RESEARCH ARTICLE

On Standard of Living and Infant Survival in Some East African Countries

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Received: 13 September 2019 **Accepted:** 14 November 2019 **Available online:** 28 December 2019

ABSTRACT

To summarize the extent of infant survival in a country, three indices have been defined. The first one is the complement to 1000 of the infant mortality rate (expressed in per thousand births). The second one takes into account the inequality in infant survival rates between population subgroups. The third indicator adjusts the average infant survival rate by giving more weight to a population subgroup with a lower socio-economic status. The computation of the last two indicators requires the use of an inequality index and a concentration ratio. We used two measures of inequality, the Gini index and the Bonferroni index, as well as two concentration ratios, derived from the Gini index and related to the Bonferroni index. A short empirical illustration, based on seven East African countries, confirms the usefulness of the approach presented in this paper.

Keywords: Bonferroni index, East Africa, Gini index, Gini concentration ratio, Infant mortality

JEL Classification: D31, D63, I14, I15, I31

1. INTRODUCTION

In the State of East Africa 2012 report, a comprehensive survey prepared by the Society for International Development (SID), inclusiveness is assumed to refer to how much the most disadvantaged East Africans are participating in the process of economic growth. "From this perspective, focusing on an average metric such as per capita GDP, to evaluate inclusiveness leads to misleading conclusions. Furthermore, average changes do not say anything about what is happening to the first and last person in the income distribution. Equity describes how the fruits of economic growth are shared among the region's citizens. Recent analysis shows that inequality is really about the share of income that goes to the richest (top 10 per cent of the population) and the poorest citizens (bottom 40 per cent of the population). Simply stated, inequality is about what is happening at the tail ends of a country's income distribution" (Executive Summary of the State of East Africa Report 2012).

Access this article online

DOI:10.25079/ukhjss.v3n2y2019.pp56-67 **e-ISSN:** 2520-7806

However, did this decrease in infant mortality affect all strata of the population equally. Studies of the link between the standard of living and infant mortality in East Africa are rather scarce. A recent paper by Odwe et al. 2017, takes a detailed look at the reasons for the decline of infant mortality in Kenya during the first decade of the 21st century, but it stresses more issues related to over- or under-estimation of infant mortality than the impact of socioeconomic factors. The purpose

of this paper is to check the extent to which infant mortality is related to the standard of living of the households/individuals. Using data from the Demographic and Health Surveys that appear in aggregate form on the World Health Organization website, we define indices taking into account the impact of standard of living on infant survival.

Several of the proposed measures, at least those related to the Gini index of inequality and more precisely to the index's concentration ratio, have appeared previously in the literature. We, however, also introduce measures derived from the less known Bonferroni index of inequality. All these measures are then applied to data concerning seven East African countries: Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Rwanda, and Uganda.

The paper is organized as follows: Section 2 summarizes the various ways of measuring inequalities in health, making a distinction between a univariate and bivariate approach to this topic. While the former simply measures inequality in health, using some inequality index, the latter considers the correlation that may exist between standard of living and health. Section 3 gives an empirical illustration based on data from the seven East African countries. Concluding comments are given in Section 4.

2. MEASURING INEQUALITIES IN HEALTH

The term "health inequalities" is measured in two ways (see, Wolfson and Rowe, 2001). The first one looks only at health and analyzes the inequality of the distribution using some health variables such as the size of individuals or the level of their nutrition. A second approach focuses on a bivariate distribution, for example, that of health and income. This section also defines three types of health achievements. Assuming that the health indicator is infant survival (the complement to 1000 of infant mortality), this paper makes a distinction between the average value, in the whole population, of infant survival, an indicator correcting this average value by taking into account the inequality existing between subpopulations, and finally an indicator of infant survival giving greater weight to infant survival among a population subgroup with lower standard of living. For each country in different years, values of the various measures previously described are given, a distinction being made between indicators derived from the Gini index (Table 1) and those related to the Bonferroni index (Table 2).

2.1. A univariate approach to health inequality measurement

2.1.1. Measuring health inequality using the Gini index

Let h be a vector whose elements h_i refer to some measure of the health of individual *i* (such as the size of an individual or his/her weight). Assume there are n individuals in the population analyzed and call e' a row vector whose elements are all equal to $(1/n)$. Let G be a squared n by n matrix, called G-matrix (see, Silber, 1989), whose typical element g_{ij} will be equal to 0 if $i = j$, to -1 if $j \succ i$, and to +1 if $j \prec i$. Let us also define a column vector s whose typical element s_i is equal to $(h_i / \sum_{i=1}^{n} h_i)$, these elements being ranked by decreasing values of h_i. We can now measure inequality in health as we measure income inequality and define, for example, the Gini index I_G of health inequality as the product (see, Silber, 1989).

