# The Quantity and Quality of Life and the Evolution of World Inequality

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*GDP per capita is usually used to proxy for the quality of life of individuals living in different countries. Welfare is also affected by quantity of life, however, as represented by longevity. This paper incorporates longevity into an overall assessment of the evolution of cross-country inequality and shows that it is quantitatively important. The absence of reduction in cross-country inequality up to the 1990s documented in previous work is in stark contrast to the reduction in inequality after incorporating gains in longevity. Throughout the post–World War II period, health contributed to reduce significantly welfare inequality across countries. This paper derives valuation formulas for infra-marginal changes in longevity and computes a "full" growth rate that incorporates the gains in health experienced by 96 countries for the period between 1960 and 2000. Incorporating longevity gains changes traditional results; countries starting with lower income tended to grow faster than countries starting with higher income. We estimate an average yearly growth in "full income" of 4.1 percent for the poorest 50 percent of countries in 1960, of which 1.7 percentage points are due to health, as opposed to a growth of 2.6 percent for the richest 50 percent of countries, of which only 0.4 percentage points are due to health. Additionally, we decompose changes in life expectancy into changes attributable to 13 broad groups of causes of death and three age groups. We show that mortality from infectious, respiratory, and digestive diseases, congenital, perinatal, and "ill-defined" conditions, mostly concentrated before age 20 and between ages 20 and 50, is responsible for most of the reduction in life expectancy inequality. At the same time, the recent effect of AIDS, together with reductions in mortality after age 50—due to nervous system, senses organs, heart and circulatory diseases—contributed to increase health inequality across countries.* (*JEL* I10, I31, J17, O57)

Although GDP per capita is usually used as a proxy for the quality of life in different countries, material gain is obviously only one of many aspects of life that enhance economic well-being. Overall economic welfare depends on both the quality and the quantity of life: yearly income and the number of years over which this income is enjoyed. Both past and recent estimates suggest that longevity has been a quantitatively important component of the overall gain in welfare in the United States during the twentieth century (Dan Usher, 1973; David Cutler and Elizabeth Richardson, 1997; William D. Nordhaus, 2003; Kevin M. Murphy and Robert Topel, 2003; similar evidence for Sweden is presented by Kristina Burström et al., 2003). This paper analyzes whether gains in life expectancy have also been an important determinant of the evolution of welfare inequality across countries.

A vast literature has investigated the evolution of the cross-country dispersion in income per capita, and whether poor countries tend to grow faster than rich ones (see, for example,

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TABLE 1—EVOLUTION OF CROSS-COUNTRY INEQUALITY IN INCOME AND LIFE EXPECTANCY, 1960–2000

| | Income per capita | | | Life expectancy | | |
|---|---|---|---|---|---|---|
| | 1960 | 1990 | 2000 | 1960 | 1990 | 2000 |
| Relative mean dev. | 0.4751 | 0.4733 | 0.4215 | 0.1179 | 0.0507 | 0.0509 |
| Coeff. of variation | 1.2344 | 1.2529 | 1.1662 | 0.2629 | 0.1245 | 0.1361 |
| Std. dev. of logs | 1.0178 | 1.0300 | 0.9620 | 0.2552 | 0.1326 | 0.1513 |
| Gini coeff. | 0.5104 | 0.5187 | 0.4873 | 0.1293 | 0.0690 | 0.0730 |
| Regression to the mean over previous date | | −0.0069 ($p$-value = 0.86) | −0.0741 ($p$-value = 0.00) | | −0.6133 ($p$-value = 0.00) | 0.0364 ($p$-value = 0.31) |

*Notes:* Income per capita is GDP per capita in 1996 international prices, adjusted for terms of trade (Penn World Tables 6.1). Life expectancy is life expectancy at birth (World Development Indicators, World Bank). Inequality measures weighted by country population (abstracting from within country inequality). Sample includes 96 countries, comprising more than 82 percent of the world population. Regression to the mean is the coefficient of a regression of the change in the variable over the period on its initial level (natural logs used in the income regressions; weighted regressions).

Robert J. Barro and Xavier Sala-i-Martin, 1995; Angel de la Fuente, 1997; Gregory Mankiw et al., 1992; Danny T. Quah, 1996; Stephen L. Parente and Edward C. Prescott, 1993). All these studies give virtually the same results, namely, that income inequality across countries was not reduced during most of the postwar period.

In contrast, evidence suggests that cross-country inequality in several different dimensions of health was substantially reduced throughout the twentieth century (see, for example, Francois Bourguignon and Christian Morrison, 2002; Brian Goesling and Glenn Firebaugh, 2004; Eric Neumayer, 2003; Randa Sap and Stephen C. Smith, 2002; Stephen Younger, 2001). So the trends in income and health inequality have indeed been strikingly different in the recent past, and, therefore, trusting on income alone to infer the evolution of welfare inequality across countries may lead to misleading results.

We illustrate the cross-country trends in health and income inequality between 1960 and 2000 in Table 1. Income is measured with the gross domestic product per capita adjusted for terms of trade (Penn World Tables 6.1), and health is measured by life expectancy at birth (World Bank World Development Indicators). The sample includes 96 countries, comprising more than 82 percent of the world population in 1960.

The table shows several dispersion measures (weighted by country populations) for income per capita and life expectancy at birth, for the years 1960, 1990, and 2000. The last row presents the regression to the mean over the previous period: the coefficient of a regression of the change in the variable on its initial level (the natural logarithm, in the case of income per capita).

These data, as previous research has found, show that regressions to the mean, Gini coefficients, coefficients of variation, and other measures of inequality do not show evidence of reduction in income inequality across countries up to the 1990s.[1] During the 1990s, the economic success of China and India, together with their huge populations, reduced the cross-country dispersion in income per capita. (Without these two countries, the sample shows increasing inequality between 1960 and 1990, and stable inequality between 1990 and 2000; this is also in good part behind the results obtained in Sala-i-Martin, 2002.)

Table 1 also presents the same dispersion measures usually used for income for the case of life expectancy at birth. In this case, the evidence is diametrically opposite. By any measure, life expectancy inequality declines substantially over the entire period. Countries starting with low longevity tended to gain more in life expectancy than countries starting with high longevity.[2] The regression to the mean

[1] As pointed out by Milton Friedman (1992), zero-mean measurement error in the initial period income tends to generate spurious negative correlation, artificially increasing the degree of regression to the mean. Even with this bias, it is not uncommon for one to obtain a positive coefficient in these regressions.

