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On the Measurement of Human Well-being

Fuzzy Set Theory and Sen's Capability Approach

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Abstract

Sen's influential work on human development has led economists to explore new areas that have become increasingly important for human well-being. In particular, Sen emphasizes the importance of the 'freedom to choose'. Freedom, however, is not always an exact (crisp) outcome, and membership in the freedom space can take place gradually. This paper proposes a framework that uses fuzzy-set theory to measure human well-being in consistence with Sen's *Capability Approach*. The results indicate that the UNDP's Human Development Index and human well-being, as measured using fuzzy sets, yield different country rankings and significantly different levels of well-being for some countries. Thus, it is important to bear in mind that preferences and choices underlying both objective and subjective indicators of human well-being are vague; and that such vagueness can have major implications for the outcome of social and economic policies.

Keywords: Sen's Capability Approach, HDI, human well-being measurement, fuzzy-set theory, freedom indices

JEL classification: I00, I31, O11

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> Now there are in humanity capacities of greater perfection, which belong to the end that nature has in view in regard to humanity in ourselves as the subject: to neglect these might perhaps be consistent with the maintenance of humanity as an end in itself, but not with the advancement of this end. (Immanuel Kant, *Fundamental Principles of the Metaphysic of Morals* 1785)
>
> Human development is the end-economic growth the means. (United Nations Development Program, *Human Development Report* 1996)

1 Introduction

The United Nations Development Program (UNDP)'s view that human development constitutes an end is consistent with the message conveyed by the German philosopher Kant's statement that the *advancement of humanity* is the end. However, it is clear that the message encompasses a much greater scope than the one covered by the mainstream view of human development.

Human well-being (HWB) includes—but extends beyond—economic growth and human development. While human development tends to summarize a small number of indicators in the widely-known human development index (HDI) produced by the UNDP, human well-being includes a wider array of components ranging from nutrition and calorie intake to freedom to attain certain achievements.

The traditional view that development is equivalent, *sine qua non*, to increased material prosperity, and hence higher per-capita income, faced criticism, particularly when strong positive correlation was found between per capita income on the one hand, and absolute poverty and inequality on the other. Thus, scholars and policymakers began to explore how to take these dimensions into account when measuring well-being.

Together with Sen, Chenery *et al*. (1974), Morris (1979), Hicks and Streeten (1979) and Streeten (1981) were among a group of scholars who have proposed measures to include poverty (or deprivation) and/or distribution. This culminated into a new paradigm of development. As argued by Qizilbash (1996),[1] '[t]he paradigm is one that envisages people living better lives consistent with the demands of distributive justice and freedom'.

As the shift of the focus from economic well-being to human well-being progressed, a major outcome transpired; human beings are no longer viewed as means in economic development but rather they constitute 'ends'. Once 'ends' are humanized the measures covering exclusively material and physical components are no longer sufficient or encompassing. Even the inclusion of indicators such as those of good health is not enough to produce adequate measures of HWB. For example, some former communist countries have traditionally ranked high on health and education measures but ranked quite low on other key measures of capability and functionings. Furthermore, an important outcome of the increased focus on human beings as 'ends' is the emphasis

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1 Qizilbash (1996) provides an insightful discussion of the new paradigm of development.

placed on freedom (see various work by Amartya Sen). While this is a major 'upgrade' of the way we view human development and permits the transition to a more encompassing set of indicators, it does give rise to several measurement issues. The first complication arises from the multiplicity of components included in HWB and the potential double (multiple)-counting that may result. Second, we must take into account the fact that there are non-uniform weights given by different societies (and different individuals within the same society) to different components of HWB. Third, the weights given to different levels of achievements in the overall achievement and in different components should not necessarily be the same. Fourth, and perhaps more important, in deciding what dimensions to involve in the computation of a HWB index, we are making assumptions with regards to preferences and relating outcomes to preferences which are, in essence, vague. For example, if we consider freedom, and given country-specific preferences, would a society that has an index of 1 (on a scale of 1 to 10, with 1 being the worst) be much worse off or equally worse off as a society that has a score of, say, 4? Should a society that has achieved a score of 6 up from 1 get more or the same credit as one that improved its score from 5 to 6? Does it make sense to have a *linear* scoring method, such as the one employed in the computation of the UNDP's human development index (HDI)?[2] Conventional measures treatment of achievements (or scores for those achievements) implies accounting even for irrelevant variation. For example, variation in education levels among the richest countries is quite irrelevant and the same statement applies to variation in life expectancy. Similarly, variation in freedom indicators and democracy among the clearly democratic countries has little or no usefulness for the analysis of human well-being.[3]

The main purpose of this paper is to review Sen's Capability Approach and the UNDP's human development indices, and propose a measurement framework that would reconcile between these approaches and the fuzziness of the preferences and the outcomes that are inherently imbedded in what constitutes human well-being.

The paper proceeds as follows. In the next section Sen's Capability Approach and the UNDP's HDI are discussed. Section 3 develops a framework based on fuzzy-set theory and outlines how certain indices can be derived. In section 4, using this framework, a human well-being index for a group of countries is constructed and the resulting indices are discussed. The last section contains concluding remarks.

2 Human well-being, human development and Sen's Capability Approach

Human well-being is not exclusively the realm of economists. While the economic well-being is an important part of human well-being, several other dimensions are equally (if not more) crucial. These dimensions have traditionally been researched in the fields of philosophy, psychology, sociology, religion and political science. These disciplines are,

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2 In setting a dimension index equal to (value of actual – minimum value)/(maximum value-minimum value), as in the UNDP-HDI computations, we are assuming that the vulnerability (non vulnerability) to underachievement (or deprivation) varies linearly between the upper and lower bounds.

3 Ragin (2000: 161) provides an interesting discussion of the issue of relevant versus irrelevant variation.

in general, critical of the way the concept of well-being has been treated in mainstream economics. For example, Tomer (2002: 23)[4] contends that:

> The ideas on what well-being is range from the material, for example, consumption of goods and services, to the spiritual, for example enlightenment or union with God. The problem is that the notion of well-being incorporated into mainstream economics is severely limited; it does not adequately reflect even many of the good ideas concerning the economic aspect of well being.

