Measuring Healthcare Inequities using the Gini Index

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Abstract

Questions of healthcare inequities have been of continuing concern to health researchers, planners, and policymakers. The answers to such questions can be difficult to interpret, but deeply affect policy formulation, resource allocation, and our perceptions of the fairness and compassion inherent in the institutions of government and society as a whole. This paper describes the data warehouse implementation of several measures of inequality drawn from the field of economics, including the Gini index. Past research has often focused on using these economic measures to characterize a small set of health status indicators, usually at fairly high levels of aggregation, with comparisons between states or nations. In this research, an ongoing healthcare data warehouse project under the auspices of the Center for Health Outcomes Research at the University of South Florida provides the infrastructure for exploring hundreds of health status indicators at the ZIP code level. The goal is to include information on healthcare inequities in the many reports generated for policymakers throughout Florida.

1 Introduction

Questions of healthcare inequities have been of continuing concern to health researchers, planners, and policymakers. The answers to such questions can be difficult to interpret, but deeply affect policy formulation, resource allocation, and our perceptions of the fairness and compassion inherent in the institutions of government and society as a whole.

A data warehouse of healthcare indicators has been implemented as part of the ongoing research on community health assessment conducted under the auspices of the Center for Health Outcomes Research (chor.hsc.usf.edu) at the University of South Florida [Studnicki et al. 1997, Berndt et al. 2001]. The data warehouse was originally designed to automate the Comprehensive Assessment for Tracking Community Health (CATCH) methodology and the production of in-depth community assessment reports. This data warehouse has grown in scope and now provides an interesting environment for the investigation of a variety of healthcare issues in Florida. Among these research initiatives are efforts to explore questions of social justice or inequities in health burdens. The data warehouse affords the opportunity to pursue such investigations at fine-grained levels of analysis. This paper describes the data warehouse implementation of several measures of inequality drawn from the field of economics, including the Gini index. These measures have been used in the healthcare arena, but have often focused on a restricted set of health status indicators, usually at coarse-grained levels of aggregation for national or international comparisons. While this macro-level focus is certainly an important perspective for national policy, this paper is aimed at investigating these measures in the county-level decision-making context.

The main objectives of this research are the following.

- Survey and adapt appropriate economic measures of inequality for use in a healthcare data warehouse environment.
- Calculate the Gini index at the fine-grained ZIP code level and assess the capability for recognizing healthcare inequalities.
- Investigate Gini index values for a selection of key healthcare indicators to determine the relative magnitude of existing inequalities and that the Lorenz curves are well-behaved at this level of analysis.

Information regarding inequities in health-related burdens is not routinely reported in the CATCH methodology or other widely used community assessment reports. The ultimate goal of this line of research is to provide quantitative measures of healthcare inequities at the local, county, and state levels for comparison.

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2 Measuring Inequality

Economics is a natural place to look for measures of inequality that can be used to quantify differences in health burdens. Of course, the topic of social justice has occupied philosophers of all types for centuries, with no end in sight. However, these debates remain of interest, being continually revisited by politicians and community activists whenever policy is formulated. One historic definition of an elite by Lasswell captures some aspects of injustice or lack of justice.

> "The influential are those who get the most of what there is to get. Available values may be classified as *deference*, *income*, *safety*. Those who get the most are *elite*; the rest are *mass*" [Lasswell 1958].

Two important issues are highlighted by this definition. First, the advantages that accrue to the elite can be multifaceted, including "skill, intellectual enlightenment, affection (family and friendship), physical and mental well-being, and moral rectitude" [Alker 1965]. Clearly, good health or "physical and mental well-being" is a very desirable value or advantage. The second issue is the need to quantify such inequities to make more precise the notion of "those who get the most."

Following Alker, a simple mathematical formalization of inequality can be developed [Alker 1965]. While very sophisticated mathematical models are possible, fairly simplistic methods may be quite useful for the somewhat broader perspectives often used in resource allocation and planning. This paper focuses on simple measures, such as the Gini index and Schutz coefficient that have been applied in a variety of situations from country-level income distribution to healthcare burdens. Therefore, let U denote a universe composed of values (V) and individuals (N) or groups (G) that share (most likely in an unequal manner) the available values. Further, let f_i denote the frequency or number of members in group g_i, and that the following equations characterize the total group membership as the number of individuals, as well as the share of available values (v_i) in the universe.

$$\sum_{i=1}^{G} f_i = N \quad (1) \qquad\qquad \sum_{i=1}^{G} f_i v_i = V \quad (2)$$

In order to define equality, there must be some expectation (e_i) of how the values should be distributed. Again, this question has occupied philosophers for some time. Aristotle debated such norms and associated notions of injustice.

