Adult Mortality, Institutions, and Cross-Country Income Differences

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Abstract

Do reductions in mortality lead to increases or decreases in income per capita? Recent research has called into question the emergent view from the late 1990s of health improvements as an important contributor to labor productivity and thus income per capita. While improved health certainly raises the quality of labor, the technique of development accounting typically recovers a relatively small direct effect of health on growth through this channel. Other studies have revealed evidence that improvements in health produce increases in population size and thus capital shallowing, which reduces income per capita through a "Solow effect." In this paper, I use a new dataset on the average and variance of adult length of life around the world to reexamine the role of the mortality transition in promoting economic growth. I find that longer adult life is associated with higher levels of capital accumulation, as life-cycle theory suggests, and with higher technology, even when controlling for the effects of institutions. But institutions appear to be relatively more important than the mortality environment for human capital accumulation.

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1 Introduction

Do reductions in mortality lead to increases or decreases in income per capita? At the microeconomic level, there is a plethora of evidence that progress against infectious disease, a major element of the epidemiological transition, unambiguously improves the productivity of current and future workers by making them healthier (Bloom and Sachs, 1998; Bloom and Canning, 2000; Bloom, Canning and Sevilla, 2004; Bloom and Canning, 2005). This perspective seems particularly true in the case of childhood diseases, whose effects can extend throughout the entire life course (Bleakley, 2003, 2007). Based on this type of reasoning, some have argued that improvements in population health, for example through public health initiatives, are desirable not only in and of themselves, but also because they should increase incomes.

But several recent studies call into question the assumption that these micro-level patterns neatly scale up into an unambiguous macroeconomic relationship between population health and growth. It is certainly puzzling in light of this posited relationship that while there has been much convergence in life expectancy around the world, convergence in income per capita has been considerably less robust (Becker, Philipson and Soares, 2005). In an important paper, Acemoglu and Johnson (2007) use an instrumental variables approach to show that midcentury improvements in life expectancy in a panel of 47 countries seem not to have raised income per capita at all, apparently because they raised the rate of population growth. This timing of events is certainly plausible; during the classic demographic transition, mortality decline typically precedes fertility decline and results in population growth (Lee, 2003). Absent any stimulus to technological growth or human capital, it is clear how in theory this could result in lower incomes (Galor and Weil, 2000; Kalemli-Ozcan, 2002). In the literature, this has been dubbed the "Solow effect" because of its connection to the basic neoclassical model of production.[1]

[1] In a study of the AIDS mortality crisis in South Africa and income per capita, Young (2005) reveals a different kind of Solow effect associated with increasing AIDS mortality: reduced fertility, which also pushes population growth down and raises income per capita. This kind of compounded effect derives from

Detailed evidence on the timing of events during the demographic transition supports this perspective but also reveals that it best characterizes the early part of the transition. Figure 1 plots growth in real GDP per capita, growth in population, the total fertility rate, and life expectancy at birth for both sexes for India from 1900 to 2007. Gains in life expectancy starting around 1920 were at first associated only with increased population growth, and the growth in GDP per capita was falling prior to 1940, presumably through a Solow effect. But after 1940, real income growth began to increase monotonically along with life expectancy, even though fertility and population growth remained high. It was not until after 1960, some twenty years later, that the latter two began to fall. Similar trends in life expectancy and income growth after 1940 are not evidence of any causal relationship, but the positive correlation between them motivates once again the question of what may explain it.

Other studies have quantified the impact of health on income per capita through the direct effect of health on labor productivity. Results have typically shown this channel to account for a relatively small amount of the global variation in income. As discussed by Caselli (2005), the method of development accounting assigns a relatively small role to the health of workers in explaining differences in incomes.[2] Weil (2007) confirms this perspective using microdata, recovering an economically significant effect of health on incomes that is much smaller than cross-country regressions suggest. Ashraf, Lester and Weil (2009) calibrate a simulation model to show that gains against mortality or against particular diseases have significantly delayed and only moderate effects of on per capita income.

The theoretical basis for a relationship between mortality and human capital quality is certainly strong; lifetime returns to human capital rise when mortality falls (Kalemli-Ozcan, Ryder and Weil, 2000). But a broader view of the mortality environment suggests that it is

a relationship between fertility and mortality that appears to be distinct from the traditional patterns of the demographic transition, while the "Solow effect" referenced in the text is definitely part of the traditional transition.

[2]Two of the unresolved issues Caselli (2005) argues may be important are whether the elasticity of substitution between physical and human capital and capital's share of output may vary across countries. If high-income countries were relatively better at using healthy human capital, the role of health in accounting for income differences might be more important than typically thought.

also likely to be important for other inputs to production, both physical and otherwise. From a life-cycle perspective, the demand for wealth accumulation is higher when average length of life is longer, thus physical capital accumulation may also be stimulated by reductions in mortality. Kalemli-Ozcan and Weil (2002) argue that in a high-mortality environment where survival uncertainty is high, workers may choose to save less and never retire. It is also possible that length of life is an important determinant of intellectual production. Edwards (2008) documents increases in adult survival during the development of empirical scientific thought and proposes that early gains against adult mortality may have fostered the early growth of ideas. In the modern world, with freer movement of labor, low mortality conditions may foster the production of ideas by attracting immigrant scientists, although income per capita and strong institutions are also obvious pull factors. Institutions themselves, meaning the social, economic, and political organization of society such as the protection of property rights and the rule of law, may respond to mortality conditions (Acemoglu, Johnson and Robinson, 2001).

