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Troubling tradeoffs in the Human Development Index☆

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ABSTRACT

The 20th Human Development Report introduced a new version of its famous Human Development Index (HDI), which aggregates country-level attainments in life expectancy, schooling and income. The main change was to relax the past assumption of perfect substitutability between its components. Most users will not, however, realize that the new HDI has also greatly reduced its implicit weight on longevity in poor countries, relative to rich ones. By contrast, the new HDI's valuations of extra schooling are now very high—many times the economic returns. An alternative index is proposed that embodies less troubling tradeoffs while still allowing imperfect substitution.

1. Introduction

The *Human Development Index* (HDI) aims to provide a broader characterization of "development" than is possible by focusing on national income alone. For this purpose, the index aggregates country-level attainments in life expectancy and education, as well as income. The index has been published since 1990 in the UNDP's *Human Development Reports* (HDRs).

Each year's HDI scores are keenly watched in both rich and poor countries. Politicians and the media take note. The countries that do well on the index are congratulated by the HDRs, and those doing poorly are flagged. The aim is not only to monitor human development, but to encourage actions that promote it. The HDIs are claimed to "…yield many novel results – and insights – that can guide development policy debates and designs" (UNDP, 2010, p.8). UNDP (undated) documents numerous examples of the policy influence of the HDI. Wolff et al. (2010) also point to applications, including donor aid allocations and in setting drug prices.

As for any composite index, users must know the weights attached to the HDI's dimensions, to properly judge if it has the balance right.[1] The marginal weight on any dimension can be defined as the first partial derivative with respect to that dimension. Since the HDI's units are arbitrary (normalized to lie in the 0, 1 interval), it the relative weights we are concerned about. In other words, we need to know the assumed tradeoffs, as given by the HDI's marginal rate of substitution (MRS), i.e., how much of one component must be given up for an extra unit of another, keeping the index constant. If a policy or economic change entails that one dimension increases at the expense of another then it is the MRS that tells us whether human development is deemed to have risen or fallen.[2] Only if we accept the tradeoffs built into such a composite index can we be confident that it is adequately measuring what it claims to measure.

In common with other "mashup indices of development" (Ravallion, 2012), the HDI's tradeoffs are not constrained by theory.[3] The authors of the HDR set themselves free to pick the HDI's variables and weights. From 1990 to 2009 the HDI gave equal (linear) weights to three functions of its core dimensions for health, education and income.[4] While

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[1] On the importance of knowing the weights built into a composite index of development see Ravallion (2010a), which also discusses a number of other issues not touched on here, including the robustness of country rankings and whether aggregation of the core dimensions is useful for policy.

[2] This argument does not presume that the HDI is the maximand of some policy calculus; we need to know the tradeoffs embodied in the index even if we do not maximize it. On this point see Ravallion's (2011a) comments on Klugman et al. (2011).

[3] Though economic theory can offer some insights into how one might form a composite index of human development. In the context of aggregating mean income and life expectancy, Dowrick et al. (2003) show how revealed preference theory can guide the methodological choices. Also see the more structural economic models in Becker et al. (2005) and Jones and Klenow (2010), and the latent-variable statistical model used by Høyland et al. (2010) to set the weights for a version of the HDI.

[4] The choice of these dimensions has been debated. For example, some observers have questioned why income is included in the HDI; while longevity and schooling are undeniably relevant, income itself is not a measure of "human development," as that term is normally understood. See the discussion in Anand and Sen (2000), who argue for including income.

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the choice of variables and their weights can be questioned, the HDI has at least appeared to be transparent and simple.

That appearance is not quite so evident on closer inspection. Indeed, the HDI has never made explicit its tradeoffs across the core dimensions. Users are only told the weights on its three derived functions of those core dimensions, even though the deeper tradeoffs between the core dimensions are clearly more salient. Since income is one of those core dimensions, the tradeoffs can also be monetized, which makes them easier to understand, and to assess whether they are appropriate by comparison with other research findings, including on the economic returns to better health and education.[5]

This paper examines the tradeoffs embodied in the new version of the HDI presented in UNDP (2010) and discussed further in Klugman et al. (2011).[6] After summarizing how the index has changed, the paper turns to the HDI's valuations of longevity and schooling. The paper first questions whether its implicit valuations are sending the right signals to governments trying to monitor and promote human development. Then the paper shows that the troubling tradeoffs in the 2010 HDI could have been avoided to a large extent using an alternative index.

2. The Human Development Index

The three core dimensions of the HDI are life expectancy (*LE*), schooling (*S*) and income (*Y*). The changes introduced in the 20th *Human Development Report* (UNDP, 2010) concern the precise measures used for these core dimensions, and how they are aggregated to form the composite index. Life expectancy is the only core dimension that is unchanged in the 2010 HDI. Gross national income (GNI) has replaced GDP, both still at purchasing power parity (PPP) and logged. The two variables used to measure the third component, education, have changed. Literacy and the gross enrolment rate (as used in the old HDI) have been replaced by mean years of schooling (*MS*) and the expected years of schooling (*ES*), given by the years of schooling that a child can expect to receive given current enrolment rates.

As in the past, the three core dimensions of the HDI are first put on a common (0, 1) scale. The rescaled indicators are:

$$I_x = \frac{x - x^{\min}}{x^{\max} - x^{\min}} \; (x = LE, \; S) \tag{1.1}$$

$$I_Y = \frac{\ln Y - \ln Y^{\min}}{\ln Y^{\max} - \ln Y^{\min}} \tag{1.2}$$

where the "max" and "min" denote the assumed bounds (in obvious notation). I assume that $x^{\min} \le x_i \le x^{\max}$ $(x = LE, S, Y)$ for all i though it will be noted that the new HDI's marginal weights are undefined at $x_i = x^{\min}$.[7] (Note also that *S* is itself a composite index of *MS* and *ES*, which I return to.)

The bounds used in rescaling all three variables to common units have also been modified. It used to be assumed that life expectancy is bounded below by 25 years, and above by 85 years, but in the 2010 HDI these bounds changed to 20 years and 83.2 years (Japan's life expectancy). In the 2010 HDI, GNI per capita is bounded below by $163 (the lowest value, for Zimbabwe in 2008) and above by $108,211 (for the United Arab Emirates in 1980). The new education variables are both taken to have lower bounds of zero with *MS* bounded above by 13.2 years (the US in 2000) and *ES* bounded above by 20.6 years (Australia, 2002).

