Why does Costa Rica outperform the United States in life expectancy? A tale of two inequality gradients

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Abstract

Mortality in the United States is 18% higher than in Costa Rica among adult men and 10% higher among middle-age women, despite the several times higher income and health expenditures of the U.S. This simultaneously provides striking evidence of the potential for substantially lowering mortality in other middle income countries, and highlights the U.S.'s embarrassingly poor health performance. The U.S.'s underperformance is strongly linked to its much steeper socioeconomic (SES) gradients in health. Although the highest SES quartile in the U.S. has better mortality than the highest quartile in Costa Rica, U.S.mortality in its lowest quartile is markedly worse than in Costa Rica's lowest quartile. This provides powerful evidence that the U.S. health inequality patterns are not inevitable. High SES-driven inequality in the U.S. persists in all broad cause of death groups and risk factors such as smoking, high blood pressure, and obesity, but Costa Rica's overall mortality advantage is explained largely by two causes of death: lung cancer and heart disease. Lung cancer mortality in the U.S. is four times higher among men and six times higher among women compared to Costa Rica. Mortality by heart disease is 67% and 18% higher in the U.S. than in Costa Rica for men and women, respectively. In addition to inequality-related prevalence patterns, the apparently higher lethality of smoking and high blood pressure in the U.S. may account for part of the higher adult mortality of the U.S. compared to Costa Rica, suggesting an important agenda for future research.

Introduction

Costa Rica has higher life expectancy than the United States even though its per capita income and its health expenditure are small fractions of those in the U.S. (World Bank, 2013). Comparing health and mortality in these two countries may help to identify pathways for improving health even under less than optimal economic circumstances as well as to improve the efficiency of health interventions in high-income settings. A recent series of reports by the National Academies of Sciences Panel on Understanding Cross-National Health Differences Among High-Income Countries (National Research Council 2011a, 2011b, 2013) have summarized an impressive evidence base that help to understand why U.S. life expectancy lags those of other wealthy countries. However, this research literature has largely failed to engage in the potentially more striking comparisons with countries that wield many fewer resources. Costa Rica is one of a handful of middle-income countries in which the availability of data allows this type of more striking comparison.

It is well established that more developed countries tend to have higher life expectancy (World Bank, 1993). Although health technologies have allowed extraordinary health improvements independently of economic development (Preston, 1975), a strong relationship persists as shown in Figure 1 that was built with World Bank data for 2003-2007 (a period with no distortions from the economic recession that started in 2008) and with per capita gross domestic product purchasing power (GDP-PPP) as the indicator of economic wellbeing. Less prosperous countries with GDP of one or two thousand dollars per capita show life expectancies of about 60 years, while rich countries with about $40,000 GDP-PPP show life expectancies close to 80 years. The correlation is not perfect but it is high: 0.83 for the 178 countries in the figure. Most interesting, there are countries whose health indicator outperforms expectations—those above the prediction line in figure 1, in contrast with underachievers below the prediction line. Costa Rica, with a life expectancy at birth of 78.5 years is a clear health overachiever given its GDP-PPP of $9,200, an income level at which the norm is a life expectancy of about 72 years according to the prediction curve and according to what is observed in countries with similar GDP-PPP, such as Iran or Romania. The life expectancy in Costa Rica is at a level expected for economies with a GDP-PPP of about $40,000, closer to the United States, which slightly underachieves expectations with a life expectancy of 77.4 years, one year lower than Costa Rica (Figure 1). Other overachievers identified in the figure are Vietnam, Israel and Japan, whereas South Africa, the Russian Federation, and Kuwait are examples of clear underachievers.

[Figure 1 here]

Costa Rica, a small Central American country comparable to the states of South Carolina or Kentucky in territory and population size, is known for being the oldest democracy in Latin America with a government that invests substantially in social redistributive programs. These investments have in part been enabled by eliminating the financial burden of military expenditures after abolishing its armed forces in the 1949 Constitution (Seligson, 1980), (Hanson & Köhler, 1993), (Mesa-Lago, 2000). However, income distribution is not particularly egalitarian in Costa Rica. Its Gini index of 0.52 in 2012 is similar to other countries in Latin America (for example: Mexico 0.51, Chile 0.52, or Brazil 0.53), which is the least egalitarian region in the world. The Costa Rican Gini is also higher than the U.S. Gini of 0.40, which itself is higher than in most high-income countries such as Sweden 0.25, Germany 0.30, or Japan 0.32 (Gini data compiled by (Underwood, 2014)).

