

Preliminary
Comments Welcome

Accounting for the Effect of Health on Economic Growth

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Abstract

I use microeconomic estimates of the effect of health on individual outcomes to construct macroeconomic estimates of the effect of average health on GDP per capita. I examine numerous individual-level structural estimates of health's effect, along with cross-country and historical data on several health indicators including height, adult survival, and age at menarche. My estimates of the fraction of cross-country variance in income explained by variation in health range from 8% to 20%.

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1. Introduction

The United States government as well as several international organizations and private charities have recently embarked on ambitious efforts to raise the level of health in developing countries. Included in these efforts are the Bush Administration's commitment of \$15 billion over five years to fight AIDS, the Roll Back Malaria partnership launched by the WHO, World Bank, and other international organizations in 1998, and the recent creation of the independent Global Fund for AIDS, TB, and Malaria. The primary justification for these programs is the potential to reduce suffering and premature death among the affected populations. However, an important secondary justification is the potential gain in economic development that is expected to follow from health improvements.

Economists have pursued two approaches to examining health's effect on economic growth. An extensive literature has looked at the effects of health on individual economic outcomes (see Strauss and Thomas, 1998, as well as the literature discussed below). However, research in this line has generally not addressed the questions of how much health explains differences in income among countries, or what the aggregate effects of health improvements on national income would be. The second line of research, which I refer to as the "aggregate regression" approach, has used cross-country data to estimate health's effect on income at the national level. Bloom, Canning, and Sevilla (2004) report the results of 13 such studies, which mostly reach similar quantitative results. Their own estimate, which comes from regressing residual productivity (after accounting for physical capital and education) on health measures in a panel of countries is that a one-year increase in life expectancy raises output by 4%. Using a somewhat similar technique, Jamison, Lau, and Wang (forthcoming) estimate that the elasticity of GDP with respect to the adult survival rate (the fraction of 15 year olds who will reach age 65, using the current life table) is 0.5.

In this paper I argue that the aggregate regression approach to determining the effect of health on income is fundamentally flawed, but that with some effort one can answer the question

that this literature addresses – that is, construct a reasonable estimate of health’s effect on national income – by starting with microeconomic estimates. The problem with the aggregate regression approach is that at the level of countries there is not an empirically usable source of variation in health, either in cross section or time series, that is not correlated with the error term in the equation determining income. This problem is particularly acute if one wants to measure the proximate effect of health differences (that is, how much richer Nigeria would be today if its citizens were as healthy as Americans) rather than the total effect of the exogenous health environment, which might include how health several centuries ago influenced today’s institutions.

Instead of using regressions at the aggregate level to determine the effect of health on a country’s income, I construct a framework in which existing estimates of health’s effects on individual outcomes can be used to answer the questions raised by economists studying aggregate economic growth. In other words, I will use the available microeconomic estimates to create an estimate of the importance of health at the macroeconomic level

Beyond looking at health’s effect on growth, a second goal of this research is to examine the broader question of what determines a country’s level of income. Recent research has used the technique of development accounting to parse variation in income among countries into the pieces explained by accumulation of physical capital and human capital in the form of education, as well as remaining residual variation due to differences in productivity. The conclusion from this literature is that productivity is by far the most significant source of income differences, explaining more than half of the variance of income. By accounting for variation in health among countries, I am able to explain some of this residual productivity variation.

The rest of this paper is organized as follows. Section 2 presents a simple theoretical framework for analyzing the determination of health and national income. Section 3 discusses the aggregate health indicators used in my analysis. Section 4 presents the empirical framework for applying structural microeconomic estimates to macroeconomic aggregates. Section 5 looks at the effect of health improvements on output in historical data. Section 6 looks at the

contribution of health to income variation in a cross section of countries. Section 7 concludes.

2. Theoretical Framework

Health is both a result and a determinant of income. People who are better off are better nourished and better cared for. At the same time, healthier people are able to work harder, think more clearly, and earn a higher return in the labor market. Similarly, at the national level, countries that are richer have, on average, healthier citizens; and the health of a country's population is an important determinant of its economic success.

My goal in this paper is to examine the magnitude of one of these relations. Specifically, I ask how much of the variation in income per capita among countries can be attributed to differences in their average level of health. My goals in this paper – and how they relates to existing literature – can be most easily thought about with reference to Figures 1 and 2. These figures show the simultaneous determination of income, y , and health, which is denoted by the symbol v for vitality.

Figure 1 shows the two structural functions that relate income and health: $v(y)$ showing the effect of income on health and $y(v)$ showing the effect of health on income. The intersection of the curves shows the simultaneous determination of health and income. Shifts in the $v(y)$ and $y(v)$ functions will lead to a change in the levels of both income and health. The figure can be thought of as showing how the determination of income and health differs between countries or over time.¹

The mechanisms that lead to a positive dependence of health on income are fairly

¹In presenting the analysis in this simple form, I am ignoring any dynamics. Since I will mostly be looking at changes over very long periods of time, or differences between countries that may be close to their steady states, this may not be a problem. Hall and Jones (1999) argue that differences in income levels between countries are well modeled as being a steady state phenomenon.

obvious. People who are richer can afford better food, shelter, and medical treatment. Countries that are richer can afford higher expenditures on public health.² The $v(y)$ function in Figure 1 is drawn with a diminishing slope at higher levels of income, reflecting the fact that income's effects on health seem to be limited. It is likely that the richest countries in the world are today at a point where further increases in income will have only minor effects on health (which is not to say that the health will not improve due to shifts in the $v(y)$ function itself).

Regarding the $y(v)$ function, existing literature has pointed out several channels by which better health will raise the level of income. Most directly, healthier workers are able to work harder and longer, and also to think more clearly. Improvements in health raise the incentive to acquire schooling, since investments in schooling can be amortized over a longer working life (Kalemli-Ozcan, Ryder, and Weil, 2000). Healthier students also have lower absenteeism and higher cognitive functioning, and thus receive a better education for a given level of schooling. Improvements in mortality may also lead people to save for retirement, thus raising the levels of investment and physical capital per worker. Lower infant and child mortality can also lower the Net Rate of Reproduction, and thus reduce population growth, leading to a higher level of capital per worker.³

One of the most important aspects of the process of economic growth over the last century has been the upward shift in the $v(y)$ function, due to improvements in health knowledge and the development of new health technologies. Just as significant as this upward shift has been a dramatic change in the *slope* of this function. As stressed originally by Preston (1980), the effect of higher income on health is much smaller today than it was prior to World War II.