An important change is in how the three scaled indicators are aggregated. The old HDI used their arithmetic mean:

$$HDI_{old} = (I_{LE} + I_S + I_Y)/3 \tag{2}$$

The 2010 HDI uses instead their geometric mean:

$$HDI_{new} = I_{LE}^{1/3} I_S^{1/3} I_Y^{1/3} \tag{3}$$

Similarly, the way the two education variables are aggregated has changed, so that the new HDI has $I_S = (MS/MS^{\max})^{0.5}(ES/ES^{\max})^{0.5}$. Using either Eq. (2) or Eq. (3) the HDI is automatically bounded below by zero and above by unity.

Note that Eq. (3) embodies two distinct sources of nonlinearity in the income effect (unlike the one source in Eq. (2), namely through the log transformation). In HDI_{new} there is both the log transformation of income built into I_Y and the power transformation in Eq. (3). On twice differentiating HDI_{new} with respect to *Y* one finds that the 2010 HDI is still strictly concave in income. And it would still be strictly concave in *Y* even without the log transformation.[8]

Why did the 2010 HDR switch from Eqs. (2) to (3)? The report offers the following explanation[9]:

> "Poor performance in any dimension is now directly reflected in the HDI, and there is no longer perfect substitutability across dimensions. This method captures how well rounded a country's performance is across the three dimensions. As a basis for comparisons of achievement, this method is also more respectful of the intrinsic differences in the dimensions than a simple average is. It recognizes that health, education and income are all important, but also that it is hard to compare these different dimensions of well-being and that we should not let changes in any of them go unnoticed." (UNDP, 2010, p.15)

These reasons are not as compelling as they may seem at first glance. It is true that the old HDI assumed that the scaled indices (I_{LE}, I_S and I_Y) were perfect substitutes (constant MRS), but this was not true of the core dimensions. Since income enters on a log scale (and is only then rescaled to the 0, 1 interval), income and life expectancy (or income and schooling) were not in fact perfect substitutes even in the old HDI. And relaxing perfect substitutability does not imply that one should switch to the form in Eq. (3), as explained in Section 5.

The above quote suggests other arguments for switching to the geometric mean. The reference to "well rounded" presumably refers to the fact that using the geometric mean implies that lower values are weighted higher; the quasi-concave aggregation penalizes inequality amongst indicators for a given country. It is not evident in what sense using the geometric mean makes poor performance more "directly" reflected in the HDI, or "more respectful of the intrinsic differences in the dimensions," or that using this aggregation formula means that we do "not let changes in any dimension) go unnoticed." Indeed, one can argue, to the contrary, that the HDI's new aggregation formula hides partial success amongst countries doing poorly in just one dimension. As dimension x approaches $x^{\min}$

[5] Advocates of making human development the overarching development goal often reject monetary valuations. However the fact of using money per se as the metric of value cannot be objectionable; rather the issue is how we assess "value." For further discussion and references to the literature on money metrics of social welfare see Ravallion (2010a).

[6] In addition to its new HDI, UNDP (2010) introduced a new "multidimensional poverty measure," which raises a number of distinct issues, as discussed in Ravallion (2011b).

[7] At times, past HDIs have set an upper bound for income that violates this condition, in which case I_Y was set to unity, implying that further income gains had no impact on the HDI. This is not the case with the 2010 HDI, which removed the binding cap.

[8] The 2010 HDR and Klugman et al. (2011) state that the log transformation of income is used to assure concavity. But it is not required for this property. In effect the HDR authors wanted some extra concavity (essentially logging income twice) but they do not explain why.

[9] A number of commentators in the literature have advocated a multiplicative form for the HDI, such as Eq. (3), including Desai (1991), soon after the HDI first appeared, and Sagar and Najam (1998) (although the 2010 HDR does not refer to these antecedents in the literature).

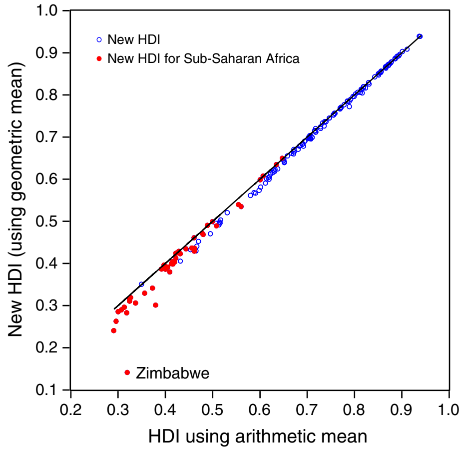

Fig. 1. Effect of the change in aggregation method on the HDI.

we see that HDI_{new} approaches zero no matter what value is taken by the other dimensions.

Consider, for example, Zimbabwe, which has the lowest HDI_{new} of 0.14 in UNDP (2010)—and it is the lowest by far, at about 60% of the next lowest. Yet this is due to one component that currently scores very low, namely income; Zimbabwe's $I_Y = 0.01$ – the lowest of any country, and by a wide margin (60% of the next lowest value) – while $I_S = 0.52$ and $I_{LE} = 0.43$, both well above the bottom. Indeed, there are 56 countries with a lower schooling index than Zimbabwe's, yet this relative success is hidden by the HDI's new aggregation formula, given its multiplicative form. Using the arithmetic mean instead (with other data unchanged), Zimbabwe still has a low HDI, but it ranks higher than six countries.

A similar effect is evident for most countries in Sub-Saharan Africa (SSA). Fig. 1 plots the HDI obtained using the new aggregation formula with that based on the old formula; to isolate the effect of the change in aggregation method I have used the same scaled indices (Eqs. 1.1 and 1.2) for both. We see that switching to the geometric mean involves a substantial downward revision for countries with low HDIs, and these are disproportionately found in SSA.[10] The switch from the arithmetic mean to the geometric mean reduces the HDI by 0.023 on average for the countries of SSA (with a standard error of 0.002), while it reduced the index for non-SSA countries by an average of 0.009 (s.e. = 0.001); the mean decline in the HDI is significantly different between the two sets of countries (t = 5.138).[11]

The rest of this paper examines the country-specific tradeoffs implied by the 2010 HDI, and how they have changed. On a priori grounds it is unclear what effect relaxing perfect substitutability between the scaled indicators (I_{LE}, I_S and I_Y) would have on the tradeoffs in the core dimensions. Whether the MRS increases or decreases will depend on the data.