In contrast to the decentralized health care system in the U.S. that leaves a large fraction of the population under age 65 years without health insurance or adequate health services, Costa Rica has a national health insurance system that cover the vast majority of residents. According to the 2011 census, 86% of Costa Ricans (96% of older adults) are covered by the public health insurance and care system known as the CCSS. The few uninsured individuals (largely a self-selected healthier group) can obtain health care from the CCSS for a subsidized fee, or no fee if social workers verify that a patient has no means of paying. The high health insurance and health care coverage of Costa Rica is achieved at a fraction of the cost of health care in the U.S.: health expenditures per capita in the U.S. are about ten times as high as in Costa Rica. Delivery of primary health care, particularly to remote or poor populations, has been singled out as a key factor to reduce mortality in Costa Rica (Rosero-Bixby, 1986). We don't readily have data to assess the relative quality of public health care services in Costa Rica compared to the U.S., but effectiveness appears high in providing basic care such as vaccinations and in controlling traditional communicable diseases such as tuberculosis and malaria.

High health inequalities by socioeconomic status (SES), race and geography have been singled out as one of the factors that explain the relatively poor performance of life expectancy in the U.S. compared to other high income countries. More precisely, low-SES individuals in the U.S., African-Americans, and residents in some areas, such as the District of Columbia, have very low levels of life expectancy that are not seen in subpopulations of other developed countries. Other factors identified as dragging down life expectancy in the U.S. are smoking and, less clearly, obesity. These other health risks also have a strong SES gradient in the U.S. (Crimmins, Preston, & Cohen, 2011).

This article aims at determining if the main explanatory factors – health inequality, smoking and obesity – of the relatively low life expectancy in the U.S. compared to other high-income countries also explain why Costa Rica outperforms the U.S. in life expectancy. It focuses on SES-driven health inequality as a "fundamental" determinant of health and mortality, in the sense that its effect is present in different times and circumstances, through multiple pathways (including behavioral factors such as smoking and obesity) and upon multiple disease outcomes because higher-SES individuals have more of the multiple resources (money, knowledge, power, prestige, connections, etc.) that allow them to avoid health risks or to obtain effective health care (Phelan, Link, & Tehranifar, 2010).

Earlier research has shown that in Costa Rica SES disparities in adult health are small, null or even contrary to the expected SES-gradients (Rosero-Bixby & Dow, 2009). This article systematically compares the SES gradients in adult mortality in newly compiled Costa Rican data with comparable data in the U.S. to test the hypothesis that Costa Rican achievements are primarily attributable to the relatively low mortality of its low-SES population. If true, it would support the argument that Costa Rica's performance might originate in health policies that made health of Costa Ricans less dependent on resources such as money, knowledge (education), power, prestige and connections. The study focuses on adult and older ages because it is in that part of the lifecycle when the Costa Rican health advantage is clearer (Rosero-Bixby, 2008).

Data and methods

The article compares adult mortality in two types of data sets, each of which has counterparts available in both countries: (1) the "*National Longitudinal Mortality Studies (NLMS)*" which link large samples of individual-level census data (including SES variables) to the death registry, and (2) household surveys (NHANES in the U.S. and CRELES in Costa Rica) with information about health risks along with mortality follow up.

For the U.S., we use Version 4 of the US-NLMS public use file (Rogot, Sorlie, Johnson, & Schmitt, 1992), which consists of a six-year follow up, starting in 1992, of a sample of *non-institutionalized* individuals in the Current Population Survey (CPS). For Costa Rica, we use a CR-NLMS that we have created from a probabilistic sample of adults in the 1984 census (Rosero-Bixby & Antich, 2010). We restrict Costa Rican observations to the 12-year follow up period starting in January 1990, so the observation period (6 years in the U.S. and 12 years in Costa Rica) in both countries is centered in early 1996. We refer to the follow-up window as the 1990s period. It is worth noting that the follow up of deaths in Costa Rica included survival checks against the voting lists for the presidential elections conducted every four years starting in 1990, to minimize the possibility of death under-registration errors. Only Costa Rican nationals (96% at the study's ages) were included in the study.

The NLMS analysis is restricted to ages 40 to 89 years. The lower age limit is determined by the Costa Rican sample. The upper age limit is determined by the lack of single year of age data in the public use US-NLMS files. Since the US-NLMS sample does not include the institutionalized population, our upper age limit reduces the bias from this exclusion that mostly affects very old individuals.

The analytical NLMS sample sizes differ substantially for the two countries: 288,000 in the U.S. and 17,500 in Costa Rica. The number of observed deaths in the analysis period is 22,440 in the U.S. sample and 2,415 in Costa Rica. The longer period of observation for Costa Rica (12 years, compared to 6 in the U.S.) ameliorates the imbalance.

