of deprivation considered in HDI correspond to basic human needs that can foreclose many other capabilities. On the one hand, averaging, in a weighted or unweighted way, implies an implicit con-

doning of part of these deprivations, most importantly, those that are most acute. On the other hand, the non-compensatory principle is consistent with the non-commensurability of the diverse aspects of development. On these ethical and practical grounds is based our proposal for a non-compensatory assessment of the HDI.

Note that we are not rejecting the possibility or convenience of devising a composite, aggregate measure of human development. Our objections are against the usual ways of carrying out such aggregation.

The structure of this paper is the following. In section 2, after detailing the calculation of HDI, the $NCHDI$ is introduced and discussed. Section 3 presents the results of the $NCHDI$ vis-à-vis HDI for the data of the last five years. The last section summarizes and concludes.

NON-COMPENSATORY HDI

The three component indexes of the HDI (life expectancy index, education index and GDP per capita index) are computed based on four indicators:

- Life Expectancy at Birth (LEB) indicator, ranging from 25 to 85 years
- Adult Literacy Rate (ALR), ranging from 0 to 100
- Combined primary, secondary and tertiary Gross Enrolment Ratio (GER), ranging from 0 to 100
- Logarithm of the Gross Domestic Product ($LGDP$) per capita in US Dollars purchasing power parity, ranging from $\log(USD100)$ to $\log(USD40000)$

The corresponding Life Expectancy Index (XLE) is computed as:

$$XLE = \frac{LEB - 25}{85 - 25}$$

The Adult Literacy Index (XAL), computed as:

$$XAL = \frac{ALR - 0}{100 - 0}$$

is combined (with respective weights $2/3$ and $1/3$) with the corresponding Gross Enrolment Index (XGE):

$$XGE = \frac{GER - 0}{100 - 0}$$

giving the Education Index (XE):

$$XE = \frac{2}{3} \cdot XAL + \frac{1}{3} \cdot XGE$$

Finally, the GDP per capita Index ($XGDP$):

$$XGDP = \frac{LGDP - \log(100)}{\log(40000) - \log(100)}$$

allows the HDI to be computed as the simple average of the three component indices:

$$HDI = \frac{1}{3} \cdot XLE + \frac{1}{3} \cdot XE + \frac{1}{3} \cdot XGDP$$

The NC approach we propose does not allow for any trade off (neither explicit nor implicit) between the different HDI dimensions. All of them are considered basic and inalienable. Neither adding nor multiplying the component indices nor any similar way of introducing compensatory effects between them is considered admissible. A suitable $NCHDI$ index may be computed as the minimum of the component indices, i.e.

$$NCHDI = \text{mín}\{XLE, XE, XGDP\}$$

This index corresponds to one minus the Tchebycheff distance between the vector of component indices and the Ideal Point $(1, 1, 1)$. This Ideal Point represents attaining the maximum values of the goalposts of the different HDI dimensions. The distance to such a reference point may represent a measure of the lack of attainment of these goals. But instead of using rectangular distance (a.k.a. l_1 metric) as HDI does, or Euclidean distance (a.k.a. l_2 metric) as the Modified HDI or Rescaled New HDI do, we propose using Tchebycheff distance (a.k.a. l_∞ metric) which does not require additivity and is NC. The Tchebycheff distance between two vectors is equal to the maximum of the absolute value of the component-wise difference between both vectors. Thus,

$$\begin{aligned} NCHDI &= 1 - |(1,1,1) - (XLE, XE, XGDP)|_\infty \\ &= 1 - \text{máx}\{1 - XLE, 1 - XE, 1 - XGDP\} \\ &= 1 - (1 - \text{mín}\{XLE, XE, XGDP\}) = \text{mín}\{XLE, XE, XGDP\} \end{aligned}$$

This minimum criterion is used in Multiple Attribute Decision Making (e.g. Yoon and Hwang 1995, p. 28) and reflects a pessimistic evaluation approach that scores an alternative according to its worst performance among the different criteria. Similarly, $NCHDI$ scores each country according to its lowest level of goal achievement. This way of assessing the HDI sends a clear signal to each country about where its priority should be. It also makes explicit that none of the HDI dimensions (a long and healthy life, knowledge and a decent standard of living) may be left behind. All of them are considered equally important and desirable. For those countries that have unbalanced component indices, the $NCHDI$ provides an

incentive to improve the lagging dimension. We consider this ability of $NCHDI$ to identify the most largely unmet needs rather useful. In addition, $NCHDI$'s maximin structure is analogous, mutis mutandis, to the difference principle in Rawls' Theory of Justice (Rawls 1971). Thus, the improvements in some dimensions of the HDI are not worth much if they are not accompanied by parallel improvements in the worst off dimensions. In other words, according to $NCHDI$, improving the most neglected dimension of human development has a higher priority than improving those better off. In this sense, it can be said that $NCHDI$ implicitly establishes priorities but in a dynamic, non-parametric and socially just way.