In this paper, I revisit the question of how mortality is associated with development by expanding the focus to more components of the production function than human capital. To be sure, Weil (2007), Ashraf, Lester and Weil (2009), and others in this field have considered more than just the responses of human capital to health; the latter also account for the indirect impact of health on production via population size and structure, physical capital accumulation, for example. I argue that it is important also to examine how total factor productivity may react to the mortality environment. A large share of the explanatory power of institutions in growth accounting rests is associated with TFP. For reasons I outlined above, life expectancy may also be important for TFP.

Methodologically, my paper is a straightforward augmentation of the cross-sectional analysis of national income per capita proposed by Hall and Jones (1999) in one of the pioneering and influential efforts in development accounting. They recover a central role for their measure of institutional quality but do not account for mortality. To proceed, I examine a new dataset of estimated life tables that cover a broad panel of countries observed in 1970 and 2000. Using the new dataset, I account for the effects of major moments of the distribution of length of life, namely life expectancy but also the variance in adult life and decompositions of life expectancy, using lagged values of mortality data as instruments. Unlike Acemoglu, Johnson and Robinson (2003), I find less support for the perspective that health affects growth only through institutions. Rather, my results suggest health, and adult longevity in particular, seems to be more important than institutions for capital accumulation and for technological change as measured by the Solow residual. Human capital accumulation responds strongly to institutions even when controlling for mortality conditions.

In the sections that follow, I first describe the problem and the empirical strategy associated with development accounting Then I discuss the data, which consist of updated versions of the macroeconomic and social indicators examined by Hall and Jones (1999) and Caselli (2005), and a new set of life table estimates presented and described in greater detail by Edwards (2009). Finally, I present and interpret my econometric results before concluding with a discussion of their implications.

2 Theory and empirical strategy

2.1 The production function and factor inputs

I adopt the benchmark framework in this literature, the aggregate production function specified by Hall and Jones (1999),

$$Y_i = K_i^{\alpha} \left(A_i H_i\right)^{1-\alpha}, \tag{1}$$

in which country i produces output Y_i with physical capital K_i, total factor productivity A_i, and the stock of human capital, H_i, which can be different from the number of workers, L_i. By convention, the capital share is set at $\alpha = 1/3$, its typical value in industrialized countries.

I estimate capital stocks using the perpetual inventory method.[3] Estimating stocks of human capital is more involved. Hall and Jones (1999), Weil (2007), and Ashraf, Lester and Weil (2009) all estimate the value of human capital per worker, h_i, as a piecewise linear function of education per worker, E_i,

$$h_i = \begin{cases} e^{\phi_1 E_i} & \text{if } E_i \leq 4 \\ e^{4\phi_1 + \phi_2(E_i - 4)} & \text{if } 4 < E_i \leq 8 \\ e^{4\phi_1 + 4\phi_2 + \phi_3(E_i - 8)} & \text{if } E_i > 8 \end{cases}$$

where $\phi_1 = 0.134$, $\phi_2 = 0.101$, and $\phi_3 = 0.068$, based on Psacharopoulos (1994). Weil (2007) and Ashraf, Lester and Weil (2009) also account for the effect of health on the value of human capital. Their preferred method is to construct a multiplicative shifter, υ_i, that varies proportionally with the adult survival rate, $ASR \equiv \ell_{60}/\ell_{15}$, where ℓ_x is the period survivorship probability to age x. Weil (2007) reports that

$$\upsilon_i = e^{0.653 \cdot ASR_i}.$$

Finally, Ashraf, Lester and Weil (2009) account for the proportional returns to labor force experience with a similar multiplicative shifter ϵ, which is a quadratic in age x:

$$\epsilon = e^{\psi_1(x-15) + \psi_2(x-15)^2},$$

where $\psi_1 = 0.0495$ and $\psi_2 = -0.0007$, per Bils and Klenow (2000). According to this parameterization, the value of experience peaks around age 50. I measure ϵ_i for country i as the average ϵ based on the age structure of the population between ages 15 and 64. With

[3] Following Hall and Jones (1999), I set the capital stock in 1970 equal to the 1970 investment level divided by the average annual rate of growth in investment over 1960–1970 plus a 6 percent depreciation rate. Then future capital stocks are equal to depreciated capital plus new investment starting in 1971.

these concepts in mind, I can rewrite the stock of human capital as

$$H_i = (\upsilon_i \cdot \epsilon_i \cdot h_i)\, L_i \equiv h_i^* L_i.$$

The shorthand h_i^* is a useful way of referring to the total value of human capital per worker, inclusive of the value of education, health, and experience. When the indexes of health, υ_i, and experience ϵ_i, are unavailable, setting them both equal to 1 recovers the familiar relationship $H_i = h_i L_i$.

