

## THE CONSTRUCT OF LORENZ CURVES AND OF THE GINI-COEFFICIENT TO DEPICT DEGREES IN INEQUALITY IN HEALTH CARE

There are a number of ways in which one can depict the *distribution* of some “magnitude” (e.g., income or wealth or health spending or any other such variable) over a given population, with the latter broken down in deciles or quintiles and arrayed from low to high on some criterion, such as family income or wealth or age. The best way to see this is to use a concrete example.

### A. The Distribution of Health Spending

In Table 1 below, we explore the distribution of *health spending* for a given population. Here we array the population in deciles, from deciles of individuals with the lowest health spending per capita to deciles of individuals with the highest per-capita health spending. These deciles are shown on the left-most column of Table 1. Individuals in the 9<sup>th</sup> and 10<sup>th</sup> deciles represent the presumably sickest and most expensive individuals, while those in the 1<sup>st</sup> decile represent the healthiest and least costly individuals.

| <b>TABLE 1<br/>THE DISTRIBUTION OF HEALTH SPENDING AMONG PRIVATELY INSURED AMERICANS,<br/>2002</b> |   |   |  |
|--|---|---|--|
| (1)  | (2)   | (3)                                     | (4)  |
| Decile, from low to high average per capita spending   | Percent of total health spending in 2002 accounted for by this decile of the population | Cumulative percentage of the population | Cumulative percentage of health spending accounted for by population |
| 1  | 0.0%  | 10.0%                                   | 0.0%   |
| 2  | 0.1%  | 20.0%                                   | 0.1%   |
| 3  | 0.6%  | 30.0%                                   | 0.7%   |
| 4  | 1.2%  | 40.0%                                   | 1.9%   |
| 5  | 2.0%  | 50.0%                                   | 3.9%   |
| 6  | 3.4%  | 60.0%                                   | 7.3%   |
| 7  | 5.4%  | 70.0%                                   | 12.7%  |
| 8  | 9.1%  | 80.0%                                   | 21.8%  |
| <b>9</b>   | <b>16.5%*</b>   | 90.0%                                   | 38.3%  |
| <b>10</b>  | <b>61.7%*</b>   | 100.0%                                  | 100.0%   |

Remarkably, each of the first 8 deciles of the population accounted for less than 10% of total health spending in 2002. Even the 8<sup>th</sup> decile accounted for only 9.1% percent of total health spending. The 9<sup>th</sup> decile accounted for 16.5 percent of total health spending and the final 10<sup>th</sup> decile for close to 62%.

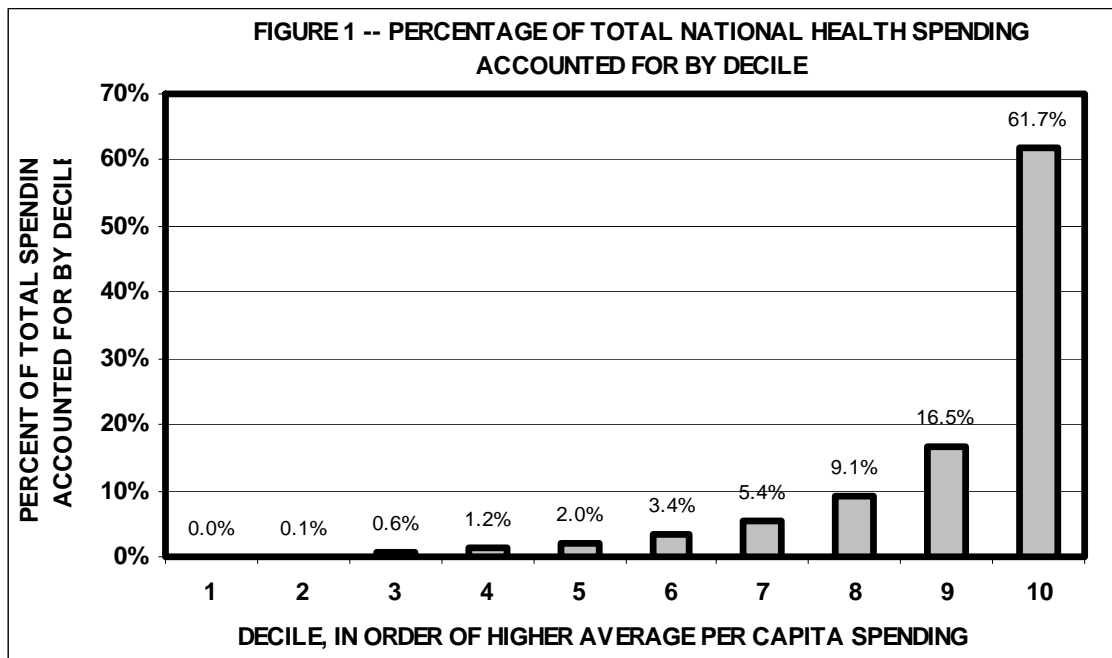
In plain English, it means that the sickest 10% of privately insured Americans accounted for over 60% of the total health spending for all privately insured Americans in 2002.