A more contentious question is the degree to which the $v(y)$ function differs among

² Pritchett and Summers (1996), using an instrumental variables procedure, find a significant effect of income on health, as measured by infant and child mortality. The instruments that they use are terms of trade shocks, the ratio of investment to GDP, the black market premium, and the deviation of the exchange rate from PPP.

³See Bloom and Canning (2000) for a discussion of many of these issues.

countries today. Gallup and Sachs (2001) argue that tropical areas have fundamentally worse health environments than do the temperate parts of the world. They claim, for example, that the fact that malaria has been eliminated in currently rich areas (such as Spain or the Southern US) but not in poor ones (such as sub-Saharan Africa) does not reflect differences in income, but rather the fact that malaria's grip is much stronger in Africa. Under this view, these fundamental differences in the health environment present a very strong obstacle to economic growth in the tropics. In contrast, recent work by Acemoglu, Johnson, and Robinson (2000) takes the view that differences in the fundamental health environment between countries are not large, and that high level of disease in tropical countries is more a result than a cause of their poverty. In terms of the $v(y)$ function, the former view is that there are large inter-country differences in the $v(y)$ function, while the latter view is that the function itself has a steep slope, but that there are not big differences across countries in the function's level.

Differences over time or between countries in the $y(v)$ function can be attributed to any influence on income other than health. For example, improvements in productive technology, accumulation of physical capital or human capital in the form of education, or development of better institutions will all shift the $y(v)$ function upward.

A full accounting of differences in income and health between two countries (or within a single country over time) would require a description of both the shapes of the $y(v)$ and $v(y)$ functions and also of the shifts that these functions had undergone. Despite the desirability of such a complete accounting, in this paper I undertake a much more modest investigation. I wish to ask how much of the variation in income that we observe between countries can be *directly* explained by differences in health – that is, how much income would differ between two countries if they had the same $y(v)$ function and their actual levels of health. As Figure 2 makes clear, doing this calculation requires only knowing the difference in health between the two countries (or the single country at two points in time) and the slope of the structural effect of health on income. In particular, one does not have to know anything about the shape of the $v(y)$

function, or about relative position of the two countries' $y(v)$ functions.⁴ It is also clear from Figure 2 that the “income gap due to health” that I calculate is not the same as the gap in income that would exist if the two countries had the same $y(v)$ functions but their own $v(y)$ functions – that is, it is not the income gap due to differences in the underlying health environment.

Beyond the advantage of its relatively modest data requirement, the measure I construct has the advantage of answering the question most relevant to policy makers: how much will given improvements in health translate into improvements in income in developing countries. (Although to get a full measure of the multiplier effect, by which higher income will feed back into better health and thus raise income further, one would also have to know the slope of the $y(v)$ function.)

In fact, the calculation that I do is even more limited than this, because in practice, I will look only at the direct effect of health on income. In the discussion of the $y(v)$ function above, one can distinguish several channels in which health differences may be an underlying cause of income differences between countries, but in which the effect of health operates via some intermediate (and measurable) variable. For example, poor health may lower the saving rate or the level of investment in education, resulting in lower levels of physical and human capital. If one looks for effects of health on income, controlling for the levels of physical and human capital, these indirect effects will not be attributed to health. Since this is exactly what I do below, the health effects that I measure will only be the direct ones.

3. Health Indicators

Development economists think about human capital as encompassing both health and

⁴Notice that I have assumed that the $y(v)$ function has a constant slope and shifts in a parallel fashion. Were this not the case, then the results of the decomposition that I undertake would depend on which country one started with. Below I present a simple model in which the constant slope assumption is justified.

education. However, as operationalized in the macro-growth literature (e.g Mankiw, Romer, and Weil, 1992), human capital has often been taken to be synonymous with education. In the case of human capital from education, we generally measure inputs, in the form of years of schooling. In the case of human capital from health, the approach taken here will be instead to look at *indicators* of health. The ideal indicator would have three characteristics. First, it would be comprehensive, measuring to the extent possible the totality of an individual's health. Second, there would exist micro structural estimates of how improvements in overall health, as proxied by the relevant indicator, affect labor productivity. Finally, data on the indicator would be available for a broad cross section of countries.

In this paper, I use data on four indicators of health: average height of adult men, body mass index (BMI) for men, the adult survival rate (ASR) for men, and age of menarche (onset of menstruation) for women. None of these measures is ideal for the purposes at hand, but each has advantages.

Adult Height

Adult height is a good indicator of the health environment in which a person grew up. Factors such as malnutrition and illness, both in utero and during childhood, result in diminished adult stature. Looking across individuals, there is also a large degree of non-health related variation in height, but much of this variation is washed out when one looks at population averages. Thus the change in average height within a single country over time provides a good indicator of the change the health environment (assuming a genetically stable population). And in settings where data such as income per capita are unavailable, height may serve as the best available measure of the standard of living.

Of course, the average height of adults is not a perfect indicator of the average *health* of adults, since height is almost completely determined by the time a person is in his or her mid-twenties. Thus it is possible that health environment in which an adult lives will be very

different from the one in which he grew up. If one is looking at historical data from periods of time in which the environment was changing only slowly, or looking cross-sectionally at countries which differ greatly in their health environments, then this timing effect will not be a serious problem; however, if one looks at countries with rapidly changing health environments, it is a possible concern.

Even where the health environment is changing rapidly, and so adult height is not a good indicator of the health environment in which adults live, it is still the case that adult height provides a lot of information about adult health. The reason for this is that, as recent literature has shown (Fogel, 1994), there is a “long reach” of childhood malnutrition and ill health into adulthood. Adults who are shorter because of a poor childhood environment have higher rates of many chronic illnesses in middle and old age. As I show below, the close correlation between adult height and adult mortality rates suggests that height is indeed a good indicator of health.

Height is the most frequently used health indicator in microeconomic studies of the relationship between health and income. Unfortunately, no comprehensive cross-country data set on height exists. Data are available for a modest number of countries. There is also relatively good historical data on height.

Body Mass Index

As in the case of height there are good structural estimates linking health as proxied by BMI to wages, but there is not consistent data for a reasonable cross section of countries. There is also less historical data on BMI than on height. For these reasons, BMI plays a relatively minor role in the analysis below.

