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Abstract

The correlation between health and economic performance is extremely robust across communities and over time. Many factors exogenous to income play an important role in determining health status, including a number of geographical, environmental, and evolutionary factors. This suggests the existence of simultaneous impacts of health on wealth and wealth on health. Potential health impacts on national economic performance are explored, and some important unanswered questions are identified.

Keywords: health, economic growth, human capital

JEL codes: I1, N3, O1

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Poverty and ill health occur together. According to medical anthropologist Paul Farmer, "studies compiled from the twelfth century onward show that the poor, quite simply, are sicker than the nonpoor and that this is true in both rich and poor countries" (Farmer 1999). It is also true across countries. Figures 1 and 2 show the remarkable cross country correlation between output per capita (adjusted for purchasing power parity) and some health indicators in 1995.

Scholars have examined poverty as cause and consequence of poor health. Poverty is detrimental to health because it restricts access to medical care and healthy living conditions. For example, the risk of tuberculosis infection increases in crowded and poorly ventilated environments like tenements or prisons, and risk of infection with malaria is higher in poorly constructed homes which are less effective at preventing the entry of vector mosquitoes (Farmer 1999; Gunawardena and others. 1998, 58:533-42). Furthermore, since both prevention and effective treatment of adverse health events cost money, the poor are not only likely to suffer from ill health more often, but also to have more severe sequelae. Poverty also restricts access to new tools; priority setting in molecular and clinical research and development favors the needs of wealthier populations (Kremer 1999).

Health, however, is also determined by a host of factors unrelated to economic well-being. Geographical, environmental, and biological factors contribute to the epidemiology of many diseases. For example, tropical diseases like malaria are particularly pernicious in certain contexts due to climate, topography, and evolutionary history, and not simply due to poverty (Hamoudi and Sachs 1999).

The robustness of the correlation between health and economic indicators, therefore, suggests that health is also a determinant of economic success. Researchers have been studying this relationship for over 30 years (Mushkin 1962, 70:129-57). In recent years, this analysis has received increasing attention (Frank and Mustard 1994, 1994:1-19; Schultz Vol. 77:141-58). Health impacts directly on household income and wealth, labor productivity, labor force participation, savings and investment rates, demographic factors, and other human capital factors. The fact that health impacts and is impacted by economic performance raises important policy issues; for example, while some would argue that improved health is among the many positive *results* of successful economic development strategies, other evidence suggests that such strategies must *incorporate* effective health interventions (Ramirez, Ranis, and Stewart 1997; Gallup, Sachs, and Mellinger 1998,127-78). Human well-being is unarguably an end in itself, but a better understanding of the complex relationships between health and economic growth is important for proper priority setting and policy implementation. This paper will explore the body of evidence that health is a determinant of economic performance, and will identify some of the important unanswered questions.

Some mechanisms by which health determines economic performance

<u>Treatment cost and lost labor productivity</u>

The most proximate costs of illness to individuals and their households include the costs of treatment and lost work time. For example, one cost of illness study finds that treatment of a single episode of malaria in Tigray, Ethiopia costs the affected household $0.80 to $1.60, and results in about 12-26 days of work lost. Therefore, the annual private cost of malaria in this region amounts to an average of 5-8% of household income (Cropper**). Mead Over and others estimate the average total cost of treatment and foregone productivity in Tanzania resulting from a single HIV infection to be about $2462-$5316 in 1985 dollars, or about 8.5%-18.3% of per capita income (Over 1992,). Similarly, a study of multiple sclerosis in the United States suggests an annual cost in terms of lost earnings and treatment expenses to each affected household of $5336 per year in 1976 dollars; aggregated, these costs amounted to about 0.04% of total US GDP in 1976 (Inman Vol. 69:651-60). In most countries, at least some of the costs of health care are subsidized by the government; therefore, treatment and prevention costs are also borne by the public sector.

Furthermore, while many traditional cost of illness studies have sought to quantify the costs of lost work time due to illness, workers who do not deliberately change their work habits in response to illness can also be expected perform sub-optimally during the term of their illness. T.P. Schultz and Aysit Tansel (Schultz and Tansel 1996, Vol. 53:251-86) suggest a methodology for quantitative assessment of this impact. They employ a wage function which relates productivity to health status, education, the square of post-schooling experience, and parental experience. Using data from Côte d'Ivoire and Ghana in this function, they find that on a "disabled day" a worker in Côte d'Ivoire can be expected to be over 10 percent less productive, and a worker in Ghana can be expected to be 11.7 percent less productive than if he or she were in good health.

Another cost of ill-health is lost time associated with higher levels of child mortality. When a larger proportion of children die, the net cost of raising each child which does survive increases. David Reher (Reher Vol. 49:519-36) has speculated on this cost in terms of lost parental time. Using data on structures and levels of infant and child mortality in historical contexts as well as modern developing countries, and speculating based on ethnographic data on the proportion of maternal and paternal time devoted exclusively to child-rearing, Reher finds that under conditions of high child mortality, each child who dies before the fifth birthday represents an average loss of 1300-1800 hours of parental work time, depending on the specific structure of mortality patterns. In order to ensure three children who survive to age five, therefore, parents would have to "waste" 800-3000 hours on children who would not survive.

Longer term effects

Chronic sequelae of some illnesses include anemia, impaired cognitive development, and other forms of permanent disability. These conditions may impact economic performance, even in the absence of severe clinical disease. Geohelminths, for example, are worms which invade a human host through unbroken skin and infest the small intestine, sapping nutrients, including iron, from the host (Hotez 1989, 8:516-20; Hotez and Pritchard 1995, 272:68-74). As a result, the host becomes anemic, more easily tired, melancholic, and distracted even though there may be no more dramatic symptoms of infection. The productivity of agricultural workers in worm infested regions has been observed to improve dramatically after treatment with anthelminthic drugs, and to remain higher than the productivity of their untreated peers. In addition, the negative cognitive impacts of helminthic infection were first observed at the beginning of the 20^{th} century, and continue to be examined (Hadidjaja and others. 1998, 59:791-95; Montresor and others. 1997, 57:294-98; Nokes and others. 1992, 247:77-81; Levav and others. 1995, 110:103-11; Kvalsvig, Cooppan, and Connolly 1991, 85:551-68).

Similarly, malaria illness also takes a massive human resource toll. For example, malaria often involves severe anemia caused by the widespread and simultaneous destruction of hundreds of millions of oxygen carrying red blood cells in regular 48-72 hour cycles. In addition, malaria illness can cause red blood cells to clump and occlude blood vessels in the brain, directly causing extensive and permanent brain damage (White 1996, 1087-164). Other long-term or permanent disabilities resulting from adverse health events include, for example, reduced endurance (tuberculosis, cardiovascular disease), encephalitis (several vector borne diseases), blindness (onchocerciasis), and paralysis (polio).

In addition to infectious and chronic illness, nutrition is an important health factor which has long-term human resource impacts. John Strauss and Duncan Thomas (Strauss and Thomas 1998, Vol. 36:766-817) review evidence that height and body mass index (as an indicator of strength) are both determined largely by nutritional factors. Using data from Brazil and the United States, they find that these variables are positively correlated with wages after controlling for differential ages and education levels.

In addition, poor nutrition may have long term costs to individuals by impairing cognitive development. Infants who receive micronutrient supplementation have been observed to develop better motor skills than peers who did not receive supplementation; motor skill development is widely employed as an accurate predictor of overall cognitive development (Hauser 1998,207-18; Sigman and Whaley 1998,155-82). Development of stature and strength is extremely sensitive to nutritional inputs and overall health during early childhood and adolescence; improved conditions later in life will not fully reverse the impacts of malnutrition and illness during this period (Martorell 1998,183-206).