While the focus here is on the HDI's implicit tradeoffs, knowing those tradeoffs is clearly not sufficient for deciding whether policies that promote health care or education will promote human development. Even leaving aside the issue of whether the HDI is an adequate representation of that goal, we would also need to know the costs, assuming that it is national income net of those costs that is valued for human development.[12] And those costs will vary across countries. The costs of lengthening life or raising school attainments are also likely to be higher in richer countries, given that health and education services are labor intensive, and (hence) will tend to be more expensive in rich countries where wages are higher.

I will note some comparisons with the costs of increasing longevity, drawing on the literature. However, this paper's focus on the valuations built into the HDI is primarily intended to inform public understanding of the HDI, rather than to inform discussions of what policies might increase human development.

In examining the implications of the changes to the HDI for its implicit valuations, I focus first on the HDI's valuation of longevity, after which I turn to its valuation of schooling.

3. The HDI's troubling valuations of longevity

While the weights attached to the HDI's scaled indices (I_{LE}, I_S and I_Y) are explicit, those on the core dimensions (LE, S and Y) are not, and arguably it is these weights that we care about in understanding the properties of the HDI.[13] The HDRs have never discussed explicitly the valuations on its core dimensions, and they can be questioned.

The HDI's marginal weights can be readily derived by differentiating Eq. (2) or (3) with respect to each variable. For the old HDI the marginal value on longevity and schooling was a constant, while the weight on income declined with income. On switching to the geometric mean, the marginal weights became:

$$\frac{\partial HDI_{new}}{\partial x} = \frac{HDI_{new}}{3(x - x^{\min})} \quad \left(x > x^{\min}; x = LE, S\right) \tag{4.1}$$

$$\frac{\partial HDI_{new}}{\partial Y} = \frac{HDI_{new}}{3Y(\ln Y - \ln Y^{\min})} \quad \left(Y > Y^{\min}\right). \tag{4.2}$$

It is clear that the assumptions made for the lower bounds are far from innocuous. In particular, the marginal weights are undefined at the lower bounds, since they require dividing zero by zero. Then there is a problem if any of the data are at the lower bound. In the 2010 HDI, the lower bounds of 20 years and zero for life expectancy and schooling (respectively) are outside the range of the data, at least for recent years.[14] The lower bound of $163 for income per capita is more problematic as it is found in the data—it is the income for Liberia in 1995 and Zimbabwe in 2008.[15] It would have been safer to have set $Y^{\min}$ at a somewhat lower level.[16]

The effect on the weights of switching to the new formula for the HDI is theoretically ambiguous, and will vary across countries according to[17]:

$$\frac{\partial HDI_{new}}{\partial x} \Big/ \frac{\partial HDI_{old}}{\partial x} = \frac{HDI_{new}}{I_x} \quad \left(x = LE, S, Y; x > x^{\min}\right). \tag{5}$$

[10] This was pointed out by Easterly and Freschi (2010) in a comment on an earlier version of this paper.

[11] Dropping Zimbabwe, the decline in the mean HDI for SSA is 0.019 (s.e. = 0.002), and the "SSA effect" is still significant (t = 4.651).

[12] For example, let *VLE* denote the monetary valuation (MRS) for longevity and let *MCLE* denote its marginal cost i.e., the income forgone for other purposes when life expectancy is increased by one year. Then higher life expectancy will increase the HDI if (and only if) *VLE* > *MCLE*.

[13] The HDI is not alone in this respect. Ravallion (2010a) discusses a range of composite indices of development which tell their users little or nothing about the weights attached to their core dimensions. Their weights are made explicit, but not in what is (arguably) the most relevant space.

[14] The lowest value for life expectancy in 2010 is 44 years while for mean schooling it is 1.2 years.

[15] The upper bounds are 83.2 years for life expectancy (Japan's life expectancy), 13.2 years for mean years of schooling (the US in 2000), 20.6 years for expected years of schooling (Australia, 2002) and $108,211 for income (for the United Arab Emirates in 1980).

[16] The reasons for the chosen lower bounds are not entirely clear. In a background paper to the 2010 HDR, Gidwitz et al. (2010, p.9) claim that "these minima represent estimates of the minimum levels a society needs to survive in each of these dimensions." (KRC make a similar claim.) But we are not told much about how the "estimates" of survival needs were done. The lower bound of $163 is clearly a very low income, but it is also clear that people survived at this level. If the chosen bound was really a "survival income" then it would need to be lower.

[17] In the old HDI incomes were capped above a high value. This had not been binding before 2001, but was binding for 12 countries by 2009 (Klugman et al., 2011). The 2010 HDR dropped the cap. For the countries where the cap was binding using the old HDI the following formula does not apply for income.

For longevity we find that $HDI_{new} < I_{LE}$ for 164 of the 169 countries. So the new HDI has lowered the weight on longevity for all but five countries (using the new bounds).

Fig. 2 plots the new and the old weights on longevity against national income per capita (on a log scale to avoid bunching up at low incomes). It can be seen that a strong positive income gradient has been introduced, with markedly lower weights for poorer countries (in terms of GNI per capita). This pattern is not confined to income; the weight on longevity is also positively correlated with the (new) HDI (r = 0.697; which is significant at 0.001 level using a robust standard error) and life expectancy (r = 0.347—also significant at 0.001 level).[18]

It is instructive to consider Zimbabwe, with a 2010 HDI of 0.14 on a (0,1) scale, which is the lowest HDI of any country; the next lowest is the Democratic Republic of the Congo (DRC) with 0.24. Given Zimbabwe's low income, the new HDI gives a marginal weight on life expectancy for 2010 of only 0.0017 per year. Yet Zimbabwe's life expectancy in 2010 of 47 years is the fourth lowest in the world. Even though the HDI is concave in *LE*, a low income can pull down the weight on *LE* to a very low level, given the index's multiplicative form.

What then would it take to get Zimbabwe off the bottom rung of the HDI ladder? To answer this one cannot simply extrapolate linearly using the marginal weights, but one must solve the appropriate nonlinear equation for the HDI (equating Zimbabwe's HDI to that of the DRC, while holding schooling and income constant at Zimbabwe's current level, then solving for the required value of *LE*). On doing so one finds that Zimbabwe would need a life expectancy of 154 years! And that would only get Zimbabwe to the DRC's HDI. That does not sound like a promising route for getting off the bottom rung of the HDI ladder.

