Health, Mortality, and Economic Development

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June 2, 2006

Draft

Abstract

The role of health in economic development is tested using three empirical approaches: a direct labour productivity effect, an interactive effect, and an incentive effect. Using proxies for health such as access to sanitation facility, clean water, immunisation, and adult male mortality, higher levels of health are hypothesised to promote higher economic growth as healthier workers are more productive per unit of labour input. The interactive model shows that the marginal effect of health on economic growth is declining as education levels increase, suggesting that health improvements in economies abundant in low skilled workers have a greater impact on growth than in economies with a highly educated workforce. Theory suggests that individuals who are healthier, live longer, and have a greater incentive to invest in education as the time horizon over which returns can be earned through higher skilled wage is extended. Using a system of equations, there is empirical support for the incentive effect of health on economic growth through its positive influence on education. Once the indirect effect of health is controlled for the direct effect of health is no longer significant. According to these findings, health policies that promote schooling attendance would have a beneficial affect on economic development.

JEL Classification: I10, J10, O12

Keywords: Mortality risk, Education, Fertility, Economic Growth

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†I am very grateful to the collegial support of members of the University of Otago Department of Economics, especially that of P. Dorian Owen and also Stephan Knowles and David Fielding and the productive work environment they offered. Thanks to Jane Golley and Alberto Posso, and to Steve Dowrick and Bob Breunig for their valuable comments.
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1 Introduction

In an empirical context the role of health in explaining cross country differences in the rate of economic growth can be categorised into three main effects. The first is the direct effect on labour productivity, where healthy workers are more productive per unit of labour input. The second is an interactive effect, where health and education are complementary in the promotion of economic growth. The third is an incentive effect, when health has an indirect effect on growth through its encouragement of education investment.

The treatment of health in the empirical literature is not consistent with that in the theoretical literature. In the empirical literature, the labour productivity effect of health is the most commonly estimated (Knowles and Owen, 1997, Webber, 2002, Bloom et al., 2004), but in the theoretical literature, the effect of health on economic growth is indirect and comes through its promotion of education (Chakraborty, 2004), which is termed the ‘incentive effect’ in this paper. Furthermore, in the empirical literature, health and life expectancy are considered endogenous to economic growth (Bloom et al., 2004), while life expectancy has been treated as exogenous in the theoretical literature (Boucekkine et al., 2003, Kalemli-Ozcan et al., 2000, Zhang et al., 2001) until recently (Blackburn and Cipriani, 2002, Chakraborty, 2004). Lorentzen et al. (2005) attempted to bridge the inconsistencies between the theoretical and empirical literature and test the hypothesis of the indirect effect of health on economic growth through education. However, there are two major problems with the Lorentzen et al. (2005) paper: the direct effect of health on economic growth is not estimated simultaneously with the indirect effect of health through education; and the system of equations that they estimate is not identified and therefore coefficient estimates are inconsistent.

Health is determined by both observed and unobserved factors. Observed factors could include access to clean water and sanitation facilities, nutrition, access to medical facilities, and health care expenditure, all for which data are available in the World Development Indicators (WorldBank, 2003). However, health is also made up of unobservable factors such as genetic disposition and attitude. In empirical studies, health is proxied by a variable that is observable. Studies by Bloom et al. (2004) and Knowles and Owen (1997) use life expectancy as this proxy of worker health to measure the direct effect of health on economic growth. Webber (2002) argues that the use of life expectancy is not an accurate proxy for worker health as an individual’s life can be cut short due to country specific negative attitudes
towards women’s medical treatment, blood transfusions, and use of modern medicines, but while the individual is a worker their health is not compromised. He suggests the use of an alternative health proxy — nutrition.

Across the different studies the conclusion of the effect of life expectancy on economic growth through an increase in worker productivity is not consistent. Knowles and Owen (1997) find that health has a positive effect, while Bloom et al. (2004) find no effect once experience in the workforce is controlled for. Webber (2002) finds that when nutrition is used as a proxy, the role of health is not significant and the positive role of education dominates the explanation of cross country differences in economic growth. As both life expectancy and nutrition are proxies for general health of a worker, the contrast of results indicates that empirical analysis is sensitive to the choice of proxy.

The labour productivity effect of health is the most frequently tested. The interaction between health and education and their influence on economic growth has not been estimated. The interaction between health and education tests the hypothesis that the marginal effect of health on economic growth depends on the level of education. An interactive term is included in the models analysing the direct effect of health.

When health, reflected in life expectancy, is modelled in an overlapping generations framework, the delay and uncertainty of the returns to investing in health are taken into consideration. Uncertainty over investment in education is also present as survival into the period in which returns can be enjoyed is not guaranteed. Investing in health is thus encouraged by a longer life expectancy. Individuals who have a higher probability of living longer will be motivated to invest more in education as the time horizon over which they can enjoy returns to education is longer. To capture this incentive effect of health on education and then the influence of education on economic growth, a system of equations is estimated.

In the overlapping generations framework decisions to invest are based on the expected utility of returns. Investments are costly in the first period, and returns gained in the second period are uncertain. In a theoretical framework, investment in education is modelled as a function of the probability of survival (Blackburn and Cipriani, 2002, Chakraborty, 2004, Finlay, 2005). However, within an empirical context, the risks of investments in other factors of production need to be taken into account as well. Investment in proximate factors of production — physical capital, labour and education — are all risky investments as returns are neither immediate nor certain, and they are conditional on the honouring of contracts, and survival through childhood and working age adulthood. The factors that influence the

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1 The use of different samples, econometric technique, and time periods could also cause the inconsistency across studies examining the effects of health on economic growth.
risk differ according to the type of investment and the environment required for returns to be gained. It is hypothesised that for an individual to enjoy the returns of investment in education, an individual must live into the later years of life. For returns to fertility (labour), a child must live beyond infant years. And for returns to physical capital investment, contracts must be honoured and financial institutions stable. These channels are estimated in this paper using variables which capture different types of risk in a system of equations.

Modelling these risk assessments and the incentive effects of investment in the factors of production is an approach that is new to the empirical literature (Lorentzen et al., 2005)\textsuperscript{2}, but has been explored in theoretical models (de la Croix and Licandro, 1999, Blackburn and Cipriani, 2002, Ehrlich and Lui, 1991, Kalemli-Ozcan et al., 2000, Zhang et al., 2001). The argument that individuals who expect to live longer will invest more in education as the time horizon over which returns can be enjoyed is extended, is convincing and worthy of empirical testing.

The aim of this paper is to explore the three effects by which ‘health’ influences economic growth: the direct labour productivity effect, the interactive effect, and the incentive effect. Moreover, the role of the different areas of risk are analysed in the empirical model. In the next section the data are discussed. The three approaches are examined in the respective order of the direct effect, interactive effect, and the incentive effect. Concluding comments are made, and the Appendix details data descriptions, identification of the system of equations and tables of results.

2 Data

Several data sets are combined in this study. A full description is offered in the Appendix of this paper. The two main data sets used are the Penn World Tables mark 6.1 (PWT) (Heston et al., 2002), and the 2003 World Development Indicators (WDI) (WorldBank, 2003). The GDP data are taken from the PWT, and the data for health, schooling, life expectancy and other social indicators are taken from WDI.

