Cognitive and Economic Development

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Preliminary

Abstract

Life expectancy has a robust correlation with economic growth in cross-country data. We show that this correlation is due to child mortality, *not* adult mortality. We investigate whether the impact of child malnutrition and disease on cognitive development is responsible for the correlation of child mortality with economic growth. Cognitive deficiencies reduce peoples' economic capabilities throughout their lives, and make investments in education less productive. In an economic growth model we distinguish three consequences of poor health: mortality, morbidity, and cognitive impairment, showing that cognitive impairment is likely to have by far the largest economic impact. We use cross-country panel data to show that indicators of child health and cognitive development including IQ have strong correlations with economic growth.

1 Introduction

Researchers compiled the first comparable data on economic growth for a large number of countries several decades ago. One of the surprises was the strong correlation of life expectancy with economic growth, clearer than the correlation of education with growth. For instance, Sala-i-Martin *et al.* (2004) found that life expectancy was the eighth-most robust correlate of economic growth from among 67 considered.[1] Life expectancy was interpreted as an indicator of the health of the working population which boosts economic productivity.

Two pieces of evidence cast doubt on this interpretation. First, we show that the strong correlation of life expectancy with economic growth is due to child survival, not adult survival. Although the death of children is a terrible human tragedy, child mortality is unlikely to have a large *economic* impact because young children require only modest material investments especially in a low income setting. If mortality is interpreted as an indicator of the disease

[1] The second most robust correlate of economic growth in this study is primary school enrollment, but as Pritchett (2001) shows, enrollment is often negatively correlated with schooling levels of adult workers, and average schooling typically does not have a very strong correlation with economic growth in cross-country data.

environment of the living, the morbidity of young children should have also small economic effects compared to the morbidity of working adults.

Second, the pattern of human capital impacts in microeconomic household studies is opposite the pattern found in cross-country data. Household studies typically shows a modest, though positive, impact of adult health on household income whereas education usually has a large impact on household income.

Although child health is unlikely to have a direct impact on economic growth, it can have a profound impact on the cognitive development of children. There is a large medical literature on the effects of *in utero* and post-natal nutrition and disease on cognitive development. The risk factors for cognitive deficiency are very high in low income countries. The average rate of stunting, the most commonly available measure of calorie and protein malnutrition, was 47% in low income countries in 1990. A national rate of stunting over 40% is classified as "very high malnutrition" by the World Health Organization. The average rate of anemia (iron-deficiency), a major cause of cognitive deficiency, was 72% in low income countries.[2]

There are several reasons to expect that cognitive capacity affects economic productivity. Cognitive deficits lower the effectiveness of education because children learn more slowly or not at all and are more likely to drop out. This lowers the economic rate of return to investment in education. Cognitive deficits early in life are *irreversible*. Most cognitive deficiencies contracted before 24 months of age two can never be overcome regardless of remediation efforts.[citation] When children with cognitive deficits enter the workforce as adults, they are less productive their whole working lives. When cognitive deficiencies are common in the population, spillover effects are likely. If a good fraction of the students in a classroom have deficiencies, the whole class is likely to be slowed down. A large fraction of workers with cognitive deficiencies is likely to be a drag on the productivity of those with good cognitive development. The microeconomic evidence on the impact of cognitive deficiencies on schooling outcomes and adult wages is well-established in both low and high income countries.

We present a model of the relationship of health to economic growth, distinguishing cognitive impairment, morbidity and mortality. We show that cognitive impairment is likely to have a much larger impact on economic growth than other effects of health. We also show that if parents focus on mortality and morbidity but do not take into account the effects of nutrition and disease on cognitive development, there will be a large externality which can be rectified by public health spending by the government.

We use cross-country panel data to estimate the correlation of child health and cognitive impairment with economic growth, using a range of indicators and estimation methods.

This paper contributes to the empirical literature on the impact of health on economic development, previously addressed by Barro and Lee (1994), Gallup

[2]Calculated by the authors using data from the WHO Global Database on Child Growth and Malnutrition (2017) for children aged less than 5 years. "Low income" is the World Bank's classification. Note that people who were children in 1990 are recent entrants into the job market.

and Sachs (2001), Bhargava, Jamison, Lau, and Murray (2001), Bloom et al. (2004), Weil (2007), Acemoglu and Johnson (2007), Weil (2014), and Bloom et al. (2014), among others.

Heckman (2007) and Marsden (2016) study the hypothesis that cognitive development plays a significant role in economic development, and were inspirations for this paper. Marsden focuses on cross-country evidence linking parasitic and infectious disease to average national IQ levels, and shows that IQ is correlated with national income levels. Jones and Schneider (2006) show that average national IQ has an exceptionally robust correlation with economic growth.

Our paper makes three main contributions. First, we establish that the strong cross-country correlation of life expectancy with economic growth is due to child, not adult mortality. Second, we develop an economic growth model showing the likely potency of cognitive development as a factor in economic growth. Third, we provide evidence that a range of indicators of cognitive deficiencies are strongly correlated with cross-country economic growth.

The next section shows that the strong correlation of life expectancy with economic growth reflects child survival not adult survival. We hypothesize that this is due to the effect of early child cognitive development on adult worker productivity. We review the evidence about the impact of disease and nutrition on child cognitive development, and the impact of cognitive development on educational and labor market outcomes. Section **??** presents a model of economic growth incorporating separate roles for cognitive capacity, morbidity and mortality in economic production. Section 5 shows that parents' lack of awareness of the effect of disease on cognitive development causes an externality. Section 6 presents cross-country evidence of the correlation of average cognitive development on economic growth. Section 7 concludes.