**These data confirm the universal “80-20 Rule” in health economics, according to which, for any large cohort of individuals, 20% of the cohort accounts for roughly 80% of that cohorts total health spending.**

Now, if a graphical presentation of these data is sought, one can do so in two distinct graphs:

1. the **percentage of total health spending** accounted for by each decile (or quintile) of the population on deciles of the population arrayed by level of spending as in Figure 1 below (it is column 2 of the table on column 1), or
2. the **cumulative percentage of total health spending** accounted for by all the members of the population up to and including the decile shown on the horizontal axis as in Figure 2 (it is column 4 of the table on column 1). **Figure 2 is the Lorenz-curve type construct.**

Figure 1 depicts the first of these two plots, in bar-graph form.



## B. Lorenz Curves

The **Lorenz-curve** was developed first by [Max O. Lorenz](#) in [1905](#) as a graphical representation of [income distribution](#).

The curve depicts on its horizontal axis a defined population – e.g., all American families or all insured members of a particular insurance pool – broken down into percentiles, or deciles or quintiles and ordered from, from left to right on the horizontal axis, from the poorest to the richest families.

On the vertical axis of the Lorenz curve is shown the **cumulative percentage** of income or wealth. For example, above the 3<sup>rd</sup> decile of the population is shown the cumulative percentage of income earned or wealth by the 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> deciles combined.

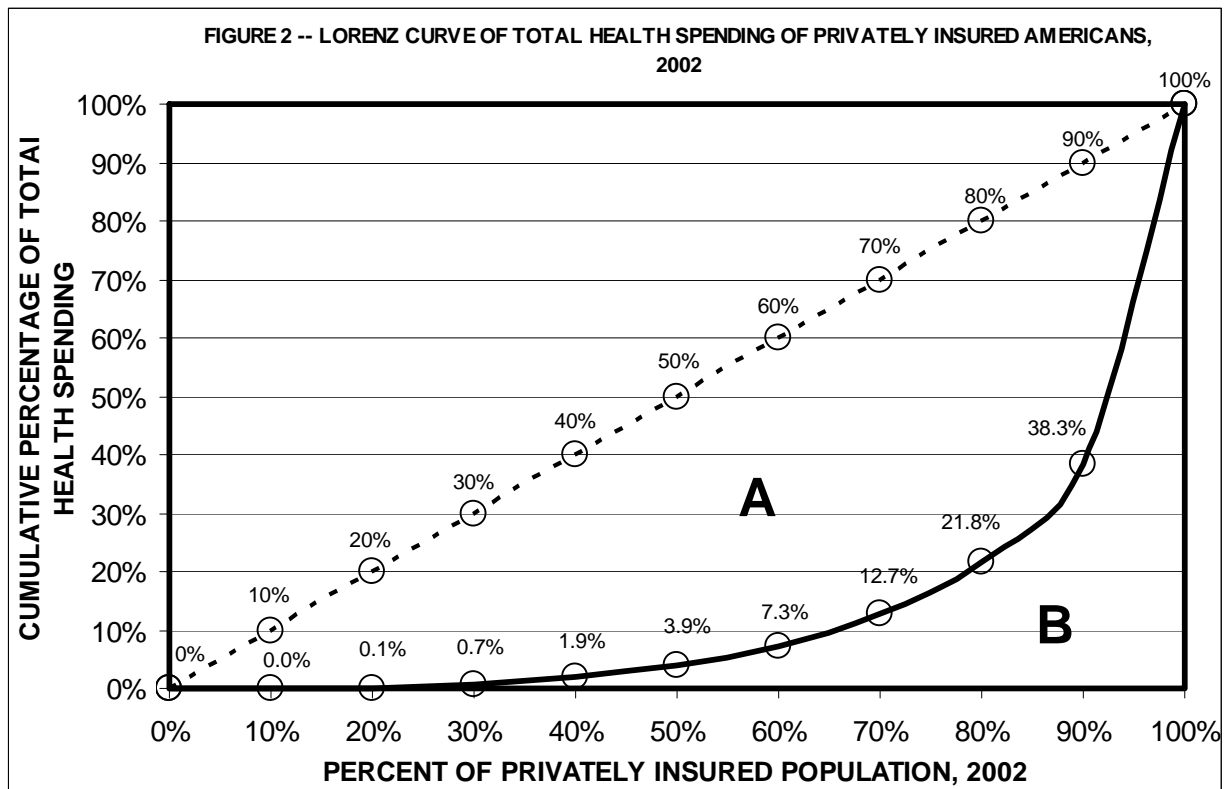
But clearly the Lorenz-curve construct can be used for many other distributions, for example, of health spending (rather than income earned) for that population, or the total number of patient visits used by that population, and so on.

