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Measuring â•œLong and Healthy Livesâ•š: Healthier Lives <=> Longer Lives?

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Measuring "Long and Healthy Lives": Healthier Lives ⇔ Longer Lives?

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Abstract

On the presumption that a healthier life means a longer life, the "Long and Healthy Life" component of the Human Development Index relies solely upon a nations' estimated life expectancy as its measure of the healthiness and life length of its populace. However, the well-established health–longevity gender paradox, that compared to Males, Females experience inferior health outcomes but superior longevity, suggests that the life expectancy-based index is insufficient for the task and potentially misleading from a health policy perspective. Here new, fit-for-purpose policy focussed Health Indices and Inequality measures are introduced and explored in the light of the paradox in 21st century China. China's longevity and health experiences are consistent with the paradox and, furthermore, they are trending in different directions. The analysis reveals that much is lost by not including a health component along with longevity in the Human Development Index.

Keywords

Health Inequality, Inequality Measurement, Healthy-Longevity Paradox

Classification Codes

D63, I31, I32

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Section1. Introduction.

According to the 1990 Human Development Report (UNDP, 1990) “The basic objective of development is to create an enabling environment for people to enjoy long, healthy and creative lives” and the Human Development Index (HDI) was produced to reflect this intent. Founded upon Sen’s Capabilities Approach (Sen, 1993) concerning individual capacities to be and do, it is a summary measure of a populations’ achievements in three key human development dimensions, a long and healthy life (HDI_1), access to knowledge (HDI_2) and a decent standard of living (HDI_3). The HDI is the geometric mean of normalized indices for each of the three dimensions:

$$HDI = (HDI_1.HDI_2.HDI_3)^{\frac{1}{3}}$$

Here the focus is on HDI_1 and the extent to which its sole reliance on life expectancy really reflects a societies fulfilment of the long and healthy lives for all imperative. Inequality sensitive versions of the index using Atkinson (1970) inequality sensitive aggregate wellbeing measures have been employed in acknowledgement of an inclusivity imperative. Furthermore, gender distinctions have been deemed important in the capability approach (Nussbaum, 2000), so that recently a Gender Development Index (UNDP, 2020) has been developed.

Clearly both longevity and health are important in facilitating and extending an individuals’ capabilities for being and doing over their life cycle and, with a healthy life presumably promoting longevity in a simple monotonic increasing relationship, it is no surprise that longevity, used as a proxy for health, ends up as the only variate employed in HDI_1. However, a recent literature on paradoxical male-female health-longevity patterns (Alberts et. al., 2014) suggests that a simple monotonic increasing relationship presumption is unwarranted, especially in a male-female comparison context. It appears that, in many societies, relative to Males, Females experience superior longevity patterns but inferior health outcomes. This evidence is consistent with Salomon et. al. (2012) which reports estimates of Healthy Life Expectancy (HALE) indices which reveal that the gap between Life Expectancy and Healthy Life Expectancy increases with age to a greater degree for women than it does for men. All of which points to the need to modulate HDI_1 by a factor recording the extent to which not all lives are lived with the same levels of disease and injury induced disabilities. The aftereffects, or sequelae of disease or injury, may well be non-fatal but non-the-less affect the health of an individual for the rest of their lives and hence, in terms of the Capabilities Approach, impair their abilities to be and do for the rest of their lives. It is the unequal distribution of these non-fatal health outcomes that are not accounted for in HDI_1.

As an objective summary measure of population health that incorporates measures of health status in a life expectancy-based measure, the HALE index would appear to be a natural substitute for HDI_1. HALE indices, which evolved from Sullivan (1971), weight the years lived within each of a designated number of age groups by a disability weighting measure[2]. The standard life expectancy tables are then recalculated using the weighted years lived measure. However, there are strong arguments for working with a more subjective measure.

In the context of creating an inclusive, enabling environment and in the spirit of the Functionings and Capabilities approach, it is an individual's perceptions of, and attitude to, their health status that in large part affects their ability to function, access knowledge, acquire human capital, and enjoy a decent standard of living, so that perceptions of a common disability may well differ across age group, gender, and habitat factors. Indeed, an individual's view of a given health outcome may change significantly over the life cycle in that what may be considered a minor health impediment early in life cycle may loom much larger later in that cycle, and more so if access to health care provision is a private rather than a public matter (Anderson and Fu 2022).

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[2] Calculation of the weights is a complex and not inconsequential matter. Vos, Flaxman, Naghavi, et al. (2012) identified 289 diseases or injuries that cause disability with 1169 sequelae which, using a vast array of data sources and empirical techniques, were systematically analysed for prevalence, incidence, remission, duration, and excess mortality. The results were distilled into disability weights for 220 unique health states which were used to capture the severity of health loss or Years Lived in Disability by gender at given age levels. The disability weights were calculated using estimates of the prevalence of a collection of sequelae (morbidity causes) for a collection of health states faced by an age group and represent its health loss (0 ⇔ ideal health, 1 ⇔ death). 1 minus the disability weight is applied to the years lived for the corresponding group and the life tables recalculated. As such it combines mortality information from a period life table with cross-sectional information on the documented prevalence of actual morbidity or health-based disability conditions in the population of interest.

Perceptions of a particular health status impediment may also differ across the gender divide. Goldin (2014) observed that Males and Females have fundamentally different home-work life cycle patterns and there is good reason to believe that men and women view a common health impediment to the home-work life pattern very differently as a consequence. HALE distinguishes between these factors only to the extent that the prevalence of disease or injury and their consequent sequalae differ across those factors, it does not account for differences in individual attitudes to, and interpretations of, a particular experienced health outcome with respect to the extent to which it is an impediment.