With values in hand for all the other variables, I can use the aggregate production function to calculate A_i as a Solow residual. Then to facilitate analysis, I rearrange equation (1) per Hall and Jones (1999) to show output per worker, y_i, as a function of the capital-output ratio, human capital per worker, and TFP:

$$y_i \equiv \frac{Y_i}{L_i} = \left(\frac{K_i}{Y_i}\right)^{\alpha/(1-\alpha)} (\upsilon_i \cdot \epsilon_i \cdot h_i)\, A_i. \tag{2}$$

As discussed by Hall and Jones, this form of the production function is particularly useful because the capital-output ratio is proportional to the saving rate along a balanced growth path. Changes in TFP can feed directly into output per worker rather than also raising an intermediate variable like capital per worker; the effects of changes in TFP can be isolated in the last term. Taking logs reveals an additive decomposition,

$$\log(Y_i/L_i) = \frac{\alpha}{1-\alpha}\log(K_i/Y_i) + \log \upsilon_i + \log \epsilon_i + \log h_i + \log A_i, \tag{3}$$

which can associate effects of exogenous variables on output per worker via specific components of production.

2.2 The structural determinants of income

Hall and Jones (1999) estimate reduced forms of log output per worker, and then separately its additive components from equation (3), specifying a single, endogenous regressor: social infrastructure.[4] They argue that a country's social infrastructure rewards private behavior and protects it from predation, and it aligns private incentives with social incentives. Their preferred measure is the average of two indexes, one of which is itself an average of five indexes of government antidiversion policies (GADP) compiled by Political Risk Services, and the Sachs and Warner (1995) measure of openness to trade.

The integrity of markets, ownership, and contracts are certainly distinct characteristics of human society. But it is also not hard to imagine causality running from other factors into social infrastructure, income being chief among them. For their instrument set, Hall and Jones choose the Frankel and Romer (1999) log predicted trade share based on a gravity model, distance from the equator, the fraction of the population speaking one of the five major Western European languages,[5] and the fraction speaking English.

Although such a link is never explicit, these instruments and social infrastructure itself are implicitly tied to the mortality environment. Distance from the equator predicts climate and geography, and thus intrinsic mortality, while the last two instruments are associated with historical mortality. Acemoglu, Johnson and Robinson (2001) argue that modern institutions like the protection of property rights and the rule of law can be traced back to colonial times, when the prevailing mortality environment dictated which institutions European settlers would import with them.

It would constitute a completely different mechanism altogether, but it is not difficult to argue that the current mortality environment may operate in a manner similar to social infrastructure. Lower mortality among natives could increase private returns to the accumulation of physical and human capital, or to the development of ideas. When mortality is high, the returns to holding physical capital may be enjoyed by future rather than current generations, because they will likely die before realizing the returns. Because human capital

[4]The term refers to "the institutions and government policies that determine the economic environment within which individuals accumulate skills, and firms accumulate capital and produce output" (page 84).

[5]These five are English, French, German, Portuguese, and Spanish.

does not last past death, private returns are made unambiguously lower. If research and development is very time intensive, higher mortality will reduce associated yield. In all these cases, it is easy to imagine that socially optimal behavior may not be privately optimal when mortality is very high, for the simple fact that private returns are zero whenever the owner has died.

As a result, I propose augmenting the analysis of Hall and Jones (1999) to include measures of mortality. I model log output per worker and its components with a reduced form that in addition to social infrastructure also includes average life expectancy and the variance in length of adult life as regressors. I measure the latter with s_{10}, the standard deviation in length of adult life above age 10 (Edwards and Tuljapurkar, 2005), which I discuss at greater length shortly. My basic estimation equations, based on equation (3) and leaving off the i subscripts, are:

$$\begin{aligned}
\log(Y/L) &= \beta_y + \gamma_y \cdot S + \theta_y \cdot e_0 + \omega_y \cdot s_{10} + u_y && (4)\\
\frac{\alpha}{1-\alpha}\log(K/Y) &= \beta_k + \gamma_k \cdot S + \theta_k \cdot e_0 + \omega_k \cdot s_{10} + u_k && (5)\\
\log h &= \beta_h + \gamma_h \cdot S + \theta_h \cdot e_0 + \omega_h \cdot s_{10} + u_h && (6)\\
\log \upsilon &= \beta_\upsilon + \gamma_\upsilon \cdot S + \theta_\upsilon \cdot e_0 + \omega_\upsilon \cdot s_{10} + u_\upsilon && (7)\\
\log \epsilon &= \beta_\epsilon + \gamma_\epsilon \cdot S + \theta_\epsilon \cdot e_0 + \omega_\epsilon \cdot s_{10} + u_\epsilon && (8)\\
\log A &= \beta_a + \gamma_a \cdot S + \theta_a \cdot e_0 + \omega_a \cdot s_{10} + u_a && (9)
\end{aligned}$$

where S is the index of social infrastructure, e_0 is period life expectancy at birth, s_{10} is the standard deviation of adult life over age 10, and the u's are random errors. Because equation (3 is additively decomposable, the main coefficient in equation (4) should equal the sum of coefficients across the component regressions (5)–(9). In each regression, I instrument for S, e_0, and s_{10} using the four original instruments of Hall and Jones plus lagged values of the mortality variables from 1970.