> "The democratic conception of justice is the enjoyment of arithmetical equality, and not the enjoyment of proportionate equality on the basis of desert [i.e., merit, as Aristotle himself would have preferred]" [Alker 1965].

The debate becomes more complex as values are classified as basic or luxury goods, and certainly good health is a value that will generate controversy as to the role of merit in any distributions. Therefore, a simple definition of *democratic equality* is used in the current implementation, though any notions of *proportionate equality* could be easily incorporated. Democratic equality requires that each group (or individual) share equally in the desired values, that is have the same average amount as in Equation 3 and 4.

$$\frac{1}{G}\sum_{i=1}^{G} v_i = \bar{v} \quad (3) \qquad\qquad e_i = \bar{v} \quad (4)$$

Measures of inequality characterize the departures from the expected values or norms or "the extent to which v_i does not equal e_i." A simple ratio of advantage or standardized version (as in Equation 5) can then be used to compare individual differences in advantage or disadvantage.

$$\frac{v_i - \bar{v}}{\bar{v}} = \frac{v_i}{\bar{v}} - 1 \quad (5)$$

It is often more important to consider cumulative measures of inequality rather than individual measures. That is, to characterize the values held by proportions of a population. Several such measures are discussed in the next section, including the Gini index, proposed by the Italian statistician and demographer Corrado Gini (1884-1965).

2.1 Lorenz Curve

Cumulative measures of inequality rank order individuals or groups according to some ratio of advantage, allowing the amount of some value held by cumulative proportions of a population to be identified. A Lorenz curve is a natural method of graphically representing such cumulative measures. Figure 1 is a Lorenz curve derived from school system data used by Alker [Alker 1965]. The data comes from a New Haven, Connecticut study on racial imbalance in schools, with four junior high schools used in the example. The x axis is a rank order of groups or individuals, with the most disadvantaged on the left-hand side, that can be used to identify the percentage of some population. The y axis represents the percentage of some value held by the corresponding cumulative proportion of the population. In this example, the x axis is the percentage of the total student population (ordered by the ratio of advantage % whites / % students) and the y axis is the percentage of white students. A 45-degree line represents democratic equality or the expected (e_i) amount of the value, in this case white students. The curve represents the departures from the norm of democratic equality.

In this example, the first two schools account for approximately 44% of the total student population (x axis), but only 22% of the white students (y axis). More importantly, measures that sum the differences and/or ratios can be used to characterize the entire distribution. There are several well-known summative measures of inequality [Alker and Russett 1964]. First, one could sum absolute differences or deviations (i.e. ignoring the sign) from the mean as in Equation 6 or normalized as in Equation 7.

$$\frac{1}{G}\sum_{i=1}^{G}\left|v_i - \bar{v}\right| \quad (6) \qquad\qquad \frac{1}{G}\frac{\sum_{i=1}^{G}\left|v_i - \bar{v}\right|}{\sum_{i=1}^{G} v_i} \quad (7)$$

A second measure is the Schutz coefficient that sums ratios of advantage rather than normalized deviations (based on the equality in Equation 5) "above or below the equal share point (at which $v_i = \bar{v}$)." Equation 8 defines the Schutz coefficient.

$$\sum_{v_i \geq \bar{v}}\left(\frac{v_i}{\bar{v}} - 1\right) = \sum_{v_i \leq \bar{v}}\left(1 - \frac{v_i}{\bar{v}}\right) \quad (8)$$

The Gini index is a third measure and is often used to characterize the national income disparities around the world. This measure has also been used to a limited extent in characterizing health-related burdens and is the focus of this paper. Referring to the Lorenz curve in Figure 1, the Gini index uses the "area of inequality" between the curve and the line of democratic equality to quantify the notion of inequity. To normalize or obtain a Gini index between 0 and 1, the area of inequality is divided by the maximum inequality value, that is the triangle below the equality line. Of course, if the x and y axes range from 0 to 1, the triangle has an area of ½ and the Gini index is twice the area of inequality. Several approaches for calculating the area of inequality are depicted in Figure 1. Essentially, for each group the area is calculated using the width along the x axis and the departure from expected equality along the y axis as defined in Equations 10 and 11.

$$\Delta x_i = x_i - x_{i-1} \quad (10) \qquad\qquad \Delta y_i = e_i - y_i \quad (11)$$

Calculating the area of inequality requires summing the area of each trapezoid defined by (x_{i-1}, y_{i-1}), (x_{i-1}, e_{i-1}), (x_i, y_i), and (x_i, e_i), or equivalently, the area of the rectangle with the height at the midpoint of the x interval. Thus, Equation 12 provides a definition for the Gini index.