Demographic impacts

Health may also affect the economic performance of communities through its impacts on demographic factors. Shorter life expectancies, for example, inhibit investment in education and other forms of human capital, since there is greater risk that each individual will not survive long enough to benefit from the investment In addition, a larger proportion of the population which is dependent— consuming more resources than it produces— has a detrimental effect on rates of savings and capital investment, and hence on subsequent growth (Kelley and Schmidt 1996, Vol. 9:365-86). Widespread incidence of disability, injury, and illness inflate these dependency ratios. Childhood diseases like malaria prevent a large proportion of birth cohorts from maturing to economically productive age. AIDS is a primarily adult disease with important demographic impacts. By decimating the urban professional class in many African countries (about a quarter of 15-49 year olds in Zimbabwe, Zambia, South Africa, and Botswana were living with HIV at the end of 1998) and producing millions of orphans each year, AIDS directly reduces the size of the economically active population (UNAIDS 1999,; Gregson, Garnett, and Anderson 1994, 48:435-58).

Furthermore, fertility decisions may be made in part by a need to ensure a given number of survivors, or in response to childhood mortality experience. T.P. Schultz (Schultz 1997,350-430) demonstrates a statistically significant inflating effect of child mortality on total fertility. Therefore, it is possible that where childhood mortality rates are very high, countries may become caught in a demographic trap, with high fertility rates leading to greater demand for household and community resources, large proportions of which are "wasted" on children who do not survive to economically productive age.

Disease endemicity and isolation

Communicable disease endemicity greatly increases the costs of inter- and intranational migration, investment, commerce, and trade. The impact of disease endemicity on economic interactions over the past several centuries has been described, for example, by Philip Curtin and also by William McNeill (Curtin 1998; McNeill 1989). Many countries whose economies rely heavily on foreign direct investment or tourism, including for example Indonesia and Trinidad, are especially energetic in controlling the spread of infectious diseases in areas of economic importance [*cf*. Footnote 25 in (Hamoudi and Sachs 1999)](World Health Organization 1997, 72:269-90). Within countries, as well, regions of intense transmission of environmental diseases remain hostile and difficult to settle (for example, the Rondonia region of Brazil, which is intensely malarious).

The costs to trade, investment, and commerce of environmental and infectious diseases like malaria remain largely unexamined both theoretically and empirically. A growing body of medical literature, however, has begun to consider the health impacts of increasing trade, commerce, and investment. Increased incidence of foot and mouth disease, diarrheal diseases, tuberculosis, malaria, and HIV have all been attributed to increasing global traffic in recent decades (Garrett 1994,312-18; Chen 1994,319-24; Ostroff and Kozarsky 12:231-41; Lewis 1986, 23:983-93; Kitching 1999, 17:1772-74; Dufour 1999, 30:27-37). As these impacts are coming to be understood, they have begun to impact social behavior and government policy, including for example trade policies. In some recent cases, nations and regions which are perceived as unhealthy have been explicitly quarantined from international commerce.

<u>The vicious cycle of adverse health events</u>

Present ill health often begets future ill health by increasing the likelihood of apparently unrelated debilitation in the future. The most dramatic example is the role played by the HIV pandemic in the spread of tuberculosis. In addition, research suggests that protein deficiency in mothers during pregnancy may result in lower birth weights, and increase the offspring’s long-term risk of cardiovascular disease (Godfrey and others. 1996, 312:410-414; Hoet and Hanson 1999, 514:617-27). Childhood health and nutrition also appear to play a very important role in determining the extent and severity of chronic conditions later in life (Fogel 1992). Many infectious illnesses, including malaria and tuberculosis, require complex cell-mediated immune responses; poor overall health and nutrition reduce the effectiveness of these responses, increasing the likelihood that infection with these diseases will be more severe, resulting in long-term disability or death (Farmer 1999).

Empirical evidence of the long term impact of health on economic performance

<u>Health and the industrial revolution</u>

The past several decades have brought unprecedented improvements in life expectancy worldwide, although these improvements have not been uniformly distributed. Economic historians have begun to consider the importance of trends in health in determining patterns of economic growth. Robert Fogel (Fogel Vol. 89:1-21) posits a “technophysio” evolutionary process, which is similar to genetic evolution in that it involves biological changes over time, but distinct in that it is faster, less stable, more directly anthropogenic, and extremely recent. The primary outcome of this process over the course of the past 300 years (beginning with the onset of the second agricultural revolution) has been extremely rapid population growth and longer life expectancy, driven primarily by improvements in nutrition. As a result, Western Europe over this period has seen rapid increases in both labor force participation rates and the average number of calories available for work, increasing productivity by about 0.3 percentage points per year. This trend, according to Fogel, accounts for about half of Britain’s economic growth over the past two centuries (Fogel Vol. 34:49-66). Modern developing economies, just as pre-industrial Europe, have low rates of labor force productivity and reduced levels of productivity per worker due to widespread stunting and malnutrition.

Health and the U.S. South

More recently, some industrialized regions have struggled with the same specific diseases which plague many developing countries today. For example, geohelminths—specifically, hookworm—were highly endemic in the U.S. South until the early part of the 20th century. The Rockefeller Sanitary Commission was endowed in 1909 and charged with eradicating hookworm from the region (Ettling 1981). Hookworm was ultimately eradicated by the 1940s, (although the most dramatic gains were been made between 1910 and 1920) through the introduction of privies and other sanitation technologies, widespread treatment with anthelminthic drugs, and extensive public outreach/education.

At the same time, historians have long puzzled over the curious pattern of Southern economic growth from the Civil War until the middle of the 20th century, marked by divergence from the North until around 1910, followed by steady convergence until World War II. Garland Brinkley (Brinkley 1994) speculates on the impact of hookworm endemicity and eradication in this pattern. His analysis suggests that the dramatic success in the control of hookworm accounted for more of the per capita growth in agricultural output over the period than any other factor except increased physical capital.

Other historians have looked at the role of disease in the cultural and economic history of the U.S. South. John Duffy, for example, describes the historical impact of malaria (Duffy 1988,29-54), which he said "tended to inhibit the growth of the southern colonies. The disease was not a decisive factor in settlement, but during the colonial period the South's reputation for fevers and agues undoubtedly discouraged many prospective immigrants, and the longer malarial season tended to reduce the energy quotient of those who settled there." At the end of the 18th century, malaria incidence in South Carolina was so high that only the farmers who could not afford to move to the relatively healthy urban environment of Charleston were left behind. During the early 19th century, malaria outbreaks twice forced the relocation of Alabama's capital city. Whereas malaria disappeared quickly in the North after areas were newly settled for cultivation and livestock, it tended to persist much longer in the South, and took a toll on regional productivity.

Malaria and national economic performance

Jeffrey Sachs and John Gallup investigate the quantitative impact of endemicity of one disease— malaria— on cross-country macroeconomic growth. Controlling for tropical location, location in Africa, life expectancy at birth, trade policy, geographical accessibility to international trade, and initial income, they find that endemicity of falciparum malaria correlates with substantially dampened annual GDP/capita growth rates over a 25 year period; they observe the same correlation using ecological zones as an instrument for malaria endemicity. They discuss the historical cases of southern Europe, Taiwan, and Jamaica, all of which saw substantial acceleration of economic growth after achieving sustained elimination of malaria transmission. They speculate that much of this impact may be through hindered integration of malarious areas into global trade networks.