$$I_G = e'Gs \qquad (1)$$

Berrebi and Silber, 1987, have proven that this Gini index could be also expressed as follows:

$$I_G = (2)\left[\left(\frac{1}{n}\right)\sum_{i=1}^{n}\left[S_i - \left(\frac{1}{n}\right)\right]\left[\left(\frac{n+1}{2}\right) - i\right]\right] \qquad (2)$$

that is, as twice the covariance between the ranks and the shares in total health of the individuals. Note that expression (2) may be also written as:

$$I_G = (2/n)\{[((n+1)/2)] - [n((1/n)((n+1)/2)] - [\sum_{i=1}^{n} is_i] + [(1/n)n((n+1)/2)]\}$$

$$= (2/n)\{[((n+1)/2)] - [\sum_{i=1}^{n}(h_i/n\bar{h})i]\} = ((n+1)/n) - [(2/(n\bar{h}))\sum_{i=1}^{n} h_i(i/n)$$

$$= [1 - (2/(n\bar{h}))\sum_{i=1}^{n} h_i(r_i)] + (1/n) \qquad (5)$$

where $\bar{h}$ is the average level of health in the population and $r_i = (i/n)$ is the relative (or "fractional") rank of individual i.

Using expression (3) we then derive the following:

$$I_G \approx [1 - (2/(n\bar{h}))\sum_{i=1}^{n} h_i(r_i)] \qquad (4)$$

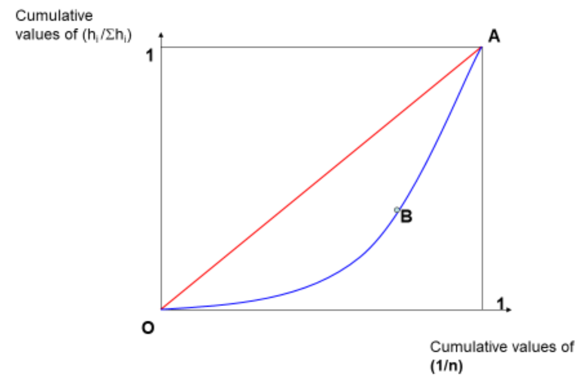
as $n \rightarrow \infty$.

It is easy to conclude (see Wagstaff and van Doorslaer, 2002) that if one measures "ill-health," then the Gini index of "ill-health" will be expressed, when $n \rightarrow \infty$, as:

$$I_G \approx [(2/(n\bar{h}))\sum_{i=1}^{n} h_i(r_i)] - 1 \qquad (5)$$

It is also possible to give a graphical interpretation of this Gini index of health inequality. Plot on the horizontal axis the cumulative values of (1/n), that is, plot the shares (i/n) with i varying from 1 to n. On the vertical axis, plot the cumulative values of the shares S_i that were defined previously, these shares being ranked by increasing values of h_i. One then obtains a curve that will start at point (0,0) and end at point (1,1). It can be shown that this curve, called a Lorenz curve (see Graph 1), has a non-decreasing slope and that the Gini index of health inequality is equal to twice the area lying between this Lorenz curve and the diagonal (the 45-degree line defined previously).

Graph 1:
The Lorenz Curve



Clearly the Gini index I_G will be equal to 0 when all individuals have the same health level h_i, in which case the Lorenz curve will be identical to the diagonal OA.

2.1.2. Measuring health inequality using the Bonferroni index

The Gini index is not the only index that can be used to measure health inequality. One interesting inequality index is the so-called Bonferroni index I_B (see Bonferroni, 1930; Tarsitano, 1990; and Chakravarty, 2007) which, in the case of health inequality, is defined as follows:

$$I_B = \{[(1/n)\sum_{i=1}^{n} h_i] - [(1/n)\sum_{i=1}^{n}(1/i)\sum_{j=1}^{i} h_j]\}/[(1/n)\sum_{i=1}^{n} h_i \qquad (6)$$

assuming that $0 \leq h_1 \leq \ldots \leq h_n$.

Bárcena-Martin and Silber, 2013, have proven that the Bonferroni index could also be expressed as follows:

$$I_B = e'Bs \qquad (7)$$

where e' is a 1 by n row vector of the n individual population shares which are evidently all equal to $(1/n)$ and B, henceforth called the B-matrix or Bonferroni matrix, is defined as:

$$B = \begin{bmatrix} 0 & n/2 & n/3 & \ldots & n/i & \ldots & n/(n-1) & n/n \\ -n/2 & 0 & n/3 & \ldots & n/i & \ldots & n/(n-1) & n/n \\ -n/3 & & 0 & \ldots & n/i & \ldots & n/(n-1) & n/n \\ \ldots & & & \ldots & \ldots & \ldots & n/(n-1) & n/n \\ -n/i & -n/i & -n/i & \ldots & 0 & \ldots & n/(n-1) & n/n \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ -n/(n-1) & -n/(n-1) & -n/(n-1) & \ldots & -n/(n-1) & \ldots & 0 & n/n \\ -n/n & -n/n & -n/n & \ldots & -n/n & \ldots & -n/n & 0 \end{bmatrix} \qquad (8)$$