In the early economic literature, well-being was equated with welfarism and focused on the concept of 'utility' derived from consumption and based on (assumed) preferences. In this theory, human beings were viewed as self-interested. Welfarism does not allow for some crucial dimensions to be included and does not consider changes in preferences, thus it was strongly criticized in many disciplines. Hausman and McPherson (1996: 73) point out that 'there are such obvious objections to a preference satisfaction view of well-being that one wonders how economists could possibly endorse it'.

In view of the strong criticism addressed to welfarism, another theory of well-being developed; the so-called basic needs approach (see the important body of research of Mahbub Ul Haq, Paul Streeten and Frances Stewart). This approach focuses on whether countries are achieving satisfactory levels of 'meeting' specific basic needs. The major criticism to this line of thought lies in the fact that it is not clear how many needs should be included.

Amartya Sen's theory, which was intended to replace welfarism as a theory of well-being, is normative and centers on capabilities and functionings or states of being (see for example, Sen 1977, 1979, 1982, 1985). The idea of capabilities and functionings is quite old and can be traced back to Aristotle. Major aspects of the Arsitotelian view are examined in the work of Martha Nussbaum on capability. In modern economics, capabilities and functionings have been first formalized and operationalized by Amartya Sen in the well-known 'Sen's Capability Approach'.[5]

Sen's influential work on human development has led economists to explore new areas that have become increasingly important for human well-being. Sen stresses the 'capabilities' and 'functionings' that an individual achieves. On the subject of capability, Sen (1990: 114) writes:

> [I]ndividual claims are to be assessed not by the resources or primary goods the persons respectively hold, but the freedoms (emphasis added) they actually enjoy to choose between different ways of living that they can have reason to value. It is this actual freedom that is represented by

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4 Tomer (2002) provides an insightful overview of how different dimensions of human well-being are examined in other fields.

5 It is worth noting that some elements of the capability approach had been spelled out in the works of Adam Smith and Karl Marx.

> the person's "capability" to achieve various alternative combinations of functionings, or doings and beings.[6]

Sen's Capability Approach has become equivalent to a human well-being theory and has been praised by many scholars (see for example, Crocker, 1992; Nelson, 1996; Anderson, 1999; Atkinson, 1999; Pressman and Summerfield, 2000). Other scholars, on the other hand, have criticized the approach on the grounds that it fails to account for many crucial dimensions. Gasper (2002: 436) criticizes Sen's capability approach and argues that 'viewed from outside economics, the [capability approach] seems primitive in some ways, insufficient as a theory of well-being, and hardly a theory of the human development'. Gasper also points out that the CA approach does not consider distinction between skills and potentials, and between different levels of 'functioning'. Moreover, Sen's approach does not outline some important aspects of the practicability of the capability view. In particular, as explained by Sen himself, issues related to the assessment of capability and the applicability of this approach need to be seriously addressed (Sen, 1993).

For a long time income (GDP or GNP) was the only indicator of well-being. The UNDP introduced the Human Development Index in 1990, mainly as an alternative to the use of GDP as an indicator of human development. It is an index that combines a measure of income with measures of longevity and education/literacy (a proxy for knowledge). All three dimensions have equal weight. Since the early 1990s, several aspects of HDI have been criticized by numerous scholars and policymakers. In general, the criticism focused on the composition of the index, the statistical construction and data quality. For example, Hopkins (1991) considers literacy as the weakest indicator since 'it is impossible to have the same standards for abilities to read and write given language differences'. According to Sen's theory of 'capability and functionings', literacy (education) is also in the set of capability, so it is very important to be able to undertake an appropriate measurement of this dimension and also to have the ability to do meaningful comparisons. However, as pointed out by Hopkins (1991), that is not possible. In many societies, the written language (the language one learns in school) is very different from the spoken language or dialect. For example, let us consider the case of Morocco which lists Arabic as the official language. In practice, the citizens of Morocco speak several dialects which, depending on the geographical location of origin, can be quite alien to the classical Arabic taught in schools. This difference is not the same as the one that exists in English, Spanish or French for instance. For a Moroccan individual, to complete the first five years of schooling and learn classical Arabic is equivalent to learning a second language. For a Berber, it is equivalent to learning a third language. Thus, to say that a Moroccan who has completed, say 7 years of schooling, has the same linguistic ability as an American individual who has completed the same number of years would be an aberration. The improvement in the Moroccan citizen's (particularly if she is Berber) capability is higher.

In his paper on the choice of principal variables for computing HDI, Ogwang (1994: 2,013) finds that life expectancy is 'the variable which best represents the three human deprivation variables'. Yet, Anand and Sen (2000: 102) maintain that income 'plays a part that the other two components of HDI cannot serve'. For the purpose of *human*

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6 Sen was greatly influenced by John Rawls' theory of justice and its implication on individual freedom.

well-being, several questions arise. First, does everyone who lives long lives well? Second, what if the person lives beyond 80 years but has a very serious and costly illness? Shouldn't a society that has many individuals in this situation account for not only the monetary cost but the emotional—and perhaps moral—side of the situation (when life is artificially extended)? Obviously, a better indicator would be the '*healthy* life expectancy' index. Third, is living in a nursing home a positive contribution to human well-being? What about people with life expectancy of, say, 65 or 70 (versus the UNDP's maximum age of 85) living with their families (a predominant phenomenon in Arab, Asian and African societies); would they have less human well-being than some of the 85-year old (and plus) in the US or other post-industrial societies?