2.3 The effects of variance in the length of life

Like income inequality, S_{10} is a measure of the dispersion in a component of well-being. As the second moment of a distribution, it may have second rather than first-order effects on average outcomes. But although they may be small, the effects of uncertainty in the length of life on economic behaviors are theoretically independent of the effects of the mean.

Other things equal, a longer average life span requires a greater accumulation of savings for retirement and a higher rate of saving. An individual whose wealth is fully annuitized will not respond to variance in length of life by altering saving. But without annuities, greater variance induces a form of precautionary saving provided the retirement age is fixed (Hubbard, Skinner and Zeldes, 1994). Because there is a greater risk of living too long when variance rises, individuals save more. When retirement can be postponed indefinitely, greater uncertainty in length of life may result in reduced saving and continued work (Kalemli-Ozcan and Weil, 2002).

Similar reasoning suggests that variance in length of life is likely to affect human capital investment and the production of ideas independently of the mean length of life. But in each of these cases, the effects of variance and of the mean are likely to be either opposite in sign or of the same sign. In the data, e_0 and s_{10} tend to be negatively correlated, as shown in Figure 2. The Pearson correlation between the two series as shown is -0.876. Thus an issue that may arise in estimation is that if the true marginal effects of the two variables are also negatively correlated, it may be very difficult to isolate them.

3 The data

With the exception of the mortality data, which are discussed below, all the data in this version of the paper are taken directly from Hall and Jones (1999). In future versions, I plan to construct new estimates of the economic variables using updated production statistics from the Penn World Table 6.2 (Summers and Heston, 1991), and education statistics from

Barro and Lee (2000). The impediment is that Hall and Jones had to impute education, openness, GADP, and GDP data for a subset of their data.

I use the social infrastructure index reported by Hall and Jones (1999), as well as their instrument set: the log predicted trade share, the distance from the equator, the fraction of the population speaking one of the five major Western European languages, and the fraction speaking English.

Mortality data are taken from Edwards (2009), who compiled a new dataset of period life tables for 180 countries in the years 1970 and 2000. Whenever possible, the life tables are based on actual vital statistics, but in many cases the data in developing countries are poor, and model life tables are applied. The World Development Indicators and other databases report life expectancy at birth for many countries and occasionally some other life table characteristics, but estimates of higher moments and the shape of the survivorship curves are typically not provided.

As an average, life expectancy at birth is additively decomposable into parts attributable to deaths under and above any particular age threshold (Tuljapurkar and Edwards, 2009). In order to explore age-specific differences in the marginal effects of life expectancy, I can decompose e_0 into parts attributable to average life years lived before and after age 10,

$$e_0 = (1 - \ell_{10}) \cdot m_0^- + \ell_{10} \cdot m_{10}, \tag{10}$$

where ℓ_{10} is the probability of surviving to age 10, m_0^- is the average life years lived under age 10, and m_{10} is the average life years lived after age 10. When infant and child mortality is low, ℓ_{10} is very high, and changes in e_0 mostly reflect changes in adult length of life, m_{10}.

4 Results

Table 1 presents the results of estimating the log output per worker equation (4) using various specifications of the right-hand side. In the first two columns, I reproduce the findings of Hall and Jones (1999) by using social infrastructure as the sole regressor other than a constant term. Results using either ordinary least squares or instrumental variables are roughly similar; social infrastructure explains a very large share of variation in log output per worker. As reported by Hall and Jones, there is roughly a factor of 35 separating the poorest and richest countries in the data. The extremes in the social infrastructure variable differ by 0.89 in the data. After correcting for apparent measurement error, Hall and Jones report that social infrastructure can account for factor of up to 38.4 separating richest and poorest, which is given by the exponentiated product of the IV coefficient shown in the second column of Table 1, 5.14, times 0.89, times an error correction term of 0.8.