The study is based on a single cross section, using 1960 values for initial conditions and averages over 1960 to 2000 for the contemporaneous variables. Each country has one data point assigned to it for each variable — the intitial condition in 1960, or the annual average from 1960–2000. Using the averages is a convenient way of avoiding problems of missing data. However, the average taken is of data that exist between 1960–2000, and not all variables

\textsuperscript{2}Who only look at adult mortality on schooling, fertility and investment, and not other possible indicators of risk such as infant mortality and the rule of law.
have a full complement of observations across this time period.

Throughout this study the determinants of health are proxied by observable factors that cause good health, (births attended by skilled health staff, hospital beds per 1000 people, dpt immunisation (dpt is an acronym for diphtheria, pertussis (whooping cough), and tetanus), access to sanitation facilities, access to clean water, and physicians per 1000 people). In addition, the factors that are the consequence of good health are proxied by low adult mortality, death rate, infant and child mortality and by high life expectancy and their relationship with economic growth is tested.

The role of fertility and investment in physical capital is modelled alongside that of education. These three key variables make up the proximate determinants of growth: labour, capital and human capital, respectively. Recently, much of the empirical literature examining cross country differences in levels of development has focused on what has been termed the deep determinants of growth: namely, institutional quality and geography. The roles of these variables in the growth process are incorporated in the structural model.

The likely endogeneity of the regressors is recognised in this study, so instrumental variables have been used. Frankel and Romer (1999) develop an index of constructed trade shares to instrument the share of exports and imports to GDP. To instrument rule of law and government effectiveness variables, the fraction of English and European language speakers series developed by Hall and Jones (1999) is used. To instrument mortality and life expectancy variables (adult male mortality, infant mortality, child mortality, death rate, and life expectancy in 1960), following Lorentzen et al. (2005), variables that reflect the concentration of malaria ecology (not the incidence of malaria, but the risk of catching the disease) in 1964 and 1999 are used. In conjunction with the malaria ecology variables used as instruments for mortality variables, climate and geography variables are also used. The climate variables measure the proportion of the country in a climate classified as rainforest, savanna, steppe, desert, warm dry winters, warm dry summers, temperate, dry with snow in winter, humid with snow in winter, highland. Geography variables detail the absolute distance from the equator, distance from the centroid to the coast, elevation, and the land area, as described in Gallop et al. (1998).

3 Direct Effect of Health on Economic Growth

There are two approaches for analysing the direct effect of health on economic growth. To estimate the labour productivity effect, Knowles and Owen (1997) use the Mankiw et al. (1992) model and incorporate health capital, along with human and physical capital. This
approach is derived from a Cobb-Douglas production function, the estimated growth equation is a linearisation around the steady state, and estimated coefficients are linear approximates of transitional dynamics. The second approach is like that of Sachs and Warner (1997), where the reduced form model has the dependent variable of economic growth, and log of initial income as one of the independent variables, along with a collection of political, geographic, demographic, and economic variables which are assumed to determine the rate of economic growth. The latter approach is used here in this paper to capture the direct effect of health on economic growth.

The growth of real GDP per capita is modelled as follows.

\[
eco_{growth_i} = \beta_1 + \beta_2(\ln(GDP \ 1960)) + \beta_3(\text{population growth}_i) \\
+ \beta_4(\text{investment}_i) + \beta_6(\text{government}_i) + \beta_8(\text{open}_i) \\
+ \beta_7(\text{rule of law}_i) + \beta_8(\text{tropics area}_i) + \beta_9(\text{education}_i) \\
+ \beta_{10}(\text{health}_i) + \varepsilon_i
\]  

(1)

The OLS estimation results of the Equation (1) are presented in Tables 4 and 5 on pages 25 and 26 respectively. A detailed description of the data and their sources is given in the Appendix. The subscript \(i\) indexes countries. Details of the countries included in this study are in the Appendix. In Table 4 on page 25, seven regressions are listed, the first excludes a health variable, and the next six have a different proxy for health in each. In this Table, the ‘health’ variable is proxied by life expectancy in 1960, death rate, adult male mortality, infant mortality, and child mortality.

The Hausman specification test results indicate that with each of the proxies, there is evidence of endogeneity. The Hausman test is a large sample test and the test is conducted here with only 87 observations. Moreover, it relies on exogeneity of instruments (those used are listed in a note under Table 4 on page 25, where it could be argued that variables such as population growth, investment, government expenditure, and secondary school enrolments are endogenous even though these variables are 1960–2000 averages). The Hausman test is a test of whether instrumental variable estimation (IV) and ordinary least squares estimation (OLS) yield results that are not statistically different, and if they are not, we conclude that there is no evidence to suggest endogeneity. Of note, there exists other reasons for IV and OLS yielding the same estimated results: omitted variables and misspecification are two examples.

With the rejection of the null hypothesis under the Hausman test of exogeneity, we advance on the assumption that the variables of the rule of law, openness, and each of the
‘health’ variables are endogenous, then the OLS results can be interpreted as partial correlates. Table 4 results on page 25 indicate that investment, education and health are all correlates of economic growth, even after controlling for initial income.

Webber (2002) suggests that life expectancy is misleading as a proxy for worker health and does not reflect morbidity. He uses calorie intake as the proxy for health, and finds that health does not have a significant effect on economic growth after controlling for education. Table 5 on page 26 presents results from various regressions estimated with different health proxies: births attended by skilled health staff, number of hospital beds per 1000 people, dpt immunisation rate, access to sanitation facilities, access to clean water, and medical physicians per 1000 people. Again, interpreting coefficients as partial correlates, rather than explanators of economic growth, the results indicate that some health proxies are related to economic growth (for example, births attended by skilled health staff and access to clean water) even when controlling for education and initial income.

Instrumental variables are then used to estimate the effects of health on economic growth in a two stage least squares model. Instruments for rule of law are fraction of English speakers and fraction of European language speakers as developed by Hall and Jones (1999). As in Lorentzen et al. (2005) malaria ecology, climate and geographic variables are used as instruments for the life expectancy and mortality variables. Constructed trade shares developed by Frankel and Romer (1999) is used as an instrument for trade shares to GDP (the variable termed ‘open’). The two stages of the estimates structured as follows:

\[
\text{eco\_growth}_i = \beta_1 + \beta_2(\ln(GDP \ 1960)_i) + \beta_3(\text{population growth}_i) + \beta_4(\text{investment}_i) \\
+ \beta_5(\text{government}_i) + \beta_6(\text{open}_i) + \beta_7(\text{rule of law}_i) \\
+ \beta_8(\text{tropics area}_i) + \beta_9(\text{education}_i) + \beta_{10}(\text{health}_i) + \epsilon_i \tag{2}
\]

with the first stage regressions,

\[
\text{open}_i = X\Gamma + \gamma_1(\text{constructed trade shares}_i) \\
+ \gamma_2(\text{EngFrac}_i) + \gamma_3(\text{EurFrac}_i) \\
+ \gamma_{ci}(\text{climate}_{ci}) + \gamma_{gi}(\text{geography}_{gi}) + \gamma_{mi}(\text{malaria}_{mi}) + \nu_i \tag{3}
\]

\[
\text{rule of law}_i = X\Gamma + \gamma_1(\text{constructed trade shares}_i) \\
+ \gamma_2(\text{EngFrac}_i) + \gamma_3(\text{EurFrac}_i) \\
+ \gamma_{ci}(\text{climate}_{ci}) + \gamma_{gi}(\text{geography}_{gi}) + \gamma_{mi}(\text{malaria}_{mi}) + \omega_i \tag{4}
\]
In the above equations, ‘c’ indexes the 10 climate variables (rainforest, savanna, steppe, desert, warm dry winters, warm dry summers, temperate, dry with snow in winter, humid with snow in winter, highland), ‘g’ indexes the four geography variables (absolute distance from the equator, distance from the centroid to the coast, elevation, log of land area km$^2$), and ‘m’ the two malaria ecology variables (concentration of malaria ecology in 1964 and 1999), and $X$ is the vector of exogenous variables in the second stage regression. Health refers to the proxy variables of life expectancy in 1960, death rate, adult male mortality, infant mortality, and child mortality.