Adult Survival Rate

The third measure of health I use is the adult survival rate (ASR): the fraction of fifteen

year olds who will survive to age 60, using the current life table.⁵ These survival rates are available in consistent form for a large cross-section of countries. Further, it seems reasonable to assume that the relation between survival and health shows less genetic variation across countries than does the relation between height and health. The ASR has the advantage of measuring survival during working years, and thus seems likely to be a good measure of health during working years, which is what should be most relevant for determining the level of output per worker.

Figure 3 shows the relation between adult mortality and income per capita across countries in 2000. Table 1 shows the unweighted means and standard deviations of the ASR over the period 1960-1998 for the 111 countries in which data was available for all years. Mean ASR rose and the standard deviation declined in the period up to 1990, reflecting a worldwide trend toward better health and the catching-up of the poorest countries toward rich country health levels (even though poor country incomes did not systematically grow faster than those in rich countries). The rise in the standard deviation of the mortality rate between 1990 and 1998 reflects the impact of AIDS, which dramatically raised mortality rates in several African countries.

There is historical data on ASR for a fair number of countries. Unfortunately, there are no good structural estimates linking an individual's health, as proxied by his survival, to wages.

Age of Menarche

Of all the indicators I use, age at menarche (the onset of menstruation) is the one most foreign to the literature on economic growth. Delayed menarche serves as a good indicator of malnutrition in infancy and childhood. Thus as countries grow wealthier, girls reach menarche

⁵Like the more common measure, life expectancy at birth, the ASR is based on a cross-sectional life table. Thus it measures how many fifteen years olds would die before age 60 if, at each age, they experienced the mortality rates of men who are currently that age. Data are from the World Bank.

earlier. As shown below, there is one structural microeconomic estimate of the relation between age at menarche and wages. To construct a cross-country data set on average age at menarche, I started with four published sources (Eveleth and Tanner, 1990, Thomas *et al.*, 2001, Parent *et al.* 2003, and Padez, 2003), each of which contains a compilation of data from 14 to 67 countries. When necessary (and possible) I followed the notes in these compilations to find the original studies from which the data came. I also found an additional 32 studies by following references and searching databases. I excluded observations that were based on highly non-representative samples (for example a single economic class or a single locality), and also took only the most recent observation for each country. Thus far my data set has 49 observations.

Despite these efforts, there remain several problems with the menarche data. Some come from surveys that are not nationally representative, examining women from a few regions, or from the national capital and its environs, for example. There are also cases where the data refer to the median rather than the mean age. Finally, data are from years ranging as far back as 1957, although the vast majority are from the 1980s and 1990s.

Figure 4 shows a the relationship between GDP per capita in 2000 and age of menarche (for various years). The mean age of menarche in my data set is 13.3 years, with a standard deviation of 0.81 years. The five countries with the oldest measured age of menarche are New Guinea (15.8 years), Haiti (15.4), Nigeria (15.0), Somalia (14.8), and Yemen (14.4). The United States has a mean age of 12.4 years, which is the sixth-youngest in the sample.

Comparisons of Health Indicators

For the samples of countries that are used in the empirical analysis below, the correlation between ASR and the log of GDP per capita is 0.767; between age of menarche and log of GDP per capita is -0.448; and between ASR and age of menarche is -0.408.

In countries that started developing earliest, there has been a long, gradual improvement

in most health indicators, while recent episodes of rapid growth have been accompanied by rapid changes in the health indicators. In Sweden, whose experience is typical for Europe, height increased by 5.5 centimeters between 1820 and 1900, and a further 6.8 centimeters between 1900 and 1965, while ASR rose by .179 in the first period and .203 in the second. By contrast, in South Korea, the height of adult males rose by 4.8 centimeters and ASR rose by 188 over the 33 year period 1962-95 (Sohn, 2000). Similarly, among industrialized countries in Europe, there was a roughly linear decline in age at menarche of 0.2 - 0.3 years per decade over the period 1860-1980 (Eveleth and Tanner, 1990). By contrast, in a study of women in rural Anhui Province in China, mean age at menarche fell from 15.2 years for women born 1959-63 to 13.7 years for women born 1974-78, a rate of 1.0 years per decade (Graham, Larsen, and Xu, 1999).

One concern in looking at health indicators across countries is that there may exist genetic variation that influences the relationship between underlying health and any particular indicator. In the case of age of menarche, Tanner (1990) reports that holding nutrition and environment constant, Africans and Asians reach menarche earlier than do girls of North European descent; thus estimates of the health gap of Europe and its offshoots vs. the rest of the world based on age of menarche will tend to understate the true degree of variation in underlying health. In the case of height, Steckel (1995) argues that although genetic differences can have some impact on differences in average heights between populations, observed differences are in fact largely attributable to environmental factors. (Despite Steckel's argument, I account for fixed effects when I use panel data on average height.)

4. Empirical Framework

I take health to be uni-dimensional. I assume that each health indicator is related to unobserved health with measurement error that is uncorrelated with other factors. My approach parallels the method used by Hall and Jones (1999) and Klenow and Rodriguez-Clare (1997) to convert years of education into a measure of human capital due to education.

Start with a Cobb-Douglas aggregate production function that takes as its arguments capital and a composite labor input,

$$Y_i = K_i^\alpha (A_i H_i)^{1-\alpha}$$

where A is a country-specific productivity term and i indexes countries. The labor composite, H_i , is determined by

$$H_i = h_i v_i L_i,$$

where h_i is per-worker human capital in the form of education, v_i is per-worker human capital in the form of health, and L_i is the number of workers. (As is common in this literature, I assume away heterogeneity in considering the aggregation to national averages, but then turn around and exploit this heterogeneity to derive parameter estimates from microeconomic data.)

In order to decompose output into the components due to human capital in the forms of education and health, we need measures of h and v from a cross-section of countries. These measures are constructed by combining data on levels of schooling and health indicators with estimates of the market value of these characteristics.