Health and Economic Growth in Asia

David Bloom and others, in a study for the Asian Development Bank, discuss the importance of the precipitous decline in mortality and fertility rates in spawning unprecedented economic growth performance in East and Southeast Asia from the 1960s to the 1990s (Asian Development Bank 1997). In the late 1940s, infant and child mortality rates in Asia plummeted and life expectancy soared. About a generation later, largely in response to the new mortality regime, fertility rates also declined; the result was a population bulge with better health prospects than any generation before. A transition which had taken centuries in pre-industrial Europe had occurred in less than three decades. Bloom and others describe this transition as Asia's "demographic gift," and speculate that it may be responsible for as much as 0.5-1.3% in accelerated annual growth over the period 1965-1990, or 15-40% of the region's total growth performance.

Health indicators and recent national economic growth performance

In analyzing cross-country data over the past quarter century, David Bloom and Jeffrey Sachs offer empirical evidence that health and demographic variables play an extremely important role in determining economic growth rates (Bloom and Sachs 1998, 1998:207-95). In 1965, an increase of life expectancy of one percent accounted for an acceleration of GDP/capita growth of over 3% each year for the subsequent quarter century. In addition, health and demographic variables explained over half of the difference in growth rates between Africa and the rest of the world over the period 1965-1990, and the proportion of land area between the Tropics— a geographical variable which operates largely by impacting human health— accounts for an additional 16% of this gap.

In addition, as table 1 shows, increased infant mortality and fertility rates both have a very strong negative impact on overall growth. Column 1 adds infant mortality rates to the basic growth model presented by Bloom and Sachs. Infant mortality replaces life expectancy as a powerful predictor of economic growth; a reduction of infant mortality by two per thousand live births accounts for a one percent acceleration of growth rates over the subsequent quarter century in the 75 countries for which data are available. In column 2, we add fertility rates to this equation, slightly reducing the magnitude and fit of the infant mortality variable, suggesting that some of the growth dampening effect of infant mortality may operate by inflating fertility rates. High fertility rates appear to be among the best predictors of poor economic growth performance; reducing fertility rates by two children per woman appears to account for a one percent acceleration of growth each year over the subsequent quarter century. Columns 3, 4, and 5 examine growth rates over the period 1980-1995. As in the 1965-1990 period, health indicators played an important role in determining growth rates during this period.

Wealth, geography, and other health determinants

<u>The role of economic performance in predicting health</u>

Improved health is both cause and consequence of economic success. The direct role played by national economic performance in long term health improvements has proven difficult to characterize, however. For example, changes in average national life expectancies over the past several decades have been much less disparate than changes in national output per person (see figure 3). Samuel Preston (Preston Vol. 29:231-48) examines the relationship between life expectancy at birth and national economic performance at three points in time. He observes that this relationship shifted throughout the first 60 years of the 20th century; although the relationship between income and life expectancy is extremely robust at any point in time, life expectancy can be observed to increase over time even after holding income constant. This observation suggests that the spectacular improvements in human health which have been observed over the past half century are not entirely explained by economic success at the national level. Preston observes that in fact only 10-25 percent of the increase in life expectancy between the 1930s and 1960s may be explained by factors directly related to national economic performance. Among the factors exogenous to income at the national level, global improvements in health technologies and practices may be the most important. However, Preston’s conclusions have spawned much debate among scholars. For example, Fogel suggests that improvements in nutrition, resulting from increasing personal and household wealth, have largely driven the “technophysio” evolutionary process over the past three centuries. S. Ryan Johansson and Carl Mosk (Johansson and Mosk 1987, 41:207-35) discuss this debate in detail, adding the results of their own research in pre- and post-war Japan.

The role of geography and other factors in predicting health

While income is an important predictor of overall health and well-being, many geographical and demographic factors also play an important role. Here, we explain life expectancy at birth and under 5 survival rates as functions of an array of economic, infrastructural, geographic, and other variables. Under 5 survival is itself a major predictor of life expectancy at birth, since the first five years of life have historically been by far the most precarious before old age. (However, in the next decades, increasing proportions of 15-49 year olds worldwide will succumb to the AIDS pandemic; this will no doubt affect the relative importance of child mortality in predicting life expectancy). Therefore, the models which explain these two variables are likely to be very similar.

In addition to income, factors which may be expected to account for under 5 survival on a national level include population density, the competence of primary caregivers, the prevalence of certain important childhood diseases, nutritional factors, and other geographic factors. Sparser populations are more difficult for health services to reach; increasing population density, therefore, would be expected to improve a child's chances of surviving to the fifth birthday. Ethnographic studies indicate almost universally that at the household level, women provide most of the direct care for children; many child survival programs, therefore, have sought to improve women's education (Thomas, Strauss, and Henriques Vol. 26:183-211). Female literacy rates function as an indicator of women's accessibility to these outreach efforts, as well as their overall ability to remain informed about issues vital to their children's survival; increasing literacy rates would be expected to improve childhood survival. The etiological agent responsible for more deaths of children under 5 worldwide than any other is *Plasmodium falciparum*, the parasite which causes the fatal form of malaria (Murray and Lopez 1996); increasing risk of malaria infection would be expected to be extremely detrimental to child survival. Much of the rest of child mortality worldwide is accounted for by vaccine preventable diseases— most notably diphtheria, tetanus, and measles (Murray and Lopez 1996). Increasing vaccination rates are likely to have a positive impact on child survival. Other devastating infectious diseases, including pneumococcal pneumonia, respiratory disease, diarrheal diseases, and meningitis have a powerfully negative impact on child survival; cross country data on incidence rates of these diseases, however, is sorely lacking, and therefore cannot be included in this analysis. Among the most important nutritional deficiencies which put child survival at risk is protein energy malnutrition (PEM), which accounts for about 75% of childhood death from nutritional conditions (Murray and Lopez 1996). PEM exists in two forms— kwashiorkor, which results from deficient protein intake as a proportion of total calories, and marasmus, which results from extreme deficiency in overall calorie supply. Therefore, a larger proportion of proteins in the total calorie supply, as well as an increasing overall calorie supply, can be expected to improve the chances of child survival. Island geography is highly advantageous in efforts to control vector-borne diseases like malaria, yellow fever, dengue fever, etc. This island effect is tested with an island/archipelago dummy variable. Finally, child mortality in Africa is by far the highest in the world; therefore, an Africa dummy is included.

Table 2 reports under 5 survival rates (survivors per 1000 live births) as a function of these variables. The first two columns consider per capita supplies of calories and protein independently. Increasing female literacy, population density, and income improve child survival in a statistically significant manner; however, the effect of increasing income is quadratic and concave. Risk of falciparum malaria and location within central or southern Africa are the primary predictors of reduced survival rates; a child born in central or southern Africa stands a 2.4% greater chance of dying before the fifth birthday than a child born into similar circumstances outside the region. The effect of immunization against diphtheria, pertussis, and tetanus is of the expected magnitude and sign, and is statistically significant at the 5% level. Island geography does not appear to have a statistically significant impact on child survival rates, although the coefficient is positive, as expected. Column 3 includes the basic specification, including the interaction between protein supply and calorie supply. Controlling for calorie supply, protein availability is a very important predictor of child survival; an increase of 1% in protein availability per capita improves a child's chances of survival to the fifth birthday by over 4%. Adding non-protein calories appears deleterious, possibly due to an increase in kwashiorkor incidence. Column 4 simply drops the insignificant male literacy and island/archipelago variables from the equation.

Table 3 reports infant survival as a function of these variables. As expected, the basic specification (in column 3) is very similar to the basic specification for under 5 mortality. The most notable difference is in the coefficient of immunization coverage, which is a more important predictor of infant survival than under 5 mortality, statistically significant at the 5% level. Increasing immunization coverage by 1% would improve an infant's chances of surviving to the first birthday by almost 2%. In addition, the risk of infection by falciparum malaria is less predictive of infant mortality than under 5 mortality. This is in keeping with the observation that deaths due to malaria are rare in very young children, and under the most common epidemiological conditions in malarious areas, malaria deaths occur between age 2 and age 5.