It is trivial to prove the following two properties:

a. $NCHDI \leq HDI$
b. $NCHDI = HDI$ if and only if $XLE = XE = XGDP = NCHDI = HDI$

Three additional considerations are in order. First, that the NC criterion has a clear drawback, which is that not all improvements in the component indices translate into improvements in the NC-HDI, i.e. it can happen that a country may improve one component while its NC-HDI may not improve. This happens whenever the lowest component index does not improve. Although this lack of monotonicity is an undesirable feature, it is unavoidable and intrinsic to its NC character.

The second remark is that $NCHDI$ selects one of three component indices, discarding the other two. This is not equivalent to the approaches (such as Ogwang 1994, Ogwang and Abdou 2003) that propose to use just one of the component indices to compute the HDI. The difference lies in that which of the three components is selected is not fixed but can change from one country to another.

Finally, the same as the HDI, the proposed $NCHDI$ can be used not only at the national level but also at the regional or local level, thus helping to detect the specific and more urgent problems in each geographical area.

ANALYSIS AND DISCUSSION OF RESULTS

The proposed $NCHDI$ has been computed for the HDI 2000 through HDI 2004 contained in the Human Development Reports (HDR) of the latest five years (i.e. HDR 2002 through HDR 2006 respectively). Table 1 shows the Pearson's correlation coefficient between $NCHDI$ and HDI for the five years. It can be seen that there is a significantly strong but not

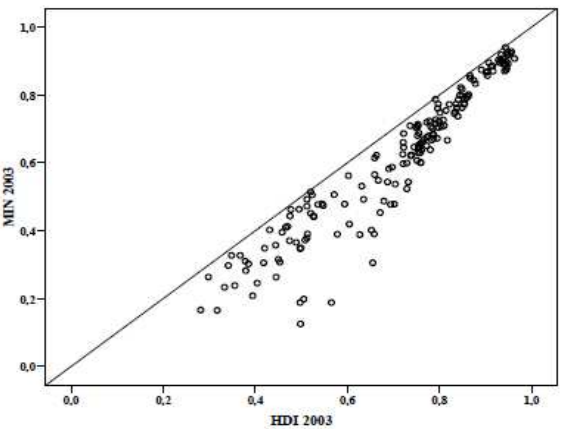
perfect linear relationship between both indices. This can also be seen in Figure 1, which shows a scatter plot of HDI versus $NCHDI$ for year 2004. The graphs for the other four years are similar and are not shown to save space. Note that, as expected, all points fall below the diagonal, which corresponds to $NCHDI$=HDI. The closer a point is to the diagonal, the more balanced are the corresponding HDI component indices and, on the contrary, the farther from the diagonal, the more unbalanced the HDI component indices. Figure 2 shows, for year 2004, the distribution of the difference between the maximum and the minimum HDI components as well as that of the difference between the average component index (i.e. the HDI) and the minimum component index (i.e. the $NCHDI$). Note that the imbalance in the HDI component indices can be important in some cases and that such imbalance is generally reflected in a larger HDI-$NCHDI$ difference.

TABLE 1.
PEARSON'S CORRELATION COEFFICIENT BETWEEN HDI AND $NCHDI$. ALL CORRELATIONS SIGNIFICANT AT THE 0.01 LEVEL (TWO-TAILED)

	2004	2003	2002	2001	2000
r_t	0.950	0.948	0.953	0.934	0.954

Source: HDR 2006, 2005, 2004, 2003, 2002.