[2] As opposed to the negative impact of measurement error on regression to the mean in income, there are reasons to believe measurement error has a positive impact in the case of longevity. An upward bias in poor-country life expectancies is commonly believed to occur due to incom-

coefficient implies that, on average, each additional ten years of life expectancy in 1960 were associated with a reduction of roughly six years in life expectancy gains in the following 40 years. But the decline in health inequality is concentrated entirely between 1960 and 1990. After that, the effects of AIDS in Africa are felt, and life expectancy inequality increases slightly between 1990 and 2000.

These two patterns suggest that incorporating longevity into an overall assessment of the changes in cross-country inequality may be important, as the extent of changes in income inequality is small compared to the changes in life expectancy inequality. In addition, changes in income and health inequality have followed completely different patterns, suggesting that a large component of the recent changes in health is orthogonal to income.

This paper tries to account for the impact of longevity on the evolution of welfare across countries during the last few decades. The use of per capita income to evaluate welfare improvements assumes that it reflects the level of economic welfare enjoyed by the average person, but it has well-known shortcomings such as not measuring nonmarket goods and home-production. We try to fill in one of those gaps by incorporating survival rates throughout a person's life. In particular, we consider the evolution of welfare for a "hypothetical life-cycle individual" (HLCI). A HLCI for a given year and country is defined to have the income per capita of the country in every year of life and to face throughout life the survival probabilities determined by the country's cross-sectional survival curve. Our results refer to inequality across different societies as measured by differences in welfare of this hypothetical individual.

We estimate the monetary value of longevity gains and add it to the observed gains in income per capita. This gives the change in income that would have been observed if all the welfare gain in the period had taken the form of income growth. We then analyze how the growth in this "full income," including both changes in income per year and the value of years enjoyed, changes the traditional results regarding cross-country inequality. Our main result is that incorporating longevity changes the conclusions related to the evolution of welfare inequality over time: countries became significantly more equal between 1960 and 2000. In particular, we estimate an average yearly growth in "full income" of 2.8 percent, of which roughly three-quarters are due to income per capita and one-quarter to longevity. For the poorest 50 percent of countries in 1960, however, there is an average yearly growth of 4.1 percent, of which 1.7 percentage points are due to health, as opposed to the richest 50 percent of countries, for which the average yearly growth in "full income" is 2.6 percent, and only 0.4 percentage points are due to health.

We also disaggregate mortality data by age groups and causes of death to try to understand the determinants of the cross-country reduction in life expectancy inequality, and the diseases responsible for the observed gains in welfare. For each age group and cause of death, we compute a counterfactual measure of the mortality rate that would be observed in the 1990s had mortality rates by all causes and at all ages but the ones in question remained at their 1960 values. This approach allows us to estimate the life expectancy gain attributable to reductions in mortality at each age and by each specific cause of death. We show that changes in mortality due to infectious, respiratory, and digestive diseases, and congenital and perinatal conditions, mostly concentrated at early ages, are the most important factors determining the reduction in life expectancy inequality. In other words, mortality at early ages by these causes of death fell more rapidly in poor than in rich countries. At the same time, reductions in mortality due to nervous system, senses organs, heart, and circulatory diseases worked toward increasing inequality, as mortality among the elderly by these causes fell more rapidly in rich than in poor countries. The large changes in mortality observed in the developing world are consistent with the interpretation that poor countries absorbed technology and knowledge previously available in rich countries, at relatively low costs, while most of the changes in mortality in developed countries took advantage of recent developments on the frontier of medical technology.

Our paper relates to the original work of Dan

plete data from rural areas. This upward bias has been reduced, however, by improved collection of mortality statistics in poor countries in the last decades. The reduction in upward bias for poor countries would induce a positive, as opposed to negative, bias on the regression toward the mean.

Usher (1973), which was developed further by Sherwin Rosen (1988) and Murphy and Topel (2003). Our work also relates to existing measures created by the United Nations that attempt to incorporate nonmaterial aspects into broader measures of well-being (UNDP, 2002). However, as discussed at length in Philipson and Soares (2002), our methods differ in that preferences revealed by market behavior, and not by arbitrary assumptions from government or international agencies, dictate the relative importance of nonmaterial aspects in the overall evaluation of welfare.

The structure of the paper is outlined as follows. Section I discusses the methodology used to value longevity gains, extending previous analysis of marginal changes in longevity to consider valuations of infra-marginal changes. Section II contains our basic results on the reduction in inequality induced by considering longevity gains. Section III considers age- and cause-specific contributions to this reduction in inequality. Section IV concludes the paper.

## I. Valuing Infra-Marginal Changes in Longevity

### A. *Theory*

Previous work of Usher (1973), Rosen (1988), and Murphy and Topel (2003) derive formulas to value marginal changes in survival rates. Here we extend this work by providing the corresponding formulas for infra-marginal changes. Consider the indirect utility function $V(Y,S)$ of an individual with survival function $S$ and lifetime income $Y$:

$$(1)\quad V(Y, S) = \max \int_0^\infty \exp(-\rho t)S(t)u(c(t))\,dt$$

subject to

$$(2)\qquad Y = \int_0^\infty \exp(-rt)S(t)y(t)\,dt$$

$$= \int_0^\infty \exp(-rt)S(t)c(t)\,dt$$

where $S(t)$ is the probability of survival to age $t$, $y(t)$ is income at $t$, $c(t)$ consumption at $t$, and $r = \rho$ the assumed interest rate. This budget constraint assumes full annuity insurance, or the existence of a complete contingent claims market.

Now consider a given country at two points in time, with lifetime income and survival functions denoted by $Y$ and $S$, and $Y'$ and $S'$ respectively. We are interested in the infra-marginal income $W(S,S')$ that would give a person in this country the same utility level observed in the first period, but with the mortality rates observed in the second:

$$(3)\quad V(Y' + W(S, S'), S) = V(Y', S').$$

The growth rate in the "full" lifetime income that values both the gains in material income and the gains in longevity then corresponds to $G = [Y' + W(S,S')]/Y - 1$. This "full" growth rate is thus the standard growth rate added with the growth rate in income measuring the gains in longevity.