Table 4 reports child survival in 1980 as a function of these variables. The most notable difference between the conditions in 1980 and 1995 is in the role of nutrition. A positive quadratic and concave relationship between either calorie or protein supply and child survival can be observed. In addition, it appears that the form of the relationship between income and child survival in 1980 may have been more linear in logarithms.

Life expectancy at birth may be expected to be affected by many of the same factors as child and infant survival. However, there are a number of important factors which impact longevity outside of the 0-5 year age range. Therefore, in addition to income, population density, literacy rates, childhood immunization, risk of malaria, and nutrition, we consider the importance of the adult disease tuberculosis, and the proportion of the population who are living abroad as refugees (used here as an indication of internal violence, political upheaval, or infrastructural collapse).

While the ratio of protein to non-protein calories is extremely important for child survival, nutrition may be expected to impact overall longevity in other ways. The availability of sufficient energy above the absolute minimum required for basal metabolism, as well as an adequate supply of specific nutrients, is essential for sustained immunocompetence and efficient physiological function which defend the body against infectious and chronic illness at all ages (Costa and Fogel 1995,; Chandra 1991, 374:129-32; Harbige 1996, 10:285-312). In addition to providing this needed energy, higher overall calorie supply suggests a greater likelihood that these specific nutrients are available. Therefore, increasing overall calorie supply may be expected to improve longevity, while the impact of protein availability is likely to be less pronounced here than in the child survival equations.

Tuberculosis is the leading infectious killer of humankind, causing about 3 million deaths each year (World Health Organization 1998,). Partially as a result of the HIV/AIDS pandemic, tuberculosis will pose an even greater threat in the future; almost a third of AIDS deaths worldwide are caused by tuberculosis. Increasing tuberculosis incidence may be predicted to impact negatively on longevity. The proportion of a country's population who have fled as refugees indicates the extent of recent infrastructural collapse, internal strife, or violence. These factors can all be predicted to impact negatively on longevity, as well. Finally, since life expectancies in Africa and the former socialist countries are on average the lowest in the world, dummies for these regions are included.

Table 5 reports log of life expectancy at birth as a function of these variables. The results in column 1 suggest that in contrast to the child survival equation, the effect of per capita income on longevity appears to be linear in logarithms. Higher population densities and female literacy rates, as expected, improve longevity in a statistically significant manner. As in the child survival equations, male literacy rates appear to have no discernible effect, although surprisingly, the coefficient on childhood immunization rates also does not appear to be statistically significant. As expected, falciparum malaria endemicity, tuberculosis incidence, and conditions leading to refugee emigration all predict shorter life expectancies, although the effect of refugee emigration not very statistically significant. The impact of overall calorie supply appears to be quadratic and concave, as expected, although in this specification the coefficients are not statistically significant at the 5% level. Finally, life expectancy in sub-Saharan Africa and the post-socialist transition countries are discontinuously low— over 8% lower in Africa, and 4% lower in the transition countries.

Dropping the highly insignificant male literacy and immunization variables and testing a linear relationship between the logs of income and life expectancy, we arrive at the basic specification shown in column 2. The effects of overall calorie availability and conditions leading to refugee emigration remain the same in this specification, and are now statistically significant at the 5% level. Testing for the effect of protein supply in column 3, we find that as expected it is less pronounced than overall calorie supply in determining life expectancy. In this equation, all other variables remain unchanged. In the child survival equations, it was possible to localize the “Africa effect” to Central and Southern Africa. However, as shown in column 4, this sort of localization is not possible in the life expectancy equation, although interestingly controlling for location within Central and Southern Africa reduces both the fit and magnitude of the nutrition variables. As in the child survival equations, column 5 shows that the “island effect” does not appear to be statistically significant.

In columns 6 and 7, we control for child survival in order to determine the extent to which these factors impact on longevity through their effect on under 5 mortality. As expected, improving a child's chances of survival to the fifth birthday by 1% improves life expectancy by 1%. Furthermore, most of the impact of virtually every variable in the basic specification appears to be through child survival. Interestingly, however, even after controlling for differences in child survival, life expectancies remain over 5% lower in Africa than in similar conditions outside of Africa, and severe malaria endemicity correlates with an almost 8% reduction in life expectancy. Because refugee data are only available for four fifths of our sample, we drop the emigration variable in column 7, and test the impact of child survival on life expectancy in the larger sample.

Table 6 shows regressions of the change in infant mortality rates over two periods against economic, nutritional, and geographic variables. Worldwide, infant mortality rates declined by an average of 21 per 1000 live births during the period 1980-1995, and 38 per 1000 live births during the period 1970-1992. The decline was more rapid in countries with higher initial infant mortality, indicating convergence over time. National economic growth is a statistically significant predictor of declining mortality over the shorter period but not the longer period, perhaps confirming Preston's observations on the long-term role of national economic performance in health improvements. Immunization has been an extremely important part of improvements in infant mortality rates worldwide; an increase of one percent in vaccine coverage rates over the period 1980-1995 accounts for an acceleration of the rate of convergence by 0.25 per 1000 live births. Infant mortality rates in malaria endemic countries and in Africa, however, have been substantially slower to converge with those of the rest of the world. Peculiarly, three countries— Sierra Leone, Zambia, and Rwanda— performed particularly badly, possibly due to severe infrastructural collapse near the end of both periods.

Conclusion: Unanswered questions and possible policy implications

The effort to understand the impact of health status on economic performance at the national level has recently received increasing attention. The evidence suggests that the remarkably robust correlation between economic and health indicators cannot simply be adduced to the fact that richer populations are better able to maintain good health; a number of factors exogenous to income also appear to be important predictors of health status. For example the endemicity of particular diseases appears to play an important role, and is often the result of conditions of climate, geography, topography, and evolutionary history. In addition, nutritional status, which is largely a result of distinct scientific challenges to agricultural productivity, also appears to play a role.

It seems likely, therefore, that the relationship between good health and economic status might be cyclical in nature. Improved health may bring about economic success, just as economic success brings about improvements in health. However, a number of important questions remain. For example:

1) What are the long-term demographic impacts of high childhood mortality? What are the economic consequences of these impacts?
2) To what extent do environmental or geographically conditioned diseases like malaria impede inter- and intranational traffic, commerce, and trade and hence economic growth?
3) What are the long term impacts of poor nutrition, in terms of longevity, productivity, cognitive development, and other aspects of human capital?
4) How important are the relative effects of national economic growth and global technological improvements in improving general human health and well-being?
5) How are changing patterns of technological development, changes in biodiversity, global climate change, and other trends enhancing the importance of ecology, climate, and other scientific factors in bringing about poor health?

6) In the face of simultaneous effects, how can the correlation between health and economic well-being be more fully understood?

Important empirical and analytical challenges remain in answering these and similar questions. Further research is essential to understanding the nature and extent of the relationships between economic and health status.

The results of such research could have important policy implications. For example, to the extent that health interventions result not only in proximate improvements to human longevity and well-being but also in long-term improvements to economic performance, their cost-effectiveness may often be underestimated. Simultaneous effects of health on wealth and wealth on health imply the existence of “multiple equilibria.” Under the bad equilibrium, ill health brings about poverty, which brings subsequent ill health; a population remains stably sick and stably poor in the long-term. Under good equilibrium conditions, improved health brings about economic growth, which enhances human longevity and well being. To the extent that these multiple equilibria exist, policies of intensified health interventions which improve a sick population’s chances of transition to the good equilibrium may be indicated. Identifying and understanding these dynamics may also improve policy-making in fields as diverse as family planning, public health, economic planning, infrastructural development, trade policy, and many others.