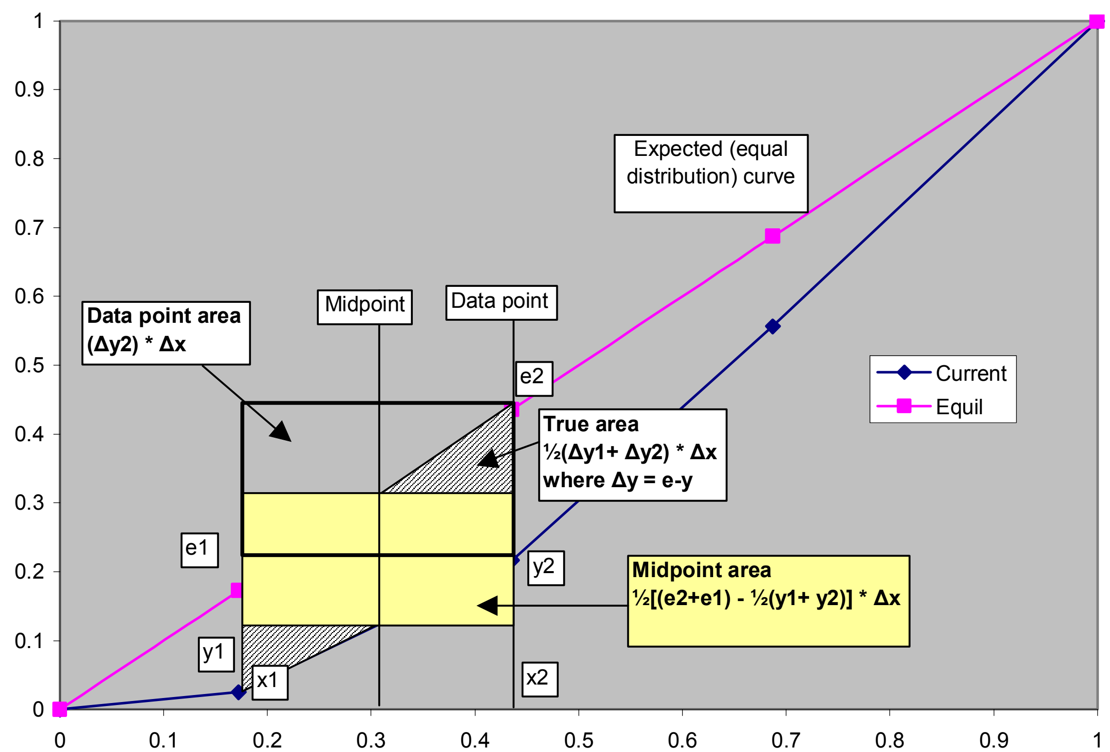

Figure 1: Calculating the Gini Index

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$$2\sum_{i=1}^{G}\left[\frac{(e_i - y_i)+(e_{i-1} - y_{i-1})}{2}\right](x_i - x_{i-1}) \quad (12)$$

Therefore, a Lorenz curve can be used to visualize the inequalities described in aggregate by the Gini index. In subsequent sections, both the example curves and Gini index values from a healthcare data warehouse are discussed.

3 Healthcare Inequities

There is an extensive international literature which links socioeconomic status (SES) to variation in a wide range of health problems and conditions. While the link is clear, the mechanisms that are responsible for the association and their potential applications have sparked ongoing discussions within the academic and policy communities [Mechanic 2002]. Socioeconomic status has most often been defined by education, income, and occupation. Education provides the knowledge and life skills a person might use to be more aware of their health status, to better access important healthcare resources, and to behave in ways that can improve and maintain well being. Levels of education have been associated with the likelihood of certain types of illness such as cardiovascular disease [Winkely et al. 1992], and early educational experiences have been suggested to confer longer term health advantages than education received at other periods in the life cycle [Hertzman 1999].

The direct effects of income on health have typically been studied in two different ways: comparisons between countries and studies of the relationship between income and mortality within countries. Generally, it has been shown that levels of national wealth are positively correlated with measures of health status such as life expectancy, although the effect is strongest at low levels of GNP [World Bank 1993]. A recent analysis has also suggested that wealthier countries or communities may improve health status, independent of income, by investing in certain common, public supports through taxation and subsidized infrastructure and services [Sen 1999]. Studies within the United States and Canada have found a consistent health gradient with personal income levels inversely related with mortality rates [McDonough 1997, Wolfson et al. 1993]. Occupational status is a more complex variable, although, a simple association between employment and health status has been demonstrated [Ross and Mirovsky 1995]. Jobs differ in prestige, pay levels, qualifications, and each of these factors has been linked to mortality risk [Gregovia et al. 1997].