The instrumental variables estimate results explaining cross country differences in economic growth are detailed in Table 6 on page 27. In Results Column (3), the death rate has a significant negative effect on economic growth, controlling for initial income, investment and education (and other variables). The over-identifying restrictions test indicates that there is no evidence of endogeneity the instrumental variables used in the model (the use of the exogenous variables is detailed below in Table 6), and thus based on this result, we can interpret the death rate as an explanator of economic growth. In Regression Columns (5) and (6), the infant mortality rate and the child mortality rate are found to have a significant negative effect on the economic growth rate. In each regression of Table 6, Columns (2) through to (6) , a different proxy is used to test the direct effect of health on economic growth. After controlling for education, health has a positive influence on economic growth. Moreover, the F–test of health and education indicates that they are jointly significant. This joint test was conducted as the correlation between health and education is high, as seen in Table 3 on page 24, and high multicollinearity can make it difficult to separate out the partial effects of the two variables.

Health variables that are classified as causes of good health (births attended, hospital, dpt immunisation, sanitation, water, physicians), are not instrumented for. A valid instrument is one that is exogenous to the structural equation, and a strong instrument will have a high correlation with the health variable. The instruments used in this study, (climate, geography, malaria ecology variables) do not have a high correlation with the causes of good health. Miguel and Kremer (2004) use country specific instruments of incidents of drought, and years of civil war. Exploring this avenue for instruments of the causes of good health is left for another study.
To summarise the direct effect of health on economic growth, the estimations detailed in Tables 4, 5 and 6, indicate that good health does have a direct positive effect on economic performance. These results are contrary to those of Webber (2002), but consistent with the findings of Knowles and Owen (1997).

4 Interactive Effect

In this section we seek a new framework to identify the role of ‘health’ in explaining economic growth. The OLS and IV results above are consistent with results of Wheeler (1980) and Knowles and Owen (1997). Contrary to this result, Webber (2002) and Bloom et al. (2004) do not find worker health to be a significant explanator of cross country differences in economic growth. This inconsistency may be due to model misspecification, and one hypothesis presented here is that the role of health in explaining cross country differences in economic growth varies with the enrolments in secondary school. An interactive term identifies how the marginal effect of health on economic growth changes as the the incidence of education changes and vice versa.

The interplay between health and schooling, and their influence in promoting economic growth can be modelled by including an interactive term in the linear regression structural model.

\[
\text{eco} \_ \text{growth}_i = \beta_1 + \beta_2(\log(\text{GDP} \ 1960)_i) + \beta_3(\text{population growth}_i) \\
+ \beta_4(\text{investment}_i) + \beta_5(\text{government}_i) + \beta_6(\text{open}_i) \\
+ \beta_7(\text{rule of law}_i) + \beta_8(\text{tropics area}_i) + \beta_9(\text{education}_i) \\
+ \beta_{10}(\text{health}_i) + \beta_{11}(\text{health}_i \times \text{education}_i) + \epsilon_i
\]  

A significant coefficient on the interactive term will infer that the marginal effect of health on economic growth depends on the level of education. For the interpretation, \( \hat{\beta}_{10} \) will give the marginal effect of economic growth with respect to health when schooling is zero. For a given country, when education is non-zero, the marginal effect of economic growth with respect to health investment is\(^3\),

\[
\frac{\partial}{\partial \text{health}_i} = \beta_{10} + \beta_{11}\text{education}_i
\]  

The interactive effect estimates the magnitude of the marginal effect of health on economic growth at different levels of education. The magnitude of the effect of good health on eco-

\[^3\text{The partial effect of education on economic growth depends on health, } \frac{\partial}{\partial \text{health}_i} = \beta_9 + \beta_{11}\text{health}_i\]
nomic growth may be lower at higher levels of education. For example, a person who is of low education may work in labour intensive activities and good health and strength are vital to production of output. Conversely, higher enrolments in secondary school reduce the marginal effect of health improvements on economic growth.

Results in Table 7 indicate that this prior has statistical support. Consider Regression Column (1) of Table 7 on page 28, where life expectancy in 1960 is the proxy for health. Life expectancy has a significant positive effect on economic growth, but the interactive term has a negative sign. This negative sign indicates that higher male enrolments in secondary school reduce the effect of life expectancy on economic growth. A more skilled labour force relies on mental capabilities rather than physical health, and it is the latter that is reflected in the health data. To illustrate the potential growth benefits of an additional five years of life expectancy when education enrollments are at 30 per cent (this is about one standard deviation below the mean), then an increase in life expectancy by five years will increase the average annual growth rate by 0.1861 percentage points. However, if education enrolments are about one standard deviation above the mean, at 90 per cent, then a five year increase in life expectancy has a negative effect on growth of -0.2879 percentage points.

Regressions in Columns (1) to (3) of Table 7 show that two-thirds of the variation in average economic growth rates is explained by the models using life expectancy, death rate and adult mortality as the proxy for health. Whereas, Columns (4) and (5) show that only half of the variation in economic growth is explained by models using infant and child mortality as health proxies.

5 Incentive Effect

Efforts to estimate the incentive effects of life expectancy on education and the consequences for economic growth have been recently explored by Lorentzen et al. (2005). These authors use a system of equations (three-stage least squares) to estimate the channel effects of adult male mortality on three key proximate determinants of economics growth: education, fertility, and physical capital investment. The three-stage least squares estimate allows for the system of equations to be estimated and the residuals from each regression to be correlated. Using this estimation technique, Lorentzen et al. (2005) find that adult mortality has an indirect effect on economic growth through the proximate determinants of growth, and low adult mortality leads to higher investment in physical capital and education; both of which have a positive effect on economic growth. Low adult mortality also leads to low fertility, which then leads to higher economic growth. When looking at the magnitudes of the ef-
fects, Lorentzen et al. (2005) find that when taking into account the channel effect of adult mortality, education plays a small role in explaining cross country differences in economic growth, and variation in physical capital investment and fertility dominate as explanators of economic growth. An explanation for the crowding out of the role of education is the high correlation between education and fertility. Disaggregation of the education variable into male and female secondary school enrolments may help disentangle the role of education and fertility \(^4\). Estimation results presented by Lorentzen et al. (2005) are, however, inconsistent as the system is not identified. In that model, each submatrix created for identification is of rank two, and a rank of three is required for just- or over-identification.

Lorentzen et al. (2005) comment that higher mortality rates lead to risky behaviour, and this is summarised as behaviour that involves not investing in the future. However, contrary to this comment, it is the investment in the future that is the risk, and risk averse individuals reduce their investment if the probability of living to see the returns from such investment is low.