When I introduce mortality variables into the equation and into the instrument set in the next three columns, the coefficient on social infrastructure drops by roughly two thirds, and it loses significance at the 5 percent level in the IV regressions. Because its coefficient is now a third of its prior level, the factor of variation in output per worker that it explains is now the old factor to the one third power, or only 3.2. In contrast, life expectancy at birth is strongly and significantly associated with output per worker, with a coefficient estimated between 0.56 and 0.65 in Table 1. Unlike the case with social infrastructure, the IV estimate of the coefficient on life expectancy is not larger than the OLS estimate; thus there is no clear evidence of measurement error nor any need to correct for it. The gap in e_0 between richest and poorest in the data is 43.3 years. Using the IV coefficient on life expectancy of 0.056, this translates into a factor of 11.3 in output per worker. There is no clear evidence in Table 1 that adult life-span variance as measured by s_{10} matters for output per worker. The coefficients are small, change sign across specifications, and are all statistically insignificant. The last two columns reveal that results do not appreciably depend on whether lagged values of the mortality variables are in the first-stage regression of the IV estimate. Overidentification tests do not reveal any glaring problems with the instruments.

Table 2 displays the first stage estimates of the second-stage regressors on the full instrument set, with lagged mortality variables. Several of the instruments turn out to affect current life expectancy and current life-span variance, the new regressors, more strongly than they affect social infrastructure. The t-statistics for coefficients on distance to the equator are the same in both the life expectancy equation and the social infrastructure equation, but it is considerably higher in the life-span variance equation. The language instruments clearly affect the mortality regressors more strongly than social infrastructure. Part of this may be due to the strong association that emerges between lagged life expectancy, a new instrument in this specification, and social infrastructure. The t-statistic on that coefficient is over 3. Lagged mortality is also a good instrument for current mortality, which is not surprising. But even when the lags are omitted, the remaining instruments seem to prefer the current mortality regressors over social infrastructure, as evidenced by higher first-stage R^2's and F-statistics.

Table 3 explores the decomposition of log output per worker by estimating equations (5), (6), and (9). In its current form, the dataset does not yet include information on the contributions of health or experience to human capital, so I omit those equations. The TFP residual will by definition absorb any effects of those terms.

Once mortality is taken into account, the impact of social infrastructure seems to be confined to explaining human capital accumulation, here measured only by the value of years of education per worker. The coefficient on social infrastructure in the log H/L equation in the middle column is 1.01 and statistically significant at the 1 percent level. In the other two regressions, social infrastructure is statistically insignificant, and it is even negative in the TFP regression shown in the third column. As was the case in Hall and Jones (1999), the human capital equation also fails the overidentification test, casting some doubt on the sole positive outcome for social infrastructure.

Table 3 reveals the strongest effects of mortality on output per worker to derive from the impact of life expectancy on total factor productivity, which rises 3.4 percent for every additional year, significant at the 5 percent level. Close behind that is the effect channeled through capital accumulation. Each additional year of life expectancy raises the capital-output ratio by $(\alpha - 1)/\alpha = 2$ times the coefficient, 0.015, although the latter is only significant at the 8 percent level. There are no signs of an effect of mortality on the accumulation of human capital derived from education, which is rather surprising. But that is the equation that fails the overidentification test.

5 Conclusion

The mortality environment matters for economic well-being. Microeconomic evidence reveals a positive relationship between health and income, but the sign and the size of the link between population health and aggregate economic performance is the subject of much debate. Previous research focusing on public health interventions early in the 20th Century shows that rising life expectancy can increase population growth and thus reduce income through a "Solow effect" predicted by the neoclassical growth model (Acemoglu and Johnson, 2007). But as historical patterns in India reveal, that result may be most relevant only for the early stages of the demographic transition.

The results in this paper suggest that the period of development during which such Solow effects tend to dominate may be relatively short. Life expectancy is positively related to macroeconomic performance for the average country in an international cross section drawn from modern times. Instrumental variables estimates reveal that life expectancy is as strong a predictor of income per worker as a previously used measure of institutional quality, the social infrastructure index popularized by Hall and Jones (1999).

Increases in population health appear to increase capital accumulation and total factor productivity, while their effect on human capital accumulation is positive but statistically insignificant. Social infrastructure is most strongly associated with stocks of human capital and actually has a negative association with TFP.

Studies based on development accounting combined with instrumental variables, like this one, are subject to clear limitations. The assumption of exogeneity required of instruments that are lagged values of regressors becomes questionable in regressions of income on health (Mankiw, 1995; Weil, 2007). One suspects there are multiple lines of causality running between those two variables and with third variables like technology. That findings are relatively robust to omitted lagged life expectancy from the instrument set is reassuring in this regard.

Research using improved panel data may be able to overcome such statistical issues and provide new insights into the relationship between the mortality environment and macroeconomic performance. Natural experiments are of course even more desirable, but it is difficult to envision a random, external shock that lowers mortality. Shocks that increase mortality are more common but may not reveal the mechanism of interest. Work by Young (2005) and Kalemli-Ozcan (2006) on the AIDS crisis in Africa has shown that the fertility response to a mortality spike is important and may not follow the standard pattern of the transition in reverse.

References

Acemoglu, Daron and Simon Johnson. 2007. "Disease and Development: The Effect of Life Expectancy on Economic Growth." *Journal of Political Economy* 115(6):925–985.

Acemoglu, Daron, Simon Johnson and James A. Robinson. 2001. "The Colonial Origins of Comparative Development: An Empirical Investigation." *American Economic Review* 91(5):1369–1401.