It has been observed by many investigators that SES inequality may be operating through a series of differential exposures or “pathways” that have a more immediate effect on health [McGinnis and Foege 1993]. SES pathways prominently discussed include environmental exposure, the social environment, the healthcare system, behavioral or lifestyle patterns, and chronic stress. Those persons of lower SES class are more likely to live in areas exposed to lead, asbestos, carbon dioxide, higher noise exposure, residential crowding, and deteriorating housing [Pamuk et al. 1998, Evans and Saegent 2000]. Social environmental factors such as isolation and lack of engagement in social networks have been linked to mortality rates as much as five times higher than in those persons with better social connections [Berkman and Glass 2000]. Access to, use of, and the quality of healthcare have all been shown to vary by socioeconomic status. Level of education is associated with the likelihood of being uninsured and the receipt of fewer healthcare services [Monheit and Vistnes 2000]. Lower SES is associated with sedentary lifestyles and lower consumption of fresh fruits and vegetables [Krebs-Smith et al. 1995], as well as heavy consumption of alcohol [Pamuk et al 1998]. Lower SES persons are also likely to live and work in more stressful environments caused by economic strain, insecure employment, and low control at work [Brunner 1997]. At the same time, more affluent persons are more likely to participate in and be successful at formal programs aimed at alleviating the harmful effects of uncontrolled stress.

3.1 The Gini Index in Healthcare

The Gini index has been used to study several aspects of health inequities. As in the often cited studies of income distributions, comparisons can be made between countries. For example, the Pan American Health Organization (www.paho.org) published a short survey applying the Gini index to infant mortality rates across a group of South American countries [Castillo-Salgado 2001]. Other investigators have found correlations between various socioeconomic factors and self-rated health status [Kennedy et al. 1998, Bobak et al. 2000]. The Gini index has also been used to study spatial patterns of care and healthcare access in Canada [Brown 1994], with the goal of understanding the relationship between competitive conditions and practitioner location. Finally, multiple measures of inequality, such as the Gini coefficient, the decile ratio, the Robin Hood index, and the Atkinson index have been shown to be highly correlated with each other and strongly associated with mortality [Kawachi and Kennedy 1997].

4 A Data Warehouse Implementation

The Center for Health Outcomes Research at the University of South Florida has developed a statewide healthcare data warehouse for Florida, using it to investigate and assess the health status of communities [Studnick et al. 1997]. The Comprehensive Assessment for Tracking Community Health (CATCH) methodology collects, organizes, analyses, prioritizes, and reports data on over 300 health and social indicators on a local community basis. The methodology has been refined in the field for more than a decade, with more than two-dozen reports prepared for communities within and outside the State of Florida.