Given the large differences in the absolute values of SES indicators in the two countries, we defined a relative scale: the SES-rank of individuals in each country measured by the relative position of individuals in each sample after they were sorted by years of attained education and quintiles of income in the U.S. or household wealth in Costa Rica.

We analyze all-cause mortality as well as mortality by nine large groups of causes, namely: (1) communicable diseases (which also includes HIV and acute respiratory diseases), (2) lung cancer, (3) other cancer, (4) heart diseases (mostly myocardial infarction and chronic ischemic heart disease) (5) cerebrovascular diseases (mostly stroke) (6) chronic respiratory diseases (mostly emphysema), (7) diabetes mellitus (8) external injuries (accidents, homicide and suicide), and (9) a residual group of other causes.

To compare the effect of selected health risk factors on mortality we use the NHANES and CRELES surveys and their survival follow-ups. The analytical sample sizes in these two data sets were close to 3,000 in each country covering ages 60 years (the minimal age of individuals in CRELES) to 84 (the highest age with detailed death information in NHANES). NHANES stands for the U.S. *National Health and Nutrition Examination Survey*. We used the 1999-2002 waves of this survey, for which the available mortality data cover the follow up period 1999-2006. NHANES data are representative of the non-institutionalized population of the U.S. (Johnson, Paulose-Ram, Ogden, & al., 2013). CRELES stands for the Spanish-language acronym of the *Costa Rican Longevity and Healthy Aging Study*. It is a set of nationally representative longitudinal surveys of health and life course experiences of older adult residents in Costa Rica. We used the information from the first CRELES wave of interviews conducted mostly in 2005 and the mortality follow up period until December 2010. Documentation and public-use CRELES data are available from the National Archive of Computerized data on Aging at the University of Michigan (Rosero-Bixby, Fernández, & Dow, 2010).

The health risk and behavioral factors studied with the NHANES and CRELES samples were:

1. Smoking classification: (1) never, (2) former smoker, and (3) current smoker.
2. Body mass index (BMI) standard classification in five categories: (1) Underweight (<18.5 kg/m2), (2) normal weight (18.5 - 24.9 kg/m2) (3) overweight (25 – 29.9 kg/m2), (4) class 1 obese (30 – 34.9 kg/m2), and (5) class 2/3 obese (35 or higher kg/m2). Both surveys actually measured weight and height of participants. We used self-reported values of height and weight to impute missing values in less than 5% of the samples.
3. Central obesity: if waist circumference is >= 102 cm in males and 88 cm in females as measured by interviewers.
4. High blood pressure (HBP) classification in four categories: (1) Not hypertensive if Systolic *and* Diastolic BP taken during the interview were below 140 and 90 mmHg, respectively, and no self-reported medical diagnosis of HBP. (2) Undiagnosed HBP (measured HBP and no medical diagnosis), (3) controlled HBP (with medical diagnosis of HBP and no HBP in the interview measurements), and (4) uncontrolled HBP (diagnosed and measured HBP).
5. Three categories of living arrangements: (1) living alone, (2) living in a two-member household (mostly an “empty nest”), (3) living in a household with 3 or more members, which usually means living with children.

Both the CR-NLMS and CRELES measured age from the exact date of birth recorded in the civil registration system to avoid self-reported age errors that may distort mortality rates.

Statistical analysis

Our outcome of interest is death or survival. We first analyzed death rates in Costa Rica and the U.S. by age, sex, SES and cause of death grouping with the NLMS data. Then we compared the prevalence of health risk factors and their effects on mortality. After splitting the databases by age segments during the survival follow-up period, we computed death rates using in the denominator the exact count of the number of person-years of exposure in the surveys. In estimating age-adjusted death rates and death rate-ratios we assumed that mortality grows exponentially with age; i.e. a Gompertz distribution—a reasonable assumption for human populations in the ages covered here (Bongaarts & Feeney, 2002). The age effect in the Gompertz function is called the *gamma* parameter, which estimates the rate of proportional increase in mortality per year of age.

The effect on mortality of the SES-rank (a 1 to 0 scale) is an estimate of the so-called "*Relative Index of Inequality*" (*RII*) or how many times higher the mortality is at the lowest SES-rank compared to the highest SES-rank (Pamuk, 1985).