2 Cognitive Development, Disease and Nutrition

Growth is correlated with child not adult survival

Life expectancy has a strong correlation with economic growth at a national level. Life expectancy depends on mortality rates, reflecting disease and health conditions, so life expectancy is frequently used as a readily available proxy for the health status of a country's population. In studies of the causes of economic growth, life expectancy is typically included as an indicator of the health of the working population, which is part of their human capital.

The first panel of Figure 1 shows the partial correlation of life expectancy with economic growth, controlling for other correlates of growth in a fixed effects regression. The details of this estimation are explained explained in Section 4 below and the regression is shown in the first column of Table 4.

The positive slope of the estimation line relating life expectancy to economic growth reflects the robust correlation almost always found between the two variables. When we separate life expectancy into the component parts child survival

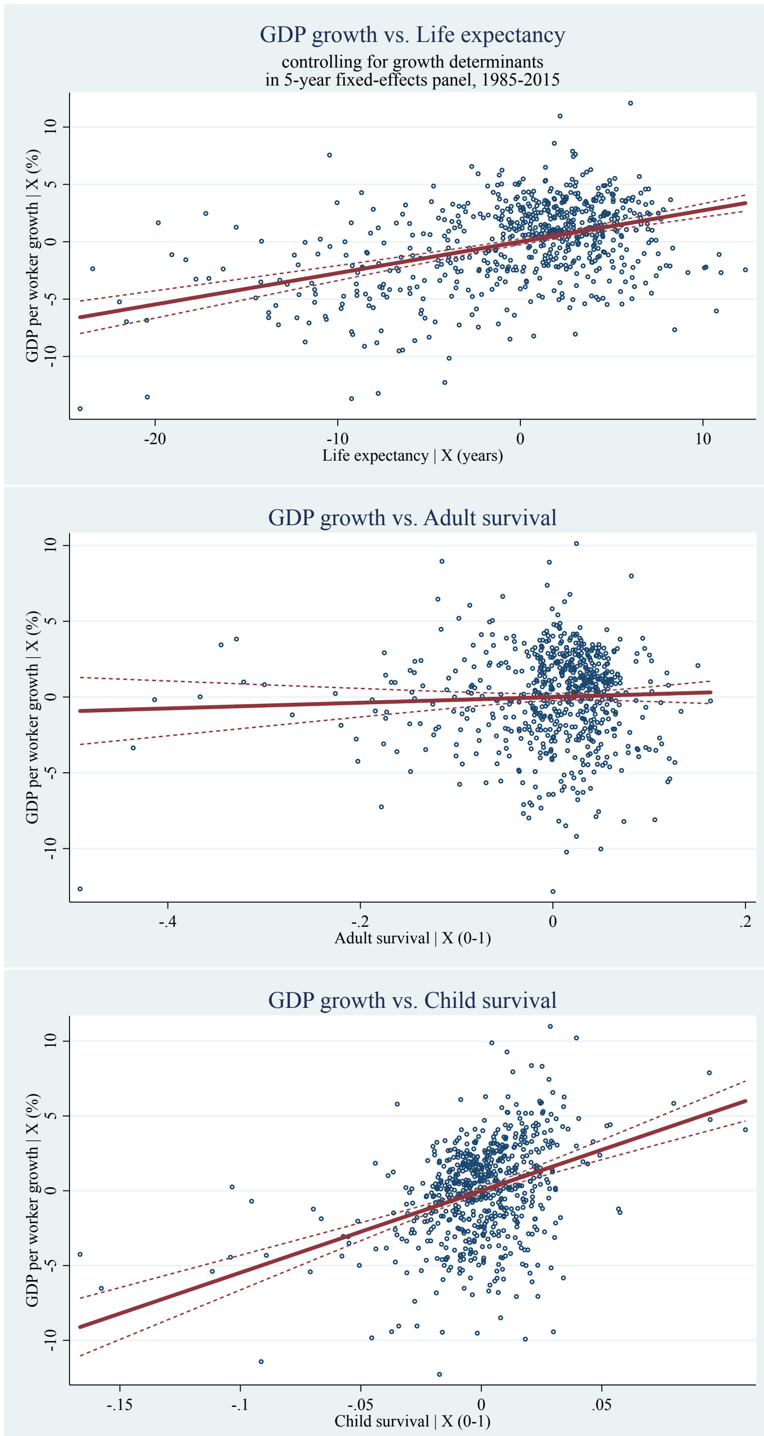

Figure 1: IQ vs. Economic Growth, controlling for other variables

and adult survival we find no statistically significant estimated relationship between adult survival and economic growth, and a strong relationship between child survival and growth.

One would expect the health of workers to be specifically correlated with the mortality of adults rather than the mortality of children. However if we distinguish the survival of adults and children, we find that economic growth has no significant correlation with adult survival and is strongly correlated with child survival.

What would explain such a strong correlation between child survival and economic growth? The direct economic loss from child mortality for children under age five largely consists of the time of parents and other family members required to raise young children. For child mortality to have a substantial effect on economic growth would require a major diversion of family member childcare time from other economically productive activities. The organization of the household in low income countries with high child mortality typically mitigates these losses because older children with a low opportunity cost of time share part of the duties, and self-employed household members can often integrate child care into their productive activities. Direct material investments in young children in low income countries are usually very modest. This means that the death of young children, despite the tremendous suffering it causes, is unlikely to have large economic consequences.