In this paper we propose that each type of investment attracts its own condition for risk assessment. Investing in education, fertility and physical capital are distinctly different types of investment, and the risk of return to each investment will differ according to different indicators. A young male will consider the probability of surviving to see their returns when making decisions over education investment. Decisions to have a child will depend on the parents’ assessment of the child’s probability of survival. Parents will make an assessment of the probability of their child’s survival and if it is low then they will have a higher number of children to ensure support in old age, or labour assistance — reasons that will drive a parent to ensure they have surviving children. The investment environment will be influenced by institutional quality as the degree to which contracts can be enforced, financial institutions can be held accountable, and assets can be secure will weigh on the decision of how much, when and what to invest in. Long term and large projects will lose their attractiveness in a volatile investment environment. These risk indicators are not mutually exclusive, but the channels mentioned here form the basis of the structural model outlines in Equation (8).

\(^4\)Discussions with P. Dorian Owen are appreciated in helping shape this idea.
The system estimated in this paper is:

\[
\text{eco\_growth}_i = \beta_{10} + \beta_{11}(\ln(GDP\_1960)_i) + \beta_{12}(\text{education}_i) + \beta_{13}(\text{fertility}_i) \\
+ \beta_{14}(\text{investment}_i) + \beta_{15}(\text{open}_i) + \beta_{16}(\text{government}_i) \\
+ \beta_{17}(\text{adult male mortality}_i) + \beta_{18}(\text{tropics area}_i) + \beta_{19}(\text{rule of law}_i) \\
+ \beta_{110}(\text{population growth}_i) + \varepsilon_1
\]

\[
\text{education}_i = \beta_{20} + \beta_{21}(\ln(GDP\_1960)_i) + \beta_{26}(\text{government}_i) \\
+ \beta_{27}(\text{adult male mortality}_i) + \beta_{28}(\text{tropics area}_i) + \beta_{29}(\text{rule of law}_i) \\
+ \beta_{211}(\text{urban}_i) + \varepsilon_2
\]

\[
\text{fertility}_i = \beta_{30} + \beta_{31}(\ln(GDP\_1960)_i) + \beta_{32}(\text{education}_i) + \beta_{38}(\text{tropics area}_i) \\
+ \beta_{312}(\text{child mortality}_i) + \beta_{313}(\text{edu differences}_i) + \varepsilon_3
\]

\[
\text{investment}_i = \beta_{40} + \beta_{41}(\ln(GDP\_1960)_i) + \beta_{42}(\text{education}_i) + \beta_{46}(\text{government}_i) \\
+ \beta_{49}(\text{rule of law}_i) + \beta_{410}(\text{population growth}_i) + \beta_{411}(\text{urban}_i) \\
+ \beta_{413}(\text{edu differences}_i) + \beta_{414}(\text{price\_inv/price\_cons}_i) \\
+ \beta_{414}(\text{gvt\_effectiveness}_i) + \varepsilon_4
\]

This system satisfies the order and rank conditions for identification as detailed in the Appendix of this paper, showing that each equation is over-identified. The variables that are instrumented are denoted by an asterisk. Estimation of this system is conducted using three different techniques. OLS results are presented in Table 8 on page 29, two-stage least squares results are presented in Table 9 on page 30, and three-stage least squares are presented in Table 10 on page 31.

The results support the hypothesis that health influences economic growth, as is found in the first two approaches of the direct effect and interactive effect. The channel effects are estimated using three techniques: ordinary least squares, two-stage least squares, and three-stage least squares. The OLS results show that adult male mortality has a negative partial correlation with economic growth (a direct relationship) and education (an indirect relationship). The two-stage least squares estimation indicates that adult male mortality influences education, but has no direct significant effect on economic growth. The three-stage least squares approach takes into account the endogeneity of economic growth, education, fertility and investment. Estimation results using this technique indicate that higher male mortality rates reduce education, and reduced education depresses economic growth. There is evidence of the indirect effect of health on economic growth through the influence on education. There is no evidence in support of the direct effect of health (adult male mortality\(^5\))

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\(^5\)Note that we use adult male mortality as opposed to the other measures such as life expectancy and
on economic growth. This finding supports theoretical models that focus on the influence of health on economic performance through its encouragement of education, and not the labour productivity models that propose health to have a direct effect on economic growth.

The hypothesis that individuals make a risk assessment based on indicators of adult and child mortality and the rule of law is supported in the system of equation estimation presented in Table 10 on page 31. Higher rates of adult male mortality lead to lower gross male enrolments in secondary school. This supports the theory that an individual will assess the likelihood of returns to education based on mortality rates — if mortality is high, then the probability of gaining returns to education is limited. Hence, the negative and significant influence of adult male mortality on education.

Child mortality rates are estimated to have an insignificant effect on fertility rates. There is no evidence in support of the hypothesis that fertility will be higher if parents observe a high child mortality rate. Factors that do influence the fertility rate are education levels: higher levels of education reduce the fertility rate. Furthermore, the differential between male and female secondary school enrolments influences fertility. A higher education differential implies a higher fertility rate, as women who are not expected to work and stay at home to care for children have little incentive to foster education for their own career benefits.

The rule of law has a weak positive effect on investment (this coefficient is significant at the 20 per cent level). An economy with a stronger rule of law has a greater capacity to ensure that contracts are honoured, thus encouraging entrepreneurial behaviour. The role of government hinders investment, with government expenditure having a negative effect, and also government effectiveness. This supports the theory of governments crowding out private investment.

The aim of this paper was to identify the relationship between health and economic growth. The system of equations estimation provides support for the hypothesis that health has an indirect effect on economic growth, through education. Estimated using this system of equations in (8), there is no evidence in support of a direct effect of health. The second aim of this paper is to identify the role of risk assessment in investment decision making. The results support this hypothesis for investment and education decisions, but not fertility decisions. The latter is influenced by male and female education differentials and levels.
6 Conclusion

Health plays an important role in the economic growth process. The results generated in this paper support this claim, and three approaches are used: the direct labour productivity effect, the interactive effect, and the incentive effect. In the OLS regressions in the first section analysing the direct effect of health on economic growth, different proxies for health are used: causes of good health (births attended by skilled health staff, hospital beds per 1000 people, dpt immunisation rate, access to sanitation facilities and clean water, and physicians per 1000 people) and consequences of good health (life expectancy, adult male mortality, death rate, infant mortality, and child mortality). The over arching result indicates that health is a partial correlate of economic growth, even after controlling for initial income and education. Instrumental variables in a two-stage least squares approach show that health improvements have a positive influence on economic growth, and there is support for the causal relationship of health improvements leading to higher economic growth.

The interactive effect shows that the marginal effect of health on economic growth is declining as education enrolments rise. The positive effect of health on economic growth is lower in countries with a higher gross male secondary school enrolments, which indicates that low skilled populations dominated by physical labour rely more on a healthy workforce than a high skilled labour forces.

These two approaches are consistent with the current literature that analyses the direct effect of health on economic growth. However, the theoretical literature examines the indirect role of health on economic growth through its promotion of education. Higher investment in education leads to improvements in economic growth. The system of equations established here in this paper simultaneously estimates the direct effect of health, and its indirect effect through education. The results generated by this estimation support the indirect effect, and there is no evidence of a direct effect of health on economic growth.