Other scholars who have criticized the UNDP's HDI include Desai (1991), McGillivray (1991), Dasgupta and Weale (1992), Ram (1992), Srinivasan (1994), and Lüchters and Menkhoff (1996). Several researchers have proposed adjustments and the UNDP, indeed, made some changes. For example, the 1994 *Human Development Report* (HDR) introduced a change in the threshold income level to underscore the fact that the poverty level of industrial countries is 'not appropriate income target for developing countries' (HDR, 1994: 91). In 1995, the HDI was adjusted in order to incorporate improvements in the computation method. More recently, the UNDP has added other indices such as the human poverty index (HPI), a gender empowerment measure (GEM), and a gender-related development index (GDI).[7] These indices reflect the extent of inequality in distribution, gender inequality, and female participation in politics and policy making. Thus, it may appear that the notion of a set of indicators covering basic needs as well as social justice is imbedded in these measures. However, nothing has been done to properly address the vagueness of the variables included in the computation of the index.

3 A fuzzy-set based approach for HDI computation

A 'social indicator' is not very useful because it helps in categorizing the achievements or the state of well-being of countries into high, medium and low. The true usefulness stems from the fact that such an indicator could provide relevant information for policymaking. If the indicator fails to do so, it becomes useless. Furthermore, a measurement technique is only useful in so far as it allows a better understanding and analysis of human well-being. As stated in section 2, Sen stresses the importance of the 'freedom to choose'. Freedom, however, is not always a crisp outcome, and membership in the freedom space can take place gradually. Sen himself agrees that 'well-being and inequality are broad and partly opaque concepts' (Sen, 1992: 48). Fuzzy sets allow for gradual transition from one state to another while also allowing one to incorporate rules and goals, and hence are more suitable for modeling preferences and outcomes that are ambiguous. For example, fuzzy-set theory is particularly appropriate for measuring vulnerability to poverty and famine.

The application of fuzzy sets to economic issues is relatively new. Moreover, in the area of human well-being the applications are rather limited in number and are exclusively

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7 The UNDP's Human Development Report actually discusses a wide range of other issues or indicators, but the emphasis changes from year to year.

focused on micro-level data and predominantly on poverty measurement. For example, Qizilbash (2002) uses fuzzy logic to construct poverty measures in order to explore vulnerability to poverty in South Africa. Other studies that used fuzzy-set theory to measure poverty include Cheli and Lemmi (1995), Cheli (1995), and Chiappero (1996, 2000). To this author's best knowledge, there has never been an application of fuzzy-set theory to assess human well-being using macro-level data.

The use of household surveys and other micro-level data is useful and does have the potential to yield important insight into disparities among groups but tends to be of little value when trying to compare across countries. Furthermore, it may not allow one to assess how the country as a whole is improving (or not improving) over time since the focus is on 'parts' that may evolve in different directions.

This is not the first attempt to apply fuzzy set theory to macroeconomic data. Von Furstenberg and Daniels (1991) and Baliamoune (2000) use this theory to assess the degree of country compliance with the G-7 economic summit commitments. The main contribution of the present paper lies in the fact that this is the first time an application of fuzzy-set theory to macroeconomic and social indicators of human well-being is undertaken. In addition, the only other study that has applied fuzzy logic in conjunction with Sen's capability approach is Lelli (2001). Using data from a representative sample of Belgian individuals, Lelli applied fuzzy sets and factor analysis to well-being measurement and found that the 'fuzzy aggregates' were insensitive to the choice of the form of the membership function. However, the author does recommend that one explore with other membership functions. More important, Lelli (2001: 25) finds that both methods (factor analysis and fuzzy sets) show that 'income accounts only for a very limited part of the story and this should definitely be seen as a reason to follow multidimensional approaches like Sen's one'.

The notion of fuzzy sets was conceptualized by Lotfi Zadeh. The publication of Zadeh's seminal paper ('Fuzzy Sets') in 1965 marked a milestone in the modern research on uncertainty and ambiguity. In his paper, Zadeh defined fuzzy sets as 'a class of objects with a continuum of grades of membership'. While the early applications of fuzzy logic were in science and engineering such as biology and artificial intelligence, fuzzy-set theory has more recently been increasingly applied to many issues in various social science and business fields.

Degrees of membership or compliance with goals are commonly expressed by numbers belonging to the interval [0,1]. Fuzzy sets allow one to model gradual transition from membership to non-membership and vice versa. It is a concept that permits a meaningful representation of ambiguous and vague objects or outcomes. Fuzzy sets are appropriate when, for example, we want to assess the statement 'it is warm today' instead of 'it is 77 or 78 degrees Fahrenheit. Another situation would be when we examine literacy or education in a country. What is the degree of membership of individuals with primary education or some secondary education in the fuzzy set of 'educated'. It cannot be zero because the person has some education but we cannot say the individual is educated because that would imply treating a college graduate the same way we treat a high school drop-out. Hence the need to derive a degree of membership in the fuzzy set 'educated'. As argued by Ragin (2000: 4):

> Fuzzy sets offer researchers an interpretive algebra, a language that is half-verbal-conceptual and half-mathematical-analytical. Thus, the

> greatest value of fuzzy sets for social scientists is their potential for enlivening, intensifying and extending the "dialogue" between ideas and evidence in social research.

The present paper uses a fairly common fuzzy membership function, which is expressed as follows:[8]

$$\mu(x) = \frac{1}{1 + e^{-a(x-b)}} \qquad (1)$$

The parameters a and b can be derived as follows. Let μ_h be the membership degree of the highest achievement (x_h) of the goal. Similarly, let μ_l be the membership degree of the lowest achievement (x_l) of the goal. From equation (1), and given μ_h and μ_l, we can solve for a and b.

It turns out that[9]

$$a = \frac{\ln(\frac{\mu_h}{1-\mu_h}) - \ln(\frac{\mu_l}{1-\mu_l})}{x_h - x_l} \qquad (2)$$

and

$$b = \frac{x_l \ln(\frac{\mu_h}{1-\mu_h}) - x_h \ln(\frac{\mu_l}{1-\mu_l})}{\ln(\frac{\mu_h}{1-\mu_h}) - \ln(\frac{\mu_l}{1-\mu_l})} \qquad (3)$$

It is worth noting that the parameters a and b serve to *operationalize* certain concepts associated with the fuzzy membership function. The slope a represents the extent of vagueness and b may be viewed as the identification threshold. The parameter b 'represents the point at which the tendency of the subject's attitude changes from rather positive into rather negative' (Zimmermann 1987: 205).