Zimbabwe is admittedly something of an outlier. Consider instead the DRC, for which the marginal weight on life expectancy is 0.003. It would take a life expectancy gain of 8.6 years (a 18% gain in life expectancy) to get the DRC to the HDI index of the third lowest country (Niger).[19] (In 2010, life expectancy in the DRC was 48 years.) And it would take 8.1 years gain (a 15% gain in life expectancy) to get the third lowest up to the fourth (Burundi). Many low-HDI countries would need large gains in longevity to improve their HDI ranking.

By contrast to longevity, the new formula for the HDI increased the weight on income for the bulk of the countries. In particular, one finds that $HDI_{new} > I_Y$ for 148 countries. In the case of Zimbabwe, the country would clearly have a much better chance of getting off the bottom by increasing their national income than by increasing life expectancy. I calculate that an income of $240 per person per year – about half way between Zimbabwe's current income and that of the DRC – would be sufficient to bring Zimbabwe up to the DRC's HDI, all other things equal. That is clearly much more feasible.

The HDI implicitly puts a monetary valuation on an extra year of life, where that valuation is defined by the tradeoff between longevity and income, i.e., the extra income needed to compensate for a year less of life expectancy, keeping the HDI constant. This is given by the ratio of the HDI's marginal weight on longevity to its weight on income. Denote this tradeoff by *VLE*. We have (in obvious notation)[20]:

$$VLE_{old} = \frac{Y\left(\ln Y^{\max} - \ln Y^{\min}\right)}{LE^{\max} - LE^{\min}} \tag{6.1}$$

[18] Given the function form, the new HDI is strictly concave in its core dimensions, but this only tells us that the weight on *x* declines with *x*, holding the other two components constant. In these data-based comparisons, the other variables are not constant, and so their interaction effects come into play.

[19] Again, these are calculated by solving the relevant nonlinear equation, rather than by extrapolating using the marginal weights.

[20] For those countries for which the income cap was binding, the old HDI attached an infinite value to longevity, which became finite with the change in the formula in the 2010 HDR.

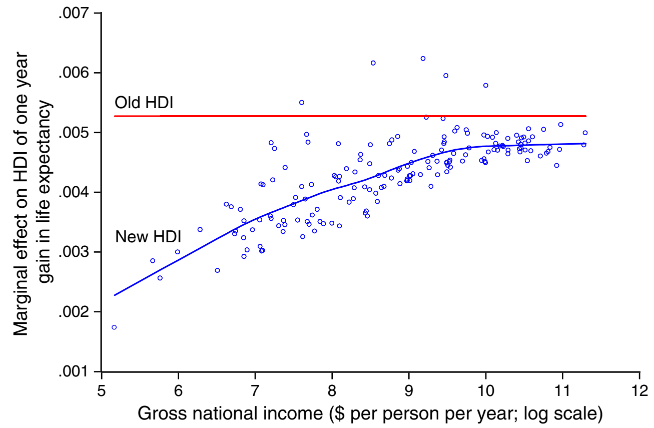

Fig. 2. Weights on life expectancy in the old and new HDI.

$$VLE_{new} = \frac{Y\left(\ln Y - \ln Y^{\min}\right)}{LE - LE^{\min}} \left(LE > LE^{\min}\right). \tag{6.2}$$

It can be seen that VLE_{old} is directly proportional to *Y*, given the bounds.[21]

The direction of the effect on *VLE* of switching from the old to the new formula for the HDI is theoretically ambiguous, and depends on both the data and the bounds used for rescaling the variables. Since the weight on longevity has fallen for the bulk of countries, while it has risen for income, we can also expect lower monetary valuations of longevity. More precisely, it is plain from Eqs. (7.1) and (7.2) that $VLE_{old} > VLE_{new}$ if (and only if) $I_{LE} > I_Y$. Out of the 169 countries, I find that the monetary valuations of longevity have been revised down for 158 countries (161 if one uses the new bounds). Fig. 3 plots the valuations against national income.[22] (I return to explain the "marginal cost" series in Fig. 3.)

The HDI's value of longevity in Zimbabwe is a remarkably low $0.51 per year, representing less than 0.3% of that country's (very low) mean income in 2008. Thus the 2010 HDI implies that if Zimbabwe takes a policy action that increases national income by a mere $0.52 or more per person per year at the cost of reducing average life expectancy by one year, then the country will have promoted its "human development."

Granted Zimbabwe has an unusually low GNI. The next lowest valuation of longevity is for Liberia, for which the HDI attaches a value of $5.51 per year to an extra year of life expectancy; this is 10 times Zimbabwe's valuation, though it is still only 1.7% of Liberia's annual income. The value tends to rise with income and reaches about $9,000 per year in the richest countries (Fig. 3). The highest valuation of longevity is 17,000 times higher than the lowest. Even dropping Zimbabwe's (exceptionally low) valuation, the differential is 1,600.

The least-squares elasticity (the ordinary regression coefficient of ln VLE_{new} on ln *Y*) is 1.208 (with a robust standard error of 0.033; n = 169). This is significantly greater than unity, implying that the HDI's valuation of longevity as a proportion of mean income tends to rise with mean income. The elasticity is also higher than most past estimates of the income elasticity of market-based estimates of the value of statistical life.[23]

The fact that the valuation of longevity as a proportion of mean income tends to rise with mean income is confirmed by Fig. 4. (The highest value as a proportion of GNI turns out to be almost 16%, in Equatorial Guinea, though this is clearly an outlier.) By contrast, the old HDI had an

[21] The fact that the HDI's VLE rises with income was first pointed out by Ravallion (1997) but the issue has not been addressed in HDR's since.

[22] A tabulation of the HDI's valuations of longevity for all 169 countries is available from the author.

[23] In reviewing the evidence, Viscusi and Aldy (2003) conclude that the income elasticity is 0.5–0.6.

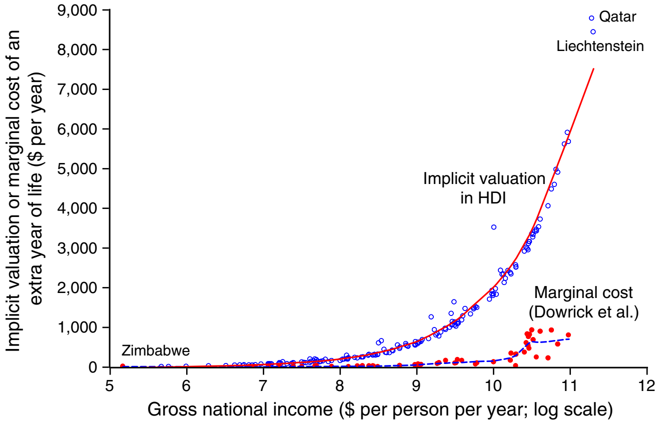

Fig. 3. Implicit valuations in HDI and marginal costs of an extra year of life expectancy.