Self Reported Health Status is a composite of the extent of a perceived disability and the individuals' attitude to it. As such it facilitates the measurement of health status in a way that reflects the combined effects of a given health outcome and its impact on the individual in terms of its abilities to be and do in a way that HALE does not and thus is more in line with the Functionings and Capabilities Approach. Furthermore, HALE does not reflect the health inequalities suffered by the population and does not meet the inclusivity objective of the inequality modulated HDI_1. Accordingly, here, self reported health-based measures of the level of health are developed and incorporated in a family of overall Healthy Life Expectancy measures. Given a health policy imperative that all should enjoy the best of health, the measures also reflect the inequalities in health experiences suffered in the society with a fit for purpose focus on the leveling upwards of health outcomes.

In the following, a family of indices for quantifying self perceived health levels and inequalities in conjunction with longevity together with a simple technique for examining distributional differences are explored in Section 2. After outlining some background to the Chinese situation, Section 3 exemplifies the indices in a study of health and longevity in groupings defined by region and gender in 21st Century China. Some conclusions are drawn in Section 4. To anticipate the results, evidence supporting the existence of the health-longevity gender paradox in China's case in the form of substantive differences in the ordering of groups with respect to longevity as opposed to health was revealed. Substantial differences were apparent across both gender and regional divides with longevity and self reported health trending in opposite directions highlighting the importance of combining the two in an overall Long and Healthy Lives index.

Section 2. The Indices.

Section 2.1 The HDI Life Expectancy-Based Index.

The first "Long and Healthy Life" dimension of the Human Development Index, HDI_1, is based upon life expectancy at birth (le) and, given presumed highest and lowest possible life expectancies of le_{max} and le_{min} , its basic "long and healthy lives" dimension index for the j'th group with life expectancy le_j is:

$$HDI_{1,\mathrm{j}} = \frac{(le_j - le_{min})}{(le_{max} - le_{min})}. \qquad [1]$$

Given $le_{j,n}$, N subgroup life expectancies indexed n=1,..,N in population i, the inequality adjusted index

$$IHDI_{1\mathrm{j}} = HDI_{1,\mathrm{j}}(1 - A(\varepsilon))$$

where the inequality measure $A(\varepsilon)$, is drawn from Atkinsons family of inequality measures (Atkinson, 1970; Foster, Lopez-Calva and Szekely, 2005) which is given by:

$$A = 1 - \left(\frac{\sqrt[N]{le_{j,1} .. le_{j,n} .. le_{j,N}}}{\frac{1}{N} \sum_{n=1}^{N} le_{j,n}} \right)^{\varepsilon}$$

Where ε is the inequality aversion parameter which, when set to 1 yields[3]:

$$IHDI_{1,i} = \left(\frac{\sqrt[N]{le_{j,1} .. le_{j,n} .. le_{j,N}}}{\frac{1}{N} \sum_{n=1}^{N} le_{j,n}} \right) HDI_{1,\mathrm{j}}. \qquad [2]$$

[3] Alternatively, to accommodate a preference for equality Sen (1976) modulated the wellbeing index by a monotonic non-increasing function of the Gini coefficient making [2] of the form: $IHDI_{1,i} = \left(1 - G(le_{j,1} .. le_{j,n} .. le_{j,N})\right) HDI_{1,\mathrm{j}}$, where $G(le_{j,1} .. le_{j,n} .. le_{j,N})$ is the life expectancy Gini Coefficient.

The latent wellbeing function underlying these indices is that a longer life is of more value especially if it is more equally shared. In focussing on the “Long” part of a “Long and Healthy Life” these indices are based upon the presumption that there is a simple monotonic one to one relationship between health and longevity or that all groups under comparison enjoy the same level of health, but there is much evidence suggesting that neither of these is the case.

The well documented male-female health-longevity paradox, observed in many developed countries, concerns the fact that women generally experience greater longevity and yet higher rates of disability and poor health than men (Crimmins et al., 2011; Thorslund et al., 2013; Oksuzyan et al., 2014). Men typically suffer higher mortality rates at all ages and lower life expectancies than women but exhibit a substantial advantage in phenotypes that in both sexes are positively correlated with health and survival (Oksuzyan et al., 2010). Indeed, in China, Self Reported Health outcomes of Males and Females seem to reflect the male phenotype advantage in that females usually report worse outcomes than their male counterparts especially amongst the aged (Anderson et. al., 2022). This suggests that, in the case of gender-based groupings, the life expectancy based HDI_1 should be modulated by some sort of health-based index.

Section 2.2 A Health Outcomes Based Index.

Switching the focus to the “Healthy” aspect of “Long and Healthy Lives”, reliance is placed upon individual agents ordered categorical responses to questions regarding perceptions of health status. The ordered categorical nature of such responses presents a challenge for the quantification of levels of and inequalities in health status in the form of [1] and [2] since the arbitrary attachment of a cardinal scale to ordinal categories is beset with problems of ambiguity because of the scale dependency problem (Bond and Lang, 2019; Schroder and Yitzhaki, 2017). However, Anderson and Leo (2021), based upon extensions of Anderson and Post (2018) and Anderson, Post and Whang (2020), developed a class of scale independent indices for this situation.