The common usage in the literature seems to be that for magnitudes other than income or wealth, Lorenz curves are called **“Concentration Curves.”** One should be mindful of it when reading that literature and not be confused by it.

In what follows, however, we shall not make that distinction and call all such curves “**Lorenz curves.**” Figure 2 presents such a Lorenz or Concentration curve.

In that graph, the population on the horizontal axis is broken down into deciles, arrayed from the decile of individuals with the lowest per capita spending on the left to the decile of individuals with the highest per capita spending on the right.

On the vertical axis we show the cumulative health spending of that population. Thus, the figure 7.3% above the 60% on the horizontal axis signifies that the least costly 60% of individuals in this population accounted for only 7.3% of the total health spending for 100% of that population.



In a Lorenz-curve construct, both the horizontal and the vertical axis go from 0% to 100%. It follows that the diagonal of the box traced out by this graph – a  $45^\circ$  line – can serve as the benchmark for a *perfectly equal* distribution of the thing (e.g., income or health spending) in question.

Deviations of the actual cumulative distribution – the so-called “Lorenz or Concentration curve” -- from the  $45^\circ$  line then denotes the degree of inequality of the thing (income earned or health spending or physician visits) being explored. The more bent the line of the Lorenz concentration curve is, the more unequal is its distribution across the population.

### C. The Gini-Coefficient

Given a Lorenz-curve plot, we can measure the degree of inequality of the distribution of the thing in question by a one-dimensional number, the so-called GINI-coefficient.

In terms of Figure 2 below, the Gini-coefficient can be defined as the ratio

[1] **GINI-coefficient = Area A / (Area A + Area B)**

The higher the GINI-coefficient is, the more unequal is the distribution of the thing being distributed across the population in question.

Because 100% is equal to  $100/100 = 1$ , and the two axes in the Lorenz curve goes from 0% to 100%, the area of the entire box must be 1. It follows that Area A + Area B must equal  $\frac{1}{2}$ . The Gini-coefficient therefore can be written also as

[2] **Gini-coefficient = (Area A)/(1/2)**  
**= 2×(Area A)**

It is the metric you see when Gini coefficients are shown.

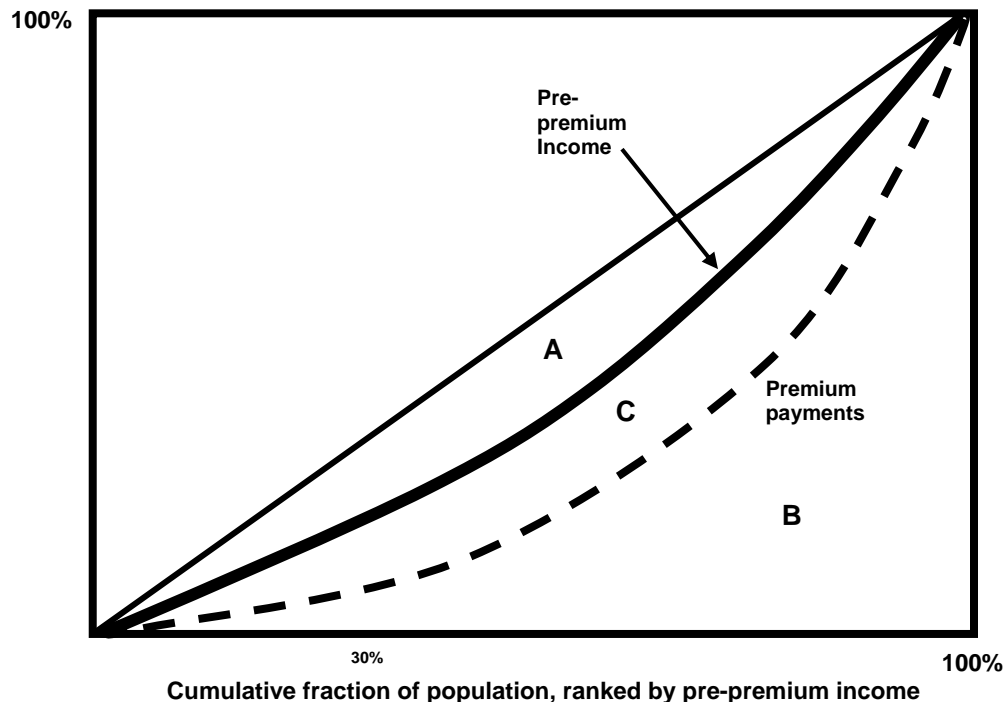
By construction, the Gini coefficient ranges from 0 to 1, with 0 signifying *perfect equality* (the Lorenz curve coincides with the diagonal in Figure 2) and 1 perfect inequality. If the Gini coefficient for some variable (e.g., income) in a country has increased over time, it means that the distribution of that variable among the population has become more unequal. Similarly, if the Gini coefficient for, say, income, in country A is larger than that for country B, country A has a more unequal income distribution.