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8 We are trying to determine the degree of achievement, given a certain (defined) standard or goal. Thus, the distance between the achievement and the goal becomes an indicator of the extent of the success in meeting the target (achievement or underachievement). If d(x) = 0, there is full membership ($\mu(x) = 1$). If d(x) > 0, then $\mu(x) < 1$. So that we can write μ as: $\mu(x) = \frac{1}{1 + d(x)}$.

Noting that, in general, the relationship between physical objects and perceptions takes an exponential form (see Zimmermann, 1987), d(x) can be expressed as: $d(x) = e^{-a(x-b)}$, so that $\mu(x) = \frac{1}{1 + e^{-a(x-b)}}$

9 From equation (1) it follows that $\ln(\frac{\mu}{1-\mu}) = a(x-b)$

In the present context, taking for example education, b would represent the threshold at which a country changes from rather negative (dismal) to a rather positive (there is hope) achievement, say an index greater than 0.5. In the case of GDP per capita, the threshold may represent the poverty line or any other level deemed appropriate to serve as a dividing line between poor and adequate or satisfactory performance. One useful aspect of having such a parameter is the ability it provides to the policymaker or researcher to conduct sensitivity analysis when the threshold changes. The membership degrees μ_h and μ_l, as well as the parameters a and b used to compute the three dimensions of HDI, are reported in Table 1a.

Table 1a

Parameters for computing degrees of membership

	μ_h	μ_l	a	b
Life expectancy				
(1)	0.99	0.294	7.8609	0.4054
(2)	0.95	0.46	6.3363	0.4853
Education				
(1)	0.9999	0.0001	18.4242	0.5000
(2)	0.9999	0.16	12.9402	0.2881
GDP				
(1)	0.99	0.0025	10.7181	0.5613
(2)	0.85	0.01	7.5354	0.6198

Once we obtain values for a and b, we proceed to compute the degree of membership (adherence) for each country. First, we apply fuzzy-set theory to three components of UNDP-HDI. Second, other dimensions are included to examine a more encompassing concept of human well-being (section 4).

Table 1b reports degrees of membership for a large group of countries. There is no rationale to selecting this group of countries except that they represent different levels of economic development, institutional structure, and/or geographical areas and cultures. The data used to compute the indices are from the UNDP *Human Development Report* 2002.

Table 1b: UNDP and fuzzy-set based indices

	UNDP			Fuzzy membership*					
	Life Exp. Index	Edu. Index	GDP Index	Life Exp. Index		Education Index		GDP Index	
High HDI				(1)	(2)	(1)	(2)	(1)	(2)
Norway	0.892	0.983	0.952	0.983	0.941	1.000	1.000	0.881	0.724
Sweden	0.912	0.993	0.917	0.985	0.946	1.000	1.000	0.620	0.476
Canada	0.897	0.983	0.940	0.984	0.943	1.000	1.000	0.809	0.640
Australia	0.898	0.993	0.926	0.984	0.943	1.000	1.000	0.704	0.542
United States	0.867	0.977	0.974	0.981	0.981	1.000	1.000	0.958	0.853
Japan	0.933	0.933	0.933	0.987	0.951	1.000	1.000	0.760	0.591
Finland	0.877	0.993	0.921	0.982	0.938	1.000	1.000	0.662	0.508
France	0.893	0.973	0.916	0.983	0.942	1.000	1.000	0.617	0.473
UK	0.878	0.993	0.911	0.982	0.938	1.000	1.000	0.570	0.440
Austria	0.885	0.960	0.933	0.983	0.940	1.000	1.000	0.761	0.592
Germany	0.878	0.973	0.922	0.982	0.938	1.000	1.000	0.671	0.515
Singapore	0.877	0.968	0.910	0.982	0.938	1.000	1.000	0.560	0.433
Korea	0.832	0.986	0.861	0.977	0.925	1.000	1.000	0.204	0.198
Argentina	0.807	0.922	0.804	0.973	0.917	1.000	1.000	0.063	0.088
Slovakia	0.805	0.920	0.788	0.973	0.916	1.000	1.000	0.047	0.072
Poland	0.805	0.945	0.752	0.973	0.916	1.000	1.000	0.027	0.049
Costa Rica	0.857	0.861	0.744	0.980	0.932	0.999	0.999	0.024	0.046
Kuwait	0.853	0.743	0.845	0.979	0.931	0.989	0.997	0.144	0.155
Qatar	0.743	0.791	0.874	0.963	0.892	0.995	0.999	0.273	0.244
Medium HDI									
Mexico	0.793	0.846	0.751	0.971	0.912	0.998	0.999	0.027	0.049
Malaysia	0.792	0.803	0.752	0.971	0.911	0.996	0.999	0.027	0.049
Saudi Arabia	0.777	0.712	0.790	0.969	0.906	0.980	0.996	0.049	0.074
Brazil	0.712	0.835	0.723	0.956	0.878	0.998	0.999	0.018	0.038
Turkey	0.747	0.774	0.708	0.963	0.894	0.994	0.998	0.016	0.034
China	0.758	0.804	0.615	0.966	0.898	0.996	0.999	0.007	0.019
Tunisia	0.753	0.720	0.693	0.965	0.896	0.983	0.996	0.013	0.030
Algeria	0.743	0.685	0.663	0.963	0.892	0.968	0.994	0.010	0.025
South Africa	0.452	0.879	0.758	0.836	0.692	0.999	1.000	0.029	0.052
Egypt	0.705	0.622	0.600	0.954	0.875	0.904	0.987	0.006	0.018
Gabon	0.462	0.760	0.690	0.855	0.701	0.992	0.998	0.013	0.029
Morocco	0.710	0.499	0.596	0.955	0.877	0.497	0.939	0.006	0.018
India	0.638	0.565	0.527	0.935	0.838	0.767	0.973	0.005	0.014
Botswana	0.255	0.748	0.713	0.632	0.482	0.990	0.997	0.016	0.035
Zimbabwe	0.298	0.808	0.546	0.686	0.531	0.997	0.999	0.005	0.015
Ghana	0.530	0.617	0.497	0.888	0.761	0.896	0.986	0.004	0.013
Cameroon	0.417	0.649	0.473	0.808	0.658	0.939	0.991	0.004	0.013
Low HDI									
Pakistan	0.583	0.421	0.494	0.914	0.802	0.190	0.849	0.004	0.013
Sudan	0.517	0.499	0.482	0.880	0.750	0.494	0.938	0.004	0.013
Yemen	0.593	0.479	0.365	0.918	0.809	0.403	0.922	0.003	0.011
Bangladesh	0.573	0.399	0.463	0.909	0.795	0.134	0.807	0.004	0.013
Nigeria	0.445	0.576	0.366	0.831	0.685	0.802	0.976	0.003	0.011
Uganda	0.317	0.597	0.416	0.707	0.551	0.857	0.982	0.003	0.012
Zambia	0.273	0.684	0.343	0.655	0.503	0.967	0.994	0.003	0.011
Angola	0.337	0.357	0.515	0.730	0.573	0.067	0.708	0.004	0.014
Chad	0.345	0.387	0.361	0.739	0.582	0.111	0.783	0.003	0.011
Burundi	0.260	0.380	0.297	0.638	0.488	0.099	0.766	0.003	0.010
Niger	0.337	0.159	0.335	0.730	0.573	0.002	0.159	0.003	0.011
Sierra Leone	0.232	0.330	0.265	0.601	0.456	0.042	0.632	0.003	0.010