Suppose individuals in group j self report their health status in one of $I = 5$ categories: Very Unhealthy, Relatively Unhealthy, Normal, Relatively Healthy, Very Healthy with respective probabilities $f_{j,i}$ $i = 1,..,5$ ($\sum_{i=1}^{5} f_{j,i} = 1$), which engenders a cumulative distribution function (CDF) vector for the j'th group $\underline{F_j}$ with typical element $F_{j,i} = \sum_{k=1}^{i} f_{j,k}$ $i = 1,..,5$. Following Anderson and Leo (2021) a Utopia-Dystopia Health Index $HI(j)$ across J groups indexed $j = 1,..,J$ can be developed by using the Utopian distribution $F_{U,i} = \min_{j=1,..,J}(F_{j,i}\ i = 1,..,5)$ and the Dystopian distribution $F_{D,i} = \max_{j=1,..,J}(F_{j,i}\ i = 1,..,5)$ [4]. $HI(j)$ for the j'th group is given by:

$$HI1(j) = \frac{\sum_{i=1}^{5}(F_{D,i} - F_{j,i})}{\sum_{i=1}^{5}(F_{D,i} - F_{U,i})}. \qquad [3]$$

In this case $0 \leq HI(j) \leq 1$, when $HI(j) = 1$ (0) j is unequivocally the healthiest (unhealthiest) group. Here, health is going to be measured against the worst possible Dystopian distribution where all members of society self report the worst outcome so that $f_{D,1} = 1$ and $f_{D,i} = 0, i = 2,..,5$ so that $F_{D,i} = 1, i = 1,..,5$. Following Anderson and Leo (2021) and Anderson, Post and Whang (2020), $HI2(j)$, a second order index embodying a weak preference for equality of outcomes (Foster and Shorrocks, 1988) can be employed using cumulated CDF's, $CF_{D,i}, CF_{U,i}$ and $CF_{j,i}$, where $CF_{D,i} = \sum_{k=1}^{i} F_{j,k}$; $CF_{U,i} = \sum_{k=1}^{i} F_{U,k}$ and $CF_{j,i} = \sum_{k=1}^{i} F_{j,k}$ respectively.

$$HI2(j) = \frac{\sum_{i=1}^{5}(CF_{D,i} - CF_{j,i})}{\sum_{i=1}^{5}(CF_{D,i} - CF_{U,i})} \qquad [4]$$

The latent wellbeing function underlying these indices values a greater probability of a better outcome (with a penalty for increased spread in the case of $HI2$) but these indices pay no attention to longevity as though all agents face the same longevity prospect or at least that it is distributed independently of health status.

Since these indices are based upon stochastic dominance principles, a simple indicator of whether one distribution dominates another would be useful. First (Second) Order Dominance of distribution j over distribution k requires $F_{k,i} - F_{j,i} \geq 0$, ($CF_{k,i} - CF_{j,i} \geq 0$) for all i with strict inequality somewhere. When this inequality prevails, j is said to unambiguously dominate k in the

[4] These indices can be shown to satisfy axioms such as Continuity, Scale Independence, Coherency, Normalization, Monotonicity and Inequality Sensitivity familiar in the welfare literature (Gravel et al., 2020; Sen, 1995; Anderson and Leo, 2021).

sense that all health indices in a given class, determined by the order of comparison, would record health state j as better than health state k. Given independent random sampling of the two states, statistical inference is easily performed following Rao (2009) since $\underline{\hat{f_g}}$, the estimator of the vector of outcome probabilities $\underline{f_g}$, is such that $\sqrt{n}\left(\underline{\hat{f_g}} - \underline{f_g}\right) \sim N\left(\underline{0}, V_g\right)$ where:

$$V_g = \begin{bmatrix} f_{1,g} & 0 & 0 & . & 0 \\ 0 & f_{2,g} & 0 & . & 0 \\ 0 & 0 & f_{3,g} & . & 0 \\ . & . & . & . & 0 \\ 0 & 0 & 0 & . & f_{5,g} \end{bmatrix} - \begin{bmatrix} f_{1,g} \\ f_{2,g} \\ . \\ . \\ f_{5,g} \end{bmatrix} \begin{bmatrix} f_{1,g} & f_{2,g} & . & . & f_{J,g} \end{bmatrix}.$$

Noting that $\underline{F_g} = D\underline{f_g}$, where D is a lower triangular matrix of one's, it follows that, for independent samples, each of size n:

$$\sqrt{n}\left(\widehat{F_{g'}} - \widehat{F_g}\right) = \sqrt{n}D\left(\underline{\widehat{f_{g'}}} - \underline{\widehat{f_g}}\right) \sim N\left(D(\underline{f_{g'}} - \underline{f_g}), D(V_{g'} + V_g)D'\right).$$

Inference can be performed using the Stoline and Ury (1979) Maximum Modulus Distribution to jointly examine the joint "non-negativity" of all the elements of the vector $\left(\widehat{F_{g'}} - \widehat{F_g}\right)$. Similarly, since the second order index works with Cumulated Cumulative Density functions $\underline{CF_g}$, where $\underline{CF_g} = \underline{DF_g} = DD\underline{f_g}$ a second order analysis is simply a case of working with:

$$\sqrt{n}\left(\widehat{CF_{g'}} - \widehat{CF_g}\right) = \sqrt{n}DD\left(\underline{\widehat{f_{g'}}} - \underline{\widehat{f_g}}\right) \sim N\left(DD(\underline{f_{g'}} - \underline{f_g}), DD(V_{g'} + V_g)(DD)'\right).$$

However, a simpler and more convenient approach is to evaluate the potential for ambiguity in the comparison (Anderson and Leo 2021) and a measure of potential First Order Ambiguity is given by:

$$AM1(g, g') = 1 - \frac{\sum_{i=1}^{5}\left(\widehat{F_{g'}} - \widehat{F_g}\right)}{\sum_{i=1}^{5}\left|\left(\widehat{F_{g'}} - \widehat{F_g}\right)\right|}$$