Likewise the morbidity of young children likely has small economic effects because they are not yet productive workers, and the care of sick children is usually a modest loss of productive time for family workers in low income countries.

Our hypothesis is that child survival is strongly correlated with economic growth because fetal and child nutrition and disease affects child cognitive development which has life-long economic consequences. The cognitive impairment due to poor health conditions need not be profound for it to have significant economic impacts since it will affect the economic productivity of the children throughout their whole working lives. An important channel by which cognitive impairments reduce worker productivity is by reducing their educational attainment. Moreover, if the cognitive level of other workers affects the productivity of everyone, the spillovers of cognitive impairment will further reduce national productivity.

There is a large and well-established medical literature on the consequences of *in utero* and child nutrition and disease on cognitive development. There is increasingly clear evidence that the developing human brain is exquisitely sensitive to nutrient and energy deficiencies with most of the long term damage occurring between conception and two years of age.

3 Model

We use the original Lucas (1988) model and incorporate cognitive deficits as well as illness. Cognitive deficits during childhood reduce worker productivity later in life because it impedes the development of human capital. There are two periods in life, an initial period of cognitive development (from time 0 to τ) followed by the period of schooling and working (from time τ to T).

As is typical in models of economic growth, mortality *per se* increases economic growth because the deceased are no longer consuming, reducing the denominator of income per capita, and the remaining workers have more capital to work with.

Let denote x the degree of cognitive development affected by childhood nutrition and disease at time τ. We can interpret T as the number of years the individual expects to live, which is equal to the average life span. The degree of cognitive development is affected by private and government health spending up until age τ

$$x = \frac{1}{\tau} \int_0^\tau b(m_t, G_t)\, dt \tag{1}$$

where $b(m_t, G_t)$ is a increasing convex function in personal expenditure m_t and public expenditure G_t.

As in Lucas (1988), for one unit of avaliable time it will be spent in production (δ_t) or in education (γ_t), with the remaining time u_t lost due to recovery from disease which depends on health expenditure $u_t = q(m_t, G_t)$ where q is a decreasing concave function in personal expenditure and public expenditure. Therefore

$$\delta_t + \gamma_t + u_t \leq 1,\ \delta_t \geq 0,\ \gamma_t \geq 0,\ u_t \geq 0 \tag{2}$$

Suppose that the individual is born with some human capital h_0 and her human capital evolves over time according to

$$\dot{h}_t = x\gamma_t h_t$$

Now consider an economy of L_t identical individuals with aggregate production function

$$Y_t = K_t^\alpha (A_t h_t L_t \delta_t)^{1-\alpha} \tag{3}$$

where K_t, A_t, h_t are capital stock, technological level and human capital, respectively, and δ_t is the amount of time devoted for working.

The change in the capital stock is given as

$$\dot{K}_t = Y_t - C_t - m_t L_t - G_t \tag{4}$$

Suppose that the technical change is given by

$$g_A = \dot{A}_t / A_t = \beta g_h + g_{\bar{A}} \tag{5}$$

where g_h and $g_{\bar{A}}$ are human capital and average world technology growth rates. Thus $A_t = h_t^{\beta} \bar{A}_t$. As usual, labor force L_t growth rate is

$$\dot{L}_t / L_t = b - d. \tag{6}$$

with birth rate b and mortality rate d. In principal, the death rate d should affect life expectancy T, but we ignore this since it is not an important dynamic in the model. For the moment, let us assume that the individual utility is $U(c_t) = \ln c_t$ where $c_t = C_t/L_t$. Denote $A = \bar{A}_t^{(1-\alpha)}$ and $\beta = (1-\alpha)\beta_1$ and g_x is growth rate of any variable x. Let define the steady state at the growth rate of variable $x = x^*$ is constant.

The individual's problem has a planning horizon T with objective U at time $t = 0$ is

$$\max_{c_t, \gamma_t, m_t} \int_0^T e^{-\rho t} U(c_t) dt$$

subject to the constraints (1)-(6).

Suppose that $q(m, G) = e^{-\theta m - \eta G}$ then $\frac{\partial q}{\partial m} = -\theta q$,and $\frac{\partial^2 q}{\partial m^2} = \theta^2 q$. Let $b(m, G)$ satisfy

$$x = \frac{1}{\tau} \int_0^{\tau} b(m_t, G_t) dt = 1 - u_\tau = 1 - q(m_\tau, G_\tau)$$

Define $m_{\max}$ such that $q(m_{\max}, 0) = 0$.

Proposition.
At the equilibrium
i) The effect of spending on health in the cognitive development period (both private and public) has a greater impact on equilibrium income than health spending during the schooling and working period of life.
ii) At steady state,

$$\frac{\partial g_y}{\partial d} > 0, \frac{\partial g_y}{\partial x} > 0$$

Proof. i) It follows from (3) and (4) that the capital stock and income growth rates are

$$\begin{aligned} g_K &= K_t^{\alpha} (A_t h_t L_t \delta_t)^{1-\alpha} - C_t/K_t - m_t - G_t/K_t \\ g_Y &= \alpha g_K + (1-\alpha)(g_A + g_h + g_\delta + b - d) \\ &= g_w + g_h + b - d \\ &= g_A + g_\delta + g_h + b - d \end{aligned}$$

The growth rate of income per head of the population is

$$g_y = \alpha g_k + (1-\alpha)(g_A + g_h + g_\delta)$$

and the growth rate of human capital is $g_h = x\gamma_t$.