The "*Population Attributable Fraction*" (*PAF*) of SES inequality is in this article the proportion of reduction in the overall mortality rate of the population if all individuals had the mortality of the highest SES-rank quartile. PAF may also be interpreted for policy purposes as the proportion of deaths that could be avoided by erasing quartile-SES disparities in health. We used the following approximate relationship to derive PAF from RII:

$$PAF = \frac{0.75 \cdot (\sqrt[2]{RII} - 1)}{1 + 0.75 \cdot (\sqrt[2]{RII} - 1)}$$

Results

Male mortality is lower in Costa Rica than in the U.S. at all adult ages above 55 years according to population vital statistics and the NLMS samples (Figure 2). The cumulative magnitude of this advantage, measured by the survival probability from age 40 to 90, is substantively quite large: 5-percentage points, or about 40%, higher chance of surviving in Costa Rica than in the U.S. (17% vs. 12% according to vital statistics and 19% vs. 14% in the NLMS). In contrast, female mortality differs little between the two countries and the differences vary with age. The cumulative indicator of 50-year survival suggests a small advantage of U.S. over Costa Rican women: 26% vs. 25% according to vital statistics and 30% vs. 25% in the NLMS samples.

[Figure 2 here]

Figure 2 also suggests that NLMS samples estimate reasonably well the mortality of the population in both countries. The confidence intervals of sample's estimates overlap the population curve in most ages. The exception are the US estimates after age 80, which are significantly lower than the population rates, probably because of institutionalized individuals being excluded in the US-NLMS sampling.

Costa Rican male mortality is 0.85 (95% CI: 0.80-0.90) relative to the U.S., or an 18% higher mortality rate in the U.S. (Table1). Among females, mortality is an insignificantly 4% higher in Costa Rica. Distinguishing the rates before and after 65 years of age is of interest given that the Medicare plan in the U.S. begins universal health insurance only starting at this age (which by contrast Costa Ricans have at all ages). The estimates for women are consistent with a relative mortality improvement after age 65 in the U.S.: Costa Rican women have 9% lower mortality than U.S. women before age 65 and 9% higher mortality after this age. However, this improvement is not present (or is hidden by other factors) in the comparison of males: the mortality disadvantage of U.S. men is larger (22% higher mortality) after age 65 than before this age (11%).

Cause of death
Two cause of death groups explain all of the mortality advantage of Costa Rican men compared to the U.S.: lung cancer and heart diseases. The death rate ratios (DRR) in Table 1 indicate that U.S. men have four times higher risk of dying by lung cancer and 67% higher risk of dying by heart diseases than Costa Rican men. Lung cancer is important as a marker of the mortality effect of smoking (Preston, Glei, & Wilmoth, 2010), and heart diseases are important due to causing about one-third of deaths at these ages. The large Costa Rican advantage in these two cause of death groups is in part counterbalanced by excess mortality of Costa Rican men by cerebrovascular conditions (DRR of 1.38), diabetes (1.30), and external injuries (1.34).

Costa Rican men also have a significant 28% lower mortality by communicable diseases (mostly influenza), probably because of the more favorable weather of the tropics. Although this advantage has only a minor impact on life expectancy given that communicable diseases now represent only a tiny fraction (5%) of deaths, the fact that Costa Rica has been able to essentially control its mortality by infectious diseases is a notable public health achievement. Not long ago, near three-fourths of deaths were caused by communicable diseases such as diarrhea, malaria, and tuberculosis (Mata & Rosero-Bixby, 1988).

Costa Rican women have a huge advantage – larger than men – in lung cancer mortality, which is one-sixth that of the U.S. But women's advantage in heart disease mortality (DRR of 0.85) is not as large as that of men (0.60). The advantage of Costa Rican women in these two causes of death is more than counterbalanced by significantly higher mortality by stroke (32% higher death rate), external injuries (59%), and chronic respiratory diseases (59%). The higher Costa Rican mortality by stroke among both men and women is a topic for further research. The higher mortality by external injuries comes from a poorer physical and institutional infrastructure to prevent and treat accidents. The higher mortality by respiratory conditions is possibly a consequence of firewood cooking until recent times in rural areas of Costa Rica.

There are no significant differences between Costa Rica and the U.S. in the mortality of the residual group of other causes of death, which includes ill-defined diseases. This result suggests similar quality of death data coding in the two countries.

Inequality
Costa Ricans in the lowest SES quartile have significantly lower mortality than their counterparts in the U.S. (figure 3). By contrast, in the highest SES quartile the U.S. has the lower mortality, at least at ages below 65 years. In the two intermediate SES quartiles there is no significant mortality difference between the two countries, nor is there in the highest quartile above age 65. In other words, from a life expectancy standpoint, it is better to live in Costa Rica for low-SES individuals, while it is better to live in the U.S. for high-SES people younger than 65 years. This is a striking result given the huge differences in living standards between the two countries for individuals at the same SES-ranks, especially at low-SES levels. Taking, for example, the most easily comparable indicator across countries — human capital as measured by educational attainment – the lowest SES quartile in the U.S. includes mostly high school drop outs, while in Costa Rica it is of people with none or less than 3 years of elementary school. In the highest

SES quartile, US adults are predominantly college graduates while few of the corresponding Costa Ricans have education above high school.