Income can be used to measure material improvements only with a set of assumptions that justifies using a single number to portray changes in a country's welfare. Similar simplifying assumptions are needed here to measure the material value equivalent to the life expectancy gains. More precisely, to calibrate the model for commonly available national income and mortality statistics for a given country and year, we consider a HLCI who receives the country's income per capita in all years of life and faces throughout life the country's cross-sectional survival function. Under the maintained assumptions, this implies that optimal consumption equals the constant income, $c(t) = c = y$, so that the indirect utility function can be expressed in terms of the yearly income $y$, as in:

$$(4)\qquad V(y, S) = u(y)A(S)$$

where $A(S) = \int_0^\infty \exp(-rt)S(t)\,dt$ is the value of an annuity based on the survival function $S$. If $w(S,S')$ is the yearly, as opposed to lifetime, income that measures the gain in longevity in a manner similar to before, $w$ satisfies

$$(3')\quad u(y' + w(S, S'))A(S) = u(y')A(S').$$

with the corresponding annual "full-income" growth rate $g = [y' + w(S,S')]/y - 1$. The value of longevity gains measured in yearly income is related to the value measured in lifetime income according to $W(S,S') = A(S)w(S,S')$. The usual critiques of GDP as a measure of "full income"—that it does not incorporate value of leisure, household production, and nonmarket goods—also apply to our methodology. In fact, we attempt to fill in one of these gaps, as it relates to home-produced or nonmarket health.

### B. *Calibration*

Here we discuss our methods for calibrating the parameters used throughout the empirical analysis to estimate the infra-marginal willingness to pay for gains in survival rates $w(S,S')$. The monetary value of the gains in longevity measured in annual income and the growth rate in "full-income" are determined implicitly from expression (3′). If we can invert the instantaneous utility function $u(.)$, they can be written as:

$$(5) \qquad w = u^{-1}\left[\frac{u(y')A(S')}{A(S)}\right] - y', \text{ and}$$

$$g = u^{-1}\left[\frac{u(y')A(S')}{A(S)}\right]\frac{1}{y} - 1.$$

As stressed by Rosen (1988), two dimensions of the instantaneous utility function affect the willingness to pay for extensions in life expectancy. The first is the substitutability of consumption in different periods of life, i.e., the inter-temporal elasticity of substitution, and the second is the value of being alive relative to being dead. We calibrate the following functional form for the instantaneous utility function to capture these two different dimensions:

$$(6) \qquad u(c) = \frac{c^{1-1/\gamma}}{1-1/\gamma} + \alpha$$

The parameter $\alpha$ determines the level of annual consumption at which the individual would be indifferent between being alive or dead, arising from the normalization of the utility of death to zero. If the inter-temporal elasticity of substitution $\gamma$ is larger than 1, then $\alpha$ is negative. With expression (5) and this functional form, we obtain closed form solutions for $w$ and $g$.[3]

The set of parameters $(\alpha,\gamma,r)$ needed to compute these values can be calibrated from other parameters more commonly estimated in the "value of life" and consumption literatures. More precisely, we have that $\alpha = c^{1-1/\gamma}(1/\varepsilon - (1/(1-1/\gamma)))$, where $\varepsilon = (u'/(c)c)/u(c)$ is the elasticity of the instantaneous utility function, often discussed and estimated in empirical studies of compensating differentials for occupational mortality risks. In particular, Murphy and Topel (2003, p .23) estimate $\varepsilon$ to equal 0.346. Martin Browning et al. (1999, p. 614), after exhaustively reviewing the estimates from the empirical literature on the inter-temporal elasticity of substitution ($\gamma$), suggest that it is slightly above unity. Using $\gamma = 1.250$, $\varepsilon = 0.346$, and $c = \$26{,}365$, we calibrate the value of $\alpha$ to equal $-16.2$.[4,5] We assume the annual interest rate $r$ to be 0.03.

[3] The closed form expression for $w$ is:

$$w = \left[y'^{1-1/\gamma}\frac{A(S')}{A(S)} + \alpha\left(1-\frac{1}{\gamma}\right) \times \left(\frac{A(S') - A(S)}{A(S)}\right)\right]^{\gamma/(\gamma-1)} - y'.$$

[4] The value of consumption is the value of U.S. per capita income in 1990 in the PWT 6.1 dataset, matching the year in which Murphy and Topel (2003) estimate $\varepsilon$ using U.S. data. With the calibrated utility parameters, an individual with annual income equal to \$353 would be indifferent between being alive or dead. The only values of the GDP per capita variable (adjusted for terms of trade, *rgdptt*) in the PWT 6.1 dataset below \$353 are the ones for the Democratic Republic of Congo between 1994 and 1997.

[5] Notice that the functional form adopted is flexible enough to accommodate an income-elasticity of the willingness to pay for changes in life expectancy that actually changes with income. So the calibration using U.S. data is not limiting in the sense of imposing a willingness to pay that does not belong to the less-developed countries we want to analyze. If we look at the income-elasticity of the marginal willingness to pay for life extensions, it varies from 1.2 for average levels of income per capita (around \$10,000 in 2000), to 1.9 and 3.8 for, respectively, \$1,000 and \$500 of income per capita. Therefore, the functional form adopted is flexible enough to identify underlying preference parameters that, in principle, can be used irrespective of the income level. Viscusi and Aldy (2003) make an extensive review of estimates of the "value of a statistical life" around the world. For the developed countries included in their review, our parameterization implies "values of a

TABLE 2—VALUE OF LIFE EXPECTANCY GAINS BY REGION OF THE WORLD AND GROUPS OF COUNTRIES, 1960–2000

| | 1960 | | 2000 | | Value of life exp. gains in annual income | Lifetime present value of life exp. gains | Yearly growth rate of full income (percentage) |
|---|---|---|---|---|---|---|---|
| | Life exp. | GDP p.c. | Life exp. | GDP p.c. | | | |
| Europe & Central Asia | 68 | 6,810 | 76 | 18,281 | 1,809 | 51,706 | 2.7 |
| East Asia & Pacific | 42 | 1,317 | 71 | 5,866 | 2,600 | 60,957 | 4.8 |
| Latin Am. & the Carib. | 56 | 3,459 | 70 | 7,161 | 1,365 | 36,935 | 2.3 |
| Middle East & N. Africa | 48 | 1,935 | 69 | 5,525 | 1,817 | 46,076 | 3.4 |
| North America | 70 | 12,380 | 77 | 32,880 | 2,804 | 81,993 | 2.7 |
| South Asia | 44 | 892 | 63 | 2,346 | 635 | 15,504 | 3.1 |
| Sub-Saharan Africa | 41 | 1,470 | 46 | 1,573 | 72 | 1,612 | 0.3 |
| Poorest 50% countries in 1960 | 41 | 896 | 64 | 3,092 | 1,456 | 33,673 | 4.1 |
| Richest 50% countries in 1960 | 65 | 7,195 | 74 | 18,162 | 2,076 | 58,957 | 2.6 |
| World | 49 | 2,983 | 67 | 7,236 | 1,627 | 40,626 | 2.8 |

*Notes:* Income per capita is GDP per capita in 1996 international prices, adjusted for terms of trade (Penn World Tables 6.1). Life expectancy is life expectancy at birth (World Development Indicators, World Bank). Regional averages weighted by country population. Sample includes 96 countries, comprising more than 82 percent of the world population. Value of life expectancy gains based on the authors' calculations.