The current-value Hamiltonian is

$$\begin{aligned} J &= U(c_t) + \lambda_1[K_t^\alpha[h_t L_t(1-\gamma_t - q(m_t, G_t))]^{1-\alpha} A h^\beta - c_t L_t - m_t L_t - G_t] \\ & \quad + \lambda_2 x \gamma_t h_t + \lambda_3 (b-d) L_t \end{aligned}$$

The optimal conditions $\frac{\partial J}{\partial c_t} = 0$ imply

$$\frac{\dot{\lambda}_1}{\lambda_1} = -g_c - g_L - \rho.$$

It follows from

$$\frac{\partial J}{\partial K_t} = -\dot{\lambda}_1$$

that

$$\alpha A[\frac{L_t \delta_t h_t^{\frac{1-\alpha+\beta}{1-\alpha}}}{K_t}]^{1-\alpha} = \frac{-\dot{\lambda}_1}{\lambda_1} = \rho + g_L + g_c$$

Denote

$$z = \frac{L_t \delta_t h_t^{\frac{1-\alpha+\beta}{1-\alpha}}}{K_t} = [\frac{\rho + g_L + g_c}{\alpha A}]^{\frac{1}{1-\alpha}} \tag{7}$$

At steady state, g_c is constant then z is constant. Thus we have

$$g_K = g_L + g_\delta + (\frac{1-\alpha+\beta}{1-\alpha}) g_h$$

The next F.O.C

$$\frac{\partial J}{\partial \gamma_t} = 0, \frac{\partial J}{\partial h_t} = -\dot{\lambda}_2$$

implies

$$\begin{aligned} \lambda_1(1-\alpha) A K_t^\alpha L_t^{1-\alpha} \delta_t^{-\alpha} h_t^{1-\alpha+\beta} &= \lambda_2 x_\tau h_t \\ \lambda_1(1-\alpha+\beta) A_t K_t^\alpha (L_t \delta_t)^{1-\alpha} h_t^{-\alpha+\beta} + \lambda_2 x_\tau \gamma_t &= -\dot{\lambda}_2 \end{aligned}$$

Then we have $\frac{\lambda_1}{\lambda_2} = \frac{x_\tau}{(1-\alpha) A K_t^\alpha L_t^{1-\alpha} \delta_t^{-\alpha} h_t^{-\alpha+\beta}}$ which implies $\frac{\dot{\lambda}_2}{\lambda_2} = -x_\tau[\frac{1-\alpha+\beta}{1-\alpha}\delta_t + \gamma_t]$. On the other hand, $\frac{\lambda_1}{\lambda_2} = \frac{x_\tau z^\alpha}{(1-\alpha) A L_t h_t^{\frac{\beta}{1-\alpha}}}$ where $z = \frac{L_t \delta_t h_t^{\frac{1-\alpha+\beta}{1-\alpha}}}{K_t}$.

At steady state, because z is constant,

$$
\begin{aligned}
g_{\frac{\lambda_1}{\lambda_2}} &= -g_L - \frac{\beta}{1-\alpha} g_h = g_{\lambda_1} - g_{\lambda_2} \\
&= -\rho - g_L - g_c - g_{\lambda_2}
\end{aligned}
$$

It implies that g_{λ_2} is constant. Since $g(h) = x_\tau \gamma_t$ is constant at steady state, we have $\gamma_t = \gamma^*, \delta_t = \delta^*$ are constant. Hence

$$
g_c + \rho = \frac{1-\alpha+\beta}{1-\alpha} x(1-u^*)
$$

The next FOC:

$$
\frac{\partial J}{\partial m} = \lambda_1[-AK^\alpha L^{1-\alpha} h^{1-\alpha+\beta}(1-\alpha)\delta^{-\alpha}\frac{\partial q}{\partial m} - L] = 0
$$

Because $\frac{\partial q}{\partial m} = -\theta u$,

$$
L[(1-\alpha)A\theta z^{-\alpha} h^{\frac{1-\alpha+\beta}{1-\alpha}} u^* - 1] = 0 \tag{8}
$$

and

$$
(1-\alpha)A\theta z^{-\alpha} h^{\frac{1-\alpha+\beta}{1-\alpha}} u^* = 1 \tag{9}
$$

Therefore $g_u < 0$, hence $u_t \to u* = 0$. It follows that $m^* = m_{\max}$ and $m_\tau \leq m^*$. At steady state,

$$
\begin{aligned}
g_Y &= g_L + \frac{1-\alpha+\beta}{1-\alpha} x(1-q(m^*, G)) \\
&= b - d + \frac{1-\alpha+\beta}{1-\alpha}[1-q(m_\tau, G)][1-q(m^*, G)]
\end{aligned}
$$

Therefore,

$$
\begin{aligned}
\frac{\partial g_Y}{\partial m_\tau} &= \frac{(1-\alpha+\beta)\theta}{1-\alpha} q(m_\tau, G)[1-q(m^*, G)] \\
\frac{\partial g_Y}{\partial m^*} &= \frac{(1-\alpha+\beta)\theta}{1-\alpha}(1-q(m_\tau, G))q(m^*, G)]
\end{aligned}
$$

Consider a function $\Psi(m) = \frac{q}{1-q}, \frac{\partial \Psi}{\partial m} = \frac{\partial q/\partial m}{(1-q)^2} < 0$. It follows that

$$
\frac{\partial g_Y}{\partial m_\tau} \geq \frac{\partial g_Y}{\partial m^*}
$$

It is similar for the effects of public health spending.