The wage paid to a unit of the labor composite, w_i , is simply its marginal product,

$$w_i = (1-\alpha)K_i^\alpha (A_i H_i)^{-\alpha}.$$

The wage earned by worker j will be a function of his own health and education as well as the national wage of the labor composite.⁶

⁶ Notice that implicit in this formulation is the notion that a worker with more education or health supplies more units of the same basic labor input as workers who are less

$$w_{i,j} = w_i h_{i,j} v_{i,j}.$$

Taking logs,

$$\ln(w_{i,j}) = \ln(w_i) + \ln(h_{i,j}) + \ln(v_{i,j}).$$

The usual Mincer-style analysis of the effect of education on wages relates the log of human capital from education to years of schooling (denoted s),

$$\ln(h_j) = \text{constant} + \beta s_j,$$

where the coefficient β can be recovered by regressing log wages on years of schooling. In the case of health, I follow the existing literature (see below) in assuming that there is a linear relation between log health and the indicator of health being examined. Letting I be the indicator of health,

$$I_j = \text{constant} + \frac{1}{\gamma} \ln(v_j) + \omega_j.$$

The error term ω_j encompasses any factor, such as genetic variation or simple luck, which causes an individual's expression of a particular health indicator to differ from the expected value based on his/her underlying health. Rearranging this equation so that it is in the same form as the equation for education:

educated or healthy. In the case of education, this assumption seems hard to justify, since one worker with a Ph.D. is hardly a perfect substitute for four workers who have no education. In the case of health, the assumption may be marginally more satisfactory: one healthy worker who can work faster or longer may indeed be a substitute for several unhealthy workers.

$$\ln(v_j) = \text{constant} + \gamma I_j + \omega_j .$$

Combining the wage, schooling, and health equations,

$$\ln(w_j) = \text{constant} + \beta s_j + \gamma I_j + \epsilon_j .$$

The coefficient γ , which represents the effect of health, as expressed by a particular indicator, on wages can in principle be recovered by regressing wages on the health indicator, controlling for education.

There are two econometric problems that arise in estimating the relation between any health indicator and wages. First, the error term in the equation relating the health indicator to underlying health has a large variance. For example, when height is used as a health indicator, the error will reflect genetic heterogeneity in the height that a healthy person will attain. Using an indicator to measure underlying health will be subject to measurement error, which will error will bias downward the coefficient on the health indicator in a wage regression.

Second, there is likely to be a positive correlation between a person's health and unmeasured determinants of his wage. People with high wages are able to take better care of themselves. And even in the case of aspects of health that are determined early in life (for example height and age of menarche), people from high-income families will be well nourished and cared for as children, and they will also carry into the labor market advantages, such as better schooling and family connections, that are not observed by the econometrician. The omission of these factors will bias upward the coefficient on a health indicator in a wage regression.

Both of these problems can be overcome by using an instrumental variables procedure. What is needed is a variable which is correlated with health but uncorrelated with the unobserved determinants of wages. One such variable that has been used in the literature is

inputs into health in childhood that are not related to family income. These inputs will be reflected in health indicators, but will not increase wages except through their effect on health. By instrumenting for health indicators with inputs into health, the estimated coefficient in the regression will reflect only the true structural effect of health on wages.

Table 2 shows the coefficients on health indicators from a variety of individual-level instrumental variables analyses. The instruments used are generally inputs into health in childhood such as the distance to local health facilities and the relative price of food in the worker's area of origin.⁷ The regressions in Table 2 control for years of education as well as the health indicator, so any indirect effects on the level of schooling are not included in the coefficient on health. Further, in all of these regressions, the dependent variable is the log of the hourly wage. Thus the extent to which good health allows a person to work more hours, as well as to do better work during the hours employed, is not accounted for. For both of these reasons, the estimates may understate the effect of health on income.

For the analysis below, I use the average of the available estimates in Table 2: 0.06 per centimeter for height, 0.14 per unit for BMI, and .261 per year of menarche.

5. The Contribution of Health Improvements to Economic Growth in Historical Data

As an initial test of my methodology, I examine growth in a single country over time. Because there is an additional comparison available, this exercise can also serve as check on the reasonableness of the structural microeconomic estimates on which the later analysis relies.

I examine the impact of health improvement in a single country – the United Kingdom –

⁷ Schultz (2002) also reports estimates, which I do not use, in which instruments are parental education and ethnicity. He also reports results for the U.S. However, because the regional price instruments do not provide a satisfactory basis for instrumenting for height in the wage regression, the IV estimates are not usable.

over a period of 200 years. An advantage of studying this case is that there is a good benchmark against which to compare my results..

In a series of papers, Robert Fogel (see 1997 for a summary) analyzes caloric intake and measures of calorie demand in the UK over the period 1780-1980. His analysis takes into account both the total quantity of calories consumed and the distribution of these calories across the population. He also carefully accounts for use of calories in basal metabolic maintenance (which increased over this period, as people got bigger) in order to calculate how many calories were left over for work. Fogel's conclusion is that increased calorie consumption had two significant impacts on labor supply. First, over this 200 year period, the fraction of the population that was simply too poorly nourished to work at all fell from 20% to zero, leading to an increase in labor input by a factor of 1.25. Second, among the adults who were working, increased caloric consumption allowed for a 56% increase in labor effort.⁸ Combining these effects, improved nutrition raised labor input by a factor of 1.95.⁹

The comparisons using my health indicators are as follows. Over the period 1775-1995, average height in the UK rose by 9.1 centimeters (Fogel, 1994). Applying the coefficient of 6% per centimeter of height implies that labor input would have increased by a factor of 1.73. In England over the 150 year period from 1832 to 1981, age at menarche declined by a total of 28.5 months (Wyshak and Frisch, 1982). Applying the coefficient of .261 per year of decline, labor input has increased by a factor of 1.86. Floud (1998, table 6) reports that mean BMI for British men aged 26-30 rose from 20.7 for the cohort born 1800-1819 to 24.9 for the cohort born 1960-79. Applying the coefficient of 0.14 per unit of BMI implies that labor input has increased by a factor of 1.80.

⁸More specifically, Fogel finds that the number of calories *available* for work increased by 56% over this period, and then further assumes, for lack of any data, that the division of energy output between work and "discretionary activities" remained constant.

⁹Fogel's work concentrates on nutrition rather than other aspects of health, but the link between the two is quite close. Fogel calculates that improvements in nutritional status accounted for 90% of the mortality decline in England between 1775 and 1875, and half of the decline between 1875 and 1975.

My conclusion from this exercise is that, applied to historical data from a single country, the different health indicators and structural estimates available paint a roughly similar picture of how health improvements affected labor input, and this picture roughly matches the information available from an independent benchmark.

6. Contribution of Health to Income Differences Among Countries

I now turn to examine the contributions of differences in health to differences in income among countries. Specifically, I extend the development accounting methodology of Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999) to include a measure of health.

Start with the aggregate production function introduced above:

$$Y_i = K_i^\alpha (A_i h_i v_i L_i)^{1-\alpha}.$$

All the terms in this equation, with the exception of productivity, A_i , can be observed directly. Thus this equation can be used to back out productivity as a residual.