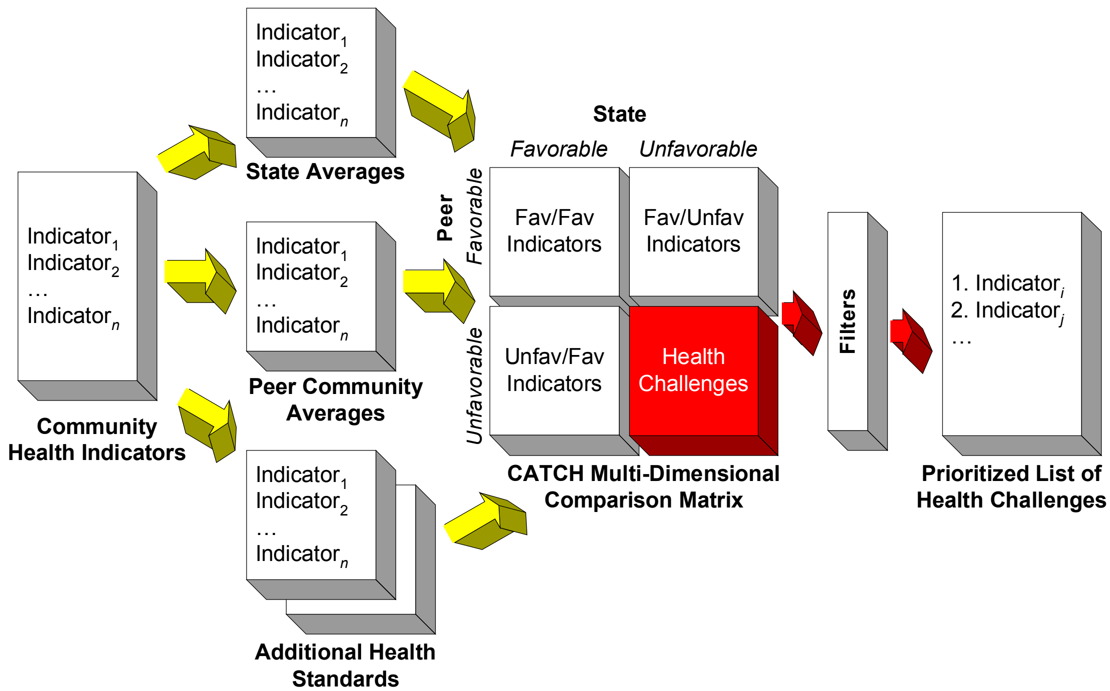

Figure 2: The CATCH Process

The CATCH methodology can be briefly described as shown in Figure 2. Community health indicator data are gathered from a variety of sources. Secondary data sources include health care data reported by hospitals, local, state, and federal health agencies, and national health care groups. Primary data sources would involve data gathered from door-to-door or mail-in surveys. All health care data are normalized into common formats and organized into a community health care report card listing values for each important community indicator.

Each indicator value is then compared against the state average, an average for a peer group of communities, and other interesting values (e.g., a national goal for that indicator). The results of these comparisons are organized into an *n*-dimensional matrix based on favorable or unfavorable comparisons against each comparison dimension. Figure 2 shows a 2-dimensional comparison matrix based on state averages and peer averages. Community indicators that demonstrate unfavorable comparisons on all dimensions are highlighted as community health challenges. The original CATCH reports included data at the county level. However, the data warehouse has enabled analysis and reporting at both the user-defined community and individual ZIP code level. This, more local perspective, has been enthusiastically received by the users of the more recent reports. Planning at the county level can be better supported through the ability to re-define communities and re-aggregate data for specific purposes.

The enhanced data warehouse provides the necessary infrastructure for studying health outcomes at finer levels of detail. One of the unique aspects of this research is that the measures of inequality are applied at the ZIP code level throughout Florida. Roughly 875 ZIP codes are rank ordered by per capita income. Each health status indicator is also calculated and age-adjusted at the ZIP code level, allowing comprehensive Lorenz curves and Gini indexes to be produced. The goal is to provide such information for selected health status indicators as part of the CATCH methodology, enabling policymakers to consider aspects of health inequities.

4.1 Gini Index Calculations

Figure 3 presents a Lorenz curve and Gini index or coefficient for total age-adjusted mortality in Florida. The curve looks remarkably democratic in terms of equality, lending some credence to the adage of the inevitability of "death and taxes." This curve also provides a context for interpreting more detailed health