## II. The Effect of Life Expectancy on World Inequality

We use expression (5) to calculate the value of the longevity gains observed between 1960 and 2000 and to evaluate the impact of the changes in longevity on cross-country inequality. Per capita income figures (adjusted for terms of trade) are taken from the Penn World Tables version 6.1 (variable rgdptt). In order to include a sample that is as representative as possible, we use life expectancy at birth numbers from the World Bank World Development Indicators and apply the deterministic version of the methodology discussed in the previous section.

Table 2 presents the results for the value of longevity gains and the growth rate of "full income," together with income and life expectancy statistics, using the value of the parameters derived in the previous section. The value of longevity gains is presented in two forms: yearly income ($w$) and total discounted lifetime value ($W$). Results are presented for the regions of the world according to the World Bank classification, and for the groups of poorest and richest countries in 1960 (population-weighted averages).

The average value of longevity gains in terms of annual income for the entire sample is $1,627. The value is somewhat higher for the richest countries: $2,076 against $1,456 (in international prices). But the relation between these values and the initial income is much higher for poor countries, where it reaches 163 percent, as opposed to 29 percent for the richest half of the sample. This tendency is also reflected in the growth rate of "full income." In this case, since the initial income level is lower for developing countries, the difference between the richest and poorest countries is reversed: the average yearly growth for the top half of the sample is 2.6 percent, against 4.1 percent for the bottom half.

The regional profile of the value of longevity changes also reflects this trend. In terms of the yearly growth in "full income," East Asia and the Pacific, the Middle East and North Africa, and South Asia emerge as the top performers. Apart from the well-known development success of the Southeast Asian countries, this also reflects to a great extent the more recent success of China and India, in both the economic and health arenas. But perhaps most striking is the dismal performance of sub-Saharan Africa, which displays the lowest growth rate of "full-income" in the sample. As we discussed before,

statistical life" between $1.5 and $2.5 million. These are typically in the lower range of estimates discussed in Viscusi and Aldy (2003). If anything, our parameterization will tend to underestimate the value of reductions in mortality rates.

TABLE 3—EVOLUTION OF CROSS-COUNTRY INEQUALITY IN FULL INCOME, 1960–2000

| | Income per capita | | | Full income | |
|---|---|---|---|---|---|
| | 1960 | 1990 | 2000 | 1990 | 2000 |
| Relative mean dev. | 0.4751 | 0.4733 | 0.4215 | 0.4397 | 0.3760 |
| Coeff. of variation | 1.2344 | 1.2529 | 1.1662 | 1.1664 | 1.0463 |
| Std. dev. of logs | 1.0178 | 1.0300 | 0.9620 | 0.9758 | 0.9476 |
| Gini coeff. | 0.5104 | 0.5187 | 0.4873 | 0.4935 | 0.4561 |
| Regression to the mean over 1960 | | −0.0069 ($p$-value = 0.86) | −0.1338 ($p$-value = 0.01) | −0.1006 ($p$-value = 0.02) | −0.2638 ($p$-value = 0.00) |

*Notes:* Income per capita is GDP per capita in 1996 international prices, adjusted for terms of trade (Penn World Tables 6.1). Full income calculated by the authors with 1960 as base year, incorporating gains in life expectancy at birth (World Development Indicators, World Bank). Inequality measures weighted by country population (abstracting from within country inequality). Sample includes 96 countries, comprising more than 82 percent of the world population. Regression to the mean is the coefficient of a regression of the change in the natural log of income over the period on its initial level (weighted regressions).

this is partly due to the reversal of the gains in life expectancy that was brought about by the outbreak of the AIDS epidemic in the 1990s. Nevertheless, the size of the sub-Saharan population is relatively small when compared to the other developing regions, and the net effect of health is to reduce overall inequality.

This indicates that, unlike income changes, longevity changes since 1960 reduced the disparity in welfare across countries. Table 3 explores this point further by repeating the same income dispersion measures presented in table 1, and by additionally calculating the same statistics for "full income" in 1990 and 2000 (taking 1960 as the base period). As the table shows, by any statistic, the inclusion of life expectancy in the measure of "full income" generates significant reductions in inequality between 1960 and 1990, and also a significant increase in the rate of reduction in inequality between 1960 and 2000. The coefficient on *ln (income in 1960)* in the "full-income" regression to the mean equations is negative and statistically significant. Higher income in 1960 is consistently associated with lower growth in "full income" in the 30-year period between 1960 and 1990 and in the 40-year period between 1960 and 2000.

The ideal independent variable in the right-hand side of this regression should be a measure of "full income in 1960." Since the approach discussed in Section I does not allow us to calculate the value of given levels of life expectancy, but only the value of changes in life expectancy, we are forced to use the 1960 value of income per capita rather than "full income." As long as the income elasticity of the value of life is not much below unity, using some measure of "full income" in this regression would unambiguously increase the degree of convergence, since richer countries in 1960 also had higher life expectancy.

These results indicate reduction in welfare inequality throughout most of the postwar period, in the sense that countries with higher initial income tended to have significantly lower subsequent welfare gains. Incomes 100 percent higher in 1960 were associated, on average, with "full-income" growth rates 10 percent lower in the following 30 years, and 26 percent lower in the following 40 years. This result is not surprising, given the negative correlation between life expectancy gains and income. As long as the income elasticity of value of life is not much above unity, any value attached to longevity would work toward increasing convergence. W. Kip Viscusi and Joseph E. Aldy (2003) conclude, from various types of evidence, that this elasticity is less than unity, but their results for countries are greatly affected by a couple of extreme observations for India. Without these observations, Becker and Julio J. Elias (2003) get an elasticity of about unity.