To assess the role of health, productivity, and other factors in accounting for income variation among countries, I start by rearranging the production function as follows:

$$\frac{Y_i}{L_i} = \left(\frac{K_i}{L_i} \right)^\alpha (A_i h_i v_i)^{1-\alpha} = \left(\frac{K_i}{Y_i} \right)^{\frac{\alpha}{1-\alpha}} A_i h_i v_i$$

The first transformation simply adjusts for labor force. The second adjusts for endogenous variations in the capital/labor ratio that result from differences in productivity, health, or education among countries (as would occur, for example, if countries had fixed investment rates).

Starting with the left-most and right-most terms in the above equations, I can take logs and variances to do a decomposition of the sources of variation in $\ln(Y/L)$ among countries. I follow Klenow and Rodriguez-Clare (1997) in simply dividing the covariance evenly between factors.¹⁰ Thus, for example, the fraction of the variance in output per worker due to health will be given by

$$\frac{\text{Var}(\ln(v)) + \text{Cov}\left(\ln(v), \frac{\alpha}{1-\alpha} \ln\left(\frac{K}{Y}\right)\right) + \text{Cov}(\ln(v), \ln(h)) + \text{Cov}(\ln(v), \ln(A))}{\text{Var}\left(\ln\left(\frac{Y}{L}\right)\right)}$$

To implement this procedure, I need an estimate of v for every country. These can be created using the cross country data on health indicators reported in section 3 and the micro-structural estimates of the effect of health on wages reported in section 4. The rest of the data used are as follows. Output is from Heston, Summers, and Aten (2002) for the year 2000;

¹⁰Klenow and Rodriguez-Clare justify their procedure as follows. Starting with the equation in the text, take logs and look at the covariance of $\ln(Y/L)$ with each side:

$$\text{Var}(\ln(Y/L)) =$$

$$\text{Cov}(\ln(Y/L), \frac{\alpha}{1-\alpha} \ln(K/Y)) + \text{Cov}(\ln(Y/L), \ln(A)) + \text{Cov}(\ln(Y/L), \ln(h)) + \text{Cov}(\ln(Y/L), \ln(v))$$

Dividing both sides by $\text{Var}(\ln(Y/L))$, the four terms on the right hand side can be interpreted as the fractions of the variance of output per worker that are attributable to each factor. So, for example, the fraction of variance due to health would be

$$\frac{\text{Cov}(\ln(Y/L), \ln(v))}{\text{Var}(\ln(Y/L))}$$

Expanding this term by substituting for $\ln(Y/L)$ gives the same expression that I present in the text.

physical capital stocks are from Bernanke and Gürkaynak (2001) and apply to 1998; human capital in the form of education is constructed using the rates of return in Hall and Jones (1999) and the breakdown of the adult population by educational attainment for the year 1999 from Barro and Lee (2000) . I use a value of one-third for α (based on the findings in Gollin, 2002) . The choice of α affects the division of variance between physical capital (K/Y) and productivity (A) , but does not affect the fraction of variance attributed to health

Age at Menarche

The first indicator I use is age of menarche, for which both a structural estimate and cross-sectional data are available. The estimate reported in Table 2 of an effect on log wages of -.261 per year of menarche implies that, in my data set a one standard deviation decline in the age of menarche results in a 24% increase in wages (and thus steady state GDP). The gap between the earliest and latest age of menarche countries in my sample (approximately 3.7 years) translates into a health gap of a factor of 2.63.

Columns (1) and (2) of Table 3 show a decomposition of the shares of the variation in output per worker attributable to each factor, excluding or including health as measured by age of menarche. I discuss these results further below.

Height and Adult Survival

As mentioned above, analysis of cross-country data on health as proxied by height and adult survival faces two problems. ASR data is available for a large cross section of countries but there are no structural microeconomic estimates linking ASR to wages; by contrast, there are good structural estimates linking height to wages, but consistent height data is not available for a cross section of countries. In this section I take advantage of the fact that data on both height and ASR is available historically for a number of countries in order to map the structural coefficient on height into a coefficient that can be applied to the data on ASR.

As described above, I assume that there is a linear relation between log health and the level of each health indicator. I further allow for a country fixed effect in the relationship between height and health, to allow for genetic variation, and for a white-noise error term:

$$\ln(v_{i,t}) = \lambda_i + \gamma \text{height}_{i,t} + \epsilon_{i,t}$$

$$\ln(v_{i,t}) = \psi + \phi \text{ASR}_{i,t} + \eta_{i,t}$$

Estimates of the coefficient γ are the structural microeconomic estimates discussed above. To map these into estimates of the coefficient ϕ , set the two above equations equal and rearrange:

$$\text{height}_{i,t} = \frac{\psi - \lambda_i}{\gamma} + \frac{\phi}{\gamma} \text{ASR}_{i,t} + \frac{\eta_{i,t} - \epsilon_{i,t}}{\gamma}$$

Thus the ratio of coefficients ϕ/γ can be estimated by regressing height on ASR with a set of country fixed effects. To implement this regression, I constructed a data set with information from 10 countries and data covering up to 180 years per country, for a total of 93 observations. The data are shown in Figure 5.

Table 4 presents the results of this regression (in column 2), as well as results from alternative specifications. The coefficient of 26.4 in column 2 implies that a difference in the adult survival rate of 0.1 (100 deaths per thousand) is associated with a difference in height of 2.64 centimeters. Excluding country fixed effects (column 1) reduces the coefficient only slightly, while allowing for a linear time trend reduces the coefficient by 40% of its initial value, although it remains extremely significant.

The estimate of $\phi/\gamma=26.4$ in column (2), along with the value of $\gamma=.06$ derived above,

yields a value of $\phi=1.58$. This coefficient implies that a difference in the adult survival rate of 0.1 would translate into an increase in labor input per worker, and thus steady state GDP per worker, of 17%.

Before proceeding further, it is useful to compare this derived effect of health on income to existing estimates. Bloom, Canning, and Sevilla (2004) estimate that a one-year change in life expectancy at birth (e_0) raises GDP per capita by 4%. To map between e_0 and ASR, I use the Brass generalized life table. Moving from $e_0=55$ to $e_0=60$, ASR rises from .675 to .739, an increase of .064. Applying the value of $\phi=1.58$ derived above, this rise in ASR would increase GDP per worker by 10.7%. By contrast, Bloom, Canning, and Sevilla's estimate is that the corresponding rise in life expectancy would raise GDP per capita by 22% – roughly twice as much. Using the estimates of Jamison, Lau, and Wang (forthcoming), a rise in ASR of this magnitude would raise GDP by only 3.2%.