## D. The Kakwani Progressivity Index

The *Kakwani Index of Progressivity* is widely used to measure the degree of *progressivity* or *regressivity* implicit in the way by which health care in a nation is financed. It is based on the Lorenz-curve construct, as is illustrated in Figure 3.

**FIGURE 3 – LORENZ CURVES FOR KAKWANI PROGRESSIVITY INDEX**

Cumulative fraction of pre-premium  
income and premium payments



In Figure 3, the solid, bent line represents the Lorenz curve for family income prior to the payment of health insurance premiums (or taxes for such premiums). It measures ability to pay and often is abbreviated as APT in the literature, which also seems to refer to that curve as the “Lorenz curve.”

The dashed curve represents the Lorenz curve for premiums paid. It measures contributions to the financial of health care. (Ideally, it should include out of pocket payments for health care.) In the literature, one often finds this curve referred to as the “Concentration curve.”

The Kakwani Progressivity Index can be measured as

$$[3] \quad K = \text{Gini of } \underline{\text{premium}} \text{ payment} - \text{Gini of } \underline{\text{pre-premium}} \text{ income}$$

or, as it may be described in the literature as

$$[3a] \quad K = \text{Concentration coefficient of } \underline{\text{premium}} \text{ payment} - \text{Gini of } \underline{\text{pre-premium}} \text{ income}$$

In terms of Figure 3 above, we would measure it as

$$[4] \quad K = (A + C)/(A + B + C) - (A)/(A + B + C) \\ = C/(A+B+C)$$

But since  $A + B + C$  must equal  $\frac{1}{2}$ , we can also write the Kakwani Index simply as

$$[4] \quad K = C/(1/2) \\ = 2C$$

To put a sign on  $C$  and hence on  $K$ , we must inspect which curve lies above the other, i.e., which Gini coefficient is greater, that of pre-premium income or that of premiums paid..

If the dashed premium-payment Concentration Curve lies below the pre-premium income (ATP) Lorenz curve (as is shown in Figure 3), then  $K > 0$ . The distribution of premiums then is **progressive**. It is so because then, at any cumulative level of pre-premium income, the cumulative fraction of premiums paid is lower than the cumulative fraction of pre-premium income.

On the other hand, if the dashed premium-payment Lorenz curve lies above the pre-premium income Lorenz curve then  $K < 0$ , and the distribution of premiums is **regressive** in the sense that, at any cumulative pre-premium income level the fraction of cumulative premiums paid is more than the fraction of cumulative pre-premium income received by those families.

Finally, if the two curves coincide, i.e., the distributions of premiums were the same as the distribution of pre-premium income, the Kakwani Index  $K$  would be 0. Some people might call that fair.

Table 2 below is taken from Adam Wagstaff and Eddy Van Doorslaer, “Equity in Health Care Finance and Delivery,” in A.J. Culyer and J. P. Newhouse eds., *Handbook of Health Economics*, Vol. 1 (2000), pp. 1803-62. The table presents Kakwani indices separately for each of a set of different sources of financing health care and one index for total payments. The latter is a weighted average of the individual indices, where the weights are the proportions of the contributions each sources makes to total financing.

In the rightmost column of the table called “Total payments”, note how much more regressive the total financing of health care in Switzerland ( $K = - 0.1402$ ) and in the U.S. ( $- 0.1303$ ) is relative to the

other countries in the table. Unfortunately, Canada is not included in the table. Chances are that the Kakwani index for Canada is positive, as it that for the U.K. ( $K = 0.0518$ ).

Note also how regressive private health insurance alone (column headed "Private Insurance") is for Switzerland ( $K = -0.2548$ ) and the U.S. ( $K = -0.2374$ ).

Finally, the incidence of out-of-pocket payments (column headed "Direct Payments") is highly regressive everywhere.