The evidence presented here also indicates that the relative importance of health improvements, when compared to income gains, was systematically higher for the developing world. The share of the welfare improvements observed between 1960 and 2000 due to mortality reductions—calculated as *value of longevity gains in annual income/(value of longevity gains in annual income + increase in annual*

*income between 1960 and 2000*)—has an average of 28 percent for the entire world. But this number is above 30 percent for East Asia and the Pacific, the Middle East and North Africa, and South Asia, and below 14 percent for Europe and Central Asia and for North America.

Overall, the evidence shows that longevity changes in the period between 1960 and 2000 worked toward reducing the disparity in welfare across countries. The actual reduction in disparity depends on the specific values of the parameters $\alpha$ and $\gamma$; that is, on the relative importance of quantity and quality of life. Nevertheless, the qualitative role played by mortality reductions, and the fact that their impact on welfare was quantitatively important, should be obvious.

These results would be even stronger if we accounted for expenditures on health and R&D, because part of the gains in life expectancy is driven by these expenditures. Since most of these expenditures are undertaken by the developed world, the share of truly exogenous reductions in mortality is certainly higher for the less-developed countries.[6] Therefore, convergence in welfare would be higher if the endogenous part of longevity gains were netted out.

## III. The Causes of Changes in Mortality Inequality

Cross-country life expectancy convergence would follow if countries shared the same concave health production technology, as the international evidence suggests, and spent the same on health. Countries with higher initial mortality would then have larger mortality reductions because they have much higher returns on investments in health than do countries with lower mortality.

The shift in the income–life expectancy profile noticed elsewhere suggests, however, that this is not the whole story, and that a considerable part of the changes in longevity is related to technological improvements (see Samuel H. Preston, 1980; Soares, 2005). Stable concave returns to investments in health cannot account for the changing cross-sectional relationship between income and life expectancy. Moreover, since investments in health are much larger for developed than for developing countries—measured either in absolute terms or as shares of income—a stable health production function could not explain the convergence in life expectancy, unless returns to investments in health were implausibly higher for the less-developed world.

### A. *Data*

To understand the nature of the changes in mortality in the developing world, we decompose the gains in life expectancy into different age groups and causes of death. The World Health Organization Mortality Database contains number of deaths by age and cause of death for the years between 1960 and 2000. Causes of death in the different years are classified according to the current International Classification of Diseases (ICD) codes, so data for different periods have to be made compatible by matching codes of the different versions of the ICD. As we will be dealing with rather broad groups of causes of death, this will not be a problem.

We define the following 13 groups of causes of death: R01: infectious diseases; R02: neoplasms; R03: endocrine, metabolic, and blood diseases, and nutritional deficiencies; R04: mental disorders; R05: diseases of the nervous system and senses organs; R06: heart and circulatory diseases; R07: respiratory and digestive diseases; R08: urinary and genital diseases; R09: abortion and obstetric causes; R10: skin and musculoskeletal diseases; R11: congenital anomalies and perinatal period conditions; R12: ill-defined conditions; and R13: accidents, suicides, and homicides. The grouping of the codes from the ICD-6/7 and ICD-9 into these 13 categories is described in the Appendix.

Mortality data by age groups and causes of death for earlier years are available only for a restricted sample of countries. In order to increase cross-country comparability in our dataset, we use the mortality data as ten-year averages centered in the reference years: 1965 corresponds to the average for the period be-

[6] For example: in 2000, health expenditures per capita in the richest OECD countries were typically above $2,000, reaching $4,252 for the United States; in the same year, these expenditures were below $300 for countries like China, India, Mexico, Poland, and Turkey. In terms of shares of GDP, these values corresponded to around 10 percent for the richest countries, as opposed to 5 percent for the developing countries cited above (data from the World Bank World Development Indicators). Expenditures on R&D are usually even more concentrated than that.

tween 1960 and 1969, and 1995 corresponds to the average between 1990 and 1999 (or years available in these intervals). Even after this, the sample includes only 49 countries.[7] The most critical problem with this dataset is that it contains only one sub-Saharan African country (Mauritius). So we cannot possibly expect this exercise to reveal the effects of AIDS mortality in the later part of the twentieth century. But, as the previous discussion pointed out, the behavior of life expectancy in sub-Saharan Africa after 1990 immediately reveals the overwhelming effects of AIDS on the recent evolution of mortality across countries. So the real puzzle lies in the reduction on life expectancy inequality prior to 1990, not in the effects of AIDS after that.

In this respect, apart from the absence of sub-Saharan Africa, there does not seem to be any specific bias induced by the reduced sample. In fact, the experience of the countries included in the sample seems to be quite typical of the cross-country changes in life expectancy observed prior to the arrival of AIDS. The coefficient of regression to the mean in life expectancy between 1965 and 1995 in this sample is equal to $-0.55$, as compared to a coefficient equal to $-0.61$ observed between 1960 and 1990 in the larger sample used in Section I.

In any case, this is a limitation imposed by data availability, and we can do nothing about it. When interpreting the results related to age- and cause-specific mortality, it is important to keep in mind that they are probably an accurate description of the pre-AIDS experience of technological diffusion from developed to developing countries, but not of the recent experiences of sub-Saharan Africa and of the extremely poor countries of the world.

[7] The countries included in this sample are the following: Argentina; Australia; Austria; Barbados; Belgium; Belize; Bulgaria; Canada; Chile; Colombia; Costa Rica; Cuba; Former Czechoslovakia; Ecuador; Egypt; El Salvador; Finland; France; Former Federal Republic of Germany; Greece; Hong Kong; Hungary; Iceland; Ireland; Italy; Japan; Luxembourg; Malta; Mauritius; Mexico; Netherlands; New Zealand; Norway; Philippines; Poland; Portugal; Puerto Rico; Romania; Singapore; Spain; Sweden; Trinidad and Tobago; United Kingdom, England and Wales; United Kingdom, Northern Ireland; United Kingdom, Scotland; United States of America; Uruguay; Venezuela; Former Yugoslavia.

### B. *Age- and Cause-Specific Changes in Life Expectancy*

To consider age-specific changes in longevity, define the survival function conditional on age $a$ according to $S(t,a)=S(t)/S(a)$, for $t \geq a$. Any change in the survival function from $S$ to $S'$ can be decomposed into changes attributable to different age groups. Without loss of generality, consider the age group between ages $a$ and $a + i$, where $a \leq a + i \leq t$. The survival function that would be observed if only changes in mortality between ages $a$ and $a + i$ had taken place would be $S'_a = S(t,a + i)S'(a + i,a)S(a)$. This counterfactual survival function gives the probability of survival up to age $t$ according to the probabilities between ages $a$ and $a + i$ observed in the second period, and the probabilities in other age groups observed in the first period.