The policy implications generated by this empirical paper are consistent with those of endogenous growth models: health programs that encourage higher enrollments in school will have beneficial outcomes for economic growth.
References


7 Appendices

7.1 Data Definitions and Sources

7.1.1 List of Countries

Countries included in Table 9 3SLS regressions: Algeria, Angola, Argentina, Australia, Austria, Benin, Bolivia, Botswana, Brazil, Burkina Faso, Burundi, Cameroon, Canada, Chad, Chile, China, Colombia, Congo, Rep., Costa Rica, Cote d'Ivoire, Denmark, Ecuador, Egypt, Arab Rep., El Salvador, Finland, France, Gabon, Gambia, The., Ghana, Greece, Guatemala, Guinea, Guinea-Bissau, Honduras, India, Indonesia, Iran, Islamic Rep., Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Korea, Rep., Lesotho, Madagascar, Malawi, Malaysia, Mali, Mauritania, Mexico, Morocco, Mozambique, Namibia, Nepal, Netherlands, Nicaragua, Niger, Nigeria, Norway, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Portugal, Romania, Rwanda, Senegal, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Syrian Arab Rep., Tanzania, Thailand, Togo, Trinidad and Tobago, Turkey, Uganda, United Kingdom, United States, Uruguay, Venezuela, RB., Zambia, Zimbabwe.

7.1.2 Data Descriptions


rule of law: index that captures the respect of citizens and the state for the rules which govern their interactions, index range [-3,3], year 2000, source: see Table G5 on page 59 of Kaufmann et al. (1999)

govt effectiveness: index that captures the capacity of the state to implement sound policies, index range [-3,3], year 2000, source: see Table G3 on page 56 of Kaufmann et al. (1999)


tropics area: proportion of land area in geographical tropics, fraction, source: Gallop et al. (1998)

Variables hosting an asterisk, ‘∗’, in Equations (2), (6), and (8) are instrumented as follows.

open ⇒ (ctsh) Constructed trade shares by Frankel and Romer (1999)
adult male mortality, infant mortality ⇒ malaria ecology 1966 (malaria66) and 1994 (malaria94), climate variables (proportion of the country in climate classified as rainforest, savanna, steppe, desert, warm dry winters warmdwin, warm dry summers warmdsum, temperate, dry with snow in winter snowdry, humid with snow in winter snowmoist, highland) and geography variables (absolute distance from the equator (dist), distance from the centroid to the coast (coast), elevation (elevation), log of land area km² (land), used by Lorentzen et al. (2005) from Gallop et al. (1998).
rule of law and govt effectiveness ⇒ fraction of English speakers (EngFrac), fraction of European speakers, (EurFrac) by Hall and Jones (1999)
7.2 Identification of the System of Equations

There are two conditions that must be met for the three-stage least squares model to be identified: the order conditions which are necessary; and the rank conditions that are both necessary and sufficient. The system of equations estimated by Lorentzen et al. (2005) does not meet the rank condition, and consequently, the estimates are inconsistent (consistency means that there is convergence of a random variable to a constant). The order conditions can be calculated prior to estimation, but the rank conditions must be calculated after estimation as estimates that are not significantly different from zero may be present.

The order condition states that the number of predetermined variables (including the constant) excluded from the equation must be greater than or equal to the number of endogenous variables (including the dependent variable) included, less one. Define K as the number of predetermined variables in the system (K=16 which includes four constants), k as the number of predetermined variables in the equation of interest, G as the number of endogenous variables in the system (G=4 in the structural equation and the endogenous variables that are instrumented such as adult male mortality are in their reduced form when entering the structural model), g is the number of endogenous variables in the equation of interest. For the order condition to be satisfied, then $K - k_i \geq g_i - 1$.

From Equation (8.1) $(K - k_1 = 8) \geq (g_1 - 1 = 3)$
From Equation (8.2) $(K - k_2 = 9) \geq (g_2 - 1 = 0)$
From Equation (8.3) $(K - k_3 = 11) \geq (g_3 - 1 = 1)$
From Equation (8.4) $(K - k_4 = 7) \geq (g_4 - 1 = 1)$

The order condition is satisfied in each of the equations with the inequality of the number of exogenous variables excluded from the equation of interest exceeding the number of included endogenous variables less one.

To show that the rank condition is satisfied, the system is first estimated. Then a matrix of coefficients is constructed, regressions are in the row, and variable coefficients in the columns. If each equation is just-identified then the three-stage least squares will give the same results as the two-stage least squares. It is only when each equation is over-identified that the three-stage least squares provides estimation results that take into account the correlation between the error terms of the regressions in the system.

To calculate the rank of of a matrix for identification of an equation in the system: take the matrix of coefficients and cross out the row of the equation of interest, and the columns of all the non-zero coefficients that are in the equation of interest, (the resultant matrix will have three rows). The system will be just-identified when the order condition is satisfied with
equality, and the rank of the sub-matrix is three. For over-identification the order condition will be satisfied such that there are more exogenous variables excluded from the equation of interest than there are endogenous variables included (less one), and the sub-matrix is of rank three. Equations are under-identified if the rank or order conditions are not satisfied, and in this case, estimates will be inconsistent.

For Equation (8.1), $\text{rank}(A_{8,1}) = 3$, where $A_{8,1}$ is the submatrix. The equation for economic growth is over-identified at the 20 per cent level of significance. The columns of this submatrix are the coefficients on investment, government, adult male mortality, urban, child mortality, edu differences, $\text{price}_{\text{inv}}/\text{price}_{\text{cons}}$, and government effectiveness. The rows are for equations of education, fertility, and investment. Coefficients that are only significant at the 20 per cent level are written in italics, all coefficients that are zero are either excluded from the regression or are not significantly different from zero, all remaining coefficients are significant at the 10 per cent level.

$$
\begin{pmatrix}
0 & -0.44387 & -0.06943 & -248.05842 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0.02347 & 0 & 0 \\
0 & -0.14928 & 0 & 178.66208 & 0 & -0.09430 & -3.82869 & -3.63425
\end{pmatrix}
$$

For Equation (8.2), $\text{rank}(A_{8,2}) = 3$. The equation for education is over-identified at the 20 per cent level of significance. The columns are the coefficients on $\ln(\text{GDP 1960})$, education, fertility, investment, open, tropics area, population growth, child mortality, edu differences, $\text{price}_{\text{inv}}/\text{price}_{\text{cons}}$, and government effectiveness. The rows are for equations of economic growth, fertility, and investment.

$$
\begin{pmatrix}
-1.55567 & 0.04938 & -0.77955 & 0 & 0.00722 & -0.51905 & 35.32712 & 0 & 0 & 0 & 0 \\
0.39403 & -0.06478 & 0 & 0 & 0 & -0.51963 & 0 & 0 & 0.02347 & 0 & 0 \\
0 & 0.19593 & 0 & 0 & 0 & 0 & 0 & -0.09430 & -3.82869 & -3.63425
\end{pmatrix}
$$

For Equation (8.3), $\text{rank}(A_{8,3}) = 3$. The equation for fertility is over-identified at the 20 per cent level of significance. The columns are the coefficients on fertility, investment, open, government, adult male mortality, rule of law, population growth, urban, child mortality, $\text{price}_{\text{inv}}/\text{price}_{\text{cons}}$, and government effectiveness. The rows are for equations of economic growth, education, investment.
For Equation (8.4), \( \text{rank}(A_{8.4}) = 3 \). The equation for investment is over-identified at the 20 per cent level of significance. The columns are the coefficients on \( \ln(\text{GDP 1960}) \), fertility, investment, open, adult male mortality, tropics area, population growth, child mortality. The rows are eco growth, education, and fertility.