Acemoglu, Daron, Simon Johnson and James Robinson. 2003. "Disease and Development in Historical Perspective." *Journal of the European Economic Association* 1(2–3):397–405.

Ashraf, Quamrul H., Ashley Lester and David N. Weil. 2009. When Does Improving Health Raise GDP? In *NBER Macroeconomics Annual 2008*, ed. Daron Acemoglu, Kenneth Rogoff and Michael Woodford. Vol. 23 Chicago: University of Chicago Press.

Barro, Robert J. and Jong-Wha Lee. 2000. "International Data on Educational Attainment: Updates and Implications." *NBER Working Paper* 7911.

Becker, Gary S., Tomas J. Philipson and Rodrigo R. Soares. 2005. "The Quantity and Quality of Life and the Evolution of World Inequality." *American Economic Review* 95(1):277–291.

Bhat, Mari. 1990. "Fertility and Mortality in Colonial India." *Economic and Political Weekly* 25(37):2107–2108.

Bils, Mark and Peter J. Klenow. 2000. "Does Schooling Cause Growth?" *American Economic Review* 90(5):1160–1183.

Bleakley, Hoyt. 2003. "Disease and Development: Evidence from the American South." *Journal of the European Economic Association* 1(2/3):376–386.

Bleakley, Hoyt. 2007. "Disease and Development: Evidence from Hookworm Eradication in the American South." *Quarterly Journal of Economics* 122(1):73–117.

Bloom, David E. and David Canning. 2000. "The Health and Wealth of Nations." *Science* 287(5456):1207–1209.

Bloom, David E. and David Canning. 2005. "Health and Economic Growth: Reconciling the Micro and Macro Evidence." *CDDRL Working Paper* 42.

Bloom, David E., David Canning and Jaypee Sevilla. 2004. "The Effect of Health on Economic Growth: A Production Function Approach." *World Development* 32(1):1–13.

Bloom, David E. and Jeffrey D. Sachs. 1998. "Geography, Demography, and Economic Growth in Africa." *Brookings Papers on Economic Activity* 2:207–295.

Caselli, Francesco. 2005. Accounting for Cross-Country Income Differences. In *The Handbook of Economic Growth*, ed. Phillipe Aghion and Steven Durlauf. Vol. 1 Amsterdam: Elsevier.

Edwards, Ryan D. 2008. "Declining Mortality Among British Scientists During the Age of Enlightenment." *Population and Development Review* 34(S):103–125.

Edwards, Ryan D. 2009. "Trends in World Inequality in Life Span Since 1970." Unpublished manuscript, May.

Edwards, Ryan D. and Shripad Tuljapurkar. 2005. "Inequality in Life Spans and a New Perspective on Mortality Convergence Across Industrialized Countries." *Population and Development Review* 31(4):645–675.

Frankel, Jeffrey A. and David Romer. 1999. "Does Trade Cause Growth?" *American Economic Review* 89(3):379–399.

Galor, Oded and David N. Weil. 2000. "Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond." *American Economic Review* 90(4):806–828.

Hall, Robert E. and Charles I. Jones. 1999. "Why Do Some Countries Produce So Much More Output Per Worker Than Others?" *Quarterly Journal of Economics* 114(1):83–116.

Hubbard, R. Glenn, Jonathan Skinner and Stephen P. Zeldes. 1994. "The importance of precautionary motives in explaining individual and aggregate saving." *Carnegie-Rochester Conference Series on Public Policy* 40:59–125.

Kalemli-Ozcan, Sebnem. 2002. "Does the Mortality Decline Promote Economic Growth?" *Journal of Economic Growth* 7(4):411–439.

Kalemli-Ozcan, Sebnem. 2006. "AIDS, Reversal of the Demographic Transition and Economic Development: Evidence from Africa." *NBER Working Paper* 12181.

Kalemli-Ozcan, Sebnem and David N. Weil. 2002. "Mortality Change, the Uncertainty Effect, and Retirement." *NBER Working Paper* 8742.

Kalemli-Ozcan, Sebnem, Harl E. Ryder and David N. Weil. 2000. "Mortality decline, human capital investment, and economic growth." *Journal of Development Economics* 62(1):1–23.

Lee, Ronald D. 2003. "The Demographic Transition: Three Centuries of Fundamental Change." *Journal of Economic Perspectives* 17(4):167–190.

Maddison, Angus. 2003. *The World Economy: Historical Statistics*. Paris: OECD Development Cenre.

Mankiw, N. Gregory. 1995. "The Growth of Nations." *Brookings Papers on Economic Activity* 1995(1):275–326.

Murray, C. J. L., B. D. Ferguson, A. D. Lopez, M. Guillot, J. A. Salomon and O. Ahmad. 2003. "Modified Logit Life Table System: Principles, Empirical Validation, and Application." *Population Studies* 57(2):165–182.