Table 2  
Progressivity indices – by country and source

| Country               | Direct taxes | Indirect taxes | General taxes | Social insurance | Total public | Private insurance | Direct payments | Total private | Total payments |
|-----------------------|--------------|----------------|---------------|------------------|--------------|-------------------|-----------------|---------------|----------------|
| Denmark (1987)        | 0.0624       | -0.1126        | 0.0372        |                  | 0.0372       | 0.0313            | -0.2654         | -0.2363       | -0.0047        |
| Finland (1990)        | 0.1272       | -0.0969        | 0.0555        | 0.0937           | 0.0604       | 0.0000            | -0.2419         | -0.2419       | 0.0181         |
| France (1989)         |              |                |               | 0.1112           | 0.1112       | -0.1956           | -0.3396         | -0.3054       | 0.0012         |
| Germany (1989)        | 0.2488       | -0.0922        | 0.1100        | -0.0977          | -0.0533      | 0.1219            | -0.0963         | -0.0067       | -0.0452        |
| Ireland (1987)        | 0.2666       | n.a.           | n.a.          | 0.1263           | n.a.         | -0.0210           | -0.1472         | -0.0965       | n.a.           |
| Italy (1991)          | 0.1554       | -0.1135        | 0.0343        | 0.1072           | 0.0712       | 0.1705            | -0.0807         | -0.0612       | 0.0413         |
| Netherlands (1992)    | 0.2003       | -0.0885        | 0.0714        | -0.1286          | -0.1003      | 0.0833            | -0.0377         | 0.0434        | -0.0703        |
| Portugal (1990)       | 0.2180       | -0.0347        | 0.0601        | 0.1845           | 0.0723       | 0.1371            | -0.2424         | -0.2287       | -0.0445        |
| Spain (1990)          | 0.2125       | -0.1533        | 0.0486        | 0.0615           | 0.0509       | -0.0224           | -0.1801         | -0.1627       | 0.0004         |
| Sweden (1990)         | 0.0529       | -0.0827        | 0.0371        | 0.0100           | 0.0100       |                   | -0.2402         | -0.2402       | -0.0158        |
| Switzerland (1992)    | 0.2055       | -0.0722        | 0.1590        | 0.0551           | 0.1389       | -0.2548           | -0.3619         | -0.2945       | -0.1402        |
| United Kingdom (1993) | 0.2843       | -0.1522        | 0.0456        | 0.1867           | 0.0792       | 0.0766            | -0.2229         | -0.0919       | 0.0518         |
| United States (1987)  | 0.2104       | -0.0674        | 0.1487        | 0.0181           | 0.1060       | -0.2374           | -0.3874         | -0.3168       | -0.1303        |

You will quite a bit of literature with estimated Kakwani indices for other countries, including those in the developing world.

## E. Lorenz Curves above the Equality Lines

In a Lorenz-curve construct, the line tracing out the actual distribution of the thing in question does not always lie below the 45° line. Figure 4 on the illustrates such a case.