When g dominates g' at the First Order, $1 - AM1(g, g')$ will equal 1 and a null hypothesis of dominance would never be rejected at any level of significance so that proximity of $1 - AM1(g, g')$ or $\frac{\sum_{i=1}^{5}\left(\widehat{F_{g'}} - \widehat{F_g}\right)}{\sum_{i=1}^{5}\left|\left(\widehat{F_{g'}} - \widehat{F_g}\right)\right|}$ to 1 provides a good indication of the first order dominance of g over g'. When comparisons are made at the Second Order with Cumulative CDF's, a measure of potential Second Order Ambiguity is given by:

$$AM2(g,g') = 1 - \frac{\sum_{i=1}^{5}\left(\widehat{CF_{g'}} - \widehat{CF_g}\right)}{\sum_{i=1}^{5}\left|\left(\widehat{CF_{g'}} - \widehat{CF_g}\right)\right|}$$

When g dominates g' at the Second Order, $1 - AM2(g,g')$ will equal 1 and a null hypothesis of dominance would never be rejected at any level of significance, again proximity of $\frac{\sum_{i=1}^{5}\left(\widehat{CF_{g'}} - \widehat{CF_g}\right)}{\sum_{i=1}^{5}\left|\left(\widehat{CF_{g'}} - \widehat{CF_g}\right)\right|}$ to 1 is an indication of Second Order Stochastic Dominance of g over g'. In such instances the value of any latent wellbeing function in the appropriate class would report superior wellbeing for state g than state g'.

Section 2.3 Measuring Inequality in Health Outcomes.

$IHDI$, the inequality adjusted health index, presumes that a society's aspiration is for all constituents to enjoy the best possible health, in essence it has two objectives, namely equalizing and leveling up health outcomes, and a measure of health outcome inequality that reflects both aspirations is required. $HI2$ which accommodates a weak preference for inequality based on the extent of concavity in the underlying value function can reflect this, but it does not explicitly embody a focus within the range of outcomes on where it is desirable to have equality. In a similar fashion, standard inequality measures, like the coefficient of variation or Atkinsons' measure, which aggregate differences from a mean focus point, aside from not being applicable in the absence of cardinal measure due to scale dependency issues[5], could be misleading and not "fit for purpose" in that the "middle" of the distribution may not be the appropriate focus point. To see this, consider three possible focus points, the lowest attainable outcome, the highest attainable outcome and some middle (for example median or modal) outcomes. A larger "average distance" from the Lowest health outcome is a "good thing" to be measured as a "Good Inequality" and, from a policy perspective, maximized. On the other hand, a larger average

[5] Allison and Foster (2004), Cowell and Flachaire (2017), and Jenkins (2021) circumvented this issue by employing measures of probabilistic distance from a median or maximal focus categories the determination of which does not need artificial calibration.

distance from the Highest health outcome is a bad thing and to be minimized. Furthermore, in securing commonality at some outcome level anywhere other than at the top of the health outcome range could be misleading vis a vis the joint policy intent in the short run. Here inequality measures focussed upon the highest attainable outcome and the modal outcome are employed, where the former measures reflect an equalizing upward policy aspiration whereas the latter does not, unless the maximal outcome is also the modal outcome.

Consider $PD(i) = 1 - f_i$, the probability that not everyone has the i'th outcome, it will be 0 when all agents are in category i and 1 when no one is in i. In effect it is an inequality measure focussed on the i'th outcome, recording the propensity for outcomes different from i, but it attaches zero weight to the spread of agents across outcomes other than i in terms of their categorical distance from the focus category. For a Categorical Distance weighted measure of spread focussed on the i^*'th outcome, consider IMS where $\underline{F}^M$ is a density cumulation function focussed on i^* with typical element $F_i^M = \sum_{j=i}^{i^*} f_j \, , i \leq i^*, F_i^M = \sum_{j=i^*}^{I} f_j \, , i > i^*$ and d is the unit vector:

$$IMS(i^*) = \frac{I - \sum_{i=1}^{I} F_i^M}{I-1} = \frac{5 - d'\underline{F}^M}{4}. \qquad [5]$$

It is readily shown that $0 \leq IMS \leq 1$ and that when all the population are in i^*, $IMS = 0$ and when all the population are in either the Lowest or Highest category $IMS = 1$.[6]

Following Anderson (2022), [5] can be motivated as an inequality measure by contemplating the average absolute difference between F_i^T, the theoretical cumulative density function that emerges when there is complete equality with all in the population enjoying outcome i^* ($F_i^T = 0, i = 1, .., (i^* - 1)$ and 1 elsewhere) and F_i, the actual cumulative density function in the form:

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[6] For inference purposes, Since $\sqrt{n}\left(\hat{\underline{f}} - \underline{f}\right) \sim N(\underline{0}, \mathrm{V})$ $\sqrt{n}(\hat{f}_i - f_i) \sim N(\underline{0}, (f_i(1 - f_i)))$, further, noting that $\underline{F}^M = D_M \underline{f}$ where D_M is a known square matrix, IMS may be written as a linear transformation of $\underline{f}$: $\frac{1}{4}(I - d'D_M\underline{f})$, it follows that, for independent samples of size n: $\sqrt{n}(\widehat{IMS} - IMS) = \sqrt{n}d'D_M\left(\hat{\underline{f}} - \underline{f}\right) \sim N\left(0, \left(\frac{1}{4}\right)^2 d'D_M V D_M{}'d\right)$.

$$\frac{\sum_{i=1}^{I}|F_i^T - F_i|}{I-1} = IMS(i^*)$$

When i^*, the focus category, is the highest category:

$$IMS(i^*) = \frac{I - \sum_{i=1}^{I} F_i}{I-1}.$$

When i^* is the lowest category:

$$IMS(i^*) = \frac{(\sum_{i=1}^{I} F_i) - 1}{I-1}.$$

It is readily shown that $0 \leq IMS \leq 1$, will equal 0 when all agents are identically in category i^* and it will equal 1 when all agents are located most remotely from i^*. Here two alternative specifications will be considered with i^* being the modal category, reflecting a neutral equalizing imperative and i^* being the highest or maximal category reflecting an upward equalizing imperative demanding the best health outcome for all as the ultimate policy goal.