Psacharopoulos, George. 1994. "Returns to Investment in Education: A Global Update." *World Development* 22(9):1325–1343.

Sachs, Jeffrey D. and Andrew Warner. 1995. "Economic Reform and the Process of Global Integration." *Brookings Papers on Economic Activity* 1:1–95.

Summers, Robert and Alan Heston. 1991. “The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950–1988.” *Quarterly Journal of Economics* 106(2):327–368.

Tuljapurkar, Shripad and Ryan D. Edwards. 2009. “Variance in Death and Its Implications for Modeling and Forecasting Mortality.” *NBER Working Paper* 15288.

United Nations Population Division. 2006. *World Population Prospects: The 2004 Revision.* New York: United Nations.

Weil, David N. 2007. “Accounting for the Effect of Health on Economic Growth.” *Quarterly Journal of Economics* 122(3):1265–1306.

Young, Alwyn. 2005. “The Gift of the Dying: The Tragedy of AIDS and the Welfare of Future African Generations.” *Quarterly Journal of Economics* 120(2):423–466.

Table 1: Models of output per worker

Dependent variable: log Y/L in 2000

	Estimation method				
Independent variable:	**OLS**	**IV**	**OLS**	**IV**	**IV**
Social infrastructure	3.29	5.14	1.29	1.66	2.03
	(0.25)	(0.46)	(0.24)	(0.94)	(1.30)
Life expectancy, e_0			0.065	0.056	0.064
			(0.009)	(0.014)	(0.016)
Life-span variance, s_{10}			0.006	−0.035	0.023
			(0.043)	(0.084)	(0.126)
Observations	127	127	121	121	121
overid test p-score		0.2497		0.4098	0.6938
Instrument set		no lagged mortality		full	no lagged mortality

Notes: The mortality data are country-level observations in 2000. Life-span variance s_{10} is the standard deviation in length of life above age 10. Income and all other data are taken from Hall and Jones (1999). Social infrastructure is an average of two indexes, one of which is itself an average of five indexes of government antidiversion policies (GADP) compiled by Political Risk Services, and the Sachs and Warner (1995) measure of openness to trade. The instrument set includes the Frankel and Romer (1999) log predicted trade share based on a gravity model; the distance from the equator; the fraction of the population speaking one of the five major Western European languages, English, French, German, Portuguese, or Spanish; the fraction speaking English; and lagged values of life expectancy and life-span variance from 1970. First stages are reported in Table 2.

Table 2: First-stage estimates of endogenous regressors on instruments

Independent variable (instrument):	Dependent variable (regressor): Life expectancy (in 2000)	Life-span variance (in 2000)	Social Infrastructure
Life expectancy in 1970	0.62	−0.04	0.132
	(0.13)	(0.03)	(0.004)
Life-span variance in 1970	−0.77	0.40	0.001
	(0.55)	(0.13)	(0.017)
Distance to equator	9.05	−4.01	0.283
	(3.72)	(0.87)	(0.117)
Log of trade share	−0.33	0.03	0.035
	(0.67)	(0.16)	(0.021)
Share speaking English	−5.42	0.24	0.063
	(2.36)	(0.55)	(0.074)
Share speaking European	5.01	0.22	−0.015
	(1.61)	(0.38)	(0.050)

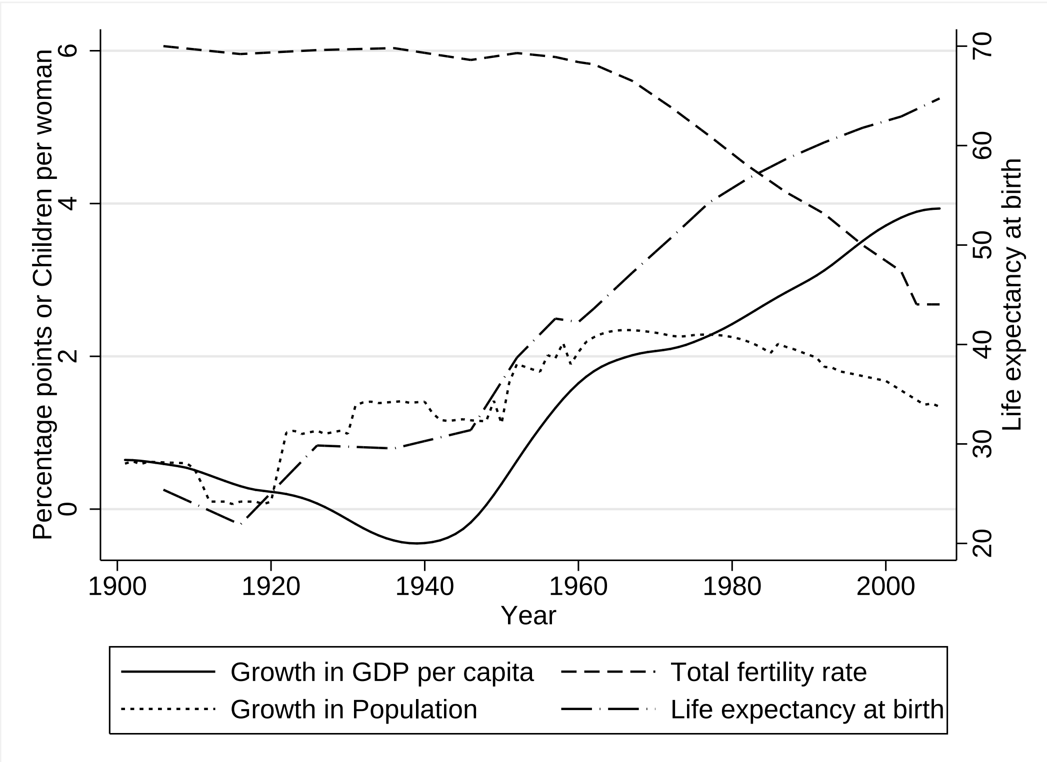
Notes: See notes to Table 1. These are the first-stage regressions in the instrumental variables regression whose final results are shown in the fourth column in Table 1.