Reference List

Asian Development Bank. 1997. *Emerging Asia: Changes and challenges*. Manila: Asian Development Bank.

Bloom David E. and Jeffrey D. Sachs. 1998. Geography, Demography, and Economic Growth in Africa. *Brookings Papers on Economic Activity* 1998(2) 207-95.

Brinkley Garland Lee. 1994. *The Economic Impact of Disease in the American South, 1860-1940*. Ph.D. dissertation, University of California at Davis.

Chandra R. K. 1991. Immunocompetence is a sensitive and functional barometer of nutritional status. *Acta Paediatrica Scandinavica* 374(Supplement) 129-32.

Chen Lincoln. 1994. *New Diseases: The human factor*. Chap. in *Disease in Evolution: Global changes and emergence of infectious disease*. New York: New York Academy of Sciences. 319-24.

Costa Dora L. and Robert Fogel. 1995. *Long-term Trends in Health, Welfare, and Economic Growth in the United States*. NBER Historical Paper 76. http://www.nber.org (Unpublished).

Curtin Philip D. 1998. *Disease and Empire*. Cambridge: Cambridge University Press.

Duffy John. 1988. *The Impact of Malaria on the South*. Chap. in *Disease and Distinctiveness in the American South*. Knoxville: University of Tennessee Press. 29-54.

Dufour B. 1999. Technical and economic evaluation method for use in improving infectious animal disease surveillance networks. *Veterinary Research* 30(1) 27-37.

Ettling John. 1981. *The Germ of Laziness: Rockefeller philanthropy and public health in the New South*. Cambridge, MA: Harvard University Press.

Farmer Paul. 1999. *Infections and Inequalities: The modern plagues*. Berkeley: University of California Press.

Fogel Robert W. 1997. A Theory of Technophysio Evolution, with Some Implications for Forecasting Population, Health Care Costs, and Pension Costs. *Demography* 34(1) 49-66

Fogel Robert W. 2000. Catching Up with the Economy. *American Economic Review* 89(1) 1-21

Fogel Robert W. Early Indicators of Later Work Levels, Disease, and Death. *National Bureau of Economic Research Working Paper Series on Historical Factors in Long Run Growth: 38.* http://www.nber.org (Unpublished)

Frank John W. and J. Fraser Mustard. 1994. The Determinants of Health from a Historical Perspective. *Daedalus* 1994(1) 1-19.

Gallup John L., Jeffrey D. Sachs, and Andrew D. Mellinger. 1998. *Geography and Economic Development*. Chap. in *World Bank Annual Conference on Development Economics*. Washington, D.C.: World Bank. 127-78.

Garrett Laurie. 1994. *Human Movements and Behavioral Factors in the Emergence of Diseases*. Chap. in *Disease in Evolution: Global changes and emergence of infectious disease*. New York: New York Academy of Sciences. 312-8.

Godfrey K., S. Robinson, D. J. Barker, C. Osmond, and V. Cox. 1996. Maternal nutrition in early and late pregnancy in relation to placental and fetal growth. *BMJ* 312(7028) 410-4.

Gregson Simon, Geoffrey P. Garnett, and Roy M. Anderson. 1994. Assessing the Potential Impact of the HIV-1 Epidemic on Orphanhood and the Demographic Structure of Populations in sub-Saharan Africa. *Population Studies* 48(2) 435-58.

Gunawardena D. M., A. R. Wickremasinghe, L. Muthuwatta, S. Weerasingha, J. Rajakaruna, T. Senanayaka, P. K. Kotta, N. Attanayake, R. Carter, and K. N. Mendis. 1998. Malaria risk factors in an endemic region of Sri Lanka, and the impact and cost implications of risk factor-based interventions: Some entomological aspects of the malaria eradication pilot project in Malaya. *American Journal of Tropical Medicine & Hygiene* 58(5) 533-42.

Hadidjaja P., E. Bonang, M. A. Suyardi, S. A. Abidin, I. S. Ismid, and S. S. Margono. 1998. The effect of intervention methods on nutritional status and cognitive function of primary school children infected with Ascaris lumbricoides. *American Journal of Tropical Medicine & Hygiene* 59(5) 791-5.

Hamoudi Amar and Jeffrey D. Sachs. 1999. *The Changing Global Distribution of Malaria: A review*. CID Working Paper no. 2. http://www.cid.harvard.edu (unpublished)

Harbige L. S. 1996. Nutrition and immunity with emphasis on infection and autoimmune disease. *Nutrition & Health* 10(4) 285-312.

Hauser Robert M. 1998. *In Support of the Nutrition Theory*. Chap. in *The Rising Curve: Long-term gains in IQ and related measures*. Washington, DC: American Psychological Association. 207-18.

Hoet J. J. and M. A. Hanson. 1999. Intrauterine nutrition: its importance during critical periods for cardiovascular and endocrine development. *Journal of Physiology* 514(Pt 3) 617-27.

Hotez P. J. 1989. Hookworm disease in children. *Pediatric Infectious Disease Journal* 8(8) 516-20.

Hotez P. J. and D. I. Pritchard. 1995. Hookworm infection. *Scientific American* 272(6) 68-74.

Inman Robert P. The Economic Consequences of Debilitating Illness: The Case of Multiple Sclerosis. *Review of Economics & Statistics* 69(4) 651-60

Johansson S. Ryan and Carl Mosk. 1987. Exposure, Resistance, Life Expectancy: Disease and death during the economic development of Japan, 1900-1960. *Population Studies* 41(2) 207-35.

Kelley Allen C. and Robert M. Schmidt. 1996. Saving, Dependency and Development. *Journal of Population Economics* 9(4) 365-86

Kitching R. P. 1999. Foot-and-mouth disease: current world situation. *Vaccine* 13-14 1772-4.

Kremer, Michael. 1999. “Purchase Pre-Commitments for New Vaccines: Rationale and a Proposed Design.” Department of Economics, Harvard University (unpublished)

Kvalsvig J. D., R. M. Cooppan, and K. J. Connolly. 1991. The effects of parasite infections on cognitive processes in children. *Annals of Tropical Medicine & Parasitology* 85(5) 551-68.

Levav M., A. F. Mirsky, P. M. Schantz, S. Castro, and M. E. Cruz. 1995. Parasitic infection in malnourished school children: effects on behaviour and EEG. *Parasitology* 110(Pt 1) 103-11.

Lewis N. D. 1986. Disease and development: ciguatera fish poisoning. *Social Science & Medicine* 23(10) 983-93.

Martorell Reynaldo. 1998. *Nutrition and the Worldwide Rise in IQ Scores*. Chap. in *The Rising Curve: Long-term gains in IQ and related measures*. Washington, DC: American Psychological Association. 183-206.

McNeill William Hardy. 1989. *Plagues and Peoples*. New York: Anchor Books.

Montresor A., C. Urbani, B. Camara, A. B. Bha, M. Albonico, and L. Savioli. 1997. [Preliminary survey of a school health program implementation in Guinea]. [French]. *Medecine Tropicale* 57(3) 294-8.

Murray Christopher J. L. and Alan D. Lopez. 1996. *The Global Burden of Disease*. Boston: Harvard University Press.

Mushkin Selma J. 1962. Health as an Investment. *Journal of Political Economy* 70(5) 129-57.

Nokes C., S. M. Grantham-McGregor, A. W. Sawyer, E. S. Cooper, and D. A. Bundy. 1992. Parasitic helminth infection and cognitive function in school children. *Proceedings of the Royal Society of London - Series B: Biological Sciences* 247(1319) 77-81.

Ostroff S. M. and P. Kozarsky. Emerging infectious diseases and travel medicine. [Review] [74 refs]. *Infectious Disease Clinics of North America* 12(1) 231-41.