Section 2.4 A "Long and Healthy Life" Index.

To temper the vagaries engendered by longevity proxying for health, given a weighting factor α and assuming strong separability of health and longevity factors in an overall wellbeing index, consider $LHLI$, an index that combines a longevity measure with a health measure where:

$$LHLI1(j) = HI1(j)^{\alpha} {HDI_{1,\text{j}}}^{1-\alpha} \quad 0 \leq \alpha \leq 1. \qquad [6]$$

Or, if inequality issues are of additional concern:

$$LHLI2(j) = HI2(j)^{\alpha} {IHDI_{1,\text{j}}}^{1-\alpha} \quad 0 \leq \alpha \leq 1. \qquad [7]$$

Or, following Atkinson (1970) and Sen (1976) but using the Health Inequality Index:

$$LHLFI(j) = (1 - IMS(i^*)_{\text{j}})^{\alpha} HDI(j)^{1-\alpha} \quad 0 \leq \alpha \leq 1. \qquad [8]$$

Section 3. Results.

Section 3.1 Background

There has long been concerns regarding the equitable provision of healthcare in China with evidence of a divergence in its provision between interior and coastal regions which coheres with the divergence in their respective income levels (Gong et. al. 2012, Meng et. al. 2012). Since the Economic Reform of the late 1970's and during a period of sustained economic growth, the Chinese Health Care system has experienced dramatic change, transiting from a situation in which healthcare provision, as part of a centrally planned socialist system, was the governments responsibility, implemented through state owned enterprises or collective commune arrangements, to one where provision is part public and part private.

With the decline of the socialist system, while the Chinese Government still invested in urban residential health care through the Urban Employee Basic Medical Insurance (UEMBI) or the Urban Resident Basic Insurance (UREBI), the rural health system counterpart simply collapsed. As a result, Inland, primarily rural, dwellers experienced very different healthcare provision situations than did coastal, primarily urban dwellers. Despite their lower incomes, Rural residents paid a much larger share "out of pocket" for their healthcare than did their urban counterparts (Naughton 2018). In 2009 China embarked upon major healthcare reforms with the intent of providing all citizens with equal access to basic health care with reasonable quality and financial risk protection, especially for people with low socioeconomic status. It had introduced the New Rural Cooperative Medical System (NRCMS) targeting rural residents in 2003, which was merged with the UREBI system in 2016, with the aim of eliminating the rural – urban health gap. Government healthcare expenditures quadrupled from 2008 to 2017, ultimately accounting for 7.48% of its general expenditures (Tao et. al. 2020, Yip et. al. 2019). Currently about half the health care costs are covered publicly leaving considerable room for the dependence of health outcomes on income status and concomitantly very different perceptions of the seriousness of a given outcome in terms of self reported health status. In the following the impact of these alternative indices will be examined in the context of groupings based upon males and females residing in 26 inland and coastal provinces[7] in 21st century China for which there is complete health data.

3.2 Life Expectancy in China.

Data on life expectancy in these regions in the years 2000 and 2010 is drawn from the Chinese Statistical Yearbook and reported in the Appendix and respectively paired with self reported health wellness data for 2008 and 2017 (the closest matchings available). Table 1 presents a summary of the Life Expectancy statistics. Life expectancy has clearly grown over the decade and is uniformly higher across all groups, with greater range and variation in coastal regions than inland. Females have significantly higher life expectancy than males in all regions and both years (a standard error for the difference of approximately 1.2 always yields a significant z-score for the difference at usual confidence levels and sample sizes) and the gaps appear to widen over time.

Table 1. Life expectancy summary statistics.

[Insert Table 1]

Table 2. The Human Development "Long and Healthy Life" Index [1] and [2].

[Insert Table 2]

Table 2 details the results for formulae [1] and [2]. The level and inequality adjusted HDI's report superior "Long and Healthy Life" wellbeing for females over males in both coastal and inland regions in both years, with coastal regions having higher indices than inland regions. Outcomes for all groups have improved over the decade (life expectancy is advancing in all groups over time) and within group inequalities appear to be diminishing over time, having less of an impact

[7] The coastal provinces are Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, and Hainan Province. The inland provinces are Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang Province. To make it consistent with the health data, Hainan, Qinghai, Ningxia, Tibet, and Xinjiang provinces are removed in this analysis.

on the basic index so that the Inequality Adjusted Index reflects the same male-female and inland-coastal patterns as does the first order index.

Section 3.2 Self Reported Health in China.

Self reported health status data is drawn from the Chinese General Social Survey (Bian and Li, 2014) for the years 2008 and 2017 for the 26 provinces[8] for which there is complete and consistent data yielding 5366 observations in 2008 and 10908 observations in 2017. Respondents, identified by gender and provincial location, were asked to report their current health status as one of: Very Unhealthy, Relatively Unhealthy, Normal, Relatively Healthy or Very Healthy. Table 3 reports the resultant Cumulative Distribution Functions defined over these ordered categories for Inland Males, Inland Females, Coastal Males and Coastal Females and and Health Indices $HI1$ and $HI2$.

