

## Productive Benefits of Improving Health: Evidence from Low-Income Countries

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### 1. Introduction

The benefits due to improving health in this century are obvious and far-reaching. It is remarkable, therefore, that there is little agreement on how to reckon these benefits and compare them to the costs of achieving such improvements. Four general reasons for this gap in our basic stock of knowledge could be relevant. First, there is no consensus among health specialists on how to conceptualize and summarily measure health status at the individual level. Consequently, developing rigorously validated survey instruments to approximate these measures of health status within a representative survey have progressed slowly. Second, there is a profound reluctance to summarize the benefits of health in terms of only their productive payoffs, or value as “human capital”, because following this path appears inevitably to deny the consumption value of health and marginalize the distinctive aspect of health as a capability that all people want and deserve, regardless of their age, sex, infirmities, or disabilities. Third, self-reported health status involves errors in measurement, even when continuous health indicators of a more objective form are analyzed. Fourth, although, healthier people should be more productive, more-productive people may also spend more resources creating and maintaining their good health. Because of this two-directional relationship, and the omission of other factors that affect a worker’s productivity, labor force participation, and health input behavior, the correlation between individual health and personal productivity is not a satisfactory estimate of the causal (one-directional) effect.

These four barriers to assessing the benefits of improving health may go a long way to account for our ignorance on these matters. But they hardly justify this state of affairs. This situation also contributes to the lack of consensus on how to analyze non-experimental survey data on individuals and families to evaluate many health programs, policies, or developments that are thought to improve health. The priority assigned to health programs and to specific categories of health expenditures are therefore often adjudicated by appeal to the best judgements of professional experts (Murray and Lopez, 1994), or assigned to a residual

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category of social welfare activity, which everyone agrees is desirable but which is not quantitatively evaluated<sup>1</sup>

Section 2 discusses these four barriers to progress and indicates which ones I will focus on. Section 3 sketches a general schematic framework within which the determinants and consequences of health can be analyzed. Section 4 reviews accumulating empirical evidence on some of these critical links giving particular attention to empirical findings from Ghana, Côte d'Ivoire, and Brazil. Section 5 concludes with some ideas on how new data and analytical approaches could be progressed.

## **2. Basic Limitations in Health Evaluation Methods**

### **A. Multiple Indicators of Health**

Health has many dimensions. There may evolve a set of core health indicators, that convey specified information and possess recognized limitations, and some of these health indicators may be approximated from household survey questionnaires. However, in the foreseeable future, it is appropriate to analyze multiple indicators of health, and seek those interventions that increase a group of health indicators in a specified environment.

The most commonly cited health indicator is survival or life expectation given a person's age and sex, which has the appeal of an intrinsic capability on which personal welfare depends (Sen, 1998, 1999). But there is as yet no agreement on how to forecast an individual's expected lifetime. Indicators of survival are estimated as averages for substantial populations for which the number of persons is known and their mortality is accurately registered over time according to the age (and sex) of the individuals. To analyze individual health status on the basis of household surveys, other indicators of health status are examined, despite their limitations.

Without a consensus on how to measure health status at the individual level, four different types of health indicators are evaluated in relationship to wages: (1) self-assessments of health status; (2) morbidity rates; (3) physical functional limitations; and (4) physical growth outcomes. In the first group, self-reported general health status may be compared by the respondent to the health of others (of a similar age, perhaps), ranging from health being much better to much worse than a comparison group. Analyzing the responses of persons of various ages requires strong

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<sup>1</sup> The comparison between program evaluation in health and education is instructive. The relationship between the schooling of workers and their wage rates (or hourly earnings of the self-employed) has been empirically replicated from household sample surveys in scores of countries for the last 30 years, and this descriptive link has gradually attained the status of causal fact in the eyes of most social scientists, though not without long technical debate and extensive exploration of alternative statistical methodologies (Card, 1999). Research into the conceptual, statistical, and empirical methods designed to link the health status and productivity of individuals might go some way toward placing health and education on a similar footing, for the purposes of making policy choices, without denying that both outcomes serve broader social objectives than human capital accumulation or economic growth.

assumptions about the metric and how to control for age in a multivariate framework determining health.<sup>2</sup> Nonetheless, these general indicators of health status are often found to be significantly related to subsequent morbidity and mortality of the individual, and were used in evaluating the Health Insurance Study in the United States (Manning, et al., 1972).