Note that the B-matrix may be defined as follows: assuming that i refers to the line and j to the column, its typical element b_{ij} is equal to 0 if $i = j$, to $-(n/i)$ if $j \prec i$, and to (n/j) if $j \succ i$. This clearly implies that $b_{ij} = -b_{ji}$ for $i \neq j$.

There exists also a graphical device to derive the Bonferroni index. Let us plot on the horizontal axis the cumulative population shares $[(1/n),(2/n),...,((n/n)=1)]$. On the vertical axis, we plot the ratio of the cumulative health shares divided by the cumulative population shares, the individuals being ranked by increasing health h_i. In other words, on the vertical axis we plot the values:

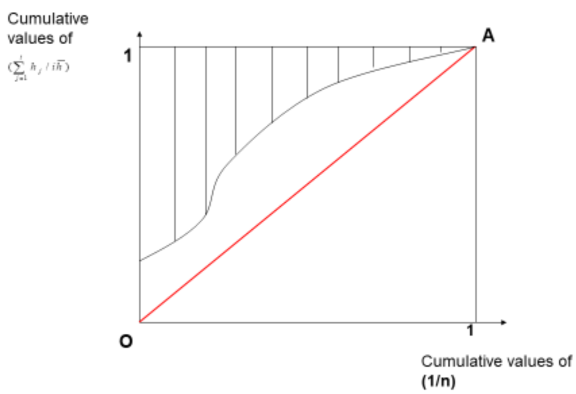
$$\left\{\left[(h_1/n\bar{h})/(1/n)\right],\left[\left(\left((h_1+h_2)/n\bar{h}\right)/(2/n)\right)\right],\ldots,\left[\left((h_1+h_2+\cdots+h_n)/(n\bar{h})\right)/(n/n)\right]\right\},$$

that is, the cumulative values $(h_1/\bar{h}),\left(((h_1+h_2)/2)/\bar{h}\right),\ldots,\left(((h_1+h_2+\cdots+h_n)/n)/\bar{h}\right)$,

where $\bar{h}$ is the average health level in the population.

The Bonferroni index I_B is then defined as the area lying above the Bonferroni curve (see Graph 2) in the one by one square defined by the two sets of cumulative values (see Tarsitano, 1990).

Graph 2:
The Bonferroni Curve



Aaberge, 2007, stressed several attractive properties of the Bonferroni index or what he called "scaled conditional mean curve" which is just another name for the Bonferroni (1930) curve. He thus stressed that the Bonferroni curve which, like the Lorenz curve, is bounded by half of the unit square and is also strongly related to the shape of the underlying distribution curve F: when F is convex (strongly skewed to the left), the Bonferroni curve is concave and when F is concave (strongly skewed to the right), the Bonferroni curve is convex. Aaberge, 2007, also proved that the Bonferroni index satisfies the principle of diminishing transfers (see Kolm, 1976; Shorrocks and Foster, 1987) for all strictly log-concave distributional functions and the principle of positional transfer sensitivity (see Mehran, 1976) for all distributional functions. Finally, the Bonferroni index may also be interpreted in terms of relative deprivation (see Chakravarty, 2007).

2.2. The bivariate approach to health inequality measurement

2.2.1. The bivariate approach and Gini's Concentration index

Let now y be a vector whose elements y_i refer to some measure of the standard of living of individual i (e.g., her/his income). We can now define the concentration index (for more details on this concept, see Kakwani, 1980) C_G as the product:

$$C_G = e'G\tilde{s} \tag{9}$$

where $\tilde{s}$ is the column vector of the health shares s_i, the latter being now classified by decreasing values of y_i rather than h_i. Here also it can be shown (see, O'Donnell et al., 2008) that C_G in expression (9) may be expressed as:

$$C_G = (2/\bar{h})Cov(h_i,\tilde{r}_i) \tag{10}$$

where Cov refers to the covariance between health and income and $\tilde{r}_i = (i/n)$ is the fractional rank of individual i in the distribution of the standard of living y_i, the individuals being ranked this time by increasing values of y_i.