Therefore, the effect of spending on health in the cognitive development period (both private and public) has a greater impact on equilibrium income than health spending during the schooling and working period of life.

ii) From above, the GDP per capita growth rate is

$$\begin{aligned} g_y &= \frac{1-\alpha+\beta}{1-\alpha} x\delta^* \\ &= \frac{1-\alpha+\beta}{1-\alpha} x \left[1 - B \left(\frac{b - d + \frac{1-\alpha+\beta}{1-\alpha} x}{\alpha A} \right)^{\frac{1}{1-\alpha}} \right] \end{aligned}$$

where $B = \frac{K^*}{L^* {h^*}^{\frac{1-\alpha+\beta}{1-\alpha}}}$ is a positive constant. Therefore, $\frac{\partial g_y}{\partial x} < 0$ and if

$$0 < 1 - B \left(\frac{b - d + \frac{1-\alpha+\beta}{1-\alpha} \gamma(x_0)}{\alpha A} \right)^{\frac{1}{1-\alpha}} \leq 1$$

then

$$\frac{\partial g_y}{\partial d} > 0$$

4 Cross-country evidence

Our model predicts that cognitive impairment will have an effect on economic growth which is distinct from the impact of adult mortality and morbidity. Child survival is unlikely to have a direct impact on economic production, so if child survival has a big correlation with economic growth, we interpret this as evidence supporting the idea that cognitive impairment affects aggregate productivity in the economy.

Many aspects of economic development must be studied at an economy-wide scale because feedbacks and agglomeration processes make microeconomic evidence inadequate to assess their impact. However, there is considerable skepticism about what can be learned from cross-country growth regressions. This is mainly due to three related problems. Empirical growth studies frequently use a cross-section of growth rates for each country regressed on initial values of variables thought to influence growth. This results in a very small sample size, with rarely much larger than a hundred countries reporting values for the all the variables needed. Second, many variables potentially affect economic growth, and most of them are correlated with each other. Constrained by a small sample, only a few variables can be included in a regression and it is difficult to be sure that covariates have not been cherry-picked to help the variable of interest appear to be statistically significant. Third, most variables affecting economic growth are likely endogenous to the process of development. In principle, this can be controlled by regressing economic growth on the initial values of explanatory variables, but correlated missing variables still makes biased estimates a problem. Truly convincing instrumental variables to address missing variable and endogeneity bias are rare since most variables measured at an economy-wide scale are causally related to each other.

The nature of our data allows us to address these statistical problems more directly than is often the case. Panel data for economic growth increases the sample size many times over. Using country and time fixed effects in the regressions greatly reduces the likelihood of missing variable bias. This controls for a host of fixed and slowly changing country characteristics, covering a multitude of sins. Country fixed effects account for geographical characteristics, which are especially important for health, and the influence of persistent culture, longstanding norms and institutions. Time effects common to all countries account for temporal variation in the ebb and flow of international trade, technological evolution and other changes, making them less likely to be confounded statistically with variables which happen to have evolved in a correlated fashion over time. Since health variables have been steadily improving in almost all countries in the world for a long time, time effects reduces the likelihood that the estimates pick up correlation with other growing variables like trade.

Studies of economic growth using panel data with fixed effects often cause variables of interest to become statistically insignificant, but if there remains a large statistically significant correlation, this is stronger evidence of a causal effect than a single cross section.

If the cognitive development of children effects economic growth through the productivity of workers, economic growth should be correlated most strongly not with contemporary measures of child health, but the health of children a generation ago who are now adult workers. By lagging measures of child health by decades, we strengthen the credibility that these variables are not endogenous to future economic growth or erroneously capturing correlations with other contemporaneous variables.

Panel data provides a much larger sample for estimation, fixed effects control for a myriad of hard-to-observe background variables, and lagging our variable of interest by decades reduces the likelihood of correlation with omitted variables.

We estimate the determinants of economic growth using a standard "Barro" model (Barro and Sala-i-Martín, 1992). Taking a linear approximation of a neoclassical growth model near the equilibrium, growth of income per worker from time 0 to time t, $g \equiv \frac{1}{t}\left(ln(y_t) - ln(y_0)\right)$, is a function of the growth of technology, g_A, and the ratio of equilibrium income per worker, y^*, and initial income per worker, y_0:

$$g \approx g_A + \theta\, ln(y^*/y_0),$$

where θ is a constant parameter. Adding a country subscript i and an error term u_i, the equation becomes

$$g_i = g_{Ai} + \theta\, ln(y_i^*) - \theta\, ln(y_{0i}) + u_i.$$

Since g_A and y^* cannot be directly observed, $g_{Ai} + \theta ln(y_i^*)$ is approximated by a linear combination of a vector of variables, $\mathbf{x}_i$, which are correlated with growth of technology and equilibrium income. The estimating equation is

$$g_i = \mathbf{x}_i'\beta - \theta\, ln(y_{0i}) + u_i, \tag{10}$$

where β is a vector of unknown parameters.

In our context of exploring the relationship of health and economic growth, one of the $\mathbf{x}_i$ variables is life expectancy (or adult and child survival). Including other important correlates of economic growth in the $\mathbf{x}_i$ variables, like initial income or institutional quality, helps address the problem of omitted variables. Reverse causation bias is reduced by using the value of correlates at the start of the growth period (at time 0). If there is a feedback from economic growth to the $\mathbf{x}_i$ correlates, growth between time 0 and t will affect the correlates after time 0, but not at time 0.