Now consider cause-specific changes in mortality. Let there be $K$ competing independent causes of mortality, inducing the overall survival function $S = \prod_{k=1}^{k} S^k$, where $S^k$ denotes the survival function of cause $k$. Define the counterfactual survival function $S'_k = S'^k \prod_{i \neq k} S^i$. Similar to the case of age-specific mortality changes, this expression gives the survival function that would be observed if only changes in mortality from cause of death $k$ had taken place.

Both these decompositions can be applied to any given survival function, so that applying them sequentially one obtains a counterfactual survival function $S'_{k,a}$, which simulates the survival function that would be observed if only changes in mortality by one specific cause of death ($k$) and in one specific age group (between ages $a$ and $a + i$) had actually taken place.

With the age- and cause-specific survival functions $S'_{k,a}$, we can immediately construct corresponding counterfactual measures of life expectancy, each one defined as $L'_{k,a} = \int_0^\infty S'_{k,a}(t)\,dt$. $L'_{k,a}$ is the exact analog of $S'_{k,a}$ in terms of life expectancy. For our purposes, it gives the life expectancy that would be observed in 1995 if only mortality rates between ages $a$ and $a + i$, and due to the $k^{th}$ cause of death, had actually changed between 1965 and 1995.

Now consider three age groups—between ages 0 and 19, 20 and 49, and above 49—and the 13 causes of death defined above. This strategy allows the decomposition of the gains in life expectancy observed in the period into changes attributable to each age group and cause of

death, plus a higher-order term.[8] Let $\mathbf{L}^{\tau}$ denote the vector of life expectancy at birth for different countries in year $\tau$, and index the age groups by the initial age. Then

$$\Delta\mathbf{L} = \sum_{a=\{0,20,50\}} \sum_{k=1}^{13} \Delta\mathbf{L}_{k,a} + \Delta\mathbf{L}_{H} \tag{7}$$

where $\Delta\mathbf{L}$ is the change in life expectancy observed between 1965 and 1995. $\Delta\mathbf{L}_{k,a}$, for $k = 1,\ldots,13$, and $a = 0, 20, 50$, is the change in life expectancy attributable to the $k^{th}$ cause of death and to the age group starting at age $a$, defined as $\Delta\mathbf{L}_{k,a} = \mathbf{L}^{95}_{\mathbf{k,a}} - \mathbf{L}^{65}$, and $\Delta\mathbf{L}^{H}$ is the change in life expectancy due to the interaction among mortality changes in the different groups of ages and causes of death (higher-order terms).

With this decomposition, we can see what types of mortality were responsible for the gains in life expectancy observed in the last few decades. In addition, we can examine the reasons behind the differential behavior of life expectancy across developing and developed countries, and shed some light on the reasons behind the reduction in cross-country health inequality observed up to the beginning of the 1990s.

In this respect, we concentrate the analysis on the regression to the mean in life expectancy. The approach outlined above gives a direct decomposition of the overall regression to the mean in life expectancy into the regression to the mean attributable to each cause and age. By definition, the regression to the mean coefficient is given by a linear regression of $\Delta\mathbf{L}$ on a constant plus $\mathbf{L}^{65}$. Define $\mathbf{X}^{65} = [\mathbf{1}\ \mathbf{L}^{65}]$, a matrix containing a column of ones, and a column with the life expectancy at birth for the different countries in 1965. The convergence coefficient is given by the second term in $\boldsymbol{\beta} = (\mathbf{X}^{65\prime}\mathbf{X}^{65})^{-1}\mathbf{X}^{65\prime}\Delta\mathbf{L}$. By substituting $\Delta\mathbf{L}$ from expression (7), we can write

$$\boldsymbol{\beta} = (\mathbf{X}^{65\prime}\mathbf{X}^{65})^{-1}\mathbf{X}^{65\prime} \times \left[\sum_{a=\{0,20,50\}} \sum_{k=1}^{13} \Delta\mathbf{L}_{k,a} + \Delta\mathbf{L}_{H}\right].$$

This expression gives a natural decomposition for the convergence coefficient:

$$\boldsymbol{\beta} = \sum_{a=\{0,20,50\}} \sum_{k=1}^{13} \boldsymbol{\beta}_{k,a} + \boldsymbol{\beta}_{H} \tag{8}$$

where $\boldsymbol{\beta}_{k,a}$ is the vector of coefficients of the OLS regression of $\Delta\mathbf{L}_{k,a}$ on $\mathbf{X}^{65}$.

In words, the coefficient of the regression of changes in life expectancy on initial life expectancy levels can be decomposed into coefficients of regressions of cause- and age-specific changes in life expectancy on initial life expectancy levels, plus a residual term ($\boldsymbol{\beta}^{H}$). That is, regression to the mean in life expectancy is decomposed into regression to the mean attributable to the 13 underlying causes of death and three age groups, plus a residual term. This allows us to evaluate the role of different causes of death in generating the observed reduction in life expectancy inequality, and also to analyze in what ages this reduction in inequality was concentrated.

### C. *Results from the Decomposition of Life Expectancy Changes*

Age- and cause-specific survival rates are constructed using death and population data from the World Health Organization Mortality Database. Mortality rates are assumed to be constant inside the age intervals for which data are tabulated. Table 4 presents the life expectancy changes that can be attributed to each

[8] Given that changes in mortality from different causes and ages interact with each other in generating the final survival function, this decomposition does not explain exactly 100 percent of the shift in this function when infra-marginal changes in mortality are being considered. (This is the competing risks nature of mortality rates, as discussed by William H. Dow et al., 1999.) Formally, this is a first-order decomposition of changes in the survival function. For marginal changes in $S$, it would indeed generate an exact decomposition. There are decomposition strategies in the demographic literature that explain 100 percent of the changes in life expectancy, but they rely on arbitrarily assigning changes in life expectancy resulting from the interaction between different causes or ages to one specific component (see Preston et al., 2001). With infra-marginal changes, the interaction among higher-order terms is relevant, and it is impossible to attribute their effects to any particular cause or age group. In any case, the decomposition suggested here accounts for more than 80 percent of the changes in life expectancy in our sample.