Columns (4) and (5) of Table 3 show the variance decomposition of output per worker using the measure of health constructed using data on ASR and the estimate of ϕ just derived.

Discussion of Results

Table 3 shows that variation in health does indeed have a large effect on variation in output per worker. Using the menarche method, health accounts for 7.7% of the variation in log GDP per worker, while using the ASR method health accounts for 19.1% of the variation in log GDP per worker. The latter figure is roughly the same as the share accounted for by human capital from education, and larger than the share accounted for by physical capital. Even the former figure implies that health variations are an important source of income variation among countries. For example, a two standard deviation difference in the age of menarche would explain a difference of a factor of 1.53 in GDP per capita between two countries.

The results in Table 3 also modify the conclusions reached by Hall and Jones (1999) and

Klenow and Rodriguez-Clare (1997) regarding the importance of productivity differences in explaining differences in output between countries. Because my procedure does not affect the shares of variation attributable to education and accumulation of physical capital, in comparison to these earlier studies, any of the variance that is explained by health in my procedure would be attributed to productivity if health were not measured. Thus using either health indicator, the importance of productivity is significantly reduced. Productivity is still left as the most important determinant of income differences, but (using ASR as the indicator) it no longer ranks as being more important than all other factors taken together.

Finally, a puzzling point about the results in Table 3 is that menarche and ASR yield such different estimates of the importance of health. Column (3) of the table shows that the difference between the ASR and menarche estimates is not a result of the different samples used. Even using the menarche sample, the fraction of the variance of output explained by health is more than two and a half times as large using the ASR method as using the menarche method.

7. Conclusion

To be added.

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Table 1: Mean and Standard Deviation of the Adult Survival Rate		
Year	Mean	Standard Deviation
1960	.623	.160
1970	.660	.151
1980	.693	.141
1990	.730	.139
1998	.740	.147

Note: The Adult Survival Rate is the fraction of 15 year olds who will live to reach age 60, using the current life table.

Table 2: Structural Estimates of the Effect of Health Indicators on Wages				
Health Indicator (unit)	Effect on ln(wage)	sample	country and year	Source
height (cm)	0.080*	males 18-60	Colombia (urban), 1991	Ribero and Nuñez (2000)
	0.094*	males 25-54	Ghana, 1987-89	Schultz (2002)
	0.078*	males 20-60	Brazil, 1989	Schultz (2002)
	-0.011	males 25-54	Côte d'Ivoire, 1985-87	Schultz (2001)
BMI (kg/m ²)	0.18*	males 18-65	Brazil, 1996-97	Rivera and Currais (forthcoming)
	0.16*	males 25-54	Côte d'Ivoire, 1985-87	Schultz (2001)
	0.079	males 20-60	Ghana, 1987-89	Schultz (2001)
Age of Menarche (yrs)	-0.261*	females 18-54	Mexico, 1995	Knaul (2000)
*Statistically significant at the 5% level.				

Table 3: Shares of Variation in Output per Worker Attributable to Each Factor					
Health Indicator:	none	Age of Menarche	ASR	none	ASR
Sample:	Menarche sample (N = 34)			ASR sample (N = 75)	
	(1)	(2)	(3)	(4)	(5)
physical capital, K/Y	.157	.157	.157	.162	.162
human capital from education, h	.170	.170	.170	.187	.187
health, v		.077	.202		.191
productivity, A	.673	.596	.471	.651	.460

Table 4: Regression of Height on Adult Survival Rate			
Independent Variable			
Constant	156.0 (1.0)	157.5 (0.8)	107.8 (11.7)
Adult Survival Rate	21.1 (2.8)	26.4 (1.0)	16.6 (2.5)
Year			.0292 (.0068)
Country Fixed Effect?	no	yes	yes
R ²	.377	.953	.961

Note: Standard errors in parentheses. N=93 for all regressions. Height is measured in cm.