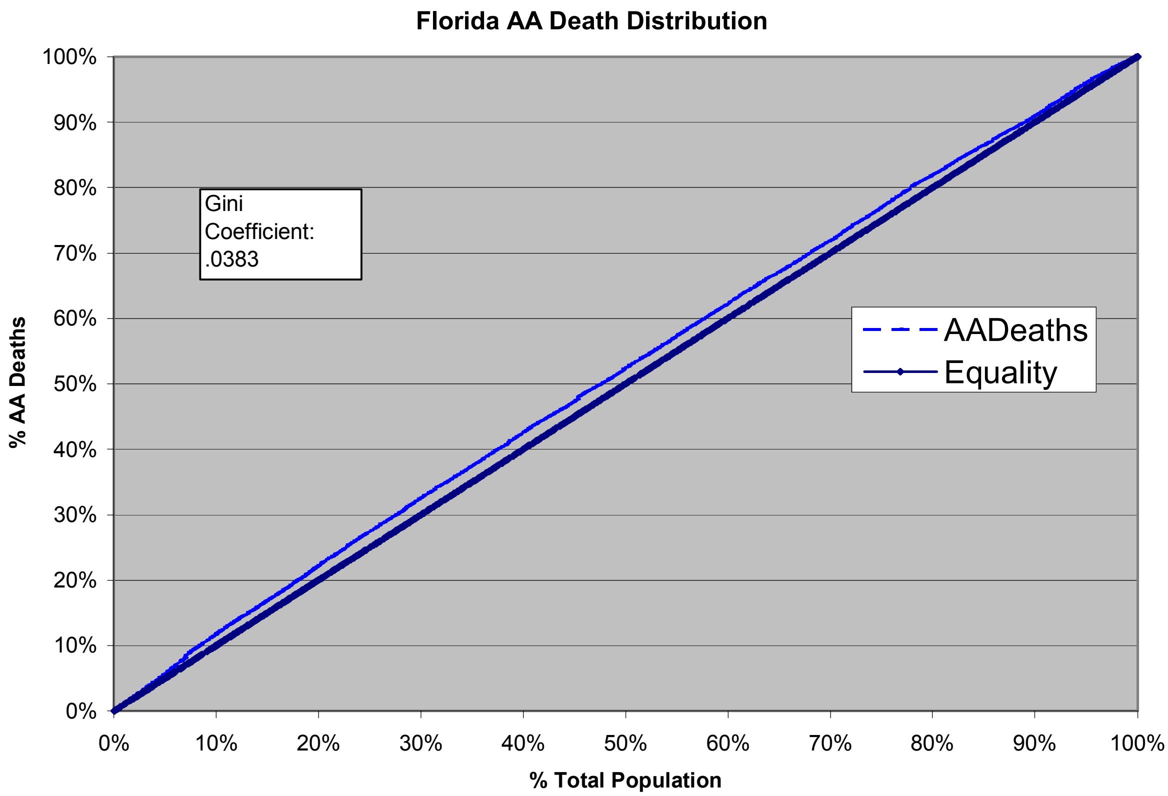

Figure 3: Gini Index for Age-Adjusted Mortality Based on Florida ZIP Codes

status indicators that comprise total mortality. While there is a slight detectable inequity in burden, this broadly defined indicator would be difficult to affect in any meaningful way through policy initiatives.

In contrast, homicide is a cause of death that demonstrates clear inequities with respect to socioeconomic status. This would be expected from past research and simple intuition. Figure 4 shows an obvious burden on the poor, with the poorest 20% of the population bearing roughly 40% of the homicides. The Gini index of 0.264 again provides a context for interpreting other health status indicators. For example, this could be considered one of the more extreme Gini index values likely to be seen in the healthcare data and might be useful for normalizing other indicator values. It is also interesting that the nearly 900 points describe a curve that is well-behaved and reminiscent of the classic curves found in textbook examples. Barata and Ribeiro also considered the correlation between economic status and homicides in Sao Paulo, Brazil [Barata and Ribeiro 2000]. One of the interesting aspects of their investigation was that income inequality, rather than simple poverty, might be a more appropriate explanation for their particular "epidemic of violence."

Figure 5 presents data on years of productive life lost (YPLL), based on an assessment of premature death. This indicator again displays fairly obvious inequalities, though less extreme than homicide. This is another health status indicator that one would expect to be affected substantially by wealth.

Figure 6 depicts a much less clear situation regarding suicide. In considering the detailed data, it appears that suicide is less a problem of the poor or rich, but more of a middle class burden (though the differences are small). This indicator also illustrates some difficulties in using the Gini index. If all the departures from democratic equality are in the same direction (have the same sign), the Gini index as defined in Equation 12 is well behaved. However, if the departures cross the line of equality the differences will begin to cancel each other out. On the other hand, if an absolute value is used, a curve that repeatedly crossed the line of equality could yield a Gini index more typical of a classic inequality. Therefore, it seems prudent to use the Lorenz curve, as well as other measures of inequality, to determine the appropriateness of the Gini index.