Choosing the right correlates of economic growth for inclusion in $\mathbf{x}_i$ is, of course, crucial for convincingly addressing omitted variable bias. Since life expectancy is known to be robustly correlated with economic growth in precisely this sort of estimation (Sala-i-Martin *et al.*, 2004), the estimated correlation of life expectancy is probably less sensitive to which additional variables are included than most other correlations.

In addition to life expectancy and initial income per worker, we include several of the most commonly used covariates: a measure of educational human capital, the average years of schooling of people aged 15 and over (Barro and Lee, 2010), and a measure of institutional quality, the Political Risk Index, from the International Country Risk Guide (PRS Group, 2013).[3]

The data on income per worker are from the Penn World Tables (PWT), version 9.0 (Feenstra *et al.*, 2015). Average income per worker is measured by the purchasing power parity real gross domestic product per worker. We construct a panel of six 5-year economic growth episodes per country from 1985-2015. The panel is unbalanced, ranging from 88 countries with all covariates in 1985 to 120 countries in 2005. The growth rates are the country-specific least squares linear time trend of the natural log of income per worker using the variable GDP^{NA}, recommended by PWT for measuring growth rates. Initial income per worker, y_0, uses the recommended variable GDP^{O} for income levels.

The results of the growth regressions are shown in Table 1. In the first column, life expectancy is statistically significantly correlated with growth in income per worker, including initial income per worker, trade as a percentage of GDP, the Political Risk Index of institutions and the average years of schooling of adults. As is common in panel regressions of economic growth, only initial income and life expectancy are statistically significant while the measure of education is not, which is a common result in this type of regression coefficients.

The second column shows a similar regression with life expectancy replaced by child and adult survival rates. Child survival has highly statistically significant positive coefficient while the adult survival coefficient is not significant and much smaller, despite the fact that child survival encompasses only a five year period while adult survival encompasses a forty-five year period of risk. The estimated response of a one standard deviation change in each of the survival

[3]The Political Risk Index (PRI) for each country is a weighted average of the following subindexes: Government Stability, Socioeconomic Conditions, Investment Profile, Internal Conflict, External Conflict, Corruption, Military in Politics, Religion in Politics, Law and Order, Ethnic Tensions, Democratic Accountability, and Bureaucracy Quality.

variables implied by the estimated coefficient is shown at the bottom of the table. A standard deviation higher child survival rate corresponds to a 2.06% higher economic growth rate, almost four times the size of a corresponding change in adult survival.

Column three shows a regression where the child survival rate is measured not a the start of each 5 year growth episode, but an average of child survival rates 15 to 35 years previously. This variable is intended to measure the health conditions for current workers at the time they were young children. This variable is also highly statistically significant, with a lower standard error than the contemporaneous child survival rate in column two. The coefficient is smaller than for contemporaneous child survival, but the variation of lagged child surivival is much larger, so that the estimated effect of a one standard deviation increase in lagged child survival is 2.23% higher growth per year, even larger than the contemporaneous child survival. The adult survival rate now has a statistically significant correlation, which may represent the effect of current worker health conditions on economic growth, but the effect of a comparable change in adult survival (affecting about nine times the number of people) is only about half the effect of a similar change to child survival.

The strong correlation of child survival from decades in the past with economic growth suggests a big impact of early child health conditions on worker productivity. Say this correlation still reflected endogeneity. If this was occuring, it would probably be due to unobservable characteristics of institutions and cultural priorities that both ensured good child health and successful economic growth. If these were not adequately controlled for by the country fixed effects, the initial level of income and the index of institutional quality, it is likely they would be manifested in good health infrastructure and generous health spending, public or private. In this scenario endogenous variables, health infrastructure and spending should be at least as closely correlated with economic growth as child survival.

The regression in column 4 of Table 1 includes the number of hospital beds per person and private and public health expenditure as a percent of GDP. This reduces the sample size because these variables are only available from 1990 onwards. When they included, the child survival rates is still statistically significantly correlated with economic growth, although with a somewhat larger standard error. The adult survival rate estimate is no longer statistically significant and becomes negative. This suggests that the child survival rate is not just a proxy for a country's pursuit of good health, which could be endogenous to income levels.

If child survival is correlated with economic growth because it is an indicator of good conditions for child cognitive development, more proximate indicators of child health conditions should also show a consistent correlation with economic growth. Table 2 includes measures of safe water, sanitation, and anemia in the growth regressions. It is not common to find additional variables correlated with economic growth in a fixed effects panel regression, but in each case, these variables are significantly correlated with growth, strengthening the evidence that it is indeed child health conditions which play a causal role in economic