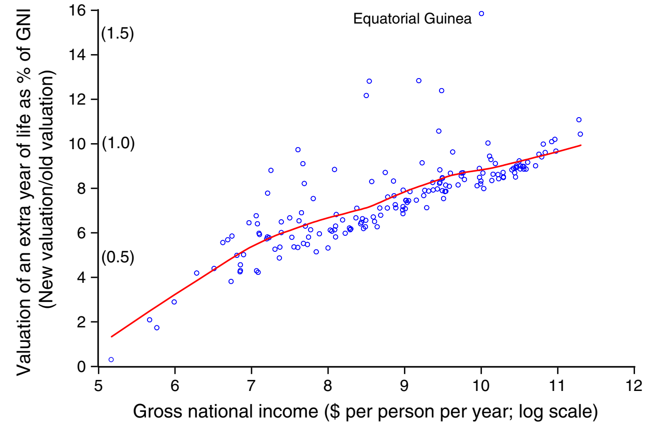

Fig. 4. Value of an extra year of life expectancy as percent of gross national income.

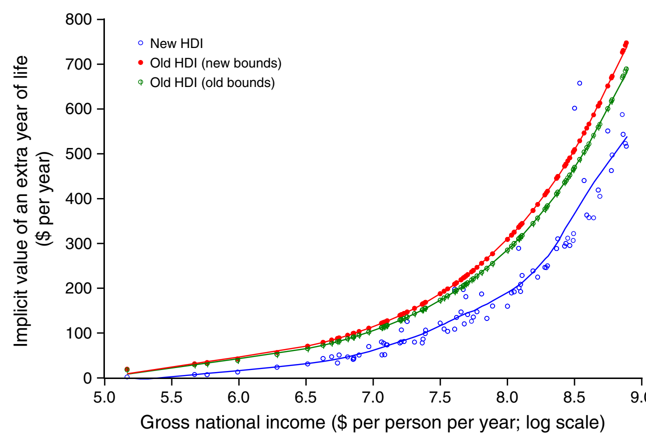

Fig. 5. HDI's revised valuations of life expectancy in the poorest half of countries.

income elasticity of unity, and (when evaluated with the HDI's new bounds) VLE_{old} is almost exactly 10% of each country's annual income.

The changes to the HDI have devalued longevity, especially in poor countries. Given the construction of the index, VLE_{new}/VLE_{old} is directly proportional to VLE_{new}/Y (Eqs. (7.1) and (7.2)); the constant turns out to be 10.014. So by dividing the vertical axis of Fig. 4 by 10 (noting that the axis is in percent), we can also read it as a graph for VLE_{new}/VLE_{old}. (Selected points for VLE_{new}/VLE_{old} are indicated on the vertical axis in parentheses.) There was a roughly 25% downward revision on average (mean $VLE_{new}/VLE_{old}=0.748$). If one focuses on the poorest half of countries (GNI per capita below the median) then the average downward revision was close to 40% (mean $VLE_{new}/VLE_{old}=0.620$; $n=84$); for the poorest quarter, the valuation of longevity has been almost halved (mean $VLE_{new}/VLE_{old}=0.545$; $n=42$).

Fig. 5 provides a "blow up" of Fig. 3 for the poorest half of countries (in terms of GNI per capita), as well as the values implied by the old HDI aggregation using the arithmetic mean. (I also give the old valuation of life using the arithmetic mean and old bounds.) It can be seen that changing the bounds alone in the old HDI would not have produced this large downward revision to the index's monetary valuation of longevity. Rather it was the combined effect of switching to the geometric mean, the form of the scales used and (of course) the data. Given the scales and aggregation formulae, the marked devaluation of longevity stems from the fact that $I_{LE}>I_Y$ for all except eight of the 169 countries, implying that $VLE_{old}>VLE_{new}$. Whether this holds depends on the assumed bounds built into the HDI. For example, a higher upper bound for LE would have lowered the value of life implicit in the old HDI; I find that VLE_{old} would have been quite close to the level of VLE_{new} at $LE^{max}=100$. The somewhat arbitrary and time varying choice of bounds has also played a role in the HDI's devaluations of longevity.

The income gradient in the HDI's monetary valuations of longevity appears to be substantially greater than the gradient in the marginal costs of longevity. Dowrick, Dunlop and Quiggin (DDQ) (1998) estimate marginal costs of an extra year of life expectancy for 58 countries in 1980, which I have simply converted to 2008 prices using the US CPI. There are a number of comparability problems between the DDQ estimates and my calculations of VLE, so these calculations should only be considered as broadly indicative for the present purposes.[24] The DDQ estimates are also given in Fig. 3. Their estimated marginal cost of a one year increase in life expectancy is 400 times higher in the country with the highest cost (Denmark in their sample) than the lowest (Madagascar). This is far less than my calculations of the differential in the valuation of longevity implicit in the HDI. The DDQ estimates are only roughly similar to the HDI's valuations for the poorest countries, but the HDI's valuations greatly exceed marginal costs among most countries, and the gap is very large for the richest countries.

Across individuals, one expects the value attached to extra longevity to rise with income. Even if (instantaneous) utility depends only on consumption, a high income allows more to be consumed in the extra years of life, giving higher expected utility.[25] Similarly, one would expect people in rich countries to be willing to pay more for extra longevity, and they clearly do.

However, such observations do not justify building an income gradient (let alone a steep gradient) into the valuation of longevity. The HDI is clearly intended to embody social values, which need not accord with private ones.

With reference to the private valuations of "statistical life" – such as derived from contingent valuation questions in surveys or wage premia paid for risky jobs – Ackerman and Heinzerling (2001, p.18) note a similar concern:

> "Calculation of the link between average income and the value of a statistical life could, if applied indiscriminately, lead to the

[24] Probably most importantly, updating solely for inflation in the US misses the structural changes in growing developing economies, which entail changes in their relative prices; in particular, we can expect that the cost of attaining higher longevity may have risen more in rapidly growing economies such as China than these estimates indicate. This is suggested by comparisons of PPP estimates across different rounds of the International Comparison Program; see Ravallion (2010b).