[Figure 3 here]

The above comparison of unadjusted death rates is confounded by the facts that low-SES people tend to be of older ages and that U.S. people are older than Costa Ricans. The smoothed regression lines (and confidence areas) in Figure 3 estimate the SES gradients as single indexes – the RII– and adjust any distorting effect of age. The slope of the regression-adjusted lines shows that mortality inequality is substantially higher in the U.S. than in Costa Rica, especially before age 65. According to the Relative Inequality Index (RII), adults younger than 65 who are at the bottom of the SES-rank die at a rate 3.4 times higher than those at the upper ranks of SES in the U.S. In contrast, the corresponding RII in Costa Rica is only 1.5. The U.S. SES gradient in mortality falls substantially to a RII of 1.6 in ages 65 and over, while in Costa Rica there is practically no gradient (RII of 1.1) at these ages.

To what extent is the high inequality of U.S. mortality statistically attributable to geographical and racial differences in mortality? The RII of 3.4 for adults below age 65 is essentially the same (RII = 3.0) when one estimates it just for the white non-Hispanic population or after controlling the state of residence with 49 dummy variables in the regression model (RII = 3.3). In the state of Hawaii, which has the highest life expectancy of the U.S. and some similarities with Costa Rica's climate, the RII is still a very high 3.0. In Florida, another state with high life expectancy and some similarities with Costa Rica, RII is 3.8. The steep mortality gradient by SES-rank of US adults is present within all states of the Union and all major races/ethnicities, with one exception: the Hispanic U.S. population has an RII of 1.5, identical to Costa Rica.

Taking SES as a health risk factor and estimating its Population Attributable Fraction (PAF) provides further information for social policy purposes. If mortality inequalities by SES quartiles were eliminated and the population had the mortality of the highest quartile, the national mortality rate would fall by 25% in the U.S. and 9% in Costa Rica (Table 2), which would essentially erase all the adult mortality advantage of Costa Rica over the U.S.

[Table 2 here]

The SES-PAF is about 40% at ages 40-64 in the U.S., which is four times higher than among Costa Rican men and double among women. This indicator falls to about 20% for older U.S. adults ages 65-84, consistent with past studies showing that at older ages SES gradients in health are less steep (Crimmins, 2005) (Elo & Preston, 1996). Among Costa Rican females, the PAF before and after age 65 changes little, which contrasting with the change in the U.S. would support the hypothesis of a Medicare effect on mortality in the U.S., but we leave this complex issue to other research. Among Costa Rican men, the data show no significant SES gradient (the confidence interval overlaps zero), especially at older ages (Table 2).

The SES gradients by causes of death, as measured by the PAF, show that substantial inequality is present in the U.S. in all cause of death groups, as posited by the "fundamental determinant" theory (Phelan et al., 2010). In contrast, in Costa Rica, the PAF is significantly higher than zero only for three causes of death groups: cerebrovascular, external injuries, and, especially, chronic respiratory mortality. The comparison between the two countries measured by the column of PAF differences in Table 2 singles out diabetes, heart diseases, and lung cancer as the pathologies in which inequality is particularly higher in the U.S. compared to Costa Rica. As seen before, lung cancer and heart diseases are also the causes of death in which the mortality advantage of Costa Ricans originates.

Selected health risk factors

Table 3 compares the prevalence of selected health risk factors and living arrangements in the elderly population, ages 60-84 years, of Costa Rica and the U.S., as measured in CRELES and NHANES surveys.

[Table 3 here]

There are substantial differences in living arrangements of the elderly population in the two countries. Independent living (alone or in couple) is substantially more frequent in the U.S. than in Costa Rica (34% vs. 11% among women). In Costa Rica most elderly people (60%) live in households of 3 or more members, primarily with grown children, compared to only about 20% in the U.S.

Current and past smoking prevalence is similar among men of the two countries, a surprising result given the big differences in lung cancer mortality of the two countries. Among women smoking is clearly more common in the U.S, consistently with its higher rates of lung cancer mortality.

Obesity is substantially more common in the U.S., especially among men: 29% vs. 16% BMI obesity and 52% vs. 22% central obesity (waist circumference). Among women there are no significant differences in obesity between the two countries as measured by waist circumference or by the prevalence of Class 1 obesity. Only in extreme (class 2 or 3) obesity is the prevalence among U.S. women (15%) higher than in Costa Rica (9%).

There are no significant differences between the two countries in the prevalence of high blood pressure (HBP), which affects about two-thirds of men and three-fourths of women in the two populations. However, the prevalence of uncontrolled HBP is about 10 points higher in Costa Rica than in the U.S., for both males and females. The primary health care system of Costa Rica seems thus less effective than the U.S. system in the control of this chronic disease risk factor that has worsened more recently in Costa Rica than in the U.S.