\[
\begin{pmatrix}
-0.77955 & 0 & 0.00722 & 0 & 0 & -0.65273 & 35.32712 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -0.44387 & -0.06943 & 13.99511 & 0 & -248.05842 & 0 & 0 & 0 \\
0 & 0 & 0 & -0.14928 & 3.25033 & 0 & 178.66208 & 0 & -3.82869 & -3.63425
\end{pmatrix}
\]
7.3 Tables of Results
Table 1: Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std.Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>eco_growth</td>
<td>153</td>
<td>2.017684</td>
<td>2.119112</td>
<td>-6.94247</td>
<td>8.066801</td>
</tr>
<tr>
<td>education</td>
<td>180</td>
<td>59.86538</td>
<td>30.49991</td>
<td>5.49661</td>
<td>127.4297</td>
</tr>
<tr>
<td>fertility</td>
<td>192</td>
<td>4.391665</td>
<td>1.754657</td>
<td>1.63579</td>
<td>8.34706</td>
</tr>
<tr>
<td>investment</td>
<td>167</td>
<td>15.6843</td>
<td>8.060191</td>
<td>2.190945</td>
<td>45.5887</td>
</tr>
<tr>
<td>ln(GDP 1960)</td>
<td>109</td>
<td>7.73736</td>
<td>0.892312</td>
<td>5.94419</td>
<td>9.614354</td>
</tr>
<tr>
<td>open</td>
<td>142</td>
<td>72.44317</td>
<td>46.69097</td>
<td>13.16</td>
<td>318.07</td>
</tr>
<tr>
<td>population growth</td>
<td>99</td>
<td>0.590266</td>
<td>0.0165</td>
<td>0.948101</td>
<td>1.014178</td>
</tr>
<tr>
<td>life expectancy 1960</td>
<td>162</td>
<td>53.26039</td>
<td>12.54233</td>
<td>31.61463</td>
<td>73.40439</td>
</tr>
<tr>
<td>death rate</td>
<td>192</td>
<td>11.69518</td>
<td>5.315458</td>
<td>4.051429</td>
<td>28.95647</td>
</tr>
<tr>
<td>adult male mortality</td>
<td>191</td>
<td>294.7147</td>
<td>132.7758</td>
<td>82.2</td>
<td>576.0838</td>
</tr>
<tr>
<td>infant mortality</td>
<td>192</td>
<td>65.59094</td>
<td>47.99317</td>
<td>13.16</td>
<td>318.07</td>
</tr>
<tr>
<td>child mortality</td>
<td>187</td>
<td>99.14305</td>
<td>81.56166</td>
<td>9.990244</td>
<td>344.5</td>
</tr>
<tr>
<td>births attended</td>
<td>184</td>
<td>73.34327</td>
<td>28.67324</td>
<td>7.33333</td>
<td>100</td>
</tr>
<tr>
<td>hospital</td>
<td>189</td>
<td>4.929774</td>
<td>8.313049</td>
<td>0.197131</td>
<td>38.80726</td>
</tr>
<tr>
<td>dpt immunisation</td>
<td>161</td>
<td>70.65829</td>
<td>21.84637</td>
<td>14.68824</td>
<td>99.176</td>
</tr>
<tr>
<td>sanitation</td>
<td>145</td>
<td>71.81634</td>
<td>27.39634</td>
<td>8</td>
<td>100</td>
</tr>
<tr>
<td>water</td>
<td>151</td>
<td>37.75286</td>
<td>20.82697</td>
<td>13</td>
<td>100</td>
</tr>
<tr>
<td>physician</td>
<td>198</td>
<td>1.140427</td>
<td>1.163303</td>
<td>0.015656</td>
<td>4.732247</td>
</tr>
<tr>
<td>urban</td>
<td>188</td>
<td>1.003439</td>
<td>0.018425</td>
<td>0.928918</td>
<td>1.038636</td>
</tr>
<tr>
<td>female labour</td>
<td>171</td>
<td>0.031637</td>
<td>0.995248</td>
<td>-1.79</td>
<td>2.22</td>
</tr>
<tr>
<td>rule of law</td>
<td>167</td>
<td>0.009882</td>
<td>1.006228</td>
<td>-2.58</td>
<td>2.48</td>
</tr>
<tr>
<td>government effectiveness</td>
<td>198</td>
<td>0.488678</td>
<td>0.47874</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2: Correlation matrix: Economic Growth and Mortality variable

<table>
<thead>
<tr>
<th>(1) eco_growth</th>
<th>(2) education</th>
<th>(3) fertility</th>
<th>(4) investment</th>
<th>(5) life expectancy 1960</th>
<th>(6) adult male mortality</th>
<th>(7) death rate</th>
<th>(8) infant mortality</th>
<th>(9) child mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) eco_growth</td>
<td>1</td>
<td>-0.364</td>
<td>-0.3307</td>
<td>0.4721</td>
<td>-0.4234</td>
<td>-0.4326</td>
<td>-0.38</td>
<td>-0.3995</td>
</tr>
<tr>
<td>(2) education</td>
<td>-0.364</td>
<td>1</td>
<td>0.8645</td>
<td>0.6758</td>
<td>0.6868</td>
<td>0.6758</td>
<td>0.8339</td>
<td>0.837</td>
</tr>
<tr>
<td>(3) fertility</td>
<td>-0.3307</td>
<td>0.8645</td>
<td>1</td>
<td>0.6758</td>
<td>0.6868</td>
<td>0.6758</td>
<td>0.8339</td>
<td>0.837</td>
</tr>
<tr>
<td>(4) investment</td>
<td>0.4721</td>
<td>0.6758</td>
<td>1</td>
<td>0.6868</td>
<td>0.6758</td>
<td>0.6758</td>
<td>0.8339</td>
<td>0.837</td>
</tr>
<tr>
<td>(5) life expectancy 1960</td>
<td>-0.4234</td>
<td>-0.4326</td>
<td>-0.4326</td>
<td>1</td>
<td>0.6868</td>
<td>0.6758</td>
<td>0.8339</td>
<td>0.837</td>
</tr>
<tr>
<td>(6) adult male mortality</td>
<td>-0.4326</td>
<td>-0.4326</td>
<td>-0.4326</td>
<td>1</td>
<td>0.6868</td>
<td>0.6758</td>
<td>0.8339</td>
<td>0.837</td>
</tr>
<tr>
<td>(7) death rate</td>
<td>-0.4326</td>
<td>-0.4326</td>
<td>-0.4326</td>
<td>1</td>
<td>0.6868</td>
<td>0.6758</td>
<td>0.8339</td>
<td>0.837</td>
</tr>
<tr>
<td>(8) infant mortality</td>
<td>-0.38</td>
<td>-0.38</td>
<td>-0.38</td>
<td>1</td>
<td>0.6868</td>
<td>0.6758</td>
<td>0.8339</td>
<td>0.837</td>
</tr>
<tr>
<td>(9) child mortality</td>
<td>-0.3995</td>
<td>-0.3995</td>
<td>-0.3995</td>
<td>1</td>
<td>0.6868</td>
<td>0.6758</td>
<td>0.8339</td>
<td>0.837</td>
</tr>
</tbody>
</table>