[25] Suppose instead that (i) utility is strictly increasing in both life expectancy and income; (ii) the marginal utility of higher life expectancy does not fall with higher income, and that (iii) there is declining marginal utility of income. Then the MRS will be an increasing function of income.

unacceptable implication that rich people, or residents of rich nations, are worth more than the poor."

While the HDI is not deriving its valuations of longevity from such sources, the fact that it puts a higher value to an extra year of life for people in rich countries than poor ones is arguably no less of an example of the "unacceptable implication" that Ackerman and Heinzerling refer to.

This troubling tradeoff in the 2010 HDI will clearly influence its rankings of performance in human development. However, a more worrying concern arises if the index influences (domestic and international) policy making. The HDI's embedded tradeoffs imply that, in the interests of promoting human development – or at least improving its HDI – the government of a poor country should not be willing to pay more than a very small sum (in $s and as a percent of national income) for an extra year of expected lifespan for its citizens, while the government of a rich country would be encouraged to spend vastly more for the same gain in longevity – 17,000 times more if one compares my calculation of VLE_{new} for the richest country with the poorest. Serious objections would naturally be raised to any proposal for public action within one country that rested on assigning a lower value to life to poor citizens than to rich ones, let alone a relative value that is such a tiny fraction. The same objections arise in a global context.

One is led to question whether these valuations are consistent with promoting "human development." Yet, the 20 HDRs have largely avoided making explicit this potentially troubling tradeoff, although the basic problem was noted in early commentaries (Ravallion, 1997).

4. The HDI's valuations of schooling

The fact that the HDI's education variables have changed is not of obvious concern in this context, so I will only use the new schooling variables in the 2010 HDI. Applying Eqs. (4.1) and (4.2), I find that that the new HDI's aggregation method has put a higher weight on schooling for 119 of the 169 countries (i.e., all those with $HDI_{new} > I_S$).

The ratio of the old and new weights in Eqs. (4.1) and (4.2) does not depend on precisely how a gain in schooling is allocated between mean actual years of schooling and mean expected years (assuming, naturally, that it is allocated the same way for both calculations). However, in calculating the HDI's new valuation of schooling one does need to know that allocation. I shall assume that an extra year is added to both mean current schooling (*MS*) and the expected years of schooling (*ES*).[26] While I will use the new education variables, I will keep their old aggregation function, including the use of the arithmetic mean of the (scaled) schooling variables. Then the HDI's implicit valuations of extra schooling are given by:

$$VS_{old} = Y\left(\ln Y^{\max} - \ln Y^{\min}\right)\left(\left(MS^{\max}\right)^{-1} + \left(ES^{\max}\right)^{-1}\right)/2 \tag{7.1}$$

$$VS_{new} = Y\left(\ln Y - \ln Y^{\min}\right)\left(MS^{-1} + ES^{-1}\right)/2. \tag{7.2}$$

Fig. 6 plots VS_{old} and VS_{new} against (log) GNI. (Later I will explain the series in Fig. 6 labeled "Chakravarty index.") Similarly to longevity, we see a marked income gradient, although flat at low incomes. The new HDI values an extra year of schooling at $1.68 per person per year in Zimbabwe, about 1% of mean income; the next lowest is for the Democratic Republic of the Congo where $VS_{new} = \$33$ per year, or 11% of annual income. At the other extreme, VS_{new} rises to

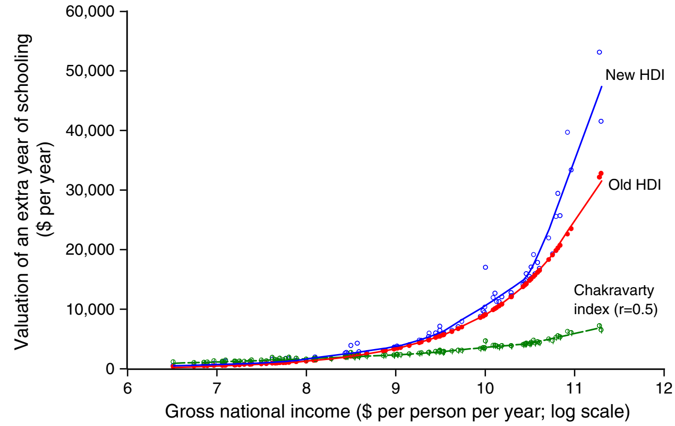

Fig. 6. Implicit monetary values attached to an extra year of schooling by the 2010 HDI.

$53,000 per year in the country with the second highest GNI per person, representing 67% of that country's GNI. The valuation of schooling has increased in 94 countries, though the increase is more marked amongst high-income countries.

While the HDI's implicit valuations of longevity seem low, it's valuations on schooling seem high. In constructing a composite index such as the HDI, there is a (rather poorly understood) issue about what dimensions are intrinsically, versus instrumentally, important. We can all agree that a longer life is valued intrinsically, independently of income. However, it is not quite so clear that education has such a large intrinsic value (as assumed by the HDI), rather than being (very) important instrumentally to income and (hence) welfare.

In defense of the HDI, one might argue that the benefits of extra schooling are not fully reflected in current incomes; better educated parents pass advantages onto their children, leading to higher future incomes. (Possibly the new HDI's introduction of the variable for expected schooling is trying to capture this effect.) But it is a moot point just how much extra one would allow for such an effect, on top of the economic return to schooling. The HDI is presumably measuring a country's current human development not its future value.

If we compare the HDI's valuations on schooling with the returns implied by earnings regressions, the HDI's valuations are clearly very much higher. The regression coefficient of log earnings on years of schooling is typically around 0.1; see Psacharopoulos and Patrinos (2002). So it seems that the HDI is putting a much larger value on the returns to schooling than is reflected in current earnings. Indeed, the HDI's valuation in developing countries appears to be roughly four times the labor market returns to schooling.[27]

Finally, Fig. 7 compares the new HDI's valuations for longevity and schooling. What is most striking is how much higher the HDI's implicit valuation of schooling is than its valuation of longevity. A shorter but better schooled life is preferred by the designers of the HDI. One is left wondering how many of the world's poor – many living short lives by rich-country standards – would agree.