The second group of measures of health status are based on morbidity. Different socioeconomic groups have access to different medical care and possess different knowledge of health needed to self-diagnose illness. Morbidity rates derived from administrative records by region or socioeconomic groups tend to therefore be unreliable evidence of the incidence of illness across individuals, groups, or regions of a low-income country, even when the specific class of morbidity, such as malaria, is reasonably well-identified by the respondent, and even when the law requires specific illnesses to be registered (Alves et al,1999).

Sample surveys also collect self-reported responses on illness or disability (e.g., for a 14, 28, or 180 day retrospective period), or the number of days ill, or days sufficiently ill to be disabled (i.e., unable to engage in one's regular activity). Questions of this form are included in many labor force and general household surveys, but are not commonly analyzed as an indicator of health status, perhaps because they are viewed as unreliably subjective or affected by socioeconomic class or culture (Johansson, 1991).<sup>3</sup> Workers paid on the basis of their time on the job may be discouraged by their employer from reporting for work, if they are sufficiently sick as to be unable to perform their jobs satisfactorily, whereas the self employed may be more latitude for adjusting the physical demands of their job to the current health status of the worker (Schultz and Tansel, 1997). Comparisons of self-reported morbidity rates within socioeconomic strata may also extract less biased information regarding health status (Foster, 1994, 1995).<sup>4</sup>

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<sup>2</sup> Are all individuals of the same age consulting the same benchmark of health, or are they referring to the health status of other persons in their neighborhood or socioeconomic class. In addition, self-reported health status could reflect conditioning experiences and perceptions of the particular individual that are potentially related to her socioeconomic behavior and outcomes, rather than being an objective index of the individual's health status.

<sup>3</sup> Most worrisome is evidence of a tendency for self-assessed morbidity rates to often appear higher in higher-income countries, where the survival (the "gold" standard measure of health) is known to be higher, or for morbidity in some surveys to be reported more frequently in the upper wealth classes of a developing country. How then can the researcher explain these divergent trends in morbidity and mortality (Schultz and Tansel, 1997; Foster, 1994). Differences in the terms and incentives of labor contracts can also affect how many days people miss work due to illness, as when labor contracts specify a worker's right to a certain number days of paid sick leave per year.

<sup>4</sup> On the one hand, many wage workers in a low-income country are casual laborers and are penalized by the loss of their wages if they do not report for work during any given day. Alternatively, if they are caught "working" while ill and presumably less productive, the employer may view the worker as shirking and not employ the individual in the future, damaging his reputation in a small rural labor market. However, if the reported number of days unable to work in the retrospective period is a more informative indicator of productive health status for wage earners than for other persons, some procedure is then needed to correct for sample selection bias (Heckman, 1979), if the statistical

A third type of health indicator is based on functional limitations experienced by people in their performance of tasks of daily living. Activities of Daily Living (ADLs) which can be performed with difficulty (or cannot be performed at all) are derived from survey responses to a sequence of questions, such as, for example, is the respondent capable of walking 300m; of carrying a heavy object such as a pail of water; of engaging in light domestic tasks. In contrast to self-reported general health status, or recent illnesses, or days disabled, the number of functional limitations currently experienced may convey a more concrete health situation, one that may even be observationally validated by the interviewer. It is argued, therefore, that health indicators based on functional limitations (ADLs) tend to be less spuriously correlated with socioeconomic endowments, conditioning factors, and perceptions, and thus less likely to be subjectively biased (Strauss, et al., 1995). Functional limitations appear to approximate a continuum of health states among the elderly for whom these physical limitations on everyday activities are relatively common. Concurrent clinical examinations have also been used to validate the reliability of ADL responses, at least for the elderly in high-income countries (Steward and Ware, 1985). How well ADLs differentiate health status among persons who are younger or are living in very poor rural societies is less well documented. Yet ADLs may reduce subjective bias in measuring health status of adults in a low-income setting and be collected at a relatively moderate cost.