Computation of HDI based on fuzzy membership

Life expectancy

a. The numbers in row (1) in Table 1a are derived as follows. Based on the UNDP's assumption of 85 years as the goal (maximum), we use 0.99 (age that is 99 per cent of 85 years) as the highest possible achievement μ_h. The UNDP's assumption of 25 years as the worst (minimum) achievement is used to generate μ_l equal to 0.294 (age that is 25 as a percentage of the maximum age 85).
b. The numbers in row (2) are derived as follows. The highest life expectancy in the world is 81 (Japan). That number, as a per cent of 85 (UNDP's goal) yields μ_h equal to 0.95. The lowest life expectancy is 38.9 (Sierra Leone) which represents 46 per cent of the goal (85 years). Thus, μ_l is equal to 0.46.
c. In order to get consistent measurement units, the actual achievement X is computed as a percentage of the goal (85 years).

Education

a. The numbers in row (1) are derived as follows. Based on the UNDP's assumption of the '100-per cent education rate' as the goal and zero as the worst achievement, we use 0.9999 (for computation feasibility) as μ_h and 0.0001 as μ_l.
b. The numbers in row (2) are derived using μ_h equal to 0.9999 and μ_l equal to 0.16 which is the lowest achievement (Niger).
c. In consistence with the UNDP, a weight of *2/3* is placed on adult literacy and a weight of *1/3* is placed on primary, secondary and tertiary gross enrollment.

GDP

a. The numbers in row (1) are derived as follows. The highest achievement is assigned μ_h equal to 0.9999 and the lowest achievement is assigned μ_l equal to 0.0025 (100/40,000) since the UNDP uses a maximum of $40,000 and a minimum of $100.
b. The numbers in row (2) are derived as follows. The highest GDP achieved is $34,142 (PPP) which represents 85 per cent of the maximum ($40,000) that the UNDP uses to derive HDI. Thus μ_h equals 0.85. Similarly, the lowest GDP per capita (Sierra Leone) as a per cent of 40,000 is used as value for μ_l.
c. In order to get consistent measurement units, the actual achievement X is computed as a percentage of the goal ($40,000).

Table 1c: HDI—composite index and country ranking

High Human Development	**(1)**		**(2)**
United States	0.98	United States	0.93
Norway	0.95	Norway	0.89
Canada	0.93	Canada	0.86
Japan	0.92	Japan	0.85
Austria	0.91	Austria	0.84
Australia	0.90	Australia	0.83
Germany	0.88	Germany	0.82
Finland	0.88	Finland	0.82
Sweden	0.87	Sweden	0.81
France	0.87	France	0.80
UK	0.85	UK	0.79
Singapore	0.85	Singapore	0.79
Qatar	0.74	Qatar	0.71
Korea	0.73	Korea	0.71
Kuwait	0.70	Kuwait	0.69
Medium and Low Human Development			
Argentina	0.68	Argentina	0.67
Slovakia	0.67	Slovakia	0.66
Costa Rica	0.67	Costa Rica	0.66
Poland	0.67	Saudi Arabia	0.66
Saudi Arabia	0.67	Poland	0.65
Mexico	0.67	Mexico	0.65
Malaysia	0.66	Malaysia	0.65
Brazil	0.66	Turkey	0.64
Turkey	0.66	Tunisia	0.64
China	0.66	China	0.64
Tunisia	0.65	Brazil	0.64
Algeria	0.65	Algeria	0.64
South Africa	0.63	Egypt	0.63
Egypt	0.62	Morocco	0.61
Gabon	0.62	India	0.61
Ghana	0.60	Ghana	0.59
Cameroon	0.58	South Africa	0.58
India	0.57	Yemen	0.58
Zimbabwe	0.56	Gabon	0.58
Botswana	0.55	Sudan	0.57
Zambia	0.54	Nigeria	0.56
Nigeria	0.55	Pakistan	0.55
Uganda	0.52	Cameroon	0.55
Morocco	0.49	Bangladesh	0.54
Sudan	0.46	Uganda	0.51
Yemen	0.44	Zimbabwe	0.51
Pakistan	0.37	Botswana	0.50
Bangladesh	0.35	Zambia	0.50
Chad	0.28	Chad	0.46
Angola	0.27	Angola	0.43
Burundi	0.25	Burundi	0.42
Niger	0.24	Sierra Leone	0.37
Sierra Leone	0.22	Niger	0.25

The results reported in Tables 1b and 1c show that the ranking of some countries based on fuzzy membership is different from that associated with UNDP-HDI. It is important to stress that fuzzy set scores convey information that does not readily transpires from the HDI. The membership degrees (scores) underline the extent of deprivation and the 'lagging behind'. For example, the UNDP measures indicate that the GDP index for Sierra Leone (the poorest country in the group) is 0.265 while Norway's is 0.952. This implies that Sierra Leone's GDP index is 27 per cent of that in Norway, which may lead to misleading interpretation (in the sense that one may consider 27 per cent of the index of income in Norway as still not a very bad outcome!). On the other hand, the fuzzy set computation indicates that Sierra Leone's GDP index is 0.34 per cent of Norway's. This clearly conveys the idea that there is absolute deprivation in this area in Sierra Leone.

