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An information theory based framework for the measurement of population health

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ABSTRACT

This paper proposes a new framework for the measurement of population health and the ranking of the health of different geographies. Since population health is a latent variable, studies which measure and rank the health of different geographies must aggregate observable health attributes into one summary measure. We show that the methods used in nearly all the literature to date implicitly assume that all attributes are infinitely substitutable. Our method, based on the measurement of multidimensional welfare and inequality, minimizes the entropic distance between the summary measure of population health and the distribution of the underlying attributes. This summary function coincides with the constant elasticity of substitution and Cobb–Douglas production functions and naturally allows different assumptions regarding attribute substitutability or complementarity. To compare methodologies, we examine a well-known ranking of the population health of U.S. states, America's Health Rankings. We find that states' rankings are somewhat sensitive to changes in the weight given to each attribute, but very sensitive to changes in aggregation methodology. Our results have broad implications for well-known health rankings such as the 2000 World Health Report, as well as other measurements of population and individual health levels and the measurement and decomposition of health inequality.

1. Introduction

Since the passing of the Patient Protection and Affordable Care Act in 2010, expanded government involvement in the health care sector has increased the ability of policy makers to influence the health outcomes of the populations they represent. However, the efficient allocation of public resources requires robust measures of the costs and benefits associated with policy. Policy makers often use rankings and other measurements of geographies' population health, such as the Robert Wood Johnson Foundation's *County Health Rankings and Roadmaps*, the Commonwealth Fund's *Health System Scorecards*, and the United Health Foundation's *America's Health Rankings*, in designing public policies (Erwin et al., 2008). In this paper, we show that implicit assumptions embedded in these popular metrics could result in misleading evaluations of health, and we describe an alternative framework that is more flexible and transparent.

Because the health of a population is a latent characteristic, these rankings, as well as many other multidimensional health measurements, aggregate health attributes into a measure of latent health using a weighted

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arithmetic mean, where the weights are chosen on a normative basis. These methods require assumptions about the relative importance of the attributes used and the relationships between attributes, and the methodology often masks the nature of these assumptions. For example, normatively chosen weights can place unintended emphasis on highly correlated dimensions of health. More importantly, linearly aggregating attributes using a weighted arithmetic mean implicitly assumes that the attributes are infinitely substitutable, where the marginal rate of substitution between any two attributes is constant, completely determined by the attribute weights, and independent of the level of each attribute.

We propose a methodology to measure and rank population health based on the concept of multivariate generalized entropy (MGE). Originally developed by Maasoumi (1986), our methodology chooses a summary measure of population health that minimizes the entropic distance between the summary measure and the multivariate distribution of underlying attributes. This preserves as much information as possible from the underlying attribute distribution when constructing the summary measure of population health. While not applied to the measurement of health, MGE has been widely used to measure economic welfare, inequality, and poverty (e.g. Hirschberg et al., 1991, 2001; Maasoumi and Nickelsburg, 1988; Maasoumi and Jeong, 1985; Lugo, 2007; Maasoumi and Lugo, 2008; Decancq and Lugo, 2013).

Unlike the weighted arithmetic mean approach currently used by health rankings, our methodology makes assumptions transparent, changeable, and comparable. The MGE summary functions coincide with the functional forms of popular utility function and production functions. This allows researchers to transparently modify the relative importance of each attribute, the substitutability or complementarity between the attributes, and compare how different weighting methodologies and social preferences change the measurement of population health. Lastly, as we show, the weighted arithmetic mean approach taken by most health rankings is a special, extreme case of our methodology, when health attributes are assumed to be infinitely substitutable.

To create a basis for comparison, we utilize data from a well-known ranking of the health status of U.S. states, America's Health Rankings, which aggregates 24 measures of health to a measure of population health. We find that states' health rankings are somewhat sensitive to changes in the weighting methodology but very sensitive to changes in aggregation methodology. As we move away from the implicit assumption of infinite substitutability in the original America's Health Rankings methodology towards a more complementary relationship between the different health attributes, the correlation coefficient between the original and new rankings falls to below 0.6. The rankings of some Southern states traditionally considered unhealthy improve dramatically while the rankings of many Midwestern states typically regarded as being healthy fall significantly. Wealthy New England states typically remain near the top of the rankings and states commonly considered to be exceptionally unhealthy, like Mississippi, remain poorly ranked. Thus, while linear rankings may accurately describe extreme parts of the population health distribution, they may not accurately characterize other aspects of the distribution. These results demonstrate the advantages of our MGE-based method, which allows for straightforward sensitivity analyses of the aggregation assumptions.

The rest of this paper proceeds as follows. Section 2 reviews different studies that rank health systems and population health. Section 3 describes the general entropy aggregation methodology and its uses in the measurement of economic welfare. Section 4 describes the data source and specifics of the America's Health Rankings methodology. Section 5 summarizes our results, and Section 6 concludes.

2. Background

We focus on the use of health rankings rather than the constructed summary measure itself, although the points we make remain relevant even outside the context of rankings.[1] A major advantage of rankings is that they provide a unit-free, relative metric that makes a complex set of information much easier to understand. We are only able to measure latent characteristics, like health, by using constructed values for which magnitudes have little intuitive meaning. This makes such metrics difficult for policy makers and researchers to understand and utilize. Transforming such measures into rankings provides context by comparing observable conditions of nature.

One of the most well-known rankings is the World Health Organization's 2000 World Health Report on health care system performance, which ranks the health systems of all World Health Organization member countries (World Health Organization, 2000). More recently, the Commonwealth Fund has published a series of reports aimed specifically at assessing the relative performance of the United States health care system. These reports compare the United States to five other, mostly English speaking, countries (Davis and Fund, 2004, 2007; Davis et al., 2010). Within the United States, attention often focuses on ranking the population health of states or counties (Kindig et al., 2008; Kindig and Stoddart, 2003; Erwin et al., 2008; Booske et al., 2010; Kanarek et al., 2011; Peppard et al., 2008). These reports often get very high profile coverage, especially with recent reforms of the United States health care system. For example, the often-cited statistic in the 2000 World Health Report that the United States health system ranks 37th in the world, between Costa Rica and Slovenia, was covered in the New York Times, Associated Press, and USA Today, and is often mentioned in other

[1] For example, quality adjusted life expectancy (QALE) is another metric commonly used to assess population health in a multidimensional fashion (see Stewart et al., 2013, for a recent example). A detailed review and comparison of QALE methods with our methodology is beyond the scope of this paper. However, like health rankings, QALE metrics essentially calculate a weighted arithmetic mean. As we detail below, the primary advantage of the MGE-based metrics we propose is a lack of dependency on linear functions to summarize the different dimensions of health. Thus, many of our general critiques of existing health rankings also apply to QALE metrics.