Figure 1

The Relationship Between Health and Income

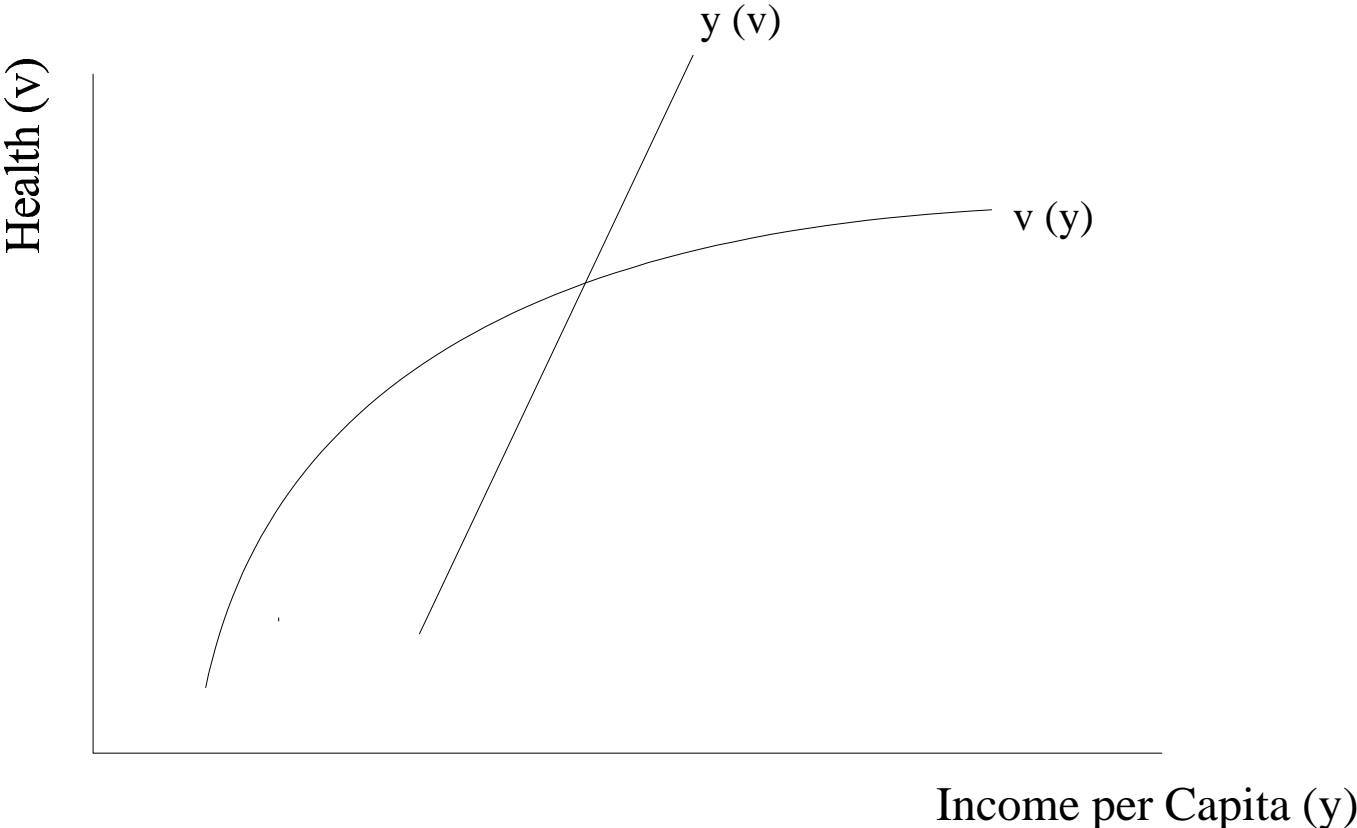


Figure 2

Decomposing Income Differences

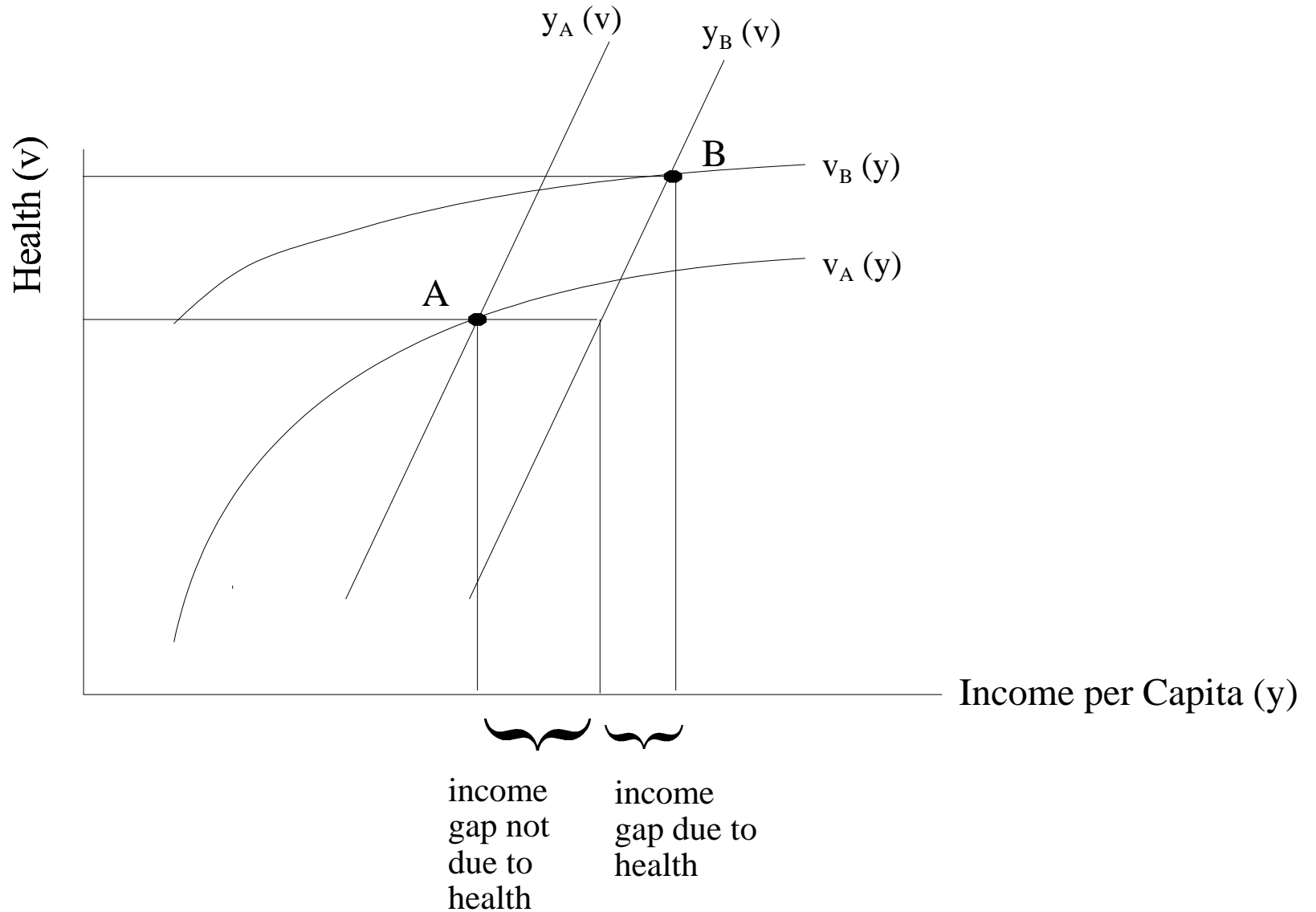