The fourth group of health indicator measures physical growth outcomes associated with health status that result from a lifetime accumulation of nutritional inputs and health care, and are diminished by exposure to infectious disease and the burdens placed on nutrition by work and other strenuous activities (Faulkner and Tanner, 1986; Floud et al. 1990; Fogel, 1994; Strauss and Thomas, 1995, 1997; Steckel, 1995). The health environment and the nutritional inputs of mother and child affect early childhood development, including uterine growth (Barker, 1992; Scrimshaw, 1997), and conditions during the adolescent growth spurt may modify the attainment of adult physical stature and behavioral capabilities (Scrimshaw and Gordon, 1968; Martorell and Habicht, 1986; Martorell, et al., 1994). These physical growth indicators of health include a variety of anthropometric dimensions, the most common being adult height, which is thought to be particularly sensitive to early childhood nutritional/ health status. Because adult height does not change substantially from about age 25 to 55, it provides an easily observed, relatively fixed, indicator of adult health potential and is thought to convey information about early nutritional/health conditions that may proxy more general living standards (Fogel, 1986, 1994; Floud et al. 1990; Steckel, 1995; Strauss and Thomas, 1997). Adult height thus conveniently bridges the widely separated moments in the life cycle when critical health inputs in childhood appear to be important, and the middle period of adulthood when the stock of health human capital is likely to impact on productivity, and the final period in the life cycle when chronic health morbidities increase. To otherwise link data on the entire life cycle from childhood environments to childhood development, to adult functional capacity and productivity is very complex and costly (Waterlow et al. 1977; Beaton et al. 1990; Fogel, 1991; Scrimshaw, 1997).

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relationship between health determinants and reported morbidity rates for wage earners is to be corrected to approximate the relationship for the entire population (Schultz and Tansel, 1997).

Weight-to-height-squared or body mass index (BMI ) reflects a shorter-term nutritional/health status, which at low levels ( less than about 21 as conventionally measured in metric units) is associated with wasting and elevated risks of mortality and chronic morbidities, and at high levels (above about 28 ) with obesity and increased risk of mortality and morbidity ( Waaler, 1984; Beaton, et al. 1990; Fogel, 1994). But in low-income countries the majority of the population is likely to have sufficiently low BMI that in representative samples the empirical tendency is for BMI to be associated with gains to health and productivity, though these gains from BMI are expected to be subject to diminishing returns (Schultz, 1995; Strauss and Thomas, 1997). Another important feature of BMI, is that it tends to be approximately orthogonal to height. Consequently, when height and BMI are both considered as determinants of productivity, the problem of multicollinearity among regressors is mitigated. Other anthropometric physical growth indicators have also been proposed, some approximating the timing of the adolescent growth spurt, body-fat ratio, and onset of puberty, and age at first menstruation (Knaul, 2000). This growth spurt and the timing of puberty occur earlier in high-income countries, presumably due to the achievement of better nutrition and health conditions (Eveleth and Tanner, 1976; Falkner and Tanner, 1986). A host of child physical development indicators, graduated by age and sex, have become standard tools for child health assessments and growth monitoring in low-income countries (Beaton et al. 1990).

But few studies have measured family endowments and local policy conditions that might be responsible for variation in a respondent's childhood that are expected to modify these subsequent physical growth outcomes, and potentially affect adult productivity. If these formative health conditions could be accurately measured, and related to adult acute and chronic health outcomes, these long-gestating health human capital investments might be analyzed more precisely, allowing one to calculate the internal rates of return on resources needed to achieve these early improvements in health.<sup>5</sup> A few longitudinal data have been reconstructed from historical archives to improve our knowledge of these lifetime links from early health indicators to adult productivity and survival.<sup>6</sup> I shall focus primarily on wage rates, or labor productivity per unit of time worked, and thus neglect the potential effects of health status on labor force participation,

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<sup>5</sup> The analyst would still face the challenge of determining how much of the costs of changing the formative health conditions, say of improving nutrition, is undertaken as a health investment and how much satisfies an immediate consumption need, i.e. reduced hunger.

<sup>6</sup> Fogel (1991) has drawn a sample of U.S. Union Army recruits into the Civil War circa 1863 who were followed through their government records as pension claimants and decennial census respondents. As these men reached old age, there were no social security or few private pensions to affect their age of retirement, except those associated with the award of pensions to veterans of the Civil War. It was then possible to link their medical examination records and labor force participation in 1890 to their health records at the time of recruitment. Body Mass Index (BMI) as adults is closely related to their health and labor force participation as elderly men, and the contemporary relationship is very similar to that observed among elderly males in the United States in the 1970s, though the frequency distribution of the US population by BMI has shifted to the right (increased) (Costa, 1996, 1998). Strauss and Thomas (1998) find a similar pattern between contemporary BMI and participation in the labor force in urban Brazil in 1975.

hours worked, and intensity of work. The potential market income of males has increased more rapidly in high income countries during the last century than has the actual realized market income, because annual hours worked have declined due to shorter work hours during prime working ages, as well as later entry and earlier exit from the labor force (Fogel, 1999). The reckoning of hours worked by women is more complex, because comparable data on nonmarket work by women and their productive outputs are not generally available.