Table 3: Correlation matrix: Economic Growth and Health variables

<table>
<thead>
<tr>
<th>(1) eco_growth</th>
<th>(2) education</th>
<th>(3) fertility</th>
<th>(4) investment</th>
<th>(5) births attended</th>
<th>(6) hospital</th>
<th>(7) dpt immunisation</th>
<th>(8) sanitation</th>
<th>(9) water</th>
<th>(10) physician</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) eco_growth</td>
<td>1</td>
<td>-0.3284</td>
<td>0.4241</td>
<td>0.3557</td>
<td>-0.3457</td>
<td>0.1759</td>
<td>0.3323</td>
<td>0.216</td>
<td>0.1185</td>
</tr>
<tr>
<td>(2) education</td>
<td>-0.3284</td>
<td>1</td>
<td>-0.5313</td>
<td>-0.8647</td>
<td>-0.8107</td>
<td>0.8105</td>
<td>0.7241</td>
<td>0.6666</td>
<td>0.7787</td>
</tr>
<tr>
<td>(3) fertility</td>
<td>0.4241</td>
<td>-0.5313</td>
<td>1</td>
<td>-0.5738</td>
<td>-0.8647</td>
<td>-0.8107</td>
<td>0.7241</td>
<td>0.6666</td>
<td>0.7787</td>
</tr>
<tr>
<td>(4) investment</td>
<td>0.3557</td>
<td>-0.8647</td>
<td>0.8107</td>
<td>1</td>
<td>-0.8647</td>
<td>-0.8107</td>
<td>0.7241</td>
<td>0.6666</td>
<td>0.7787</td>
</tr>
<tr>
<td>(5) births attended</td>
<td>-0.3457</td>
<td>-0.8647</td>
<td>-0.8647</td>
<td>1</td>
<td>-0.8647</td>
<td>-0.8107</td>
<td>0.7241</td>
<td>0.6666</td>
<td></td>
</tr>
<tr>
<td>(6) hospital</td>
<td>0.1759</td>
<td>0.8105</td>
<td>0.8105</td>
<td>1</td>
<td>0.7241</td>
<td>0.7241</td>
<td>1</td>
<td>0.6666</td>
<td></td>
</tr>
<tr>
<td>(7) dpt immunisation</td>
<td>0.3323</td>
<td>0.7241</td>
<td>0.7241</td>
<td>1</td>
<td>0.7241</td>
<td>0.7241</td>
<td>1</td>
<td>0.6666</td>
<td></td>
</tr>
<tr>
<td>(8) sanitation</td>
<td>0.216</td>
<td>0.6666</td>
<td>0.6666</td>
<td>1</td>
<td>0.7241</td>
<td>0.7241</td>
<td>1</td>
<td>0.6666</td>
<td></td>
</tr>
<tr>
<td>(9) water</td>
<td>0.2752</td>
<td>0.7036</td>
<td>0.7036</td>
<td>1</td>
<td>0.6666</td>
<td>0.7241</td>
<td>1</td>
<td>0.6666</td>
<td></td>
</tr>
<tr>
<td>(10) physician</td>
<td>0.1185</td>
<td>0.7787</td>
<td>0.7787</td>
<td>1</td>
<td>0.7241</td>
<td>0.7241</td>
<td>1</td>
<td>0.6666</td>
<td></td>
</tr>
</tbody>
</table>
Table 4: Partial correlations of mortality variables with Economic Growth. OLS estimation of Equation (1)

<table>
<thead>
<tr>
<th>Dependent variable: GDP average annual growth rate 1960-2000, chain index</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(GDP 1960)</td>
<td>-0.92624</td>
<td>-1.22232</td>
<td>-1.38427</td>
<td>-1.43199</td>
<td>-1.46358</td>
<td>-1.41702</td>
<td>-1.44252</td>
</tr>
<tr>
<td>(0.22548)*****</td>
<td>(0.16165)*****</td>
<td>(0.17972)*****</td>
<td>(0.15715)*****</td>
<td>(0.16095)*****</td>
<td>(0.16464)*****</td>
<td>(0.16530)*****</td>
<td></td>
</tr>
<tr>
<td>population growth</td>
<td>-1.7755</td>
<td>6.70921</td>
<td>11.64261</td>
<td>-6.07998</td>
<td>4.02377</td>
<td>7.58796</td>
<td>6.64142</td>
</tr>
<tr>
<td>(8.75113)</td>
<td>(7.57919)</td>
<td>(6.27313)</td>
<td>(5.50653)</td>
<td>(7.71092)</td>
<td>(7.51941)</td>
<td>(7.39884)</td>
<td></td>
</tr>
<tr>
<td>investment</td>
<td>0.09990</td>
<td>0.06725</td>
<td>0.05569</td>
<td>0.084004</td>
<td>0.04884</td>
<td>0.04234</td>
<td>0.03894</td>
</tr>
<tr>
<td>(0.02415)*****</td>
<td>(0.02169)*****</td>
<td>(0.02290)*****</td>
<td>(0.028050)**</td>
<td>(0.02050)****</td>
<td>(0.02337)***</td>
<td>(0.02216)***</td>
<td></td>
</tr>
<tr>
<td>government</td>
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<td>-0.01839</td>
<td>-0.02240</td>
<td>-0.03328</td>
<td>-0.02752</td>
<td>-0.03138</td>
<td>-0.03584</td>
</tr>
<tr>
<td>(0.01578)</td>
<td>(0.01302)</td>
<td>(0.01505)</td>
<td>(0.01526)****</td>
<td>(0.01332)****</td>
<td>(0.01430)****</td>
<td>(0.01391)****</td>
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</tr>
<tr>
<td>open</td>
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<td>0.00249</td>
<td>0.00332</td>
<td>0.00509</td>
<td>0.00470</td>
<td>0.00394</td>
<td>0.00406</td>
</tr>
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<td>(0.00387)</td>
<td>(0.00378)</td>
<td>(0.00371)</td>
<td>(0.00389)</td>
<td>(0.00343)</td>
<td>(0.00338)</td>
<td></td>
</tr>
<tr>
<td>rule of law</td>
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<td>0.11792</td>
<td>0.22486</td>
<td>0.22151</td>
<td>0.11168</td>
<td>0.17816</td>
</tr>
<tr>
<td>(0.30666)</td>
<td>(0.20422)</td>
<td>(0.20472)</td>
<td>(0.20533)</td>
<td>(0.19979)</td>
<td>(0.19038)</td>
<td>(0.19085)</td>
<td></td>
</tr>
<tr>
<td>tropics area</td>
<td>-0.91121</td>
<td>-0.51673</td>
<td>-0.61131</td>
<td>-0.58613</td>
<td>-0.38480</td>
<td>-0.74310</td>
<td>-0.87669</td>
</tr>
<tr>
<td>(0.34868)****</td>
<td>(0.31551)</td>
<td>(0.30350)****</td>
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<td>(0.28865)</td>
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<td>(0.0033)****</td>
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Robust standard errors in parentheses. * significant at 10%, ** significant at 5%, *** significant at 1%. Hausman test probability: p-value on a Hausman specification test endogeneity, null hypothesis of exogeneity vs the alternative of endogeneity. Variables tested for endogeneity: open, rule of law, and each of the mortality/life expectancy variables. Exogenous variables used in the test: ln(GDP 1960), population growth, investment, government, education, tropics, ctrsh, EngFrac, EurFrac, rainforest, savanna, steppe, desert, warmwin, warmsum, temperate, snowdry, snowmoist, highland, malaria66, malaria94, dist, coast, elevation, and land. Joint test is an F-test of the joint significance of the education coefficient with each of the mortality variables.
Table 5: Partial correlations of health determinants with Economic Growth. OLS estimation of Equation (1)