Over Mead. 1992. *The Macroeconomic Impact of AIDS in sub-Saharan Africa*. Population and Human Resources Department, World Bank. http://www.worldbank.org

Preston Samuel H. The Changing Relation between Mortality and Level of Economic Development. *Population Studies* 29(2) 231-48

Ramirez Alejandro, Gustav Ranis, and Frances Stewart. 1997. *Economic Growth and Human Development*. EGC Discussion Paper 787 http://www.yale.edu (Unpublished).

Reher David. Wasted Investments: Some Economic Implications of Childhood Mortality Patterns. *Population Studies* 49(3) 519-36

Schultz T. Paul. Assessing the Productive Benefits of Nutrition and Health: An Integrated Human Capital Approach. *Journal of Econometrics* 77(1) 141-58

Schultz T. Paul. 1997. *Demand for Children in Low Income Countries*. Chap. in *Handbook of Population and Family Economics*. Elsevier Science. 350-430.

Schultz T. Paul and Aysit Tansel. 1996. Wage and Labor Supply Effects of Illness in Cote D'Ivoire and Ghana: Instrumental Variable Estimates for Days Disabled. *Journal of Development Economics* 53(2) 251-86

Sigman Marian and Shannon E. Whaley. 1998. *The Role of Nutrition in the Development of Intelligence*. Chap. in *The Rising Curve: Long term gains in IQ and related measures*. Washington, DC: American Psychological Association. 155-82.

Strauss John and Duncan Thomas. 1998. Health, Nutrition, and Economic Development. *Journal of Economic Literature* 36(2) 766-817

Thomas Duncan, John Strauss, and Maria Henriques. How Does Mother's Education Affect Child Height? *Journal of Human Resources* 26(2) 183-211

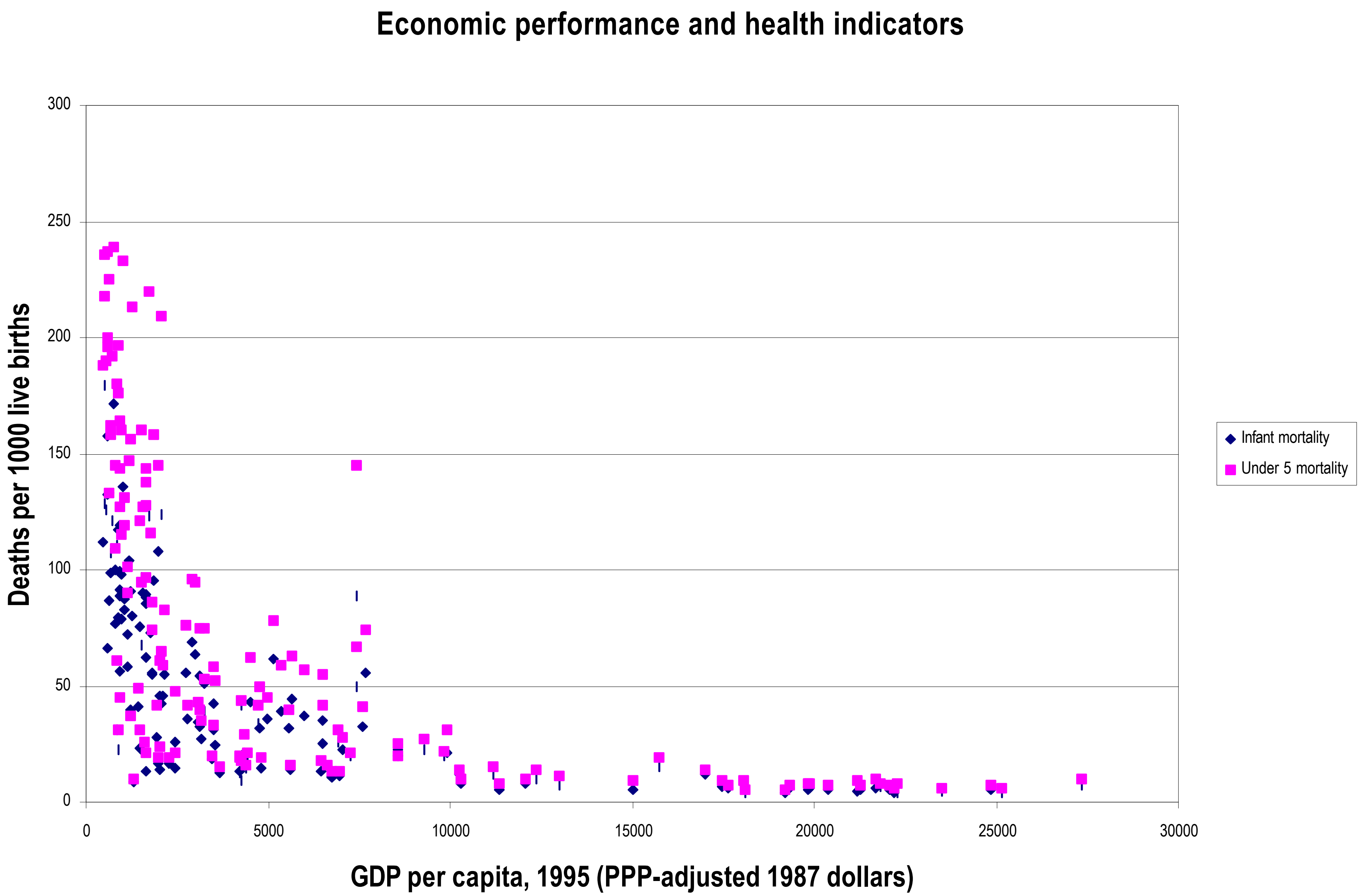
UNAIDS. 1999. *AIDS Epidemic Update: December 1998*. Joint United Nations Programme on HIV/AIDS. http://www.unaids.org

White N. J. 1996. *Malaria*. Chap. in *Manson's Tropical Diseases*. Twentieth ed. London: WB Saunders Company, Ltd. 1087-164.

World Health Organization. 1997. World malaria situation in 1994. *Weekly Epidemiological Record* 36-38 269-90.

World Health Organization. 1998. *WHO Report on the Global Tuberculosis Epidemic, 1998*. Geneva: World Health Organization.

Figure 1



Economic performance and health indicators
Deaths per 1000 live births
300
250
200
150
100
50
0
0
5000
10000
15000
20000
25000
30000
GDP per capita, 1995 (PPP-adjusted 1987 dollars)
Infant mortality
Under 5 mortality