FIGURE 1.
SCATTER PLOT SHOWING $NCHDI$ 2004 VERSUS HDI 2004

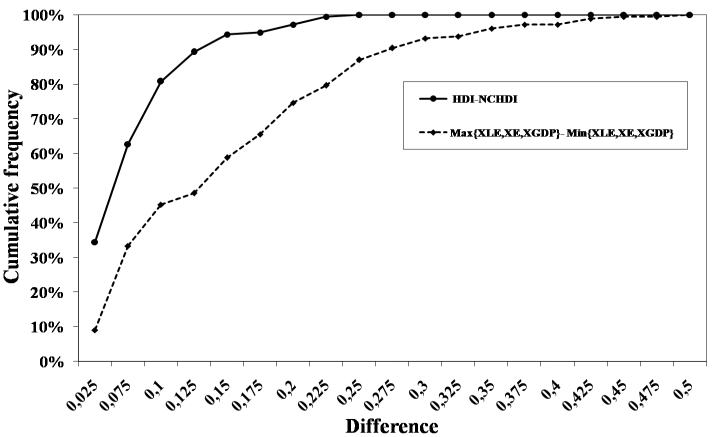


Source: HDR 2006.

$NCHDI$ highlights the need to improve in those HDI dimensions that fare worst for each country. HDI, on the contrary, can mask underperformance of a certain dimension with a good performance in another, thus

in a certain sense hiding or de-emphasizing the problem. Take the case of Botswana, for example. In 2004, its HDI has been a low but seemingly "reasonable" value 0.570 that makes it in position 131 out of 177 in the HDI ranking. This relatively high HDI is the average of two high components $XE = 0.777$ and $XGDP = 0.768$ and a worrisomely low value $XLE = 0.165$. The latter is the one that $NCHDI$ takes and corresponds to next to last position in $NCHDI$ ranking. Our claim is that the relatively high GDP per capita and enrollment and literacy rates of Botswana cannot compensate its dramatic 34.9 years of Life Expectancy at Birth. This is why we believe that the proposed $NCHDI$ is more valid the HDI, i.e. because it gives a clearer picture of the real situation of Human Development.

FIGURE 2.
DISTRIBUTION OF THE DIFFERENCES BETWEEN HDI COMPONENTS FOR YEAR 2004.



Source: HDR 2006.

Since, as Booysen (2002) argues, composite indices such as the HDI have an ordinal nature (insofar as the magnitude of the differences between the index values for two countries cannot be interpreted meaningfully), we have carried out the non-parametric Mann-Whitney rank sum test to see if the rankings derived from HDI and $NCHDI$ belong to the same distribution. Table 2 shows the corresponding U statistic and p-value for each of the five years. Since in all cases the statistic is significant at 0.01 level, the null hypothesis that the ranking given by HDI and $NCHDI$ are similar is rejected, i.e. the $NCHDI$ leads to a different ranking from that of the HDI. Whether the $NCHDI$ ranking is more or less valid than that of HDI depends on whether the NC criterion is adopted or not.

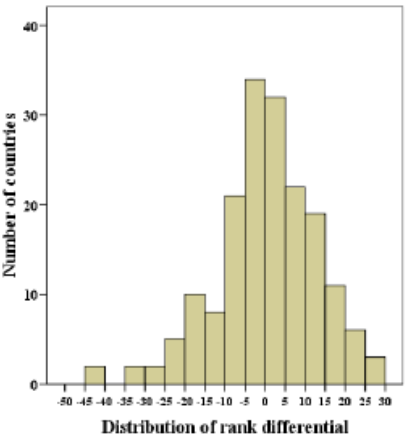
TABLE 2.
MANN WHITNEY'S U TEST BETWEEN HDI AND $NCHDI$. IN ALL FICE YEARS THE STATISTIC IS SIGNIFICANT AT THE 0.01 LEVEL

	2004	2003	2002	2001	2000
U	11663	11548.5	11442.5	11146.5	11108.5
p-value	0.000	0.000	0.000	0.000	0.000

Source: HDR 2006, 2005, 2004, 2003, 2002.

Figure 3 shows, for the year 2004, the histogram showing the distribution of the rank difference between and $NCHDI$. Its apparent normality (with zero mean and a standard deviation of 12.9) is confirmed, at a 0.01 significance level, by a Kolmogorov-Smirnov-Lilliefors normality test. The same normality behavior happens (with similar means and standard deviations) for the other four years.