Here again it is possible to give a graphical interpretation, called Gini concentration curve, to this concentration index. As before, plot on the horizontal axis the cumulative values of $(1/n)$, that is, plot the shares (i/n) with i varying from 1 to n. On the vertical axis, plot the cumulative values of the shares s_i that were defined previously, these shares being ranked by increasing values of y_i. One then obtains a curve that will start at point (0,0) and end at point (1,1). It can be shown that if this curve lies mostly under the 45-degree line joining the points (0,0) and (1,1), the concentration index C_G will be positive, indicating that as a whole health increases with the standard of living. If, on the contrary, this curve lies mostly above the 45-degree line, C_G will be negative, indicating that health decreases with the standard of living. C_G will be equal to 0 either when all individuals have the same health level h_i, whatever their standard of living y_i, or when the sum of the areas lying below the 45-degree line is exactly equal to the sum of areas lying above the 45-degree line (the concentration curve, although increasing, can clearly cut several times the 45-degree line). It can be proven that the concentration index C_G is in fact equal to the sum of the areas lying between the concentration curve and the 45-degree line, the areas below the 45-degree line being given a positive sign and those above this line being given a negative sign.

Here also, when n is big enough ($n \to \infty$), the concentration index may be expressed as (see Wagstaff and van Doorslaer, 2002):

$$C_G \approx [(2/\bar{h})\sum_{i=1}^{n} h_i \tilde{r}_i] - 1 \qquad (11)$$

where $\tilde{r}_i$ is individual's i fractional rank in the distribution of the standard of living indicator y_i, this indicator being ranked by increasing values.

Note (see O'Donnell et al., 2008) that expression (11) may also be written as:

$$C \approx 1 - \{(2/n\bar{h})\sum_{i=1}^{n} h_i (1-\tilde{r}_i)\} \qquad (12)$$

Using Yitzhaki's, 1983, ideas on the extension of the Gini index, we can also define an *extended concentration index* (see O'Donnell et al., 2008) written as $C(\nu)$:

$$C_G(\nu) = 1 - \{(\nu/n\bar{h})\sum_{i=1}^{n} h_i (1-\tilde{r}_i)^{(\nu-1)}\} \qquad (13)$$

with $\nu \succ 1$.

It is easy to observe that when ν, the *inequality aversion parameter*, is equal to 2, one obtains the definition of the concentration index given in (11).

Note that when one works with grouped data, expression (12) will be written (see O'Donnell et al., 2008) as:

$$C \approx 1 - \{(\nu/\bar{h})\sum_{t=1}^{T} f_t h_t (1-\tilde{r}_t)^{(\nu-1)} \qquad (14)$$

where f_t refers to the share of group *t* in the population (sample), h_t is the average level of health in the t[th] group and $\tilde{r}_t$ is the fractional rank of group *t* and is defined (see O'Donnell et al., 2008) as:

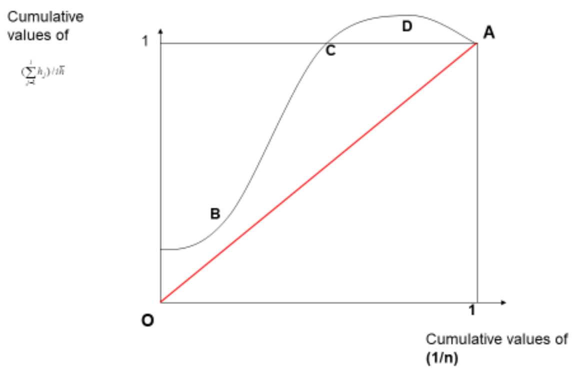
$$\tilde{r}_t = \sum_{k=1}^{t-1} f_k + (1/2) f_k \qquad (15)$$

2.2.2. *Implementing the bivariate approach on the basis of the Bonferroni index*

We can also try to define a "Bonferroni concentration index" C_B. This time, however, the "conditional means" would be based on a ranking of the health variable by increasing income rather than by increasing values of the health variable.

To compute this "Bonferroni concentration index," we could also draw a graph (see Graph 3) called a "Bonferroni concentration curve." Note that this curve may at times lie above the equality line (horizontal line at height 1) and, in such a case, the area above such an equality line would be given a negative sign.

Graph 3:
The Bonferroni Concentration Curve



2.3. Measuring Health Achievements

2.3.1. *Health achievement as a measure of welfare*

Following earlier work by Kolm, 1968, and Atkinson, 1970, Sen, 1974, suggested an index of welfare combining per capita income and the inequality of incomes. This index corresponds to the concept of "equally distributed equivalent level of income" proposed by Atkinson, 1970, a notion identical to that of "equal equivalent income" defined by Kolm, 1968. The "equally distributed equivalent level of income" is in fact equal to the product of the average income times the complement to one of the inequality index (e.g., Gini or the Atkinson indices of inequality) which can be derived from the social welfare function selected by some social planner.