FIGURE 4 – LORENZ CURVES FOR ACTUAL UTILIZATION OF HEALTH CARE

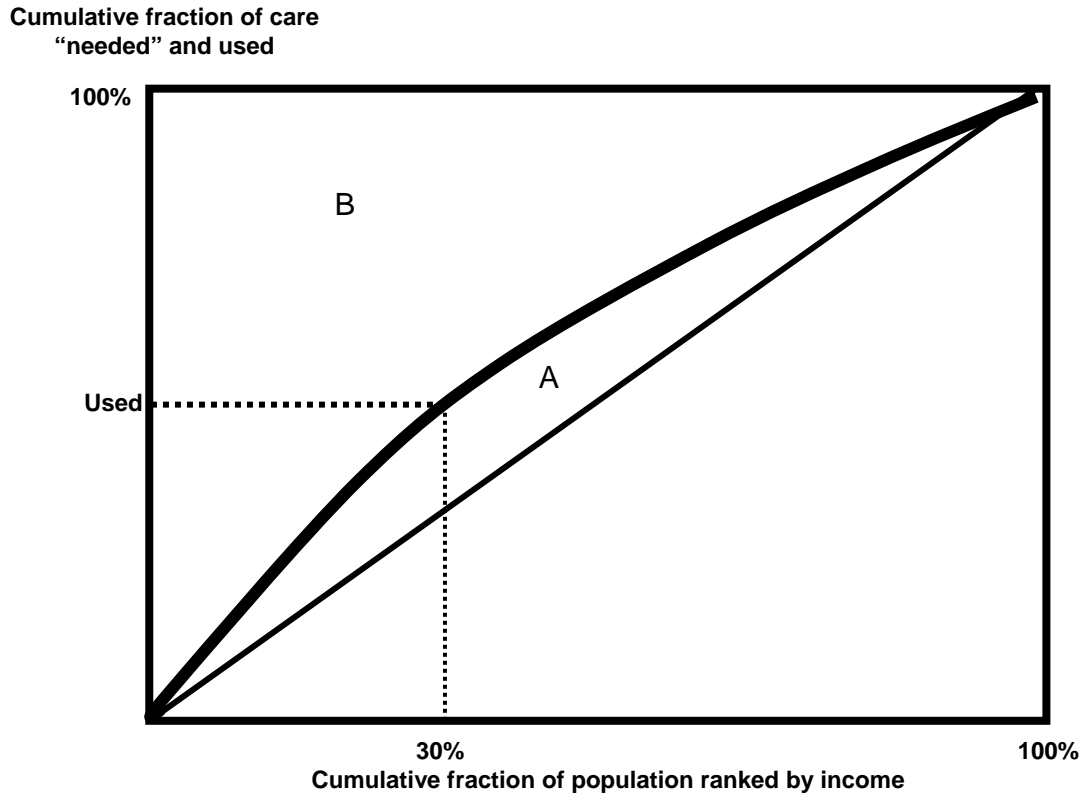


Figure 4 reflects the observed fact that in a **well insured** population (universal, comprehensive health insurance with low cost sharing) the use of healthcare tends to fall with income, because higher-income people tend to be healthier on average than lower income people and need (and use) less health care (if the cost of care is paid by a third party).

Thus, if we depict on the horizontal axis of the graph deciles of such a population, in ascending order of the **average per capita (or family) income** for the deciles, and on the vertical axis the **cumulative percentage of all physician visits or hospital admissions** for this population, then we would be likely to get a Lorenz-curve construct that might look like Figure 4.

Here the GINI-coefficient would be calculated, as before, as the ratio

$$[4] \quad \text{GINI-coefficient} = \text{Area A} / (\text{Area A} + \text{Area B})$$

Once again, because  $\text{Area A} + \text{Area B} = \frac{1}{2}$ , we can also say that

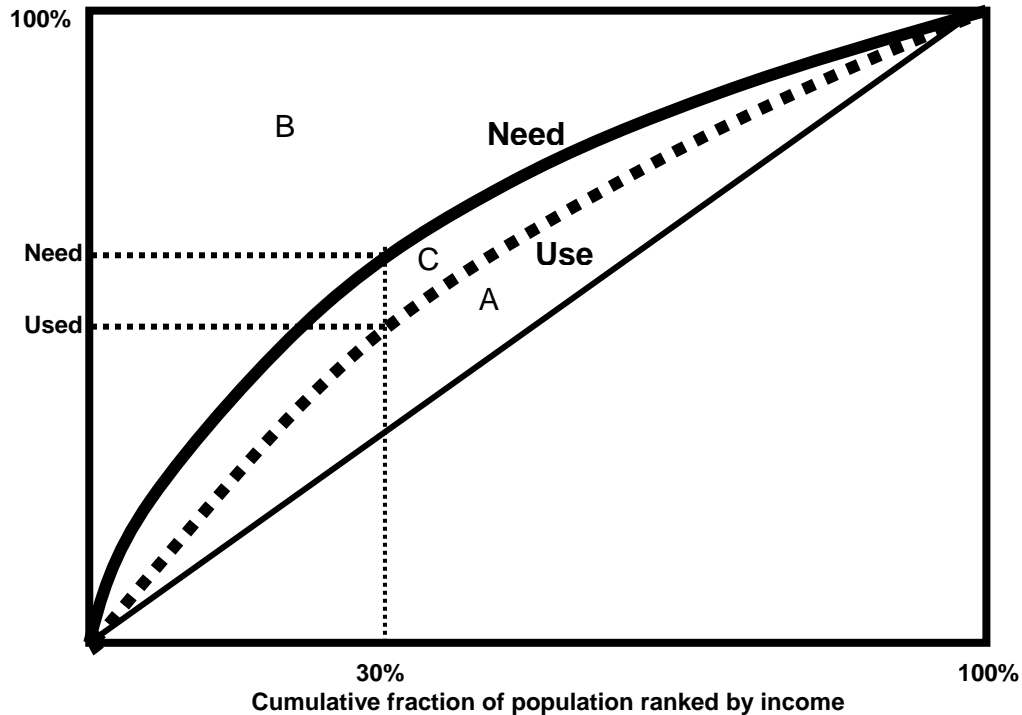
$$[4a] \quad \text{GINI-coefficient} = 2 \times \text{Area A}$$

In a paper by Eddy van Doorslaer *et al.* entitled "Equity in the delivery of health care in Europe and the U.S." (Journal of Health Economics, vol. 19, 2000:553-83), this general idea is sketched out in their Figure 1, p. 556. The authors find that in all 10 countries being compared, lower income groups are more intensive users of health care than higher income groups.