Figure 2

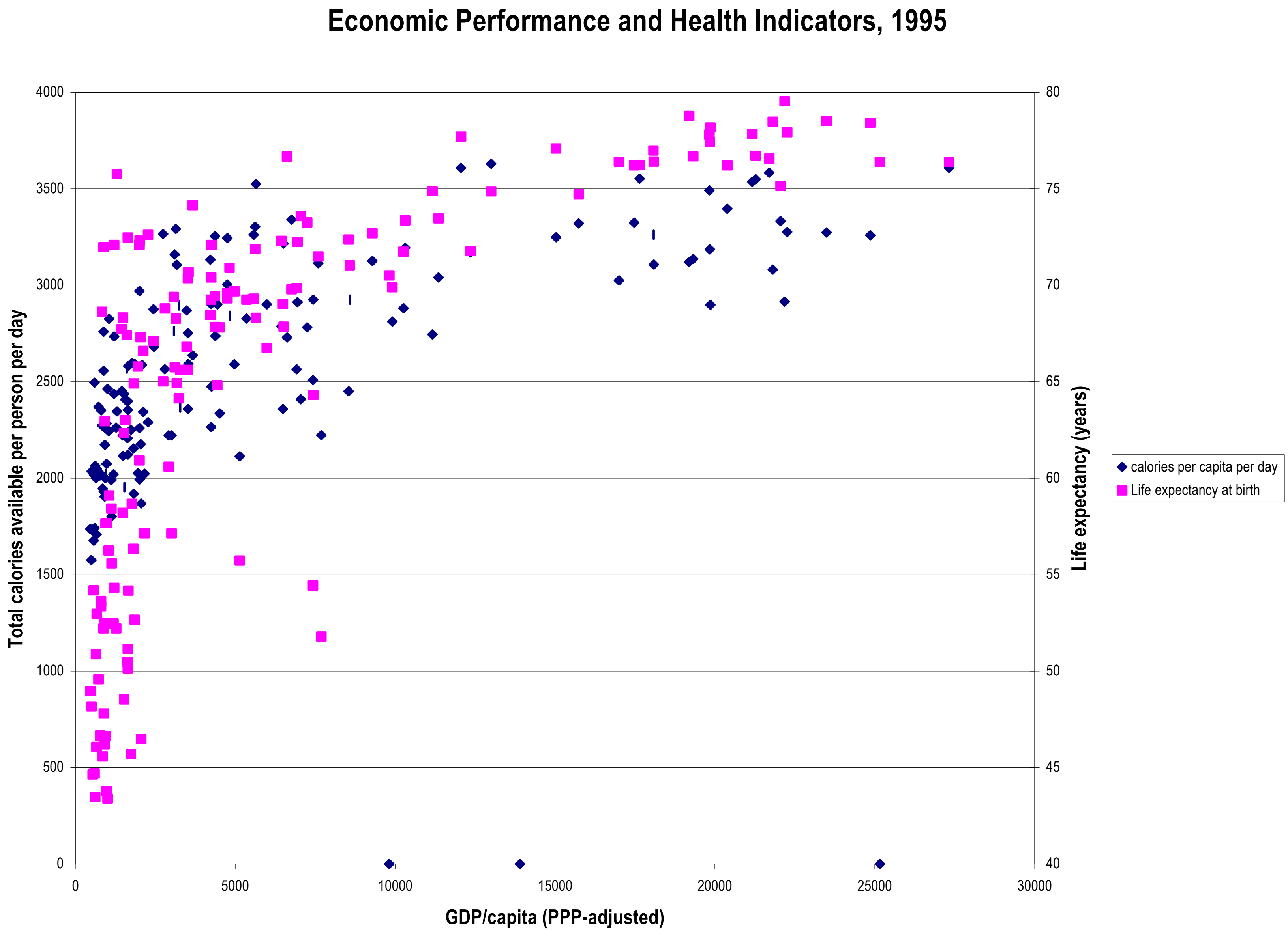

Economic Performance and Health Indicators, 1995
Total calories available per person per day
Life expectancy (years)
GDP/capita (PPP-adjusted)
calories per capita per day
Life expectancy at birth
0
500
1000
1500
2000
2500
3000
3500
4000
40
45
50
55
60
65
70
75
80
0
5000
10000
15000
20000
25000
30000

Table 1

Average annual GDP per capita growth, period:	(1) 1965-1990	(2) 1965-1990	(3) 1980-1995	(4) 1980-1995	(5) 1980-1995
Log GDP per worker, beginning of period	-.019 (7.46)**	-.020 (7.94)**	-.025 (6.16)**	-.025 (6.42)**	-.028 (12.10)**
Index, Quality of Institutions, 1980	0.001 (1.22)	0.001 (0.82)	0.004 (3.17)**	0.004 (3.00)**	0.002 (1.99)
Proportion, years open to international trade, 1965-1980	0.018 (5.16)**	0.017 (4.94)**	0.025 (4.29)**	0.024 (4.55)**	0.024 (5.49)**
Net gov't savings (% GDP)	0.002 (4.37)**	0.001 (4.34)**	0.002 (4.09)**	0.002 (3.89)**	0.002 (3.85)**
Tropical land area (proportion of total)	-.010 (2.46)*	-.010 (2.79)**	-.012 (2.39)*	-.015 (2.48)*	-.017 (4.26)**
Log, coastal population density, beginning of period	0.002 (3.17)**	0.002 (2.52)*	0.002 (1.69)	0.001 (1.39)	0.000 (0.45)
Growth rate, total population over period	-1.224 (1.81)	-1.314 (2.31)*	-1.459 (2.73)**	-1.402 (2.63)*	-.942 (1.59)
Growth rate, working age pop. over period	1.443 (2.78)**	1.954 (4.29)**	1.814 (3.78)**	1.810 (3.81)**	2.235 (4.82)**
Log, life expectancy at birth, beginning of period	-.002 (0.11)	-.006 (0.31)	0.072 (3.53)**	0.017 (0.52)	-.023 (0.69)
Infant mortality rate (per 1000 live births), beginning of period	0.0002 (2.27)*	0.0002 (1.95)		0.0002 (1.93)	0.0002 (2.54)*
Fertility rate (children per woman), beginning of period		-.005 (2.71)**			-.010 (4.35)**
Log, protein supply per capita, 1965	0.013 (1.62)	0.009 (1.21)			
Dummy (sub-Saharan Africa)	-.005 (1.12)	-.005 (1.04)	-.008 (1.19)	-.012 (1.86)	-.009 (1.32)
Constant	-.011 (0.13)	0.038 (0.48)	-.102 (1.47)	0.145 (1.05)	0.374 (2.65)*
Number of observations	75	75	78	78	78
R-squared	0.81	0.83	0.77	0.78	0.83

Absolute value of robust t-statistics in parentheses
* significant at 5% level; ** significant at 1% level

Figure 3


Changes in income and life expectancy, 1965-1992
(N=78)
Frequency
1995
PPP GDP per capita (constant 1985 dollars)
Life expectancy at birth (years)
65
0
292
2537.2
5346.4
11638
25
33.5
54.4
66.5
74.1
408
5194.5
10448
17945
34.4
64.6
76 79.1

Table 2

Survivors to age 5 per 1000 live births, 1995	1	2	3	4
Log PPP GDP per capita, 1995	102.036 (3.40)**	108.175 (3.60)**	133.697 (4.21)**	135.324 (4.24)**
Log PPP GDP per capita squared, 1995	-5.096 (2.88)**	-5.694 (3.15)**	-7.051 (3.74)**	-7.073 (3.73)**
Log population density, 1995	3.157 (1.99)*	2.539 (1.62)	3.673 (2.25)*	4.478 (2.89)**
Adult literacy (female) 1995	1.342 (5.19)**	1.330 (5.28)**	1.184 (4.61)**	0.915 (8.87)**
Adult literacy (male) 1995	-.592 (1.61)	-.631 (1.77)	-.443 (1.23)	
DPT coverage, 1994-95	30.925 (2.18)*	27.354 (1.93)	24.992 (1.79)	19.867 (1.44)
Falciparum malaria risk, 1994	-36.026 (4.73)**	-34.624 (4.28)**	-32.504 (4.05)**	-33.103 (4.12)**
Log calorie supply/capita/day, 1995	-11.349 (0.63)		-56.022 (2.21)*	-66.459 (2.69)**
Log g protein available/person/day, 1995		16.048 (1.37)	42.336 (2.55)*	42.807 (2.61)*
Dummy: Island or archipelago	4.891 (0.73)	8.645 (1.28)	8.103 (1.22)	
Dummy: Central/Southern Africa	-24.546 (3.26)**	-21.616 (2.95)**	-24.721 (3.36)**	-28.000 (3.93)**
Constant	459.132 (2.70)**	300.846 (2.14)*	505.895 (3.04)**	559.456 (3.39)**
Number of observations	133	132	132	132
R-squared	0.90	0.90	0.90	0.90