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<td>(0.00657)</td>
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Robust standard errors in parentheses. * significant at 10%, ** significant at 5%, *** significant at 1%. Joint test is an F-test of the joint significance of the education co-efficient with each of the mortality variables.
Table 6: Life expectancy and mortality and economic growth. Instrumental variable estimation of Equation (2)

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<th>Dependent variable: GDP average annual growth rate 1960-2000, chain index.</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
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<td>ln(GDP 1960)</td>
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<td>-1.23409</td>
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<td>0.00001</td>
<td>0.00001</td>
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<tr>
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<td>-0.00379</td>
<td>0.00001</td>
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<tr>
<td>child mortality</td>
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</tr>
</tbody>
</table>

Robust standard errors in parentheses. * significant at 10%, ** significant at 5%, *** significant at 1%. Over id test gives the chi-squared statistic, and the Over id Crit Value is the critical value under the chi-squared distribution with 15 degrees of freedom. Tests the null of exogeneity versus the alternative of endogeneity. Exogenous variables external to the model are: ctrsh, EngFrac, EurFrac, rainforest, savanna, steppe, desert, warmdwin, warmdsum, temperate, snowdry, snowmoist, highland, malaria66, malaria94, dist, coast, elevation, and land. Endogenous variables: open, rule of law, and the mortality/life expectancy variables. Joint test is an F-test of the joint significance of the education co-efficient with each of the mortality variables.
Table 7: Life expectancy and mortality and economic growth. Instrumental variable estimation of Equation (6), including an interactive term of education and health variable

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<td>(12.04581)*</td>
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<td>(14.31421)</td>
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<td>9.40102</td>
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<td>Adj-Rsq</td>
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<td>0.67</td>
<td>0.49</td>
<td>0.47</td>
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<tr>
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<td>15.712032</td>
<td>10.874092</td>
<td>13.006424</td>
<td>5.600843</td>
<td>4.922553</td>
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<tr>
<td>Over id Test Value</td>
<td>23.68</td>
<td>23.68</td>
<td>23.70</td>
<td>23.71</td>
<td>23.72</td>
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</table>

Robust standard errors in parentheses. * significant at 10%, ** significant at 5%, *** significant at 1%. Over id test gives the chi-squared statistic of the over identifying restrictions test, and the Over id Crit Value is the critical value under the chi-squared distribution with 14 degrees of freedom. Tests the null of exogeneity of the instruments versus the alternative of endogeneity. Exogenous variables external to the model are: ctrsh, EngFrac, EurFrac, rainforest, savanna, steppe, desert, warmdwin, warmdsum, temperate, snowdry, snowmoist, highland, malaria66, malaria94, dist, coast, elevation, and land. Endogenous variables: open, rule of law, each of the mortality/life expectancy model, the interaction term in the model.
Table 8: Channel effects explaining economic growth. OLS estimation of each equation in System (8)

<table>
<thead>
<tr>
<th></th>
<th>(1) eco_growth</th>
<th>(2) education</th>
<th>(3) fertility</th>
<th>(4) investment</th>
</tr>
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<td>ln(GDP 1960))</td>
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<td>2.998</td>
<td>-0.25347</td>
<td>-1.27412</td>
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<td>(0.14776)***</td>
<td>(1.04)</td>
<td>(0.13056)*</td>
<td>(1.31715)</td>
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<tr>
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<td>-0.65481</td>
<td>(0.00680)**</td>
<td>(0.00508)***</td>
<td>(0.03136)***</td>
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<tr>
<td>investment</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>0.01982</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>-0.286</td>
<td></td>
<td>-0.19762</td>
</tr>
<tr>
<td>adult mortality</td>
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<td>(1.90)</td>
<td></td>
<td>(0.07028)***</td>
</tr>
<tr>
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<td>-9.732</td>
<td>0.30165</td>
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</tr>
<tr>
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<td>(2.15)**</td>
<td>(0.23197)</td>
<td></td>
</tr>
<tr>
<td>population growth</td>
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<td>9.121</td>
<td></td>
<td>4.65958</td>
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<td>(9.13001)***</td>
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<td></td>
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<td>(3.06)**</td>
<td></td>
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<td></td>
<td>(81.22978)</td>
</tr>
<tr>
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<td>(0.01056)</td>
<td>-0.04589</td>
<td>(0.06626)</td>
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<td>7.09450</td>
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<td>97</td>
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<td>Rsq</td>
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* significant at 10%, ** significant at 5%, *** significant at 1%.
Table 9: Channel effects explaining economic growth. Instrumental variable estimation of each equation in System (8)

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<th>Equation</th>
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<th>(3)</th>
<th>(4)</th>
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<td>ln(GDP 1960))</td>
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<td>-0.70688</td>
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<tr>
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<td>(0.23184)***</td>
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<td>0.15702</td>
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</tr>
<tr>
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<td>(0.00875)***</td>
<td>(0.00675)***</td>
<td>(0.03281)***</td>
<td></td>
</tr>
<tr>
<td>fertility</td>
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<td>-0.07565</td>
<td>0.27433</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.23445)***</td>
<td>(0.01598)**</td>
<td>(0.05634)**</td>
<td></td>
</tr>
<tr>
<td>investment</td>
<td>0.03004</td>
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<td></td>
</tr>
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<td></td>
<td>(0.00568)**</td>
<td>(0.00785)**</td>
<td></td>
<td>(0.08043)**</td>
</tr>
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<td>-0.07565</td>
<td>2.75438</td>
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<tr>
<td></td>
<td>(0.00207)</td>
<td>(0.00785)**</td>
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<tr>
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<td>(0.39380)**</td>
<td>(6.24329)</td>
<td>(0.25925)</td>
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<tr>
<td></td>
<td>(0.43571)*</td>
<td>(3.85563)**</td>
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<tr>
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<td>(1.53906)*</td>
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<td>(1.53906)*</td>
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<td>0.83</td>
<td>0.84</td>
<td>0.79</td>
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* significant at 10%, ** significant at 5%, *** significant at 1%.
Table 10: Channel effects explaining economic growth. Three-stage least squares estimation of System (8)

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<th></th>
<th>(1) eco_growth</th>
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<th>(3) fertility</th>
<th>(4) investment</th>
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<tr>
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<td>(0.00790)***</td>
<td>(0.16809)**</td>
<td>(0.02281)</td>
</tr>
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<td>(0.16809)**</td>
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<td>(0.16809)**</td>
<td>(0.02281)</td>
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<td>17.23009**</td>
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<td>(17.23009)**</td>
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<td>(0.00255)</td>
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<td>(0.00255)</td>
<td>(0.00255)</td>
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</table>

* significant at 10%, ** significant at 5%, *** significant at 1%.