Health risk factors and mortality

The very low lung cancer mortality rate of Costa Ricans suggests that smoking could explain much of the high life expectancy of males in this country. However, the similar levels of prevalence of past and current smoking among Costa Rican and U.S. men suggests that the role of smoking is not as clearly a.factor explaining the differential mortality. Additional information not shown in table 3 regarding dose of exposure to smoking (age when it started and stopped and amount of cigarettes smoked) in NHANES and CRELES does not show significant differences in smoking exposure between males of the two countries. Table 4 suggests a potential explanation of this paradox, but raises another, by estimating the effect of smoking and other factors in the U.S. and Costa Rica on adult mortality. These estimates suggest that exposure to smoking has different lethality in the two countries: high lethality in the U.S. and little impact in Costa Rica. The group of former smokers (which includes more than half of adult men in the two countries) compared to the group that never smoked have 45% higher risk of dying in the U.S. while in Costa Rica they don't have significantly higher mortality. The DRR of current smokers is 2.79 in the US compared to 1.31 in Costa Rica.

[Table 4 here]

Results for obesity are also puzzling. A broadly used procedure to estimate the effect of obesity on life expectancy is to combine information about its prevalence with external estimates of the death rates by category of obesity classifications (Preston & Stokes, 2011) (Preston, Stokes, Mehta, & Cao, 2014). If one accepts that obese people have higher mortality, the substantially lower prevalence of obesity among Costa Rican men would be a factor explaining the lower mortality level in their country. However, the data in table 4 do not support the claim that obese people have higher mortality. People with BMI of 35 or more (Class 2 or 3 obese) do not show significantly different mortality than people with normal weight in the U.S. (DRR of 0.72) or in Costa Rica (DRR of 1.29 with 95% CI of 0.82 to 2.03). Alternative model formulations using BMI at age 25 (to avoid reverse causation and survival selection effects) or central obesity measured by waist circumference produce similar results. These results are consistent with other recent analyses showing that the effect of obesity on mortality that existed in the past has declined or even disappeared in more recent data (Mehta & Chang, 2011).

Although there were no differences in the prevalence of hypertension between the US and Costa Rica, in the US there were more individuals who are hypertensive but keep their blood pressure at normal levels. This group of "controlled HBP", which includes close to half of adults in the two countries, has 56% higher mortality in the U.S. compared to people with no high BP (table 4). In contrast, this group in Costa Rica has a non-significant 8% higher mortality. The group with uncontrolled HBP has higher mortality among men in the two countries but the effect is larger in the U.S. (MRR of 1.87) than in Costa Rica (MRR of 1.46). Curiously, women with uncontrolled HBP do not show higher mortality in either country. As with smoking, the available data suggest that the possibility that high BP is less damaging in Costa Rica than in the U.S., which again raises important new questions beyond the scope of this analysis.

Estimates in table 4 confirm that SES inequality in mortality, as measured by the RII, is substantially higher in the U.S. than in Costa Rica: 1.92 vs. 1.15 in the regression models that included health risk factors. A supplemental regression model (not shown in table 4) with no controls for health risk factors estimated a RII of 2.43 in the U.S. and 1.14 in Costa Rica. The control for such risk factors as smoking and hypertension reduced importantly the inequality index in the U.S. but did not change the Costa Rica's RII. Therefore, a considerable part of mortality inequality in the U.S. arises from inequality in risk factors such as smoking and hypertension. This mechanism does not appear to operate in Costa Rica.

In turn, estimates of SES-rank gradients in the odds of prevalence of health risk factors obtained with logistic regressions with NHANES and CRELES data confirm significantly higher RII in the U.S. than in Costa Rica in current smoking (3.65 vs. 1.55) and BMI obesity (1.59 vs. 0.70), as well as marginally significantly higher RII in uncontrolled high BP (1.73 vs. 1.14).

Living arrangements do not appear to explain mortality differences between the two countries. Mortality of elderly people living alone is 19% higher in the US and 30% higher in Costa Rica, but these are not statistically significant effects and thus we cannot categorically say that the lower Costa Rican proportion of lonely individuals is a factor in its low mortality levels. A factor *against* low Costa Rican mortality could be its higher household size since, according to table 4, individuals in households with 3 or more members have higher mortality. However, this mortality effect of larger families must be taken cautiously since it could be due to reverse causation: the likelihood of children living with parents may be higher when parents are ill in order to take care of them.