## **B. Health Human Capital**

The objective of this paper is to estimate how labor productivity per hour worked is affected by different components of health status, both the component which is affected by the behavior of individuals, families, and society and can therefore be viewed as a form of health human capital, and the component which is unaffected by social behavior or referred to as uncontrolled. This focus is not intended to deny the existence of other social benefits of health, especially for the young, old, and infirmed, for which additional health assessment methods are needed. Who works in the labor force is jointly determined with health. Improvements in health might be associated with changes in other social and institutional incentives, such pressures which encourage youth to extend their schooling longer and delay their entry into the labor force, and other institutions such as social security which encourage the elderly to retire from the labor force earlier.

## **C. Measurement Error in Health Human Capital**

A perennial problem in statistics is measurement error in explanatory variables. In estimating the effect of human capital, such as education, on wages, the education variable – years of education completed – is measured with error. In the simple classical model with random error, the resulting ordinary least squares estimate of education's effect on the wage tends to be biased downward, or more precisely biased downward in proportion to the ratio of the variance of the measurement error in education to the total variance of the measured education variable (Griliches, 1977). Neglecting the measurement error thus has the tendency to bias downward the estimated impact of the education human capital variable on labor productivity. Extending this approach to the estimation of the effect of health human capital on the individual's wage, it is expected that health status variables are also measured with error. The error in measured health might arise because of the subjective nature of health, but also because of the heterogeneous sources of variation in individual health.

Measured health status may be thought of as being the sum of genetic endowments and behaviorally determined accumulation of health capital. There is no reason to believe that the productive effects of genetic and human capital health variations are identical. The productive benefits of the socially-accumulated health component is, of course, the payoff that is relevant for

most policy interventions that seek to improve health.<sup>7</sup> One way to formulate the problem of evaluating the productive benefits of health human capital is how to identify this benefit independent of genetic factors, when the genetic component cannot be fully observed and the two components are likely to be intercorrelated.<sup>8</sup>

Although the causes for measurement error in health are not precisely the same as in the case of education, the statistical methods required to correct for measurement error are analogous. If there are instrumental variables (IV) that one has reason to expect to be correlated with the human capital component of health, and they are uncorrelated with the genetic (non-human capital) component, it may be possible to predict the health human capital based on the variation in the instruments, and use this mapping to estimate in a second stage the impact on the wage of only the component of health associated with the instrumental variables. These methods lead to unbiased estimates of the impact of the health human capital on wages under certain conditions. If we suspect that the return to human capital investments differ for different groups in the population, this form of individual heterogeneity in response to a policy treatment suggests that the instrumental variable that identifies the labor market returns to human capital will reflect disproportionately the groups that are most strongly affected in their decisions to invest in the human capital by variations in that instrument (Imbens and Angrist, 1994; Kling, 2000). For example, if the demand of relatively rich households for health care or nutrition inputs for their children are price inelastic whereas the demand of the relatively poor are price elastic, the price instrument used to identify the return to child health care will describe, for the most part, the payoff to poor households who increase investment in their children's health care, not a population average of the payoff for a heterogeneous population. Consequently, the choice of an instrument on which to estimate health human capital returns should be selected to approximate feasible policy options.

### **3. Feedbacks from Productivity to Health Behavior**

There are several overlapping relationships involving health that must be analytically disentangled to identify the benefits of improving health. First, there is a health production function that summarizes the technical/biological relationship between the initial genetic endowments of the person, subsequent health related input behavior, and exposure to uncontrolled shocks to health, such as infectious diseases. Second, there is the demand function for health inputs which depends on current health status (or sickness) and the time and market costs and perceived efficacy of the health inputs, the individual's (family's ) time and income

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<sup>7</sup> Discredited eugenic approaches to improving the fitness of populations might have promoted selective reproduction, and thereby sought to enhance genetic health potential. But modern biotechnology may be redrawing the limits of health human capital today to remedy genetic deficits.