FIGURE 3.
DISTRIBUTION OF RANK DIFFERENCES BETWEEN HDI AND $NCHDI$ FOR YEAR 2004

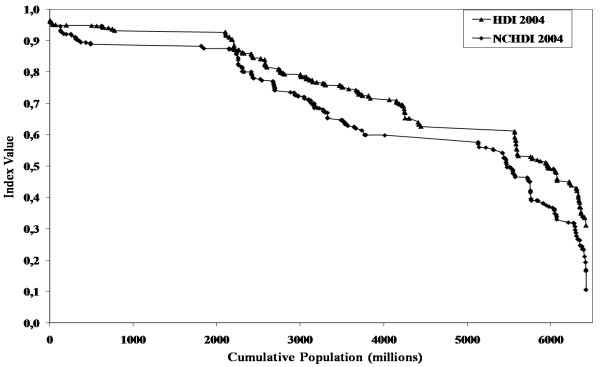


Source: HDR 2006.

Figure 4 plots HDI and $NCHDI$ versus Cumulative Global Population for year 2004. The HDI graph results from ordering the countries in decreasing order of HDI and accumulating their population in that order. The same is done for the $NCHDI$ graph. Note that, since , the $NCHDI$ graph is always below that of HDI and this implies that $NCHDI$ presents a bleaker picture of global HD than the more optimistic HDI. Think that the horizontal line $HDI = NCHDI = 1$ corresponds to the Ideal Point given by the $UNDP$ goalposts. Therefore, the lower the graph, the clearer

is the work that has still to be done to bring the HD of the world population up to those goalposts.

FIGURE 4.
HDI AND $NCHDI$ VERSUS CUMULATIVE GLOBAL POPULATION FOR YEAR 2004



Source: HDR 2006.

Table 3 shows how many times each of the three HDI component indices gives the minimum that determines the value of the $NCHDI$. Note that the $XGDP$ component has lagged behind in more than $50\,\%$ of the cases, XLE in more than $35\,\%$ of the cases and XE in only $10\,\%$ of the cases. This seems to indicate that half of the countries should concentrate on improving the economic well being of their citizens, another significant number of countries should concentrate in improving their health and life expectancy and only a minority should worry most about the educational level of the population. Although the distribution was fairly stable for four years it seems that in year 2004 there was an increase in the number of countries with minimum value of XLE at the expense of component $XGDP$. This seems to imply that for some countries the $XGDP$ improved enough to stop being lower than $XLEB$. This type of reasoning, however, must be made with caution since if the difference between the HDI component indices of a country is small then a small differential improvement may be enough for changing the component that is the minimum. It may also happen that both components decrease but one decreases less than the other by an amount enough to stop being the minimum. Therefore, the changes in the HDI component indices must be analyzed on a case-by-case basis. What $NCHDI$ does, with respect to HDI, is to increase the visibility and individual importance of the component indices, a visibility and an importance that are highly diminished after the additive aggregation process performed by the HDI.

TABLE 3.
NUMBER OF TIMES THAT EACH HDI COMPONENT INDEX IS THE MINIMUM

Year	XLE	XE	XGDP
2004	75	20	82
2003	65	19	93
2002	63	17	97
2001	64	18	93
2000	60	17	98
Average	65.4 (37.1 %)	18.2 (10.3 %)	92.6 (52.6 %)

Source: HDR 2006, 2005, 2004, 2003, 2002.

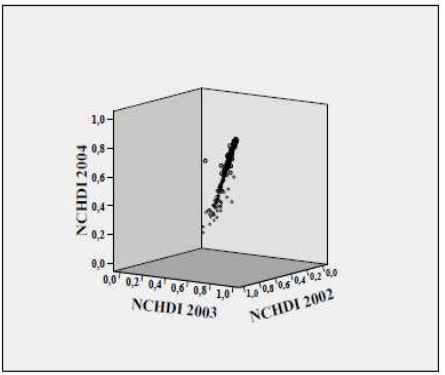
As for inter-temporal comparisons using the $NCHDI$, Table 4 shows the Pearson's correlation coefficient between consecutive years for both HDI and $NCHDI$. It can be seen that in both cases there is a significantly strong correlation between the values of the indices in one year and the next and that the strength of the correlation is similar for both indices. The linear relationship between the $NCHDI$ in consecutive years can also be seen in Figure 5, which shows a 3D scatter plot of the $NCHDI$ for the last three years.

TABLE 4.
INTER-TEMPORAL PEARSON'S CORRELATION COEFFICIENTS FOR HDI AND NCHDI. ALL CORRELATIONS SIGNIFICANT AT THE 0.01 LEVEL (TWO-TAILED)

	2004,2003		2003,2002		2002,2001		2001,2000	
	HDI	NCHDI	HDI	NCHDI	HDI	NCHDI	HDI	NCHDI
$r_{t,t+1}$	0.999	0.993	0.995	0.988	0.984	0.995	0.983	0.985

Source: HDR 2006, 2005, 2004, 2003, 2002.