To summarize results of the regression models in table 4, the panel at the bottom shows the predicted mortality rates for some selected groups. The group of former smokers and controlled high BP stands out with mortality rates that are more than double in the U.S. (predicted rate of 0.073) than in Costa Rica (0.032). This estimate is for males, aged 75 years, and in the lowest SES quartile. If we took individuals in the highest SES quartile, mortality is still about 50% higher in the U.S. (rate of 0.045) than in Costa Rica (0.029). If we compare individuals who never smoked and who are not hypertensive, mortality in the two countries is essentially the same.

Discussion

We have found that adult mortality of men is 18% higher in the U.S. than in Costa Rica and this difference is larger at older ages. Among women, U.S. mortality is 10% higher than in Costa Rica before age 65, but 8% lower after age 65.. The simple fact that Costa Rica has achieved similar or lower adult mortality than the U.S. is a singular achievement considering the vastly higher living standards and health expenditures in the U.S.. Costa Rica's data are extremely high quality for a less developed country, thus providing strong new evidence that the substantially lower life expectancy in many middle income countries is not inevitable.

From the many factors driving mortality levels in the two countries, SES inequalities stand out as strikingly different. According to the Relative Inequality Index (RII), at the bottom of the socioeconomic hierarchy death rates are 3.4 times higher than at the highest SES ranks among middle-age adults in the U.S. In contrast, the corresponding RII is 1.5 in Costa Rica and the SES gradient disappears after age 65 (while in the U.S. it decreases to 1.6 RII). These disparate gradients imply that the mortality advantage of Costa Rica compared to the U.S. is concentrated in the lowest SES quartile. At the highest SES quartile, adult mortality is higher in Costa Rica than in the U.S., as expected considering the large advantages in income and health infrastructure of the U.S. But at the lowest SES quartile Costa Rican mortality is substantially superior to that of the U.S., again providing powerful evidence that the U.S.'s large health inequalities are not inevitable, but are driven by larger health and social policy choices (Dow & Rehkopf, 2010).

The high mortality inequality in the U.S. is not just a manifestation of its vast geography or its racial heterogeneity, since it persists within every state and ethnic group. The exception is the Hispanic U.S. population whose low-inequality levels of mortality are similar to those observed in Costa Rica. Although the lower health inequality of Hispanics in the U.S. is known in the literature (Turra & Goldman, 2007), its causes are still poorly understood.

Substantial SES-driven inequality is present in the U.S. in all cause of death groups and risk factors (smoking, high blood pressure, and obesity), as posited by the "fundamental determinant" theory (Phelan et al., 2010). In Costa Rica, SES-driven inequality is substantially lower than in the U.S. in all of the studied dimensions (the exceptions, with similar SES gradients in the two countries, are mortality caused by stroke, emphysema and external injuries) or it is even non-existent in some, such as heart disease mortality and non-lung cancer mortality, or it is in the opposite direction such as in prevalence of obesity with a RII of 0.7.

Why is health inequality lower in Costa Rica? It is not because of a more equal income distribution (i.e., shorter economic distances between SES extremes). Its Gini index of income inequality, for example, is 0.52 in 2012 which compares unfavorably to the U.S. Gini of 0.40 (Underwood, 2014).

Part of the explanation might be in the lifetime universal health insurance with excellent primary care access in Costa Rica. The Costa Rican system clearly lacks capabilities to provide highly specialized health care, and it cannot even meet some basic standards as shown by the high prevalence of uncontrolled hypertension in Costa Rica compared to the U.S. But this system has two remarkable accomplishments: (1) it has erased the typical disadvantage of developing societies regarding communicable-disease mortality, with cost-effective interventions that are well known in public health; and (2) it has made the outcome of the two key pathologies of cancer and heart diseases less dependent on individual resources (money, knowledge, power, prestige) in order to avoid health risks or to obtain effective health care, as postulated by the "fundamental determinant" theory (Phelan et al., 2010). The data from the U.S. population reinforce this concept by showing that after age 65 health inequalities are substantially lower, which in part could be driven by the improved health care after age 65 in the U.S., but there are many competing factors in this pre-post age 65 comparison that are beyond the scope of this paper. Although this age-reduction of inequality occurs also in Costa Rica, the effect is substantially stronger among U.S. women.