5. An alternative HDI with less troubling tradeoffs

As we have seen, the new multiplicative form of the HDI generates a steep income gradient in the index's implicit valuations of life expectancy and schooling. The functional form assumptions leading to these valuations were made to allow for imperfect substitution. However, one does not need to adopt the problematic multiplicative form

[26] There is some support for this assumption in the data; the regression coefficient of expected schooling on mean current schooling is 0.88, which is close to unity, although it is still significantly less than unity (t = 2.54, based on a robust standard error; n = 169).

[27] For high-income countries, the ratios of the valuation of extra schooling to mean income in Fig. 6 are roughly seven times the coefficients on years of schooling reported by Psacharopoulos and Patrinos (2002, Table 4, p.14). However, Banerjee and Duflo (2005) question whether the evidence supports the claim that returns to education vary much across countries.

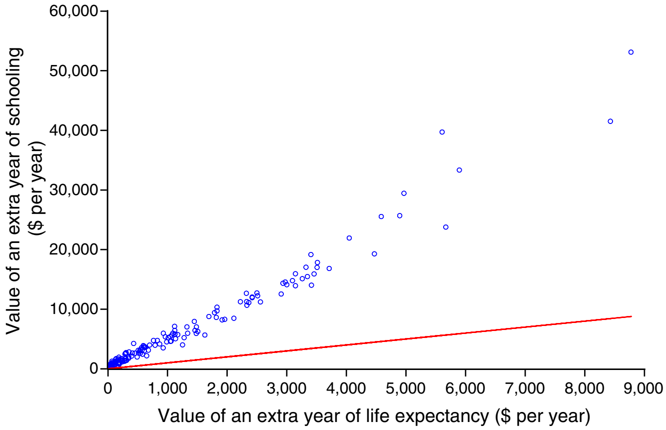

Fig. 7. HDI's valuations of schooling and longevity across countries.

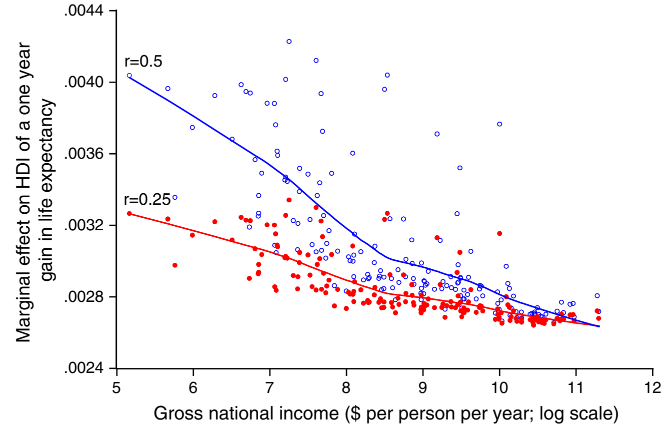

Fig. 8. Weights on life expectancy in the proposed alternative HDI.

of the new HDI to relax perfect substitutability across the scaled indices.

To see how, consider the generalized form of the old HDI proposed by Chakravarty (2003):

$$HDI^C = [f(I_{LE})+f(I_S)+f(I_Y)]/3 \quad (8)$$

where f is some smoothly increasing and strictly concave function mapping from the [0,1] to [0,1] with $f(0)=0$ and $f(1)=1$. This implies imperfect substitutability (non-constant MRS). Chakravarty (2003) shows that the form in Eq. (8) also satisfies three axioms: normalization (if all three components, $f(I_x)$, take the same value then that value is the HDI), consistency in aggregation (the HDI for a sum of component indices is equal to the corresponding sum of the HDIs across the components) and symmetry (the HDI is unaffected by permutations of its components).[28] Consistency of aggregation forces the HDI to be linearly additive in the $f(I_x)$s, as in Eq. (8). Chakravarty proposed a parametric special case of Eq. (8) in which $f(I_x)=I_x^r$ for $(0<r<1)$, giving an index that I will label HDI_r^C. The old HDI is the limiting case when $r=1$, and only then does the index impose perfect substitutability between the I_xs.

With two further modifications, this special case of the Chakravarty index can take us a long way toward avoiding the troubling tradeoffs in the new HDI. The first change is to replace ln$Y$ with Y in Eq. (1.2) so that $I_Y=(Y-Y^{min})/(Y^{max}-Y^{min})$. This change is important, since it removes a source of the positive income effect on the weights implicit in the new HDI. Notice that this still allows diminishing marginal returns to income. The log transformation of income in the old HDI was necessary to assure concavity in income but that is not longer necessary using the alternative index HDI_r^C. (By keeping the old log transformation the new HDI's "double log" functional form – in which income is logged within the scaled index, and then the index is raised to the power of 1/3 – was arguably an overkill.) The second change is to use the arithmetic mean of the two schooling variables, *MS* and *ES* (and their bounds), rather than their geometric mean.

With these modifications, the alternative index largely avoids the troubling property of the 2010 HDI in Fig. 2, whereby the marginal effect on the index of an extra year of life rises with income per capita (and the HDI itself). Indeed, we now have the reverse slope, with higher weight on longevity in poorer countries as seems more reasonable; Fig. 8 gives the weights on longevity implied by HDI_r^C, for $r=0.5$ and 0.25. Instead of a higher weight on longevity in richer countries, we now find that the weight rises from 0.0026 in one of the richest countries to 0.0042 in the poorest ($r=0.5$). The pattern is similar using $r=0.25$, though the gradient is less steep.

The implied tradeoffs with income are given by:

$$Vx_r = \left(\frac{I_Y}{I_x}\right)^{1-r}\frac{\left(Y^{max}-Y^{min}\right)}{\left(x^{max}-x^{min}\right)}(x=LE,\ S). \quad (9)$$

We still find higher monetary valuations on longevity and schooling in richer countries, but HDI_r^C gives higher valuations for poor countries than HDI_{new} and the troubling income gradient is much attenuated. Fig. 9 compares the valuations on longevity in HDI_{new} with those implied by HDI_r^C for $r=0.5$ and 0.25; Fig. 6 gives the corresponding valuations for schooling (only for $r=0.5$ to avoid cluttering up the graph; the series for $r=0.25$ is similar to the pattern in Fig. 9). In both cases, the implied valuations rise with income per capita, but much less steeply than implied by the 2010 HDI. The lower value of r reduces the income gradient.

The alternative index still puts higher valuations on schooling than longevity, similarly to the 2010 HDI. This property appears to be hard to avoid given the differences in the distributions of these variables and the assumed bounds. Of course, increasing the weight on I_{LE}^r relative to that on I_S^r will narrow the gap in the valuations of schooling and longevity. However, I found that on even doubling the weight on the life expectancy component (equally weighting the other two components), the valuation on schooling still exceeded that on longevity.