Table 3. Cumulative Densities

[Insert Table 3]

Unlike the longevity based HDI indices, females systematically report lower health status than males in the HI indices. Like the HDI indices, inland outcomes tend to be inferior to coastal outcomes. Furthermore, unlike the HDI indices, progress in health is universally downward with all groups reporting unambiguously inferior health outcomes in 2017 relative to 2008 as Table 4 attests, despite the increasing health-care expenditure from government (Yip et. al., 2019; Tao et al., 2020).

Table 4. 2017-2008 Cumulative Distribution Function Differences.

[Insert Table 4]

Noting that, if distribution A stochastically dominates distribution B at a given order and distribution B stochastically dominates distribution C, then distribution A stochastically dominates

[8] Due to data limitation, Hainan, Qinghai, Ningxia, Tibet, and Xinjiang provinces are not included in this analysis.

distribution C at that order, Table 5 provides a sequential comparison of the rank ordered distributions. The Table indicates that differences are relatively unambiguous at the second order with a worst to best ordering of A) Inland Female17, B) Inland Male17, C) InlandFemale08, D) Coastal Female17, E) Inland Male08, F) Coastal Male17, G) Coastal Female08, H) Coastal Male08.

Table 5. Stochastic Dominance of rank ordered distributions.

[Insert Table 5]

While $HI2$, the 2nd order Health index, admits a weak preference for equality of outcomes, it does not explicitly reveal the within group inequality comparisons and trends, to examine these, the PD measures for the maximal and modal categories together with $IMS(5)$ and $IMS(mode)$, the maximal and modal category focussed spread indices are employed and reported in Table 6, recall that Modal focussed measures do not reflect an equalizing upward imperative whereas Maximal focussed measures do.

Under both Highest and Modal Category focussed inequality measures, Females experience significantly more health inequality than Males in both Inland and Coastal regions in both years, with Inland groups experiencing significantly more inequality than Coastal groups. With regard to intertemporal differences reported in Table 6a, the Modal Focussed index records an insignificant reduction in health-related inequalities whereas the Highest outcome focussed index records significant increases in health inequality over the decade. Clearly, whether an equalizing upward imperative or an equalizing neutral imperative is embodied in the index matters.

Table 6. Health Inequality.

[Insert Table 6]

Table 6a. 2017-2008 subgroup differences

[Insert Table 6a]

Section 2.3 A Joint Longevity – Health Analysis.

Given the lack of concordance between longevity and health outcomes, a joint analysis is appropriate. For comparison purposes Table 7 reports the results for [6], [7] and [8] alongside the for various values of α together with their respective ranks (1 being best, 10 being worst). Note the very different rankings that emerge when $\alpha = 0$ as opposed to when $\alpha = 1$, with Coastal Males moving from 9th in the longevity ranking to 1st in the health ranking in the early years comparison and Inland Females moving from 2nd in the longevity rankings to 10th in the health rankings in the later year comparisons. This makes comparison of $\alpha = 0$ with $\alpha = 0.5$ indices even more pertinent since the $LHLI$ $(\alpha = 0)$ lays claim to being a longevity and health index without having a health component whereas $LHLI$ $(\alpha = 0.5)$ does contain both components. The differences are quite striking with a substantive downgrading of later year Inland and overall outcomes and a substantive upgrading of early year Coastal and overall outcomes. When comparison is made using the Long and Healthy Life Inequality Focussed index $LHLFI$, which attaches more weight to health inequality by modulating the HDI_1 with a health inequality index as in [8] the rankings are similar to the $LHLI$ indices.

Table 7. Combined Analysis.

[Insert Table 7]

What is most pertinent here, in the case of China, is that Life Expectancy is universally improving over time whereas perceived health in terms of self reported health outcomes is universally declining. Consequently, use of only one of the health and longevity components will fail to adequately reflect the true progress of the “Long and Healthy Life” dimension of Human Development.

Section 3. Conclusions.

The multidimensional Human Development Index relies solely upon a life expectancy measure in its “Long and Healthy Lives” component, presumably on the understanding that there is a monotonic one-to-one relationship between healthiness and longevity. Paradoxical evidence on gender diversity in the health-longevity relationship, that relative to Males, Females experience inferior health outcomes but superior longevity patterns, suggests this understanding may be misplaced. If this is the case, a multidimensional health and longevity index is called for. To explore the issue, the progress of longevity and self reported health of coastal and inland male and female groupings in over decades 21st century China was examined using new health indices and inequality measures. The new measures facilitated examining health inequalities in an ordered categorical environment where the direction of equalization, whether it was direction neutral, or whether equalizing upward so that all would ultimately experience the best outcome, was a matter of consequence. Alternative ways of amalgamating health and longevity measures were outlined and illustrated.

Evidence supporting the existence of paradox in China's case in the form of substantive differences in the ordering of groups with respect to longevity as opposed to health was revealed. While females experienced superior longevity, males experienced superior health outcomes and coastal outcomes tended to be superior to inland outcomes for both genders. Indeed, females uniformly experience significantly more health outcome inequality than males in both Inland and Coastal regions with greater inequality in inland regions and when focussed on highest outcome objectives, inequality is seen to have increased over the decade. Furthermore, whereas longevity increased over a decade for all groups, health outcomes diminished for all groups and assuming separability in health and longevity, a "Long and Healthy Life" indices were formed which generated substantially different orderings from the corresponding component of the Human Development Index, this was even more so the case when fit for purpose focussed inequality measures reflecting an upward equalizing imperative were employed.

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Table 1. Life expectancy summary statistics.