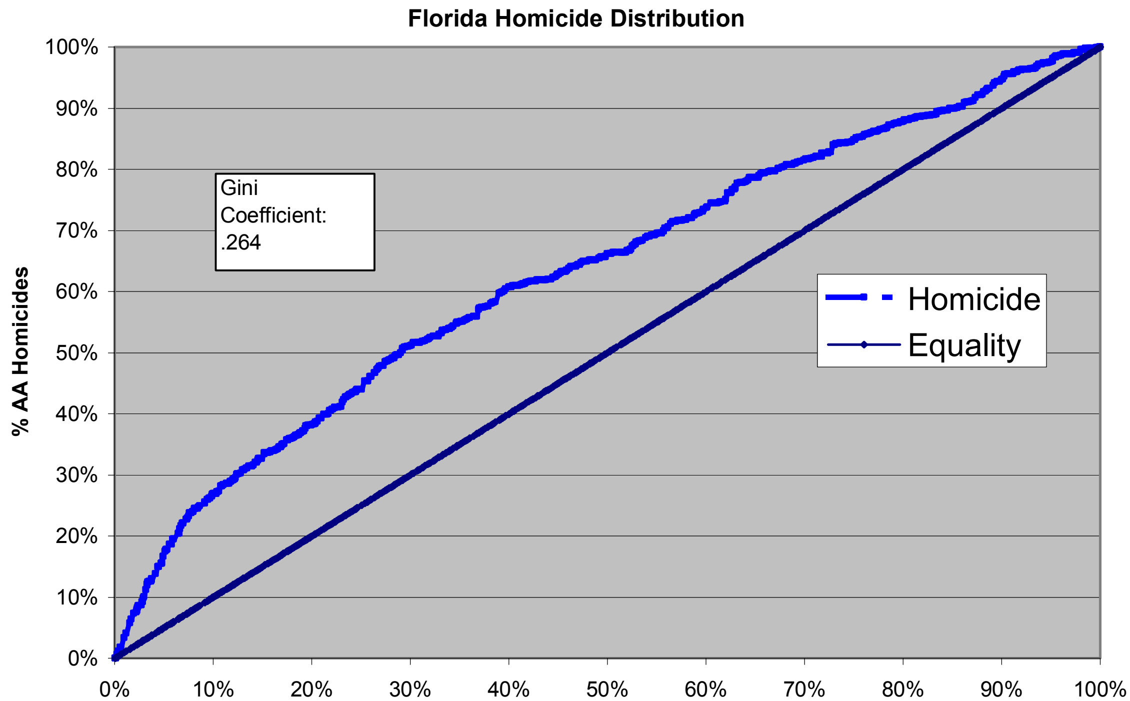

Figure 4: Gini Index for Homicide Based on Florida ZIP Codes

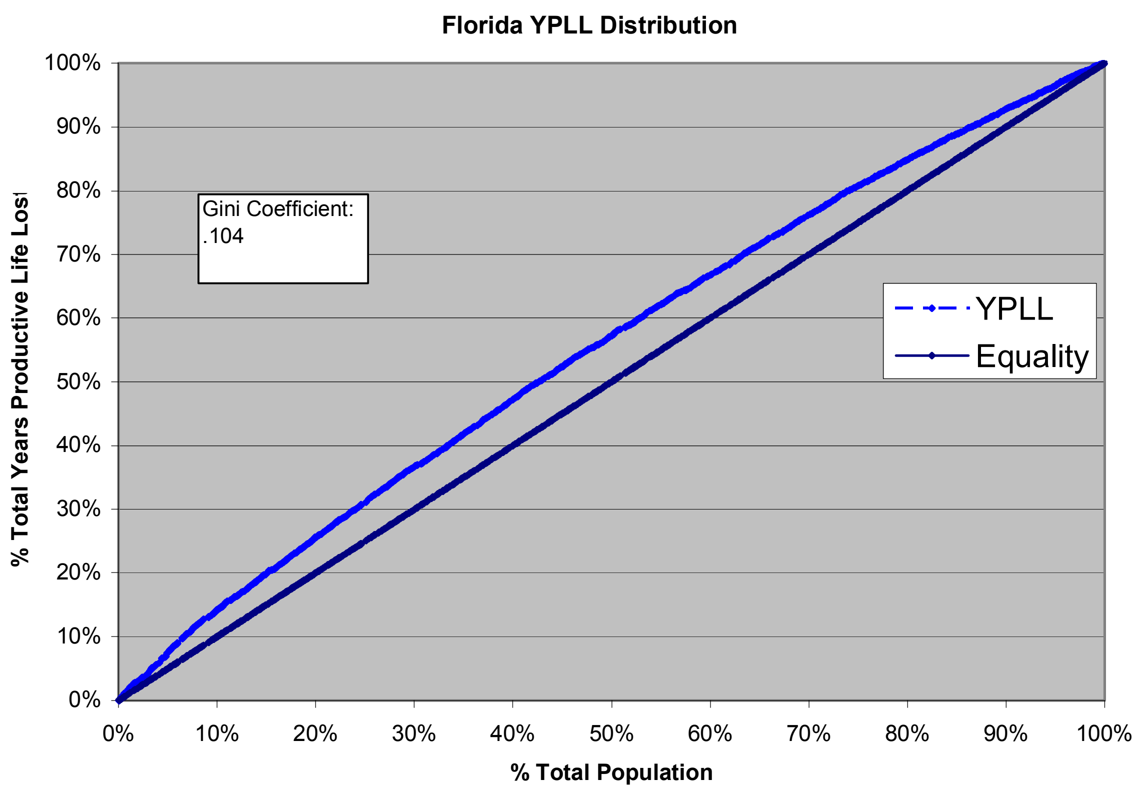

Figure 5: Gini Index for Years of Productive Life Lost (YPLL) Based on Florida ZIP Codes