Another feature that is worth highlighting is that the fuzzy-set approach emphasizes relevant variation and downgrades (or even ignores) irrelevant variation. For the reasons explained earlier (see the introduction section) this is an improvement over other widely used computation methods. For example, while the UNDP-HDI shows different scores (indices) for education in the group with high HDI, the fuzzy-set approach yields indices that are the same (1.00) for countries included in this group. As we move to low HDI countries, membership degrees (indices) drop dramatically. It is worth noting that the extreme cases (very high and very low levels are not, in general, affected but the middle ones (because of the fuzziness) are affected, as some countries which are borderline on development either fall to a lower level (for example, Argentina, Slovakia, Poland, Morocco) or move to a higher rank (for example, Zambia).[10] This is, however, expected given the construction of the fuzzy membership function which is context-specific.

4 Computation of fuzzy set-based HWB sub-indices: a simple illustration

The model developed in the previous section can be used to derive an index of human well-being that is consistent with Sen's Capability Approach. However, two major questions arise, First, do we need an indicator (similar to HDI) that measures human well-being and summarizes the result in one *composite* index or a set of indicators (indices) that could be more useful in understanding human well-being in different countries, and which we could use to do some sort of country ranking? Second, what are the major non-income components of human well-being?

Oswald (1997: 1,815) argues that:

> The relevance of economic performance is that it may be a means to an end. That end is not the consumption of beefburgers, nor the accumulation of television sets, nor the vanquishing of some high level of interest rates, but rather the enrichment of mankind's feeling of well-being. Economic things matter only in so far as they make people happier.

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[10] In fact, had the cut-off point been 0.800 (as in the HDR's ranking method) Korea, Kuwait and Qatar would have dropped to the next level of human development (Table 1c, column 1).

While the UNDP's HDI is a useful indicator for researchers concerned with how countries fare in relative income (mainly), literacy and life expectancy, it is by no means a good indicator for human well-being. There is a large body of debates regarding what we should include in HWB. Perhaps the most encompassing measure is the Genuine Progress Index (GPI) which covers dimensions traditionally ignored in the computation of GDP and HDI. These components take into account negative outcomes usually associated with higher GDP (and more common is some wealthy nations), such as crime, natural disasters, divorce rates, reduction in leisure time, and pollution.

An important goal of this paper is to illustrate how fuzzy sets can be used to compute a human well-being index. We do not claim that such index is inclusive. Rather, it is hoped that the proposed methodology will serve as a framework that can be expanded to include policy goals, identification thresholds, and other dimensions deemed useful for assessing human well-being. Table 2 reports the degrees of membership for several human well-being components. Data used in the computation of these indices are for the year 2000.

The first three components displayed in Table 2 are the ones derived earlier and reported in Table 1b, columns labelled (1). These components are consistent with the dimensions included in the UNDP-HDI. Perhaps, it is useful to provide a brief review of the rationale for their inclusion.

Income represents an important aspect of command over resources and is a type of functioning. It also serves as a means to achieve a capability that would help to make functionings happen (for example, a life without hunger or disease). Health and knowledge (or education) are examples of capabilities to achieve functionings.

However, there are diminishing returns to income, so that returns (impact) may become nil at moderate to high levels of income. Anand and Sen (2000: 86) argue that '[t]he income level enjoyed, especially close to poverty lines, can be very crucial information on the causal antecedents of basic human capabilities'. The use of the logarithm transformation (as in the HDI) of the PPP value of GDP per capita is meant to reflect diminishing returns as income rises.

The information and communication technology (ICT) index measures both functionings and capability (knowledge and freedom to communicate). This index may also be used as an indicator of the extent of social exclusion. The ICT index is constructed using four components (data are from the ITU, 2002); cell phones per 100 inhabitants, Internet hosts per 10,000 people, Internet users per 10,000 people, and personal computers per 100 inhabitants.

The dimension labeled 'other' is constructed based on four components; infant mortality rates, under-five mortality rates, percentage of population with access to urban sanitation, and percentage of population with access to improved water source. Data are from the World Bank CD-ROM 2002.

The last two components represent freedom dimensions. They include political liberties and civil rights (produced by Freedom House). The relationship between freedom and income (GDP) or other socioeconomic indicators is not always clear. For example, Dasgupta and Weale (1992) construct a measure of well-being that includes political and civil liberties and find that per-capita income and life expectancy are positively

correlated with improvements in political and civil liberty, while infant mortality and—oddly—improvements in literacy show a negative correlation with political and civil liberties. Similarly, some researchers have shown that, as income reaches high levels, so do some factors that have negative impact on human well-being. For example, many wealthy societies have higher suicide rates, divorce rates, pollution and crimes compared to poorer societies. For example, Jungeilges and Kirchgässner (2002) examined the link between suicide rates, and economic welfare (economic growth and per capita income) and civil liberties. They found a positive relationship between suicide rates and economic welfare, and a negative relationship between suicide rates and civil liberty. Thus, freedom dimensions are very important for human well-being. Indeed, the foreword to the 2002 HDR (prelim v) states:

> This Human Development Report is first and foremost about the idea that politics is as important to successful development as economics. Sustained poverty reduction requires equitable growth – but it also requires that poor people have political power.