FIGURE 5.
3D SCATTERPLOT OF NCHDI FOR YEARS 2002 THROUGH 2004

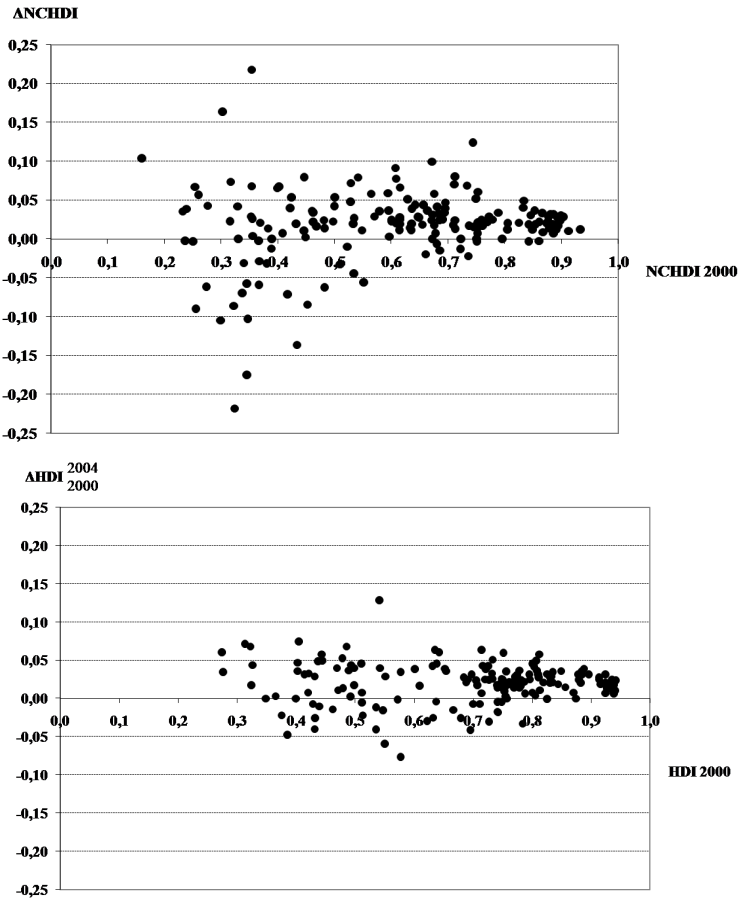


Source: HDR 2006, 2005, 2004

Finally, Figure 6 shows the temporal variation of the proposed $NCHDI$ between 2000 and 2004. For comparison, the temporal variation of HDI

over the same period is also shown. Note that, surprisingly, in both indexes negative variations have occurred in a relatively high number of cases. In general, the changes of $NCHDI$ have been greater than those of HDI. Also, it can be seen that the changes in $NCHDI$ are the largest for those countries with low $NCHDI$ values.

FIGURE 6.
TEMPORAL VARIATION OF NCHDI AND HDI



Source: HDR (2006, 2002).

SUMMARY AND CONCLUSIONS

This paper suggests departing from the additive character of the HDI and adopting an NC criterion that assumes that the different HDI dimensions are inalienable and therefore cannot be traded off. The rationale is that

so long as a crucial aspect of human development lags behind, the whole goal of human development is hindered. It makes sense, therefore, to try to identify and remove the most important obstacles that are impeding the integrality of this process. The usual way of aggregating the HDI components can mask existing problems, while adopting a NC approach highlights them.

The specific $NCHDI$ proposed corresponds to taking the minimum of the values of the HDI component. This $NCHDI$ is related to the Tchebycheff distance to the Ideal Point that represents the maximum values of the goalposts assumed by $UNDP$ for computing the HDI. Several properties and features of the proposed $NCHDI$ have also been presented.

Numerical results comparing the $NCHDI$ and the HDI and their respective rankings for the last five years of data available are reported. They show that although the numerical values of both indices are highly correlated their rankings are not and that the $NCHDI$ reflects and highlights possible imbalances in the HDI component indices. The $NCHDI$ also allows for a more detailed analysis of the inter-temporal evolution of the HDI dimensions. Overall, the $NCHDI$ provides a more realistic (i.e. less optimistic) assessment of the situation of HD than the HDI does. Finally, as it happens with the HDI, $NCHDI$ can be applied not only to countries but also at the regional or local levels.

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