On its face, this finding might appear more inequitable, and some Libertarians would, indeed find it so (see further on). But the authors then compare the Lorenz (alias Concentration) curve for the actual use of health care by different income deciles with a Lorenz curve that represents their estimated "need" for health care by different income deciles, as is done in Figure 5 and then compare it with the Lorenz curve for actual use of health care. Figure 5 illustrates how such a comparison looks.

FIGURE 5 – LORENZ CURVES FOR NEEDED AND ACTUAL UTILIZATION OF HEALTH CARE

Cumulative fraction of care  
“needed” and used



When the Lorenz curve for “need” is found to lie above the Lorenz curve for actual use, it indicates that, say, that families in the bottom 30% of the income distribution under **underserved**, relative to their “need” for health care and relative to higher income groups. Figure 5 illustrates that case. In this case, the degree of inequity “relative to need and other income groups” can be calculated as the difference

$$\begin{aligned}
 [5] \quad \text{Index of inequity} &= \text{Gini coefficient of need} - \text{Gini coefficient of use} \\
 &= (A + C)/(A + B + C) - A/(A + B + C)
 \end{aligned}$$

We know by now that, because  $(A + B + C) = \frac{1}{2}$ , this reduces to

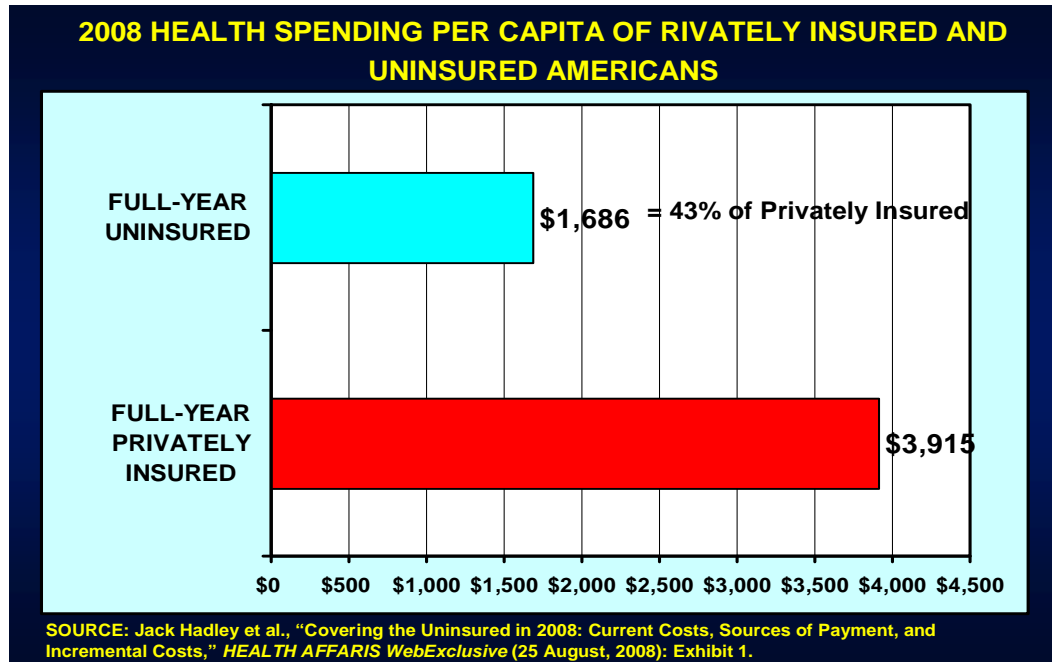
$$= 2C$$

If  $C$  is positive, it means that there is inequity in favor of the higher income groups. If  $C$  is negative, that is, if the Lorenz curve for the “need” for health care lies below the Lorenz curve for actual use of health care one would reach the conclusion that relative to need and the rest of the population, the lower-income groups are **overserved**, which might be judged inequitable as well.

Van Doorslaer et al., by the way, conclude from their study that, after standardization for “need” as shown above, “there is little or no evidence of significant inequity in the delivery of health care overall, though in half of the countries, significant pro-rich inequity emerges for physician contacts.” A particularly interesting finding for the much maligned U.S. health system is that

“... for a given need, the U.S. higher income groups do not seem to receive a higher *volume* of care than the worse-off, but they do *spend* more on health care. Whether this higher spending can be regarded as inequitable, given our definition, depends largely on whether it also translates into better treatment (*Italics added*; p. 570, and Table 8 p. 571).