It is clear that the inclusion of other components of HWB yields useful insight in this area. For example, based on UNDP-HDI Costa Rica, Kuwait and Qatar were ranked 17, 18 and 19, respectively and were included in the high development group (UNDP ranking). According to the measure of human well-being employed here (Table 2), Costa Rica will still be included in this group, based on an average rank or Borda ranking. On the other hand, Qatar and Kuwait will drop to the next group since their membership degrees in most dimensions of well-being are relatively low. We observe similar outcomes in the case of other countries with low membership degrees in the component 'freedom'.

The fuzzy-set membership approach handles both saturation levels (diminishing, or even no, returns) and minimum requirements (threshold levels). For example, we observe that membership degrees for countries with low income drop abruptly. If we consider ICT indicators as a type of functioning that helps to achieve a specific capability; namely knowledge and freedom to communicate, we can see that 35 out of 48 countries are far below what would be a satisfactory achievement. Concerning freedom indicators, at least half the countries in the group have below satisfactory levels.

In addition, the fuzzy-set methodology indicates that the inter-country ranking is different from the UNDP-HDI ranking. A more significant point, however, is the fact that several countries that had been labeled as 'high or medium development' countries (in the UNDP's 2002 HDR) seem to fit more in the 'low human well-being' sub-group (for example, Qatar, Kuwait, Cameroon, Morocco).

The membership approach used in this paper allows comparison over time in order to see if a country has reached a 'critical' level with regard to a human well-being component. For example, an acceptable membership degree in the space 'freedom' requires moving from a score of 0.271 to 0.729; implying a *non-transformed* freedom index equal to 3 (or less) which, according to Freedom House is interpreted as 'partly free'. This required change is substantial, reflecting the understanding that partial freedom is an important—though not sufficient—step towards freedom.

Table 2

Rank	Life Expectancy Index		Education Index		GDP Index		ICT Index		Other		Political Rights		Civil Rights	
1	Japan	0.987	Sweden	1.00	U.S.	0.958	Norway	0.998	Sweden	0.981	Norway	1.00	Norway	1.00
2	Sweden	0.985	Australia	1.00	Norway	0.881	Finland	0.991	Singapore	0.981	Sweden	1.00	Sweden	1.00
3	Australia	0.984	Finland	1.00	Canada	0.809	Sweden	0.991	Norway	0.981	Canada	1.00	Canada	1.00
4	Canada	0.984	U.K.	1.00	Austria	0.761	Australia	0.976	Japan	0.980	Australia	1.00	Australia	1.00
5	France	0.983	Korea	1.00	Japan	0.760	U.S.	0.967	Finland	0.980	U.S.	1.00	U.S.	1.00
6	Norway	0.983	Norway	1.00	Australia	0.704	Singapore	0.919	France	0.980	Japan	1.00	Finland	1.00
7	Austria	0.983	Canada	1.00	Germany	0.671	Canada	0.903	Germany	0.980	Finland	1.00	Austria	1.00
8	U.K.	0.982	U.S.	1.00	Finland	0.662	Japan	0.861	Austria	0.979	France	1.00	Japan	0.95
9	Germany	0.982	France	1.00	Sweden	0.620	Austria	0.830	Australia	0.979	U.K.	1.00	France	0.951
10	Finland	0.982	Germany	1.00	France	0.617	U.K.	0.811	Canada	0.979	U.K.	1.00	U.K.	0.951
11	Singapore	0.982	Singapore	1.00	U.K.	0.570	Germany	0.790	U.K.	0.979	Austria	1.00	Germany	0.951
12	U.S.	0.981	Austria	1.00	Singapore	0.560	Korea	0.688	U.S.	0.977	Germany	1.00	Korea	0.951
13	Costa Rica	0.980	Poland	1.00	Qatar	0.273	France	0.609	Slovakia	0.976	Argentina	1.00	Argentina	0.951
14	Kuwait	0.979	Japan	1.00	Korea	0.204	Malaysia	0.265	Korea	0.972	Slovakia	1.00	Slovakia	0.951
15	Korea	0.977	Argentina	1.00	Kuwait	0.144	Slovakia	0.242	Costa Rica	0.972	Poland	1.00	Poland	0.951
16	Argentina	0.973	Slovakia	1.00	Argentina	0.063	Kuwait	0.231	Malaysia	0.967	Costa Rica	1.00	Costa Rica	0.951
17	Slovakia	0.973	South Africa	0.999	Saudi Arabia	0.049	Qatar	0.194	Poland	0.967	South Africa	1.00	South Africa	0.951
18	Poland	0.973	Costa Rica	0.999	Slovakia	0.047	Turkey	0.158	Kuwait	0.965	Korea	0.951	Botswana	0.951
19	Mexico	0.971	Mexico	0.998	South Africa	0.029	Poland	0.139	Saudi Arabia	0.957	Mexico	0.951	Mexico	0.729
20	Malaysia	0.971	Brazil	0.998	Malaysia	0.027	South Africa	0.132	Argentina	0.957	India	0.951	Brazil	0.729
21	Saudi Arabia	0.969	Zimbabwe	0.997	Poland	0.027	Costa Rica	0.127	Mexico	0.924	Botswana	0.951	India	0.729
22	China	0.966	China	0.996	Mexico	0.027	Argentina	0.121	Tunisia	0.918	Ghana	0.951	Ghana	0.729
23	Tunisia	0.965	Malaysia	0.996	Costa Rica	0.024	Mexico	0.091	Brazil	0.913	Brazil	0.721	Gabon	0.271
24	Turkey	0.963	Qatar	0.995	Brazil	0.018	Brazil	0.086	Algeria	0.910	Bangladesh	0.721	Morocco	0.271
25	Qatar	0.963	Turkey	0.994	Botswana	0.016	Botswana	0.069	China	0.904	Kuwait	0.271	Bangladesh	0.271

Table 2 (continued)