An extension of this idea to the field of health was proposed by Silber, 1983, who defined what he called "the equivalent length of life." Silber, 1983, suggested using the "equivalent length of life" as a measure of development, on the basis of a recommendation made by Hicks and Streeten, 1979, to use life expectancy as a measure of development because "…some measure of health, such as life expectancy at birth, would be a good single measure of basic needs."

Calling $\bar{l}$ the life expectancy at birth and $I(l)$ some measure of the inequality of the durations of life (life expectancy corresponds evidently to the average duration of life) derived from a life table, Silber defined the "equivalent length of life" ELL as:

$$ELL = \bar{l}[1 - I(l)] \tag{16}$$

As indices of inequality in the durations of life (for a very recent survey of length of life inequality in the world, see Smits and Monden, 2009), one may use, as proposed by Silber, 1983, those suggested by Atkinson, 1970, or Kolm, 1976. One can also use the Gini index, as was stressed by Silber, 1988.

While the "equivalent length of life" was originally introduced as a measure of development, it can naturally be used also as a measure of health achievement (see Kolm, 2002, for a thorough analysis of the application of concepts of justice to the domain of health). Expression (16) may in fact be applied to any indicator of health and will then measure health achievement on the basis of such an indicator. One would then assume that a measure of health achievement should be an increasing function of the average level of the health indicator selected and a decreasing function of the degree of inequality of the distribution of this health indicator. This would in fact imply that in computing the measure of health achievement, the weight of an individual would be higher, the lower the value for this individual of the health indicator selected.

First graphical interpretation: The Generalized Lorenz Curve

We know that in the case of income inequality analysis, the Lorenz curve is obtained by plotting on the horizontal axis the cumulative population shares and on the vertical axis the cumulative income shares. If, on the vertical axis, we now multiply the product of the cumulative income shares by the average income, we will obtain what has been called a *Generalized Lorenz curve* (see Shorrocks, 1983). This curve will therefore start at point (0,0) and end at point $(1,\bar{x})$ where $\bar{x}$ is the average income. As the area lying between the diagonal and a Lorenz curve is known to be equal to half the Gini index I_G, the area lying between a generalized Lorenz curve and a line starting at point (0,1) and ending at point $(1,\bar{x})$, will be equal to half the product $\bar{x}I_G$. As a consequence, the area lying below a generalized Lorenz curve will be equal to half the product $\bar{x}(1-I_G)$.One may remember that Sen, 1974, suggested, in fact, to use the product $x_{EG}=\bar{x}(1-I_G)$ as a measure of welfare.

One can naturally apply the concept of generalized Lorenz curve to measure the welfare derived from some health attainment. Such a welfare measure x_{EG} would in fact give a greater weight to an individual, the lower the level of his or her health.

A second graphical interpretation: Defining a generalized Bonferroni curve

We can similarly derive a generalized Bonferroni curve. In the case of health, one would plot on the horizontal axis the cumulative population shares and on the vertical axis the cumulative values $\{(h_1),((h_1+h_2)/2),...,((h_1+h_2+...+h_n)/n)\}$. Such a generalized Bonferroni curve, like the generalized Lorenz curve, will start at point (0,1) and end at point $(1,\bar{h})$. As the Bonferroni index I_B is equal to the area lying above the Bonferroni curve, the area lying above the generalized Bonferroni curve will be equal to $B\bar{h}$ and therefore the area lying below the generalized Bonferroni curve will be equal to $h_{EB}=\bar{h}-B\bar{h}=\bar{h}(1-B)$. The measure h_{EB} can therefore be considered a measure of welfare similar to the index x_{EG} defined by Sen, 1974. This measure h_{EB} gives in fact a greater weight to an individual, the lower the level of his health.

However, one may think of an alternative approach, one where the weight of an individual, when measuring health-related welfare, would be higher, the lower his/her income, rather than the lower his/her health. This is in fact the approach taken by Wagstaff, 2002, in his definition of health achievement. We will call such an approach the pro-poor approach to the measurement of health achievement.

2.3.2. A pro-poor approach to the measurement of health achievement

Using what was defined previously as the bivariate approach to health inequality measurement, Wagstaff, 2002, proposed to define health achievement as the weighted average of the health levels of the various individuals, the weights being higher, the poorer the individual. More precisely the health achievement A_ν is defined as follows:

$$A_\nu=(1/n)\sum_{i=1}^{n}h_i\nu(1-\tilde{r}_i)^{(\nu-1)} \qquad (17)$$

and it can be proven (see Wagstaff, 2002) that

$$A_\nu=\bar{h}(1-C_G(\nu)) \qquad (18)$$

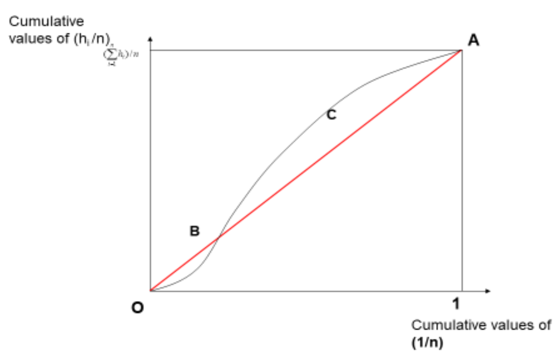
Note that if h_i refers to "ill-health," so that higher values of A_ν refer to a worse situation, and if the concentration ratio $C(\nu)$ is negative (implying that ill health is higher among the poor), we will end up with an achievement index A_ν which will be higher than $\bar{h}$. In other words, health achievement turns out to be worse than what we would have concluded on the basis of only the mean level of "ill-health" $\bar{h}$.

A relevant illustration of health outcomes in the present case could be, for example, the hemoglobin levels expressed in grams per deciliter (g/dl). Maasoumi and Lugo, 2008, used this indicator in their analysis of multivariate poverty in Indonesia, the reason being that low levels of hemoglobin indicate deficiency of iron in the blood, and iron deficiency is thought to be the most common nutritional deficiency in the world today (see Thomas et al., 2003, p. 4). Given that normal values of hemoglobin depend on sex, age, altitude, and eventually also on the ethnic group to which the individual belongs, one generally has to use adjusted individual values of levels of hemoglobin.

A graphical interpretation: Defining a generalized Gini concentration curve

In the same way as we derived generalized Lorenz curves, we can now derive generalized Gini concentration curves. We simply have to order the vertical coordinates of the generalized Lorenz curves not by increasing values of the health variable but by increasing income (see Graph 4). It is then easy to derive that the area under such a generalized Gini concentration curve will be equal to half the product $\bar{h}(1 - C_G)$. One may then observe that this product $\bar{h}(1 - C_G)$ is in fact identical to what we labeled before the health achievement index A_2.

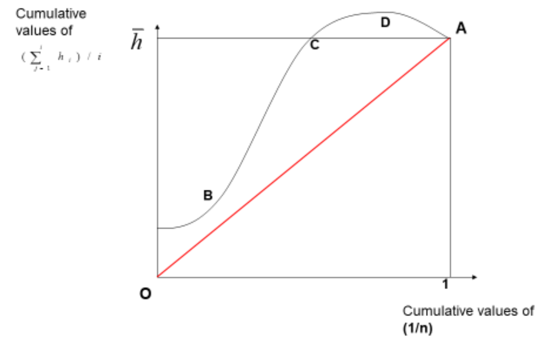
Graph 4:
The Generalized Gini Concentration Curve



A second graphical interpretation: The generalized Bonferroni concentration curve

One can similarly show (see Graph 5) that the area under a generalized Bonferroni concentration curve will be equal to the product $\bar{h}(1 - C_B)$. This product is, in the case of health, evidently identical to the health achievement index A_B that was previously defined.

Graph 5:
The Generalized Bonferroni Concentration Curve



3. AN EMPIRICAL ILLUSTRATION: SURVIVAL RATES AND SURVIVAL GROWTH RATES IN SEVEN EAST AFRICAN COUNTRIES

The database on which the empirical investigation is based is the Health Equity Monitor of the Global Health Observatory Data Repository of the World Health Organization (see W.H.O., 2015a). The health indicator we use (infant mortality, from which we derive infant survival) and the dimension of inequality we analyze (socioeconomic status) were originally obtained from Demographic and Health Surveys (DHS) and Multiple Indicator Cluster Surveys (MICS). DHS and MICS are large-scale, nationally representative household health surveys that are routinely conducted in low- and middle-income countries. Standardized questionnaires are used to collect information through face-to-face interviews with women aged 15 to 49 years. These surveys provide all the data required for health inequality monitoring. DHS and MICS data have high comparability between settings and over time (for more details, see W.H.O., 2015b).

Economic status is described in terms of a household wealth index. Country-specific indices were based on owning selected assets and having access to certain services, and constructed using principal component analysis. Within each country, the index was used to create quintiles, thereby identifying five equal subgroups, each accounting for 20% of the population.

In Table 1, we compute for seven East African countries (Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Rwanda, and Uganda) during various years, the five Gini-related indicators defined previously. These are the Gini index I_G of inequality of survival rates, the Gini Concentration ratio C_G of survival rates, the average survival rate $\bar{h}$ (per thousand), the "equivalent survival rate" h_{EG} (per thousand), and the "pro-poor survival rate" $A_2 = \bar{h}(1 - C_G)$ (per thousand).