To be sure, the analytic construct they use is highly aggregated and probably cannot pick up the known fact that those of the roughly 45 million found to be without health insurance in the U.S. at any time who do get sick (which is only a minority of the uninsured) are known to receive, on average, much less health care than that received by similarly situated but well insured Americans. The graph below, taken from a study by Hadley et al. (as shown in the citation), shows that in a large nationwide sample of U.S. families, health spending by or on uninsured Americans in 2008 was only about 43% of spending for insured Americans with similar demographic characteristics. One could interpret it as the result of rationing health care by price and ability to pay.



Could we conclude from the graph that uninsured Americans are **underserved**? One's answer depends on one's social ethic.

Libertarians probably would answer "No," on the grounds that the uninsured got all of the health care they were willing to pay for, and then some, if they received care on a charitable basis or simply did not pay the providers of health care *ex post*, leaving the providers to absorb the loss or to shift the cost of that care to other paying customers.

Rawlsians might argue that willingness to pay is constrained by ability to pay, that there are clinical norms of what "adequate and timely health care is" and social norms on who should have access to it, and that against those norms the uninsured were **underserved**.

We may note in passing that, according to the *Institute of Medicine of the National Academy of Sciences*, some 18,000 Americans die each year prematurely as a result of being uninsured.<sup>1</sup>

## E. A Libertarian View on Inequities in Health Care

It may seem natural among students at North-Eastern universities to regard situations such as that illustrated in Figure 5 "inequitable," because low-income families appear "underserved" by the health system relative to richer families. That is only a particular ethical perspective which cannot claim roots in some natural law.

<sup>1</sup> In this regard, see Institute of Medicine, *Hidden Costs, Value Lost: Uninsurance in America*, The National Academy Press, 2003: Figure ES1.

As the debate over tax cuts in recent years has demonstrated, many high-income Americans or their champions among intellectuals do seem to believe, that ours is an almost perfect meritocracy, in which a person's wealth reflects the value of his or her contribution to society. On that view, a distribution of health care that Van Doorslaer *et al.* might score as "equitable" would actually be interpreted as "inequitable." High income families would be thought to deserve of better health care, education, housing and so on, precisely because they contribute relatively more to society than do low income people, who are poor precisely because their contribution to society is relatively more modest.

How that Libertarian social ethic is to be reconciled with inheritance, or with the legacy of slavery and more than a century of blatant subsequent racial discrimination in this country is an intriguing question, not even to speak of the many other imperfections in our market system in which political favors routinely can be purchased, like fast food.

Be that as it may, to illustrate the Libertarian line of thinking on health care, I shall cite Richard Epstein, Distinguished Professor of Law at the University of Chicago.

After the demise of the Clinton health-reform initiative, I had published a commentary in the *Journal of the American Medical Association (JAMA)*<sup>2</sup> in which I posed to the reader the following question:

"As a matter of national policy, and to the extent that a nation's health system can make it possible, should the child of a poor American family have the same chance of avoiding preventable illness or of being cured from a given illness as does the child of a rich American families?"

Speaking for myself, I had answered this question in the affirmative.

Of the 5 or so letters triggered by this commentary, 4 were from physicians, who uniformly refused to answer the question I posed, but instead decried me as a Socialist propagandist (or worse). In my experience, it is par for the course when one raises questions of social ethics in this country.

A more respectful response, however, came from Prof. Epstein<sup>3</sup> who wrote:

"The correct answer is no. ... his [Reinhardt's] proposal for equal medical treatment *perverse*ly requires more care to children of poor parents than to children of rich ones, precisely because the rich families can more easily avoid injury and illness and can better pick up the slack in the health care delivery system." (Italic added).

I interpreted the Professor's use of the word "perverse" as "directed away from what is right or good."

Evidently, Professor Epstein would not accept Van Doorslaer *et al.*'s interpretation of a positive index in equation [4] above as "inequitable." Presumably he would call them "perverse" as well. For my part, I do not view Prof. Epstein's answer to my question "wrong" or "perverse." It simply reflects a different theory of justice than might be held by others in the debate on health policy, myself included.

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<sup>2</sup> Uwe E. Reinhardt, "Wanted: A Clearly Articulated Social Ethic for American Health Care," *Journal of the American Medical Association*, 278(5) (November 5, 1997): 1446-7.

<sup>3</sup> Richard A. Epstein, "Articulating a Social Ethic for Health Care," *Journal of the American Medical Association* 279(10) (March 11, 1998): 745.