<sup>8</sup> The correlation could arise from behavioral response to the realization of the genetic health endowment, as conjectured by Becker (1981), or to a fortuitous relationship, e.g. children of richer parents who invest more in their children's health also inherit on average healthier genetic predispositions, and then the two correlated health components may interact in their impact on measured health.

resources, and the person's (family's) preferences over alternative consumption possibilities. Third, there is a wage function summarizing the relative productivity of different types of workers in the labor force, distinguished by alternative health indicators and possibly the sources of variation in those health indicators.

To identify the socially productive effect of health, it is essential to understand how household and community factors produce good health. This is true if the productive effect of health status as it is measured is heterogeneous, or in other words is generated from different sources that have different productive consequences, or if there is simultaneous feedback from productivity to the demand for inputs which affect health. The standard example of this latter situation involves estimating the contribution of improved nutrition to worker productivity, while recognizing the reverse causal effect due to a more productive workers being able to purchase more nutrients (Strauss, 1986; Deolalikar, 1988). Although progress has been made at the individual level in separating out these two overlaying causal relationships, it is doubtful that at the country level the aggregate relationship between the average health and the average productivity of workers has yet been satisfactorily identified (Pritchett and Summers, 1996; Schultz, 1997).

#### **4. A General Analytical Framework for the Analysis of Health Human Capital**

Two questions motivate this paper. What is the effect of change in health status on the productive capabilities of an individual, and what malleable conditions of the individual, family, and community determine change in health status. With answers to these questions, one can assess the resource costs of modifying those conditions that will improve health, and then calculate the internal rate of return on those outlays as a human capital investment. Several studies have begun to answer the first question, but few studies have taken the next step to estimate the social costs of programs that have demonstrably produced the improvements in health (e.g., Savedoff and Schultz, 2000).

To evaluate the returns to health human capital involves many of the same problems that have occupied economists in estimating the returns to schooling, plus a few added complications specific to health. There is agreement that years of schooling completed by a worker is a reasonable first approximation for the physical units of education, although it may be further refined to include various dimensions of quality associated with that education. But in the case of measuring the stock of health human capital there is no natural metric at the individual level. Multiple health indicators are therefore considered and the impacts of different units of health may have little in common. In sum, health presents greater problems for survey measurement, more leeway for measurement error, and a need to distinguish more carefully between at least two parts of health: a fixed genetic endowment and a socially acquired human capital component.

The literature on health economics has emphasized that individual health heterogeneity can bias direct estimation of health production functions,  $h(\cdot)$ , that seeks to describe the technological relationship between health inputs (I) and health outcomes (H), and residual variation in health ( $e_1$ ) (Rosenzweig and Schultz, 1983). Individuals, their families, and perhaps their medical advisors will know more about the severity of illness or the frailty of individuals ( $g$ )

than does the social statistician trying to account for health outcomes. The health production function can thus be described, where both  $g$  and  $e_1$  are unobserved:

$$H = h ( l, g, e_1 ) , \tag{1}$$

where subscripts for individuals have been suppressed for simplicity.

The demand for medical care and other health-related inputs,  $l$ , may be modified by,  $g$ , as well as by other factors affecting health input demand,  $X$ , such as the market prices of health inputs, and another error,  $e_2$ , inclusive of differences in the preferences of individuals or families:

$$l = d ( X, g, e_2 ) . \tag{2}$$

For example, individuals who know they are particularly ill will be the first to seek out medical care, contributing to a negative correlation between demand for curative health inputs and good health, rather than the anticipated positive relationship that is expected to emerge if beneficial health treatment is randomly allocated to equally sick patients. Unobserved health heterogeneity is subsumed in the error in the health production function,  $e_1$ , causing this error to be correlated with the unexplained use of health inputs,  $e_2$ , imparting an omitted variable bias to the health production function (1) when it is estimated by single-equation methods, such as ordinary least squares (OLS) or probit maximum likelihood.