First, as far as the Gini index of survival rates is concerned, we observe that the values of the Gini index are much lower than those observed when analyzing income inequality. The highest value equal to 0.018 is observed for Mozambique in 1997. Hence, it is clear that differences in survival rates between the five socioeconomic groups distinguished are relatively small. Also note that the Gini index of survival rates generally decreased over time but there are exceptions. Thus, there was some increase in Ethiopia between 2005 and 2011, in Rwanda between 2000 and 2005, and in Uganda between 2000 and 2006.

Second, as far as Gini's concentration ratio is concerned, we see that it is almost always positive, indicating that infant survival is higher if the economic status of the subpopulation (quintile) is also higher. The only exceptions are Ethiopia and Uganda in 2000 where the concentration ratio is negative but extremely small in absolute value.

Third, the average survival rate increased regularly over time in all countries except Kenya. In Ethiopia, the survival rate increased by 4.5% between 2000 and 2011. In Madagascar, between 1997 and 2008, there was an increase of 4.7%. The increase in Malawi between 2000 and 2010 was 3.2% while, between 1997 and 2011, it was 8% in Mozambique. In Rwanda, between 2000 and 2010, the increase was equal to 6.6% while it was equal to 2.4% in Uganda between 1995 and 2011. Finally, in Kenya there was a decrease between 1993 and 2003 but between 1993 and 2008 there was still a small increase (0.3%) in the infant survival rate.

If we now compute the rate of increase in what we called the equivalent growth rate h_{EG}, we observe that the increase was of 4.9% in Ethiopia between 2000 and 2011, of 5.7% in Madagascar between 1997 and 2008, of 5.1% in Malawi between 2000 and 2010, of 9.5% in Mozambique between 1997 and 2011, of 7.2 in Rwanda between 2000 and 2010, of 2.8% in Uganda between 1995 and 2011, and of 0.9% in Kenya between 1993 and 2008. Clearly, the rates of increase in the equivalent survival rates h_{EG} are always higher than those in the average survival rates because, in all countries, there was generally both an increase in the average infant survival rates and a decrease in the inequality in survival rates.

Let us finally compute the rates of increase in the "pro-poor survival rates" $A_2 = \bar{h}(1 - C_G)$. This increase was equal to 3.7% in Ethiopia between 2000 and 2011, of 5.7% in Madagascar between 1997 and 2008, of 4.8% in Malawi between 2000 and 2010, of 9.4% in Mozambique between 1997 and 2011, of 7.3% in Rwanda between 2000 and 2010, of 2.6% in Uganda between 1995 and 2011, and of 1.0% in Kenya between 1993 and 2008. We note that in all countries except Madagascar, the rate of increase in the "pro-poor infant survival rate"

$A_2 = \bar{h}(1 - C_G)$ was smaller than that of the "equivalent infant survival rate" h_{EG}. In Madagascar, the rates of increase were identical. These results clearly indicate that if we give more weight to the infant survival rates, the poorer (in terms of standard of living) the quintile, the smaller the improvement over time in survival rates .

Table 1: Computing inequality in survival rates and health achievements in seven East African countries on the basis of Gini index

Country and year	Gini index I_G of inequality of survival rates	Gini Concentration ratio C_G of survival rates	Average survival rate $\bar{h}$ (per thousand)	Equivalent survival rate h_{EG} (per thousand)	Pro-poor survival rate $A_2 = \bar{h}(1 - C_G)$ (per thousand)
Ethiopia 2000	0.0108	-0.0006	887.7	878.1	888.2
Ethiopia 2005	0.0052	0.0035	920.9	916.1	917.7
Ethiopia 2011	0.0074	0.0069	927.7	920.8	921.3
Kenya 1993	0.0117	0.0113	939	928.1	928.4
Kenya 1998	0.0116	0.0115	932	921.2	921.3
Kenya 2003	0.0092	0.0078	926	917.5	918.8
Kenya 2008	0.0054	0.0036	941.5	936.4	938.1
Madagascar 1997	0.0146	0.0146	905.3	892.1	892.1
Madagascar 2003	0.0126	0.0122	933.8	922.1	922.4
Madagascar 2008	0.0056	0.0056	948.3	943	943
Malawi 2000	0.0095	0.0056	898.1	880.6	884.1
Malawi 2004	0.0083	0.0083	908.5	900.9	900.9
Malawi 2010	0.0018	0.0002	927.1	925.4	926.1
Mozambique 1997	0.0179	0.0173	860.8	845.4	845.9
Mozambique 2003	0.0172	0.0168	881	865.8	866.2
Mozambique 2011	0.0048	0.0044	929.7	925.3	925.6
Rwanda 2000	0.0096	0.0093	882	873.5	873.8
Rwanda 2005	0.0107	0.0064	898.4	888.8	892.7
Rwanda 2010	0.0038	0.0024	939.8	936.2	937.6
Uganda 1995	0.0092	0.0075	914.5	906.2	907.7
Uganda 2000	0.0034	-0.0009	910.8	907.7	911.6
Uganda 2006	0.0074	0.0074	917.9	911.1	911.1
Uganda 2011	0.0053	0.0053	936.3	931.3	931.3