Region	Statistics	2000			2010		
		overall	male	female	overall	male	female
Coastal	Maximums	78.1400	76.2200	80.0400	80.2600	78.2800	82.4400
	Minimums	65.4900	64.2400	66.8900	69.5400	67.0600	72.4300
	Means	73.2077	71.2315	75.3354	76.3823	74.0685	78.9708
	Std devs.	2.9684	2.8618	3.0915	2.7650	3.0344	2.4766
Inland	Maximums	73.1000	71.3800	75.0400	76.1800	74.1200	78.8100
	Minimums	65.9600	64.5400	67.5700	71.1000	68.4300	74.0600
	Means	70.4585	68.9423	72.1438	74.5354	72.2600	77.1254
	Std devs.	2.0108	1.7442	2.4003	1.4132	1.4280	1.4813
Overall	Maximums	78.1400	76.2200	80.0400	80.2600	78.2800	82.4400
	Minimums	65.4900	64.2400	66.8900	69.5400	67.0600	72.4300
	Means	71.8331	70.0869	73.7396	75.4588	73.1642	78.0481
	Std devs.	2.8523	2.5988	3.1625	2.3485	2.4998	2.2097

Table 2. The Human Development “Long and Healthy Life” Index [1] and [2].

Region	Index	2000			2010		
		overall	male	female	overall	male	female
Coastal	HDI	0.8186	0.7882	0.8513	0.8674	0.8318	0.9072
	Atkinson Inequality	0.0008	0.0008	0.0008	0.0006	0.0008	0.0005
	IHDI	0.8179	0.7876	0.8506	0.8669	0.8312	0.9068
Inland	HDI	0.7763	0.7530	0.8022	0.8390	0.8040	0.8789
	Atkinson Inequality	0.0004	0.0003	0.0005	0.0002	0.0002	0.0002
	IHDI	0.7760	0.7527	0.8018	0.8389	0.8039	0.8787
Overall	HDI	0.7974	0.7706	0.8268	0.8532	0.8179	0.8930
	Atkinson Inequality	0.0008	0.0007	0.0009	0.0005	0.0006	0.0004
	IHDI	0.7968	0.7701	0.8260	0.8528	0.8175	0.8927

Table 3. Cumulative Densities

		Very Unhealthy	Relatively Unhealthy	Normal	Relatively Healthy	Very Healthy	$HI1$	$HI2$
2008	overall	0.0253	0.1400	0.3936	0.7538	1.0000	0.9174	0.9352
	InlandM	0.0296	0.1420	0.4248	0.7590	1.0000	0.9029	0.9235
	InlandF	0.0387	0.2063	0.4637	0.7872	1.0000	0.8549	0.8816

	CoastalM	0.0126	0.0863	0.2832	0.6945	1.0000	0.9981	0.9993
	CoastalF	0.0103	0.0829	0.3430	0.7502	1.0000	0.9606	0.9759
2017	overall	0.0418	0.1992	0.4622	0.8168	1.0000	0.8467	0.8779
	InlandM	0.0558	0.2363	0.4963	0.8268	1.0000	0.8142	0.8479
	InlandF	0.0617	0.2798	0.5303	0.8550	1.0000	0.7761	0.8161
	CoastalM	0.0174	0.1090	0.3592	0.7612	1.0000	0.9399	0.9574
	CoastalF	0.0255	0.1463	0.4384	0.8116	1.0000	0.8802	0.9109
Utopian CDF		0.0103	0.0829	0.2832	0.6945	1.0000		
Dystopian CDF		1.0000	1.0000	1.0000	1.0000	1.0000		
Utopian CCDF		0.0103	0.0932	0.3821	1.0766	2.0766		
Dystopian CCDF		1.0000	2.0000	3.0000	4.0000	5.0000		

Table 4. 2017-2008 Cumulative Distribution Function Differences.

Category	Very Unhealthy	Relatively Unhealthy	Normal	Relatively Healthy	Very Healthy	$1-AM$ 1st order dominance Test
inlandM	0.0262	0.0943	0.0715	0.0678	0.0000	1.0000
InlandF	0.0230	0.0735	0.0666	0.0678	0.0000	1.0000
CoastalM	0.0048	0.0227	0.0760	0.0667	0.0000	1.0000
CoastalF	0.0152	0.0634	0.0954	0.0614	0.0000	1.0000

Table 5. Stochastic Dominance of rank ordered distributions.

	A v B	B v C	C v D	D v E	E v F	F v G	G v H
1st Order $1-AM1$	1.0000	1.0000	0.6029	0.8901	0.9611	1.0000	0.9059
2nd Order $1-AM2$	1.0000	1.0000	1.0000	0.9457	1.0000	1.0000	0.9432

Table 6. Health Inequality.

Year	Cat	$PD(5)$ (StdEr)	$PD(mode)$ (StdEr)	$IMS(5)$ (StdEr)	$IMS(mode)$ (StdEr)
2008	All	0.7538 (0.0029)	0.6398 (0.0033)	0.3282 (0.0071)	0.4843 (0.0111)
	In M	0.7590 (0.0029)	0.6658 (0.0032)	0.3388 (0.0072)	0.4963 (0.0109)
	In F	0.7872 (0.0028)	0.6765 (0.0032)	0.3740 (0.0076)	0.5059 (0.0107)
	Co M	0.6945 (0.0031)	0.5887 (0.0034)	0.2692 (0.0065)	0.4718 (0.0118)
	Co F	0.7502 (0.0030)	0.5928 (0.0034)	0.2966 (0.0063)	0.4446 (0.0112)
2017	All	0.8168 (0.0026)	0.6454 (0.0033)	0.3800 (0.0074)	0.4746 (0.0107)
	In M	0.8268 (0.0026)	0.6695 (0.0032)	0.4038 (0.0077)	0.4944 (0.0106)