The story of health inequality is, however, more than just about access to health care. Other populations with universal health care systems show very high SES gradients in health outcomes (M. G. Marmot et al., 1991). In turn, the Hispanic population in the U.S. shows modest SES gradients under the same health care system that produces high health inequality in the rest of society. An important literature (M. Marmot & Wilkinson, 2001) postulates that psychosocial pathways link social hierarchy and health above and beyond material resources and access to health care. Those pathways involve concepts such as control over life, insecurity, anxiety, social isolation, bullying, self-image, happiness, and depression. Heart disease, in particular, has been shown in several studies to be related to low control in the work place, low social support, hostility, depression, and anxiety (Hemingway & Marmot, 1999). Research has also identified a variety of plausible biological pathways through which psychosocial factors can "get under the skin" (M. Marmot & Wilkinson, 2001). The magnitude of such factors in explaining broad mortality patterns is still poorly understood though. Future work is needed to investigate the importance of these psychosocial factors in mediating the relatively lower SES mortality gradient among adult Costa Ricans, as well as in the Hispanic U.S. population.

Socioeconomic distances in health risk behaviors seem to be shorter in Costa Rica than in the U.S. The RII in current smoking is 1.55 in Costa Rica vs. 3.65 in the U.S., in obesity is 0.70 vs. 1.59, and in uncontrolled hypertension is 1.14 vs. 1.73. These differences are consistent with a potential role for the aforementioned psychosocial factors, but they are also consistent with a more recent transition toward worse behaviors, in which higher SES individuals can afford to adopt such behaviors earlier but then at a later stage are surpassed by low SES individuals.

The adult mortality advantage of Costa Rica over the U.S. concentrates in two causes of death: lung cancer and heart disease. Lung cancer mortality is four times higher among men and six times higher among women in the U.S. compared to Costa Rica. Mortality by heart disease is 67% and 18% higher in the U.S. than in Costa Rica for men and women, respectively. These results suggest that smoking is an important part of the explanation, as it has been in other international comparisons of mortality (Preston et al., 2010) (Bongaarts, 2014). There is, however, a paradox in this effect: current and past exposure to smoking is significantly higher in the U.S. only among women. Exposure to smoking is about the same among men in the two countries. The available data suggest that smoking related mortality is higher in the U.S. than in Costa Rica because of a higher smoking lethality in the former. The data also show parallel results regarding high blood pressure (HBP); i.e. that lethality of HBP is higher in the US. Further research is needed to confirm that smoking and HBP are less damaging in Costa Rica and to test potential explanations.

Prevalence of obesity is much lower in Costa Rica than in the U.S., especially among men. However, available data suggest that this is not as relevant for life expectancy as it appeared to be in the past, since obese people in our data at the studied ages (60 years or more) do not show higher mortality. Alternative model formulations using BMI at age 25 (to avoid reverse causation and survival selection effects) or central obesity measured by waist circumference produce similar results of lack of mortality effects, particularly in the U.S.. These results are consistent with recent analyses showing that the effect of obesity on mortality that existed in the past has declined, or even disappeared, in more recent data of the same longitudinal surveys (Mehta & Chang, 2011). However, before discarding obesity as a non-factor in explaining these mortality patterns, further research is needed to explore indirect pathways of obesity effects through synergies with other risk factors.

The comparison of mortality in the U.S. and Costa Rica suggests that countries with less than optimal economic circumstances can enjoy levels of life expectancy of rich countries, and that health interventions in high-income settings could be more efficient and produce more with less. Costa Rica would not have its high life expectancy if the country had the SES gradients in mortality seen in the U.S.. By contrast, the U.S. could have substantially higher life expectancy if its residents in the lowest socioeconomic hierarchy had the reduced mortality levels of low-SES Costa Ricans, and it could reach even higher life expectancy if they had the health of high-

SES U.S. residents. Our estimates of the population attributable fraction (PAF) to SES suggest that as much as 40% of deaths of middle-age adults in the U.S. and 20% of deaths at older ages are statistically attributable to SES driven inequality. The corresponding PAFs in Costa Rican men are 10% and 0%, respectively.

A known limitation of estimates of SES effects on health is reverse causation—some individuals fall into low-SES ranks because of their poor health. If that were the case, the comparison with Costa Rica would suggest that a hypothetically high negative SES impact of poor health of the U.S. might be neutralized.

Known limitations of adult mortality data in developing countries are age exaggeration of older individuals and under-registration of deaths. The data used in this article for Costa Rica should be virtually free of those limitations since age was established from the date of birth in the national registry and the follow up of deaths double checked survival with independent sources—the voting lists in the NLMS and household visits in the CRELES (Rosero-Bixby & Antich, 2010) (Rosero-Bixby, Dow, & Rehkopf, 2014). Two limitations in the databases used in this article are: (1) the exclusion of institutionalized individuals in the U.S. samples, which would slightly underestimate U.S. mortality and (2) the exclusion of foreigners (about 5% of the population) in the Costa Rica follow up, which might slightly overestimate mortality if we believe that immigrants are a select group with better than average health (Herring, Bonilla, Borland, & Hill, 2010). The effect of these two limitations would be, however, to understate the outperformance of Costa Rican mortality.

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