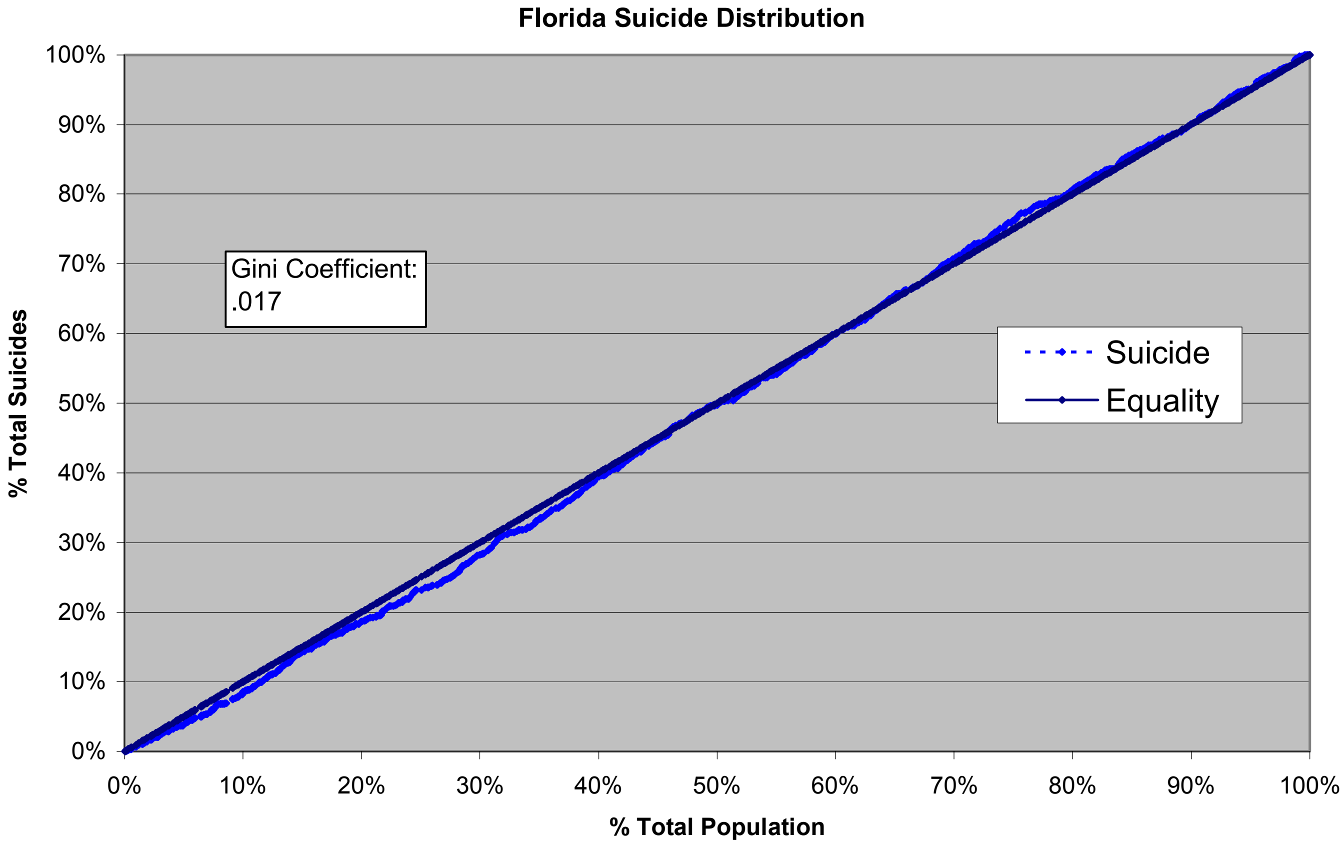

Figure 6: Gini Index for Suicide Based on Florida ZIP Codes

5 Conclusions

Equity in health is of concern to healthcare researchers, practitioners, and policymakers throughout the world. Drawing on basic measures of inequality, this paper reports on the potential use of the Gini index, the Lorenz curve, and other cumulative measures of inequality in a data warehouse environment. In particular, a data warehouse of health status indicators for Florida is used to investigate these measures at the ZIP code level for the entire state. Roughly 875 ZIP codes are rank ordered by per capita income and paired with some example age-adjusted indicators of health status. A Gini index and Lorenz curve is presented for each of these indicators. Overall age-adjusted mortality is compared with indicators, such as homicide and years of productive life lost, which display a classic pattern of inequality. The goal of the research is to implement measures of inequality in the data warehouse context so that a social justice perspective can be presented to policymakers as part of a health status assessment process.

The preliminary results are encouraging, confirming the utility of the Gini index and other measures in quantifying inequities in health-related burdens. For instance, some indicators such as homicide and years of productive life lost, are clearly more burdensome in the less affluent ZIP codes. The associated Lorenz curves have a classic shape, which provide an effective visualization of the inequities. As this research effort continues, measures of inequality will be computed for possibly hundreds of additional indicators. The ultimate goal is to provide local community measures in the context of statewide Gini indexes as part of the community health status reports. It is hoped that this information will contribute to the ability of county planners and other local stakeholders to reduce wealth-related variations in the health status of defined populations.

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