A similar study can be conducted on the basis of the five Bonferroni-related indices that are presented in Table 2. The results turn out to be very similar and therefore, we will not repeat the detailed analysis made previously on the basis of the Gini-related indices

Table 2: Computing inequality in survival rates and health achievements in seven East African countries on the basis of Bonferroni index

Country and year	Bonferroni index I_B of inequality of survival rates	Bonferroni Concentration ratio C_B of survival rates	Average survival rate $\bar{h}$ (per thousand)	$h_{EB}=\bar{h}(1 - I_B)$ (per thousand)	$A_B=\bar{h}(1 - C_B)$ (per thousand)
Ethiopia 2000	0.01431	-0.004355	887.7	875.0	891.5
Ethiopia 2005	0.00547	0.002798	920.9	915.8	918.3
Ethiopia 2011	0.00976	0.009369	927.7	918.6	919.0
Kenya 1993	0.01508	0.01485	939.0	924.9	925.1
Kenya 1998	0.0148	0.01469	932.0	918.2	918.3
Kenya 2003	0.01162	0.01033	926.0	915.3	916.5
Kenya 2008	0.005873	0.004306	941.5	936.0	937.4
Madagascar 1997	0.0168	0.0168	905.3	890.1	890.1
Madagascar 2003	0.01506	0.01412	933.8	919.8	920.7
Madagascar 2008	0.00631	0.00631	948.3	942.4	942.4
Malawi 2000	0.01149	0.007421	889.1	878.9	882.5
Malawi 2004	0.009842	0.009842	908.5	899.5	899.5
Malawi 2010	0.002527	0.000333-	927.1	924.7	927.4
Mozambique 1997	0.02339	0.02263	860.8	840.7	841.3
Mozambique 2003	0.01977	0.01868	881.0	863.6	864.5

Mozambique 2011	0.006258	0.00607	929.7	923.9	924.1
Rwanda 2000	0.0117	0.01125	882	871.6	872
Rwanda 2005	0.01245	0.007374	898.4	887.2	891.8
Rwanda 2010	0.004579	0.003089	939.8	935.5	936.9
Uganda 1995	0.01177	0.009969	914.5	903.8	905.4
Uganda 2000	0.004916	0.001077-	910.8	906.3	911.8
Uganda 2006	0.009004	0.009004	917.9	909.6	909.6
Uganda 2011	0.006444	0.006444	936.3	930.3	930.3

4. CONCLUDING COMMENTS

In this paper, we defined three indices that summarize the extent of infant survival in a given country. The first one is simply the average infant survival rate, that is, the complement to 1000 of the infant mortality rate (expressed in per thousand births). The second indicator takes into account the inequality in infant survival rates between population subgroups, in the same way as Sen, 1974, suggested a measure of welfare which would be an inequality adjusted per capita GDP or income. Finally, a third indicator was defined, based on a bivariate approach to the measurement of health inequality. This indicator adjusted the average infant survival rate by giving more weight to a population subgroup whose socioeconomic status is lower. The computation of the last two indicators requires the use of an inequality index and of a concentration ratio. We selected two measures of inequality, the Gini and Bonferroni index, as well as two concentration ratios, derived from the Gini index and related to the Bonferroni index.

The empirical illustration of this paper looked at infant survival in seven East African countries (Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Rwanda, and Uganda) mainly during the first decade of the 21st century. It appears that there was an increase over time in the average infant survival rate and that this improvement was stronger when taking into account changes in the inequality in infant survival rates. Giving a greater weight in the computations to population subgroups with a lower socioeconomic status did not show as strong an improvement in infant survival than when taking into account the inequality in infant survival. These findings have some important implications as they show how policy makers should look at infant mortality before reaching any conclusion concerning its evolution over time and how it is affected by the standard of living.

ACKNOWLEDGMENT

The author would like to thank Almas Heshmati and other organizers of the First Conference on “Recent Trends in Economic Development, Finance and Management Research in Eastern Africa” that took place on May 5-6, 2015 in Kigali, Rwanda, for inviting him to attend this conference, thus allowing him to become a bit more familiar with economic research and reality in this part of the world. This paper was however written well after this conference took place. Part of the methodological tools presented in this paper were described in a report entitled “Equity in the Delivery of Public Services in Selected DMC's” which the author wrote for the Asian Development Bank in October 2009. The empirical illustration is based on the data available on the website of the World Health Organization.

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