Fig. 10 compares HDI_{new} with HDI_r^C.[29] The overall means are similar for $r=0.5$ (an un-weighted mean of 0.643 for $HDI_{0.5}^C$, versus 0.637 for HDI_{new}), but higher for $r=0.25$ (mean of 0.773). Switching to HDI_r^C increases the index for low HDI countries (many in Sub-Saharan Africa as already noted). The change also decreases the upper values of the HDI for $r=0.5$. The proposed alternative index implies lower overall inequality in the HDIs across countries; for example, the CV falls from 0.291 to 0.194 for $r=0.5$ and 0.121 for $r=0.25$. While it is clear that the two HDIs in Fig. 10 are highly correlated (r = 0.980 $r=0.5$ and 0.987 for $r=0.25$), there are some large changes. For $r=0.5$, Zimbabwe's index rises by over 300%, from the lowest value (by far) of 0.140 based on HDI_{new} to 0.454; it also rises relatively, to be the 12th lowest—reflecting the fact that the additivity property of the alternative index puts a higher premium on Zimbabwe's schooling attainment. Using $r=0.25$, the upward revision to Zimbabwe's index is even more dramatic, with $HDI_{0.25}^C=0.583$. The largest decrease is that for New Zealand, for which the index falls by 0.094 in switching to $HDI_{0.5}^C$, and the ranking falls from third place to 18th. The differences are small at high HDIs using $r=0.25$ (Fig. 10).

[28] Chakravarty (2003) actually proves a more powerful result: an even more general index will satisfy these three axioms if and only if it takes the form of Eq. (8).

[29] A complete tabulation of $HDI_{0.5}^C$ by country is available from the author.

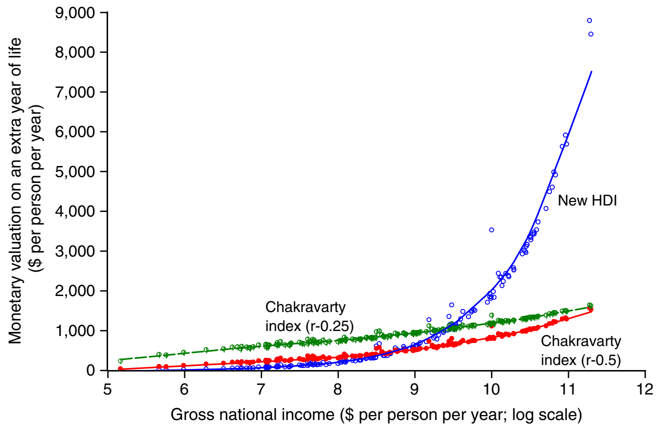

Fig. 9. Valuations of longevity in the 2010 HDI vs. alternative HDI.

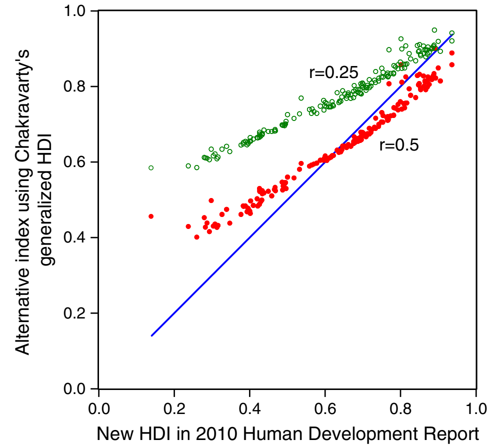

Fig. 10. Comparison of the 2010 HDI with alternative HDI.

6. Conclusions

The Human Development Index was introduced in 1990 as an alternative to using national income per capita as the metric of development success. Until 2010 the index was an equally weighted mean of scaled attainments in three dimensions: life expectancy, education and income. The simplicity of the HDI gave it a transparency that was clearly appealing to many users, although the HDI was never quite as simple as one might think at first glance, given the transformations embedded in its components. Over 20 years, the Human Development Reports (and numerous offshoot reports at national level) have applauded those countries that do well in the HDI, and offered advice to others on how they might do better in the HDI stakes.

A new version of the index was introduced in the 2010 edition of the HDR. The main change was to switch from the original additive aggregation function (the arithmetic mean of the three components) to a multiplicative function (their geometric mean). The main reason given for this change was to allow for imperfect substitutability between the HDI's three components.

However, good intentions alone do not make for good measurement. The 2010 HDI is both more complicated and more problematic in its tradeoffs across core dimensions. Longevity in poor countries has been substantially devalued, though it seems unlikely that this was intended. The HDI's valuation of longevity in the poorest country is now a mere 0.006% of its value in the richest country—a far greater difference than in their average incomes (for which the poorest country has 0.2% of the national income per capita of the richest). A poor country experiencing falling life expectancy due to (say) a collapse in its already weak health-care system could still see its HDI improve with even a small rate of economic growth. By contrast, the valuations of extra schooling have risen for most countries and they seem high—some four times higher than the valuations typically placed by the labor market on extra schooling.

There are some contentious value judgments buried in the maths of the HDI. It can be granted that a rich person will be able to afford to spend more to live longer than a poor person, and will typically do so. But that does not justify building such inequalities into our assessment of progress in "human development." Given what we know about the marginal costs of extending life expectancy, if one accepted the tradeoffs embodied in the new HDI, one would be drawn to conclude that the most promising way to promote human development in the world would be by investing in higher life expectancy in rich countries—surely an unacceptable implication of the HDI's tradeoffs. And it is unclear why we would want to put a vastly higher value on schooling than implied by its economic returns.

Of course, any composite index of this sort will entail potentially troubling tradeoffs. But the new multiplicative form introduced in 2010 appears to generate highly problematic tradeoffs from the point of view of assessing human development. Ironically, the troubling tradeoffs in the new HDI are not in fact essential to relaxing the perfect substitutability property of the old HDI. The less appealing properties of the new index could have been avoided to a large extent, while allowing imperfect substitutability, by using the alternative index proposed here, exploiting the aggregation function proposed by Chakravarty (2003)—in fact a straightforward generalization of the functional form used by the old HDI. Arguably the switch in 2010 to a multiplicative index was ill-considered, and future HDR's will hopefully give serious consideration to the alternative index proposed here.

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