Absolute value of t-statistics in parentheses
* significant at 5% level; ** significant at 1% level

Table 3

Infants surviving per 1000 live births, 1995	1	2	3
Log PPP GDP per capita, 1995	60.932 (3.27)**	69.769 (3.77)**	83.325 (4.20)**
Log PPP GDP per capita squared, 1995	-2.980 (2.71)**	-3.634 (3.25)**	-4.359 (3.70)**
Log population density, 1995	1.731 (1.76)	1.693 (1.75)	2.299 (2.27)*
Female literacy rate, 1995	0.600 (9.34)**	0.581 (9.06)**	0.570 (8.92)**
DPT coverage, 1994-1995	18.509 (2.19)*	17.158 (2.05)*	16.973 (2.04)*
Falciparum malaria risk	-14.571 (3.14)**	-12.119 (2.46)*	-10.693 (2.16)*
Log calorie supply/capita/day, 1995	2.051 (0.18)		-27.805 (1.81)
Log g protein available/capita/day, 1995		15.628 (2.15)*	28.738 (2.81)**
Dummy: Island or archipelago	2.735 (0.66)	4.942 (1.21)	4.298 (1.06)
Dummy: Central or Southern Africa	-16.545 (3.69)**	-14.623 (3.32)**	-15.668 (3.56)**
Constant	582.962 (5.58)**	506.570 (5.83)**	606.414 (5.93)**
Number of observations	134	133	133
R-squared	0.89	0.90	0.90

Absolute value of t-statistics in parentheses
* significant at 5% level; ** significant at 1% level

Table 4

Survivors to age 5 per 1000 live births, 1980	1	2	3	4
Log GDP per capita, 1980	118.043 (3.07)**	89.825 (2.29)*	106.867 (2.84)**	15.920 (3.82)**
Log GDP per capita squared, 1980	-6.205 (2.66)**	-4.481 (1.89)	-5.372 (2.33)*	
Log population density, 1980	3.796 (2.64)**	3.875 (2.82)**	4.462 (3.22)**	4.132 (2.98)**
Female literacy rate, 1977-1985	0.587 (4.88)**	0.587 (4.97)**	0.631 (5.31)**	0.633 (5.39)**
Falciparum malaria risk	-26.035 (2.44)*	-26.482 (2.71)**	-20.418 (1.93)	-26.893 (2.71)**
Log Calorie supply/capita/day, 1980	25.272 (0.84)	1684.131 (1.81)		2417.093 (2.82)**
Log Calorie supply squared/capita/day, 1980		-105.974 (1.79)		-152.685 (2.79)**
Log g protein available/capita/day, 1980	-.822 (0.04)		439.274 (2.02)*	
Log g protein squared available/capita/day, 1980			-51.462 (1.97)	
Dummy: sub-Saharan Africa	-32.616 (3.70)**	-32.112 (3.81)**	-34.628 (4.03)**	-32.348 (3.78)**
Constant	161.985 (0.79)	-6215.691 (1.74)	-546.577 (1.23)	-8792.821 (2.62)*
Number of observations	92	92	92	92
R-squared	0.90	0.90	0.90	0.90

Absolute value of t-statistics in parentheses
* significant at 5% level; ** significant at 1% level

Table 5

Log life expectancy at birth, 1995	1	2	3	4	5	*6*	*7*
Log income per capita, 1995	0.124 (1.27)	0.037 (3.80)**	0.038 (3.72)**	0.038 (3.87)**	0.036 (3.71)**	*0.015* *(1.87)*	*0.012* *(1.52)*
Log income per capita squared, 1995	-.005 (0.89)						
Log population density, 1995	0.012 (2.32)*	0.011 (2.44)*	0.011 (2.32)*	0.009 (1.91)	0.011 (2.31)*	*0.003* *(0.83)*	*0.004* *(1.32)*
Female literacy rate, 1995	0.002 (2.01)*	0.002 (5.44)**	0.002 (5.35)**	0.002 (5.62)**	0.002 (5.20)**	*0.001* *(1.81)*	*0.001* *(1.87)*
Male literacy rate, 1995	0.000 (0.07)						
DPT immunization rate, 1995	0.013 (0.31)						
Risk of falciparum malaria, 1994	-.117 (3.73)**	-.121 (4.21)**	-.117 (3.58)**	-.122 (4.25)**	-.121 (4.20)**	*-.079* *(3.45)***	*-.054* *(2.96)***
TB incidence per 1000 population, 1996	-.024 (2.23)*	-.022 (2.16)*	-.022 (1.98)	-.021 (2.03)*	-.023 (2.23)*	*-.009* *(1.15)*	*-.019* *(3.17)***
Log refugees per capita, 1996	-.859 (1.90)	-.897 (2.10)*	-.923 (2.08)*	-1.003 (2.32)*	-.887 (2.07)*	*-.478* *(1.43)*	
Log calorie supply/capita/day, 1995	3.567 (1.39)	4.381 (2.03)*	3.602 (1.19)	3.193 (1.38)	4.369 (2.02)*	*1.942* *(1.16)*	*2.643* *(1.62)*
Log calorie supply squared/capita/day, 1995	-.230 (1.40)	-.281 (2.05)*	-.232 (1.20)	-.207 (1.40)	-.280 (2.03)*	*-.125* *(1.17)*	*-.168* *(1.61)*
Dummy: sub-Saharan Africa	-.083 (3.27)**	-.088 (3.73)**	-.089 (3.47)**	-.082 (3.38)**	-.087 (3.64)**	*-.054* *(2.90)***	*-.057* *(3.84)***
Dummy: post-socialist transition	-.041 (2.15)*	-.037 (2.20)*	-.038 (2.16)*	-.038 (2.26)*	-.035 (2.01)*	*-.048* *(3.73)***	*-.048* *(3.83)***
Log g protein available/person/day			0.333 (0.51)				
Log g protein available squared/person/day			-.038 (0.48)				
Dummy: Central or Southern Africa				-.036 (1.35)			
Dummy: island or archipelago					0.013 (0.70)		
Survivors to age 5 (per 1000 live births)						*0.002* *(8.33)***	*0.001* *(8.61)***
Constant	-10.422 (1.05)	-13.272 (1.57)	-10.896 (1.00)	-8.551 (0.94)	-13.236 (1.56)	*-4.912* *(0.75)*	*-7.692* *(1.20)*
Number of observations	103	108	107	108	108	*107*	*133*
R-squared	0.92	0.93	0.93	0.93	0.93	*0.96*	*0.94*

Absolute value of t-statistics in parentheses
* significant at 5% level; ** significant at 1% level

Table 6

Change in infant mortality rate (deaths per 1000 live births), period:	1980-1995	1970-1992
Infant mortality rate, beginning of period	-.461 (13.35)**	-.496 (16.13)**
Change in log GDP per capita over period	7.233 (2.15)*	-2.512 (0.65)
Change in daily calorie supply per capita over period	-13.993 (1.43)	-13.638 (1.44)
DPT vaccine coverage, beginning of period	-.269 (3.64)**	
Change in DPT vaccine coverage over period	-.247 (3.24)**	
Falciparum malaria index, beginning of period	10.287 (2.04)*	19.902 (4.08)**
Change in falciparum malaria index over period	2.175 (0.29)	27.064 (3.37)**
Sub-Saharan Africa (dummy)	9.661 (2.45)*	11.996 (2.78)**
Sierra Leone, Rwanda, and Zambia (dummy)	47.445 (7.19)**	52.191 (6.70)**
Constant	20.207 (2.93)**	-2.787 (0.94)
Number of observations	78	78
R-squared	0.82	0.84

Absolute value of t-statistics in parentheses

* significant at 5% level; ** significant at 1% level