Table 1: Life Expectancy Versus Child Survival

	(1)	(2)	(3)	(4)
$ln(y_0)$	-4.941	-4.535	-4.831	-4.068
	[0.705]**	[0.688]**	[0.717]**	[1.016]**
Trade openness	0.005	0.007	0.009	-0.004
	[0.009]	[0.008]	[0.009]	[0.009]
Institutions	0.002	-0.007	-0.002	-0.081
	[0.019]	[0.018]	[0.020]	[0.027]**
Schooling	0.106	0.149	-0.168	0.167
	[0.254]	[0.238]	[0.257]	[0.312]
Life expectancy	0.248			
	[0.069]**			
Child Survival Rate (age 0-5)		35.221		
		[9.027]**		
Adult Survival Rate (age 15-60)		4.927	9.566	-5.025
		[3.404]	[3.532]**	[5.236]
Child Survival Rate lagged 15-35 years			24.479	28.097
			[6.116]**	[13.328]*
Hospital beds per 1,000 people				0.053
				[0.106]
Health expenditure, private (% of GDP)				-0.003
				[0.179]
Health expenditure, public (% of GDP)				-0.258
				[0.239]
Constant	31.348	7.453	20.310	26.318
	[5.791]**	[9.621]	[7.757]**	[15.371]
R^2	0.24	0.27	0.25	0.26
Countries	120	120	120	119
N	648	648	648	376
% Growth from 1 s.d. Δ CSR		2.06	2.23	
% Growth from 1 s.d. Δ ASR		0.59	1.15	

Robust standard errors in brackets

* p¡0.05; ** p¡0.01

Table 2: Child Health Determinants

	(1)	(2)	(3)	(4)
$ln(y_0)$	-5.465	-5.793	-5.490	-5.733
	[0.987]**	[1.034]**	[1.019]**	[1.032]**
Trade openness	0.011	0.006	0.010	0.007
	[0.010]	[0.010]	[0.010]	[0.010]
Institutions	-0.022	-0.016	-0.024	-0.021
	[0.027]	[0.028]	[0.029]	[0.027]
Schooling	0.047	-0.216	-0.153	-0.132
	[0.312]	[0.312]	[0.335]	[0.319]
Safe water (%)	0.145			0.092
	[0.044]**			[0.047]
Sanitation (%)		0.169		0.117
		[0.037]**		[0.045]*
Anemia (%)			-0.129	-0.025
			[0.047]**	[0.041]
Constant	42.898	48.387	62.035	44.532
	[8.681]**	[8.396]**	[9.360]**	[9.231]**
R^2	0.28	0.28	0.25	0.30
Countries	118	117	119	117
N	545	537	555	535
% Growth from 1 s.d. Δ Safe water	2.37			1.52
% Growth from 1 s.d. Δ Sanitation		5.05		3.49
% Growth from 1 s.d. Δ Anemia			-2.92	-0.57
F test, Water=Sanitation=Anemia=0				10.13
p value				(0.0000)**

Robust standard errors in brackets

* p¡0.05; ** p¡0.01

growth. These variables are correlated with each other and when we include all three in the last column, only access to sanitation is statistically significant, although a joint test of significance for all three is very highly significant. The coefficients and the estimated impact of a one standard deviation change in each of these variables becomes smaller, as well, but they each have large estimated effects on growth.

5 IQ and Economic Growth

We would like to find a direct measure of cognitive capability and estimate its effect separate from current health conditions. We can do that with data on average IQ by country.

The IQ test was first developed to provide an objective measure of severe cognitive deficiency, unlike its current reputation as a measure of high intellectual capacity. IQ tests have become controversial for their possible cultural biases. In response, psychologists developed non-verbal pattern matching tests which minimize the cultural content of the exams. In developing countries, by far the most common used tests are Raven's Progressive Matrices, which are pattern matching tests (Raven, 1936). You can see an example at www.iqtest.dk.

Lynn and Meisenberg (2010) present data on average IQ for 93 countries collected from published studies. The data are derived from 2.8 studies per country on average, with most combined sample sizes for most countries from 1000-5000 people. The smallest sample size is Norway with one study of 100 people. All other countries have a sample size of more than 200. Most of the studies test school-age children, but a small number test adults.

IQ tests generate relatives scores, so all the test data were scaled relative to British average IQ tests where were assigned a mean of 100 and a standard deviation of 15.

These data are not perfect for our purposes. The samples of IQ test takers are not always nationally representative, and the studies are carried out at different times. Eighty-three percent of the studies were published in the 1960s to the 1990s, but small numbers were published before or in the early 2000s. In none of the countries used in the estimation sample were all the studies outside the 1960s - 1990s period.[4]

Despite these issues of Wichert et al. (2010) finds the Lynn and Meisenberg country IQ data highly consistent with scholastic achievement surveys (including PISA and TIMSS scores), which is a principal method of evaluating the validity of cognitive tests. Wichert et al. find that the outliers are almost all sub-Saharan African data. They undertake an intense literature search for high quality African IQ test data. Their revised average IQ scores for African coun-

[4]IQ researchers have identified a tendency for mean IQ tests to rise over time, known as the Flynn effect (Flynn, 1987). Since this is interpreted the data compilas exogenous change, the data are "corrected" at a rate of 3 IQ points per decade (2 IQ points for Progressive Matrix tests). If this change is due to falling rates of cognitive impairment, this adjustment may make studies conducted at different dates more comparable.

Table 3: IQ-growth regressions, 1990-2015

	(1)	(2)
$ln(y_0)$	-1.402	-1.770
	[0.318]**	[0.402]**
Trade openness	0.002	0.002
	[0.002]	[0.003]
Institutions	-0.005	-0.003
	[0.013]	[0.014]
Schooling	0.290	0.291
	[0.099]**	[0.099]**
IQ	0.067	0.051
	[0.025]*	[0.025]*
Adult Survival Rate (age 15-60)		5.028
		[2.893]
Child Survival Rate lagged 15-35 years		0.052
		[3.935]
Constant	7.609	8.585
	[2.447]**	[2.499]**
R^2	0.36	0.41
N	67	67
% Growth from 1 s.d. Δ IQ	0.73	

* $p < 0.05$; ** $p < 0.01$

Robust standard errors in brackets

tries are no longer outlying. The data used in this paper substitutes Wichert et al.'s scores for Lynn and Meisenberg's sub-Saharan African countries.