	In F	0.8550	(0.0024)	0.7495	(0.0030)	0.4317 (0.0078)	0.4955	(0.0105)
	Co M	0.7612	(0.0029)	0.5980	(0.0033)	0.3117 (0.0067)	0.4500	(0.0112)
	Co F	0.8116	(0.0027)	0.6268	(0.0033)	0.3555 (0.0069)	0.4506	(0.0106)

Table 6a. 2017-2008 subgroup differences

Cat	$1-f_5$			$1-f_{Mode}$			$IMS(5)$			$IMS(mode)$		
	Diff	Std Err	"Z"	Diff	Std Err	"Z"	Diff	Std Err	"Z"	Diff	Std Err	"Z"
All	0.0630	0.0040	15.9326	0.0056	0.0046	1.2099	0.0518	0.0103	5.0365	-0.0098	0.0154	-0.6336
In M	0.0678	0.0039	17.3841	0.0037	0.0045	0.8133	0.0650	0.0106	6.1486	-0.0019	0.0152	-0.1267
In F	0.0678	0.0037	18.3878	0.0730	0.0044	16.7630	0.0577	0.0109	5.3056	-0.0104	0.0150	-0.6926
Co M	0.0667	0.0043	15.5604	0.0093	0.0047	1.9604	0.0425	0.0093	4.5734	-0.0218	0.0163	-1.3429
Co F	0.0614	0.0040	15.4116	0.0340	0.0047	7.2211	0.0589	0.0093	6.2955	0.0060	0.0155	0.3849

Table 7. Combined Analysis.

Year	Cat	$\alpha=0$				$\alpha=1$				$\alpha=0.5$				$\alpha=0.5$	
		HDI_1	rank	$IHDI_1$	rank	$HI1$	rank	$HI2$	rank	$LHLI1$	rank	$LHLI2$	rank	$LHLFI$	rank
2000/08	All	0.7974	8	0.7968	8	0.9174	4	0.9352	4	0.8553	5	0.8632	6	0.7744	5
	In M	0.7530	10	0.7527	10	0.9029	5	0.9235	5	0.8245	9	0.8337	9	0.7478	8
	In F	0.8022	7	0.8018	7	0.8549	7	0.8816	7	0.8281	7	0.8407	8	0.7522	7
	Co M	0.7882	9	0.7876	9	0.9981	1	0.9993	1	0.8869	3	0.8871	4	0.8002	3
	Co F	0.8513	4	0.8506	4	0.9606	2	0.9759	2	0.9043	1	0.9111	1	0.8132	1
2010/17	All	0.8532	3	0.8528	3	0.8467	8	0.8779	8	0.8499	6	0.8653	5	0.7669	6
	In M	0.8040	6	0.8039	6	0.8142	9	0.8479	9	0.8091	10	0.8256	10	0.7318	10
	In F	0.8789	2	0.8787	2	0.7761	10	0.8161	10	0.8259	8	0.8468	7	0.7446	9
	Co M	0.8318	5	0.8312	5	0.9399	3	0.9574	3	0.8842	4	0.8920	3	0.7962	4
	Co F	0.9072	1	0.9068	1	0.8802	6	0.9109	6	0.8936	2	0.9089	2	0.8032	2

Appendix: Life Expectancy Data

Province	Coastal (1) / Inland (0)	2000			2010		
		overall	male	female	overall	male	female
Beijing	1	76.1000	74.3300	78.0100	80.1800	78.2800	82.2100
Tianjin	1	74.9100	73.3100	76.6300	78.8900	77.4200	80.4800
Hebei	1	72.5400	70.6800	74.5700	74.9700	72.7000	77.4700

Shanxi	0	71.6500	69.9600	73.5700	74.9200	72.8700	77.2800
InnerMongolia	0	69.8700	68.2900	71.7900	74.4400	72.0400	77.2700
Liaoning	1	73.3400	71.5100	75.3600	76.3800	74.1200	78.8600
Jilin	0	73.1000	71.3800	75.0400	76.1800	74.1200	78.4400
Heilongjiang	0	72.3700	70.3900	74.6600	75.9800	73.5200	78.8100
Shanghai	1	78.1400	76.2200	80.0400	80.2600	78.2000	82.4400
Jiangsu	1	73.9100	71.6900	76.2300	76.6300	74.6000	78.8100
Zhejiang	1	74.7000	72.5000	77.2100	77.7300	75.5800	80.2100
Anhui	0	71.8500	70.1800	73.5900	75.0800	72.6500	77.8400
Fujian	1	72.5500	70.3000	75.0700	75.7600	73.2700	78.6400
Jiangxi	0	68.9500	68.3700	69.3200	74.3300	71.9400	77.0600
Shandong	1	73.9200	71.7000	76.2600	76.4600	74.0500	79.0600
Henan	1	71.5400	69.6700	73.4100	74.5700	71.8400	77.5900
Hubei	0	71.0800	69.3100	73.0200	74.8700	72.6800	77.3500
Hunan	0	70.6600	69.0500	72.4700	74.7000	72.2800	77.4800
Guangdong	1	73.2700	70.7900	75.9300	76.4900	74.0000	79.3700
Guangxi	1	71.2900	69.0700	73.7500	75.1100	71.7700	79.0500
Hainan	0	71.7300	69.8400	73.8900	75.7000	73.1600	78.6000
Sichuan	0	71.2000	69.2500	73.3900	74.7500	72.2500	77.5900
Guizhou	0	65.9600	64.5400	67.5700	71.1000	68.4300	74.1100
Yunnan	1	65.4900	64.2400	66.8900	69.5400	67.0600	72.4300
Shaanxi	0	70.0700	68.9200	71.3000	74.6800	72.8400	76.7400
Gansu	0	67.4700	66.7700	68.2600	72.2300	70.6000	74.0600