Figure 3: GDP per Capita vs Adult Survival Rate

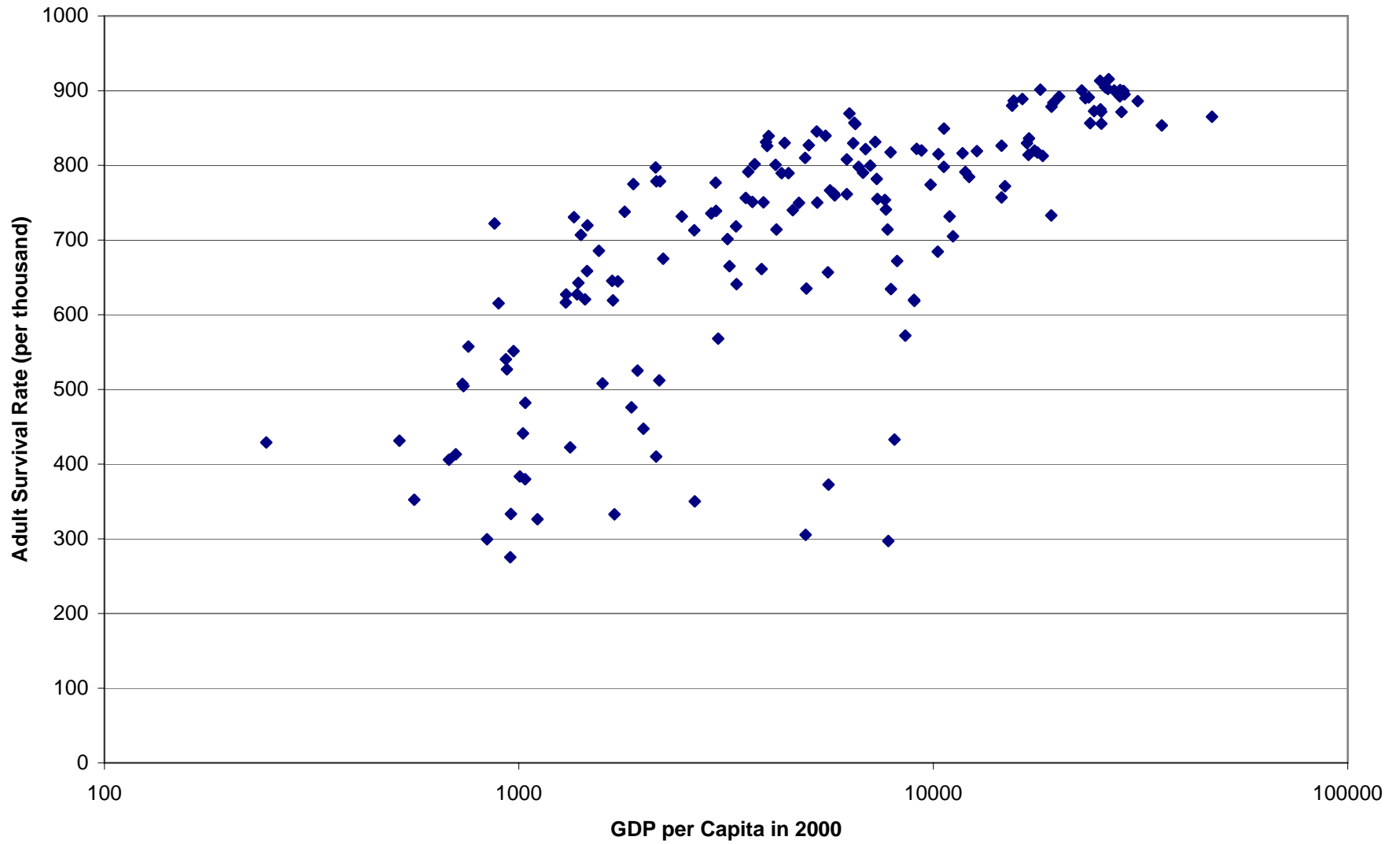


Figure 4
Age of Menarche vs GDP per Capita

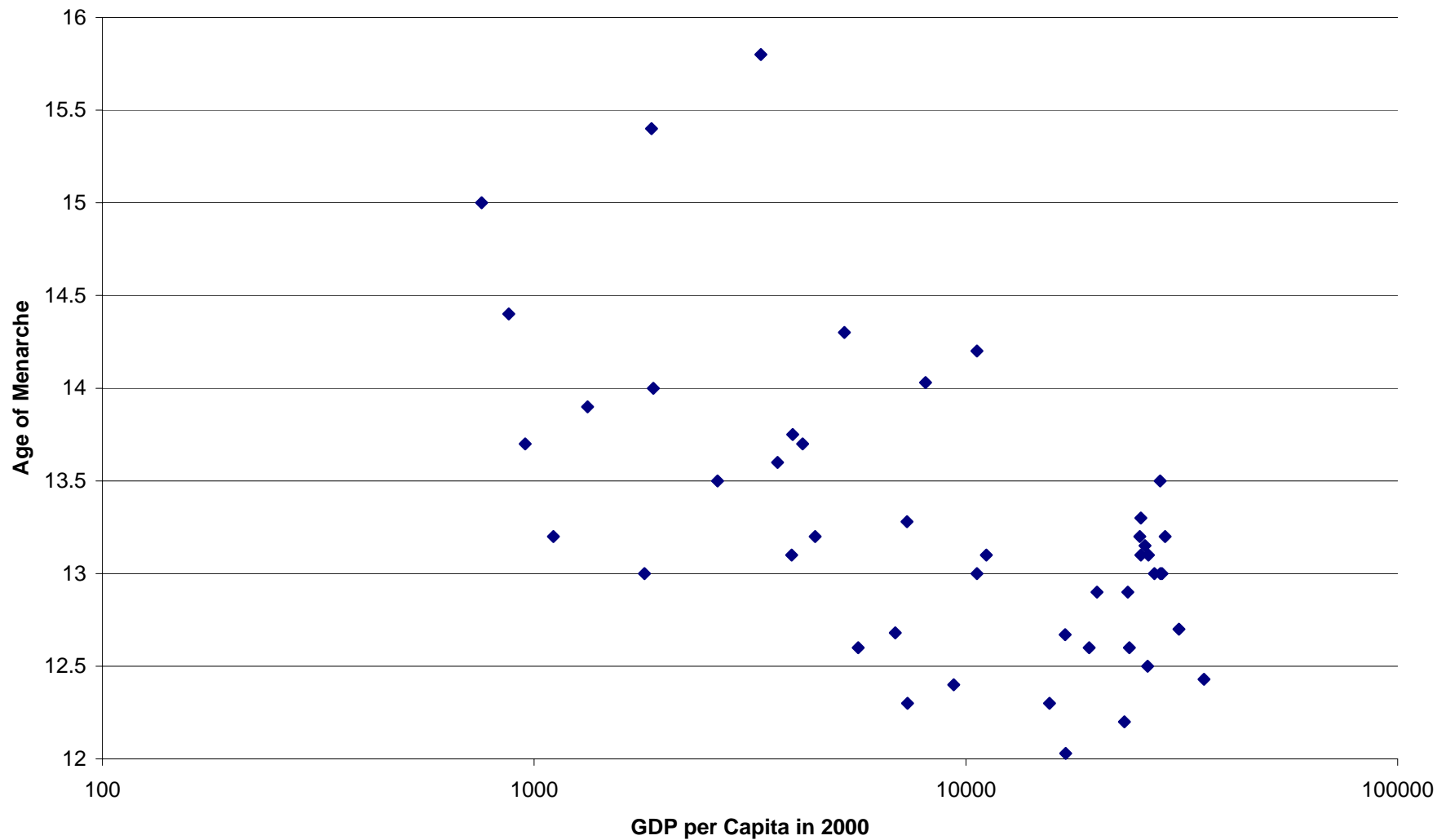


Figure 5: Data on Height and Adult Survival