Table 3 presents the results of Barro-type growth regressions for a single cross section of national economic growth rates from 1990-2015. Since some countries have only one observation, it is possible to use panel data. The first column includes the adult survival rate but excludes the child survival rate. As with life expectancy, the adult survival rate has a highly significant positive correlation with economic growth when child mortality is not included.

In the first column, the average IQ score is included and it has a significant correlation with economic growth. To evaluate whether the IQ data is just a proxy for health conditions, in the second column we include child and adult survival rates. The IQ variable remains statistically significant and child survival is not, which is consistent with our hypothesis that cognitive development rather then health conditions is most important for economic growth.

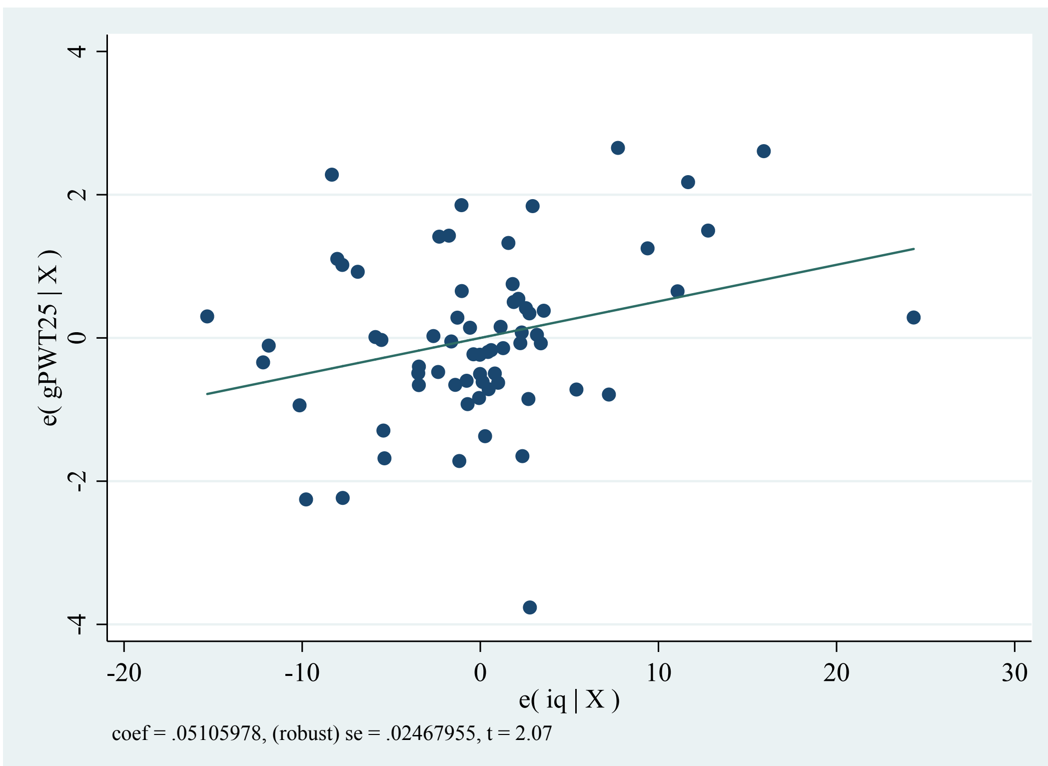

Figure 2: IQ vs. Economic Growth, controlling for other variables

6 Conclusion

The debate about the role of health in economic growth in the empirical literature has focused on the correlation of life expectancy with growth. We present evidence that the robust correlation of life expectancy with economic growth is due to child survival, not adult survival, casting doubt on life expectancy as a measure of worker health. We explore the hypothesis that child survival is strongly correlated with growth because it is an indicator of good cognitive development of children. Healthy cognitive development makes children better able to succeed in building their human capital through education, as well as making them more productive throughout their working lives.

The medical literature has accumulated increasingly clear evidence of the tremendous importance of the period a child is *in utero* and an infant for good cognitive development, as well as for susceptibility to health problems in later life. This period of time is very short compared to the length of people's working lives, so it is not surprising that health conditions which affect cognitive development have a disproportionate impact on economic outcomes relative to exposure to disease as an adult.

Our model of economic growth incorporates the impact of cognitive capacity on the accumulation of human capital and thus worker productivity. The model also incorporates mortality and morbidity, but the impacts of these three factors are quite different. Since we assume that human capital affects the absorption of new technology, cognitive impairment reduces growth both in and out of equilibrium. Morbidity, in contrast, has no effect on economic growth in equilibrium. Mortality has a positive effect on economic growth because it frees up additional capital for the remaining workers, making them more productive.

Our empirical results show that child survival has a statistically significant correlation with economic growth across countries when controling for other variables researchers have proposed as important determinants of growth. A more direct measure of cognitive capacity, the country's average IQ, also has a statistically significant correlation with growth.

If our conclusions are correct, and not already incorporated in health planning, the planners should give higher priority to disease and malnutrition in pregnant women and young children than they do now. Diseases which are important causes of cognitive impairment appear to have large economic consequences in addition to the direct suffering they cause. Health conditions which ensure good cognitive development should be prioritized even relative to those that cause adult and child mortality because the prosperity which results will provide the material means to improve all health in the next generation.

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