TABLE 4—DECOMPOSITION OF LIFE EXPECTANCY GAINS BY CAUSE OF DEATH AND AGE GROUP, REGIONS OF THE WORLD, 1965–1995

| Change in life expectancy | Europe & Cent. Asia | E. Asia & Pacific | Latin Am. & the Carib. | Middle East & N. Africa | North America | Whole sample |
|---|---|---|---|---|---|---|
| Total | 8.6 | 5.4 | 10.2 | 18.0 | 5.8 | 7.1 |
| By cause of death: | | | | | | |
| R01: Infectious | 0.8 | 0.4 | 1.1 | −0.1 | 0.0 | 0.4 |
| R02: Neoplasms | 0.2 | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 |
| R03: Endocrine, metabolic, and blood diseases, nutritional deficiencies | 0.3 | 0.0 | 0.0 | 0.4 | −0.2 | 0.0 |
| R04: Mental disorders | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| R05: Nervous system and senses organs | 2.3 | 1.4 | 0.9 | 0.1 | 1.2 | 1.4 |
| R06: Heart and circulatory | −0.2 | 0.0 | −0.4 | −1.6 | 2.3 | 0.4 |
| R07: Respiratory and digestive | 1.3 | 1.1 | 3.5 | 12.1 | 0.5 | 1.6 |
| R08: Urinary and genital | 0.2 | 0.2 | 0.1 | 0.0 | 0.1 | 0.1 |
| R09: Abortion and obstetric causes | 0.1 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 |
| R10: Skin and musculoskeletal | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| R11: Congenital anomalies and perinatal period conditions | 0.7 | 1.0 | 1.1 | 2.6 | 1.0 | 1.0 |
| R12: Ill-defined | 1.2 | 0.5 | 2.8 | 2.9 | 0.0 | 0.9 |
| R13: Accidents, suicides, and homicides | 0.5 | 0.3 | −0.1 | 0.4 | 0.4 | 0.3 |
| By age group: | | | | | | |
| Between 0 and 19 | 2.5 | 2.2 | 5.9 | 16.2 | 1.5 | 3.0 |
| Between 20 and 49 | 1.2 | 0.4 | 1.4 | 0.8 | 0.6 | 0.7 |
| 50 and above | 4.6 | 2.7 | 2.3 | 0.5 | 3.5 | 3.1 |

*Notes:* Decomposition of life expectancy calculated by the authors based on age- and cause-specific mortality data from the World Health Organization. Regional averages weighted by country population. Sample includes 49 countries. The total life expectancy change for East Asia & Pacific is very different from the one presented in Table 2 because the sample used here excludes some of the main beneficiaries of the life expectancy gains in the region, such as China, Indonesia, Korea, and Thailand.

cause of death and each age group, by regions of the world and for the whole sample.

The table shows that, overall, the most important changes in life expectancy came from diseases of the nervous system and senses organs, respiratory and digestive conditions, congenital anomalies, perinatal period conditions, and ill-defined causes. Also, most of these reductions in mortality were concentrated before age 20 or after age 50.

But the composition of these mortality changes in terms of causes of death and age groups was very different across the different regions. Mortality reductions in nervous system and senses organs diseases were very important in Europe and Central Asia, but almost irrelevant in the Middle East and North Africa. On the other hand, respiratory and digestive conditions, together with ill-defined causes, were the main factors in determining life expectancy gains for the Middle East and North Africa and for Latin America and the Caribbean, but were much less important for North America, Europe, and Asia. At the same time, there are certain diseases that had a relatively small impact on the overall change in life expectancy, but were very important in one particular region. This is the case of heart and circulatory diseases, which had a relatively small overall impact, but were the most important factors determining changes in life expectancy in North America. This is also the case of infectious diseases, which had a significant impact in life expectancy in Latin America and the Caribbean.

These differences are also clear in the age profile of life expectancy gains across the different regions. The most expressive gains in the age group under 20 are observed in the Middle East and North Africa, and in Latin America and the Caribbean, while most of the gains above 50 are observed in Europe and Central Asia, and in North America.

In order to further understand the differential impact of mortality by different causes and age groups on the evolution of cross-country

TABLE 5—CONTRIBUTION OF AGE- AND CAUSE-SPECIFIC MORTALITY CHANGES TO REGRESSION TO THE MEAN IN LIFE EXPECTANCY, 1965–1995
*(Percentage)*

| Cause of death/age group | 0–20 | 20–50 | Above 50 | All ages |
|---|---|---|---|---|
| R01: Infectious | 3.7* | 3.0* | 1.0 | 7.8* |
| R02: Neoplasms | −0.7* | −0.7 | −0.4 | −1.8 |
| R03: Endocrine, metabolic, and blood diseases, nutritional deficiencies | 1.3* | 1.6* | −0.5 | 2.4 |
| R04: Mental disorders | −0.1* | 0.2 | 0.2 | 0.3 |
| R05: Nervous system and senses organs | 0.0 | −0.2 | −11.4* | −11.5* |
| R06: Heart and circulatory | −0.8* | −2.0* | −20.0* | −22.7* |
| R07: Respiratory and digestive | 77.8* | 3.0* | −0.5 | 80.7* |
| R08: Urinary and genital | 0.3* | −0.4* | −1.3* | −1.3* |
| R09: Abortion and obstetric causes | 0.1* | 1.1* | 0.0* | 1.2* |
| R10: Skin and musculoskeletal | 0.1* | 0.1* | 0.3* | 0.5* |
| R11: Congenital anomalies and perinatal period conditions | 10.5* | −0.1* | 0.0* | 10.4* |
| R12: Ill-defined | 8.5* | 4.1* | 20.4* | 33.7* |
| R13: Accidents, suicides, and homicides | −0.7 | −1.2 | −1.6* | −3.4* |
| All causes | 109.6* | 8.9* | −23.7* | 100.0* |

*Notes:* Calculations based on coefficients from (population-weighted) regressions of the changes in life expectancy attributable to each specific cause of death and age group on the life expectancy at birth in 1965. * denotes statistical significance at 5 percent of the coefficients in these regressions. Decomposition of the life expectancy changes based on the authors' calculations using World Health Organization data (49 countries).

inequalities in health, we apply the decomposition strategy described in the previous section to the regression to the mean in life expectancy. As mentioned before, regression to the mean in life expectancy can be decomposed into regression to the mean in changes in life expectancy attributable to each cause of death and age group. The coefficient of regression to the mean in this restricted sample is equal to −0.55 (statistically significant at any standard significance level). We run 56 regressions of age- and cause-specific changes in life expectancy (13 causes of death, three age groups, plus all ages and all causes of death together) on the initial life expectancy level (each one giving one of the $\beta_{k,a}$ coefficients from the previous section). We then calculate the contribution of the specific age group and cause of death to the overall regression to the mean in life expectancy (ignoring the constant, $\beta_{k,a}/\beta$). The results are presented in Table 5.