Table 3: Decomposing log output per worker

Independent variable:	Dependent variable: $\frac{\alpha}{1-\alpha} \log K/Y$	$\log H/L$	$\log A$
Social infrastructure	0.697	1.010	−0.133
	(0.556)	(0.425)	(1.042)
Life expectancy, e_0	0.015	0.007	0.034
	(0.008)	(0.006)	(0.016)
Life-span variance, s_{10}	0.040	0.016	−0.090
	(0.050)	(0.038)	(0.093)
Observations	121	121	121
overid test p-score	0.8015	0.0121	0.0936
Instrument set	full	full	full

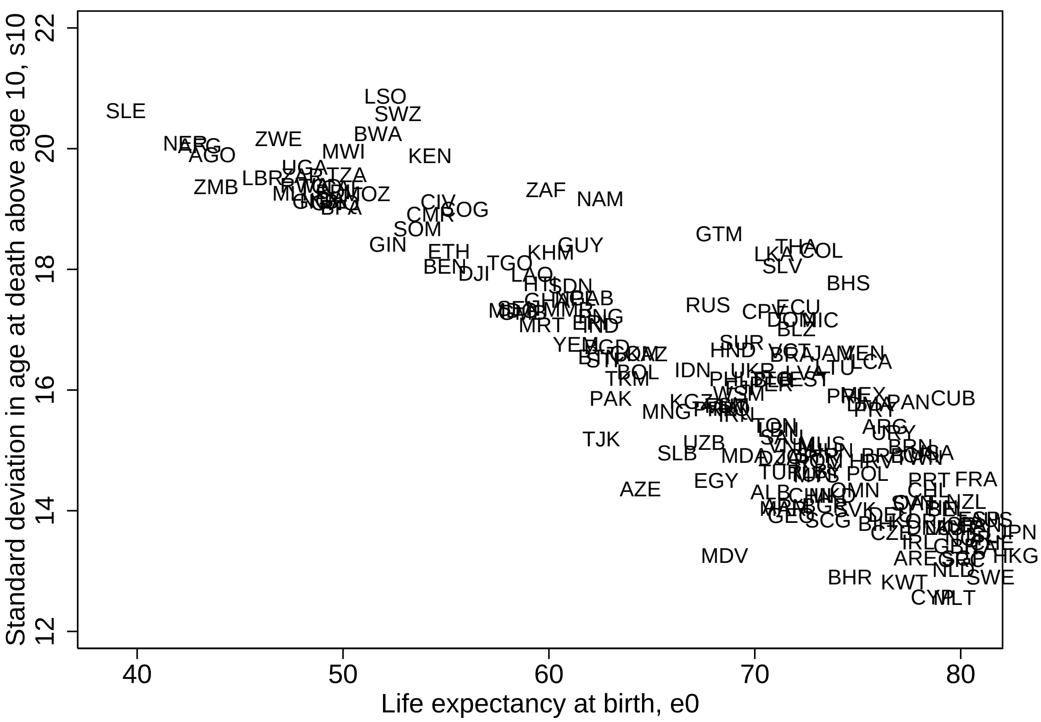
Notes: See notes to Table 1.

Figure 1: The demographic transition in India, 1900-2007



Sources: Real GDP per capita: prior to 1950, Maddison (2003), then the Penn World Table 6.2 (Summers and Heston, 1991). The figure shows the percentage point change in trend real GDP per capita, the latter obtained using a Hodrick-Prescott filter. Population: prior to 1960, Maddison, then the World Development Indicators (WDI) For life expectancy at birth and the total fertility rate: prior to 1950, Bhat (1990); between 1950 and 1960, United Nations Population Division (2006); after 1960, WDI.

Figure 2: Variance in adult length of life versus life expectancy at birth, 2000



Source: Edwards (2009). The plot depicts s_{10}, the standard deviation in length of life above age 10 based on the period life table, against e_0, life expectancy or average length of life starting from birth, for 180 countries in the year 2000.