Rank	Life Expectancy Index		Education Index		GDP Index		ICT Index		Other		Political Rights		Civil Rights	
26	Algeria	0.963	Gabon	0.992	Turkey	0.016	Saudi	0.056	Turkey	0.902	Nigeria	0.271	Nigeria	0.271
27	Brazil	0.956	Botswana	0.990	Tunisia	0.013	Gabon	0.053	Egypt	0.864	Niger	0.271	Zambia	0.271
28	Morocco	0.955	Kuwait	0.989	Gabon	0.013	Morocco	0.048	Morocco	0.831	Sierra Leone	0.271	Niger	0.271
29	Egypt	0.954	Tunisia	0.983	Algeria	0.010	China	0.047	Bangladesh	0.727	Singapore	0.049	Singapore	0.049
30	India	0.935	Saudi Arabia	0.980	China	0.007	Egypt	0.038	South Africa	0.725	Malaysia	0.049	Kuwait	0.049
31	Yemen	0.918	Algeria	0.968	Egypt	0.006	Tunisia	0.037	Qatar	0.716	Gabon	0.049	Malaysia	0.049
32	Pakistan	0.914	Zambia	0.967	Morocco	0.006	Zimbabwe	0.036	Sudan	0.699	Morocco	0.049	Turkey	0.049
33	Bangladesh	0.909	Cameroon	0.939	Zimbabwe	0.005	Zambia	0.033	India	0.679	Yemen	0.049	Tunisia	0.049
34	Ghana	0.888	Egypt	0.904	India	0.005	Cameroon	0.032	Ghana	0.645	Zambia	0.049	Algeria	0.049
35	Sudan	0.880	Ghana	0.896	Angola	0.004	India	0.032	Yemen	0.643	Qatar	0.007	Egypt	0.049
36	Gabon	0.855	Uganda	0.857	Ghana	0.004	Uganda	0.032	Zimbabwe	0.621	Tunisia	0.007	Zimbabwe	0.049
37	South Africa	0.836	Nigeria	0.802	Pakistan	0.004	Algeria	0.032	Pakistan	0.600	Algeria	0.007	Pakistan	0.049
38	Nigeria	0.831	India	0.767	Sudan	0.004	Ghana	0.032	Cameroon	0.545	Egypt	0.007	Uganda	0.049
39	Cameroon	0.808	Morocco	0.497	Cameroon	0.004	Nigeria	0.032	Gabon	0.532	Zimbabwe	0.007	Chad	0.049
40	Chad	0.739	Sudan	0.494	Bangladesh	0.004	Pakistan	0.031	Nigeria	0.522	Pakistan	0.007	Sierra Leone	0.049
41	Angola	0.730	Yemen	0.403	Uganda	0.003	Angola	0.031	Uganda	0.502	Uganda	0.007	Qatar	0.007
42	Niger	0.730	Pakistan	0.190	Nigeria	0.003	Sudan	0.031	Zambia	0.499	Angola	0.007	China	0.007
43	Uganda	0.707	Bangladesh	0.134	Yemen	0.003	Yemen, Rep.	0.031	Niger	0.485	Chad	0.007	Cameroon	0.007
44	Zimbabwe	0.686	Chad	0.111	Chad	0.003	Bangladesh	0.031	Angola	0.403	Burundi	0.007	Yemen	0.007
45	Zambia	0.655	Burundi	0.099	Zambia	0.003	Sierra Leone	0.031	Botswana	0.393	Saudi Arabia	0.001	Angola	0.007
46	Burundi	0.638	Angola	0.067	Niger	0.003	Burundi	0.031	Burundi	0.351	China	0.001	Burundi	0.007
47	Botswana	0.632	Sierra Leone	0.042	Burundi	0.003	Chad	0.031	Chad	0.347	Cameroon	0.001	Saudi Arabia	0.001
48	Sierra Leone	0.601	Niger	0.002	Sierra Leone	0.003	Niger	0.031	Sierra Leone	0.149	Chad	0.001	Sudan	0.001

5 Concluding remarks

This paper has developed a framework that uses fuzzy-set theory to measure human well-being in consistence with Sen's Capability Approach. Fuzzy sets allow for gradual transition from one state to another while also allowing one to incorporate rules and goals, and hence are more appropriate for modeling preferences and outcomes that are ambiguous. The fuzzy-set based indices suggest that several countries that had been included in the high (or medium) human development group in various HDRs seem to score much lower on the *human well-being* front. Application of the model to data from a large group of developing and developed countries indicates that the UNDP's Human Development Index and human well-being as measured using fuzzy set theory yield different country rankings. This raises significant questions regarding the potential policy implications of empirical results obtained from different measurement methodologies. In particular, it is important to bear in mind that preferences and choices underlying both objective and subjective indicators of human well-being are, in essence, broad and vague; and that such vagueness can have major implications for the outcome of social and economic policies. The main contribution of the paper lies in its use of country-level (macro) data to measure capabilities while accounting for the ambiguity of preferences and goals.

The paper has derived several HWB indices and has deliberately left the question of how to compute a composite HWB index (and whether a composite index can be useful) open. The underlying rationale is that individual indicators (indices) may be able to convey more relevant information about the state and components of a country's human well-being. Separate indicators could be more useful than one composite index if the aggregation procedure is based on shaky grounds. Using individual indicators, one could produce an overall country ranking, for example using Borda ranking or another method that is deemed appropriate given the context of the analysis.

Finally, it is worth pointing out that human well-being is sometimes interpreted as human happiness. In economics—as well as in other behavioral and social sciences—there are some interesting debates regarding happiness, economic performance and well-being (see for example Oswald, 1997). Perhaps the question of whether wealth (income) ensures happiness has been best addressed by the French philosopher Jean-Jacques Rousseau when he confessed:

> It was only in my happiest days that I traveled on foot, and ever with the most unbounded satisfaction; afterwards, occupied with business and encumbered with baggage, I was forced to act the gentleman and employ a carriage, where care, embarrassment, and restraint, were sure to be my companions, and instead of being delighted with the journey, I only wished to arrive at the place of destination. (*The Confessions of Jean-Jacques Rousseau* 1782)

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