Of the 13 causes of death, five contributed to increased dispersion in life expectancy across countries, meaning that the behavior of mortality due to these causes worked against regression to the mean in life expectancy. Most of these five "divergent" causes of death had virtually no impact on overall health inequality, but two played a considerable role in increasing inequality: mortality by nervous system and senses organ diseases, and heart and circulatory diseases reduced convergence by more than 34 percent of its actual value. In the case of nervous system and senses organs diseases, mortality reductions were experienced by both developed and developing countries, but the extent of these reductions was considerably larger for developed countries. In terms of heart and circulatory diseases, mortality reductions were considerable for North America, but basically nonexistent—or even negative—for the rest of the world.

In relation to the causes of death that worked toward reducing health inequality, the action is concentrated in a handful of cases: infectious, respiratory, and digestive diseases, congenital anomalies, perinatal period conditions, and "ill-defined" conditions accounted for roughly 133 percent of the observed regression to the mean. Among these, respiratory and digestive diseases were by far the most important, accounting for 81 percent of the regression to the mean. Note that this group also includes infectious diseases related to the respiratory tract, such as pneumo-

nia and influenza, and digestive tract diseases such as appendicitis and cirrhosis. The second most important contribution to convergence comes from "ill-defined" causes and conditions. This most likely reflects the relative improvement of medical practice and record keeping behavior in developing countries.[9]

The age-specific pattern of these causes of death is also obvious from the decomposition. Almost all of the inequality enhancing effect of nervous system and senses organs diseases, and heart and circulatory diseases, took place via reductions in mortality after age 50. At the same time, the reduction in inequality via respiratory and digestive diseases was almost entirely concentrated before age 20, with some effects still being felt between ages 20 and 50; infectious diseases had similar effects across these two age groups. Overall, reductions in mortality up to age 20 were responsible for most of the regression to the mean in life expectancy observed in the period, with some additional contribution from changes in life expectancy between ages 20 and 50. In contrast, changes in mortality after age 50 significantly contributed to increase health inequality across countries.

These results support the view that recent reductions in mortality in the developing world have been due in part to the absorption of previously available technologies (for arguments in this direction, see Preston, 1980; Soares, 2005). The group of infectious, respiratory, and digestive diseases, congenital anomalies, and perinatal period conditions includes the types of diseases for which educational health programs and simple interventions can have large beneficial effects. On the other side of the spectrum, developed countries benefited relatively more from reductions in mortality that required new technological developments, relatively costly change of habits, and expensive surgical interventions (heart, circulatory, and nervous system diseases). The concept is of a developed center that generates health and medical knowledge to be absorbed eventually by the underdeveloped periphery.

[9] The fact that "ill-defined" conditions were relatively more common in developing countries in 1965 tends to underestimate the actual convergence in the other causes of death. This is so because a larger share of the reduction in mortality in developing countries is being attributed to "ill-defined" causes and conditions. Which causes of death experience the biggest underestimation depends on the correlation between cause of death and misreporting ("ill-defined"). We do not deal with this problem.

## IV. Concluding Remarks

This paper shows that life expectancy gains in the 40 years between 1960 and 2000 have been an important component of improvements in welfare throughout the world. We estimate the value of the gains in health during this period to be of the same order of magnitude as the gains in income and, for the poorest half of the world, to represent 40 percent of the overall welfare gains. The effects of health are sufficient to revert the results regarding the evolution of cross-country inequality up to the 1990s. Once health is accounted for, there is a significant reduction in inequality throughout the world up to 1990 and, even with the AIDS epidemic, a much more significant reduction in inequality between 1960 and 2000 than can be perceived from income alone.

The decline in life expectancy inequality can be attributed, to a great extent, to reductions in mortality due to infectious, respiratory, and digestive diseases in developing countries. Nevertheless, some causes of death have actually contributed toward increased health inequality. This is obviously true for AIDS, but it is also true for the cases of nervous system, senses organs, heart, and circulatory diseases, for which developed countries took advantage of recent advances on the frontier of medical technology. The ongoing AIDS epidemic in Africa and rising infection rates in Asia, coupled with recent advances in medical technology that are unlikely soon to become available in the developing world, raise the possibility that the postwar trends in health inequality may be reversed in the near future.

## Appendix: Classification of ICD Codes into Cause of Death Groups

*R01: infectious diseases:* icd-6/7 a: a001-a043; icd-6/7 b: b001-b017; icd-9: b01-b07. *R02: neoplasms:* icd-6/7 a: a044-a060; icd-6/7 b: b018-b019; icd-9: b08-b17. *R03: endocrine, metabolic and blood diseases, nutritional deficiencies:* icd-6/7 a: a061-a066; icd-6/7 b: b020-b021; icd-9: b18-b20. *R04: mental disorders:*

icd-6/7 a: a067-a069; icd-9: b21. *R05: diseases of the nervous system and senses organs:* icd-6/7 a: a070-a078; icd-6/7 b: b022-b023; icd-9: b22-b24. *R06: heart and circulatory diseases:* icd-6/7 a: a079-a086; icd-6/7 b: b024-b029; icd-9: b25-b30. *R07: respiratory and digestive diseases:* icd-6/7 a: a087-a107; icd-6/7 b: b030-b037; icd-9: b31-b34. *R08: urinary and genital diseases:* icd-6/7 a: a108-a114; icd-6/7 b: b038-b039; icd-9: b35-b37. *R09: abortion and obstetric causes:* icd-6/7 a: a115-a120; icd-6/7 b: b040; icd-9: b38-b41. *R10: skin and musculoskeletal diseases:* icd-6/7 a: a121-a126; icd-9: b42-b43. *R11: congenital anomalies and perinatal period conditions:* icd-6/7 a: a127-a135; icd-6/7 b: b041-b044; icd-9: b44-b45. *R12: ill-defined:* icd-6/7 a: a136-a137; icd-6/7 b: b045-b046; icd-9: b46. *R13: accidents, suicides, and homicides:* icd-6/7 a: a138-a150; icd-6/7 b: b047-b050; icd-9: b47-b56.

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