A solution to this health heterogeneity problem is to treat the health inputs as endogenous in the health production function (1) and employ instrumental variables (IV), such as the prices of, or access to, health inputs,  $X$ , as the variation on which to predict the health input demands. Then, estimates of the health production function by these two-stage methods are free of heterogeneity bias caused by the unobservable  $g$  (Rosenzweig and Schultz, 1983). Assuming that the input prices and access are not correlated with individual health heterogeneity, or that the covariance  $(X, g)=0$ , and that the prices and access variables explain a statistically significant share of the variation in input demand, these instrumental variable estimates of the health production technology are consistent and should have desirable properties (Bound, et al. 1995).

In the case at hand of evaluating how health human capital affects wages, an analogous problem arises. Assume that health status can be decomposed into two components,  $H_b$ , which is explained by the technological effect of behaviorally controlled health inputs responding to exogenous prices,  $X$ , and a remainder,  $H_g$ , that subsumes genetic heterogeneity, differences in preferences, other unexplained factors, misspecifications, and stochastic errors from both the production and input demand equations (Schultz, 1996):

$$H = H_b ( X ) + H_g ( g, e_1 , e_2 ) . \tag{3}$$

Only the first component can be viewed as man-made or a form of reproducible human capital, derived from predicting the health outcome from the fitted reduced form equation for health that embodies both the health production function (1) and the health input demand equations (2). If the

goal is to evaluate how this health human capital affects productivity, it is necessary to predict from the reduced form health equation (3) the behavioral variation in this health outcome, and use only this predicted health component,  $H_b$ , in the wage equation (4) as a human capital variable that is uncorrelated with health heterogeneity and random errors. Following the health production literature, the instrumental variables  $X$ , that are suitable for predicting the human capital component in the health outcome would be such variables as the individual's local price of health inputs and access to health care, or community level institutional investments that affect exposure to disease and efficacy of treatment when ill.

Variation in individual outcomes are often decomposed into those factors associated with nature (genetics) and nurture (human capital). There is no entirely satisfactory method for identifying the human capital component from the other factors including genetic potential, in part due to the covariances between the two sets of factors which cannot be allocated to one side or the other. Some genetic variation in health will be correlated with household income, price, and community variables, and thus may be captured in the predicted health outcome,  $H_b$ . Then, the instrumental variable estimate of the effect of health capital on wages will contain some of the genetic health effect, in addition to the behaviorally induced variation in health human capital.<sup>9</sup>

Labor productivity, approximated by the hourly wage rate, is then fitted to variation in individual human capital stocks, where health human capital ( $H_b$ ) is only the variation in health status that is accounted for by the instrumental variable, and hence uncorrelated with  $e_1$ ,  $e_2$  or  $g$ , which is desirable because these production and demand errors are likely to be correlated with  $e_3$ , due to omitted variables in the wage function and other sources of simultaneous equation bias:

$$W = w ( H_b(X), E, Z, e_3 ), \tag{4}$$

where  $W$  is the logarithm of the hourly wage rate,  $E$  education,  $Z$  other observed factors affecting the wage that are not behaviorally determined, such as age and ethnicity, and  $e_3$  the error in the wage function. This IV approach to estimating the effect of health human capital on the wage has the additional benefit of correcting for classical measurement error in the health indicators.<sup>10</sup>

## 5. Empirical Evidence of the Productivity of Health Status in Low-Income Countries

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<sup>9</sup> Hausman (1978) specification tests could be performed to determine whether the health human capital variable appears to be exogenous (or endogenous) in the wage function. The endogeneity would be confirmed if the behavioral and genetic components of health human capital variable received significantly different coefficients in the wage equation. In some health measures the genetic component appears to account for most of the variable's variation, such as height, whereas the categorical or disability measures of health are more readily explained by individual/family/community instrumental variables.

<sup>10</sup> If the measurement error is not of the classical form which is uncorrelated with other explanatory variables in the wage function, however, estimation problems remain.

The relationship between labor productivity and indicators of adult health and nutritional status has been recently analyzed in a number of low income countries. Those indicators of adult health that have comparable meaning across ages, such as height, can also clarify changes occurring over time in underlying investments in health human capital in a sequence of birth cohorts. This line of research started with the analysis of the intake of calories, as an endogenous demand decision by individuals and families in response to various factors including the local prices of nutrients (Strauss, 1986). This approach was then extended to other nutritional intakes, such as proteins, and the translation of nutritional intakes into a Body Mass Index (BMI= weight/height-squared) that was expected to increase the physical productivity of a laborer and help him resist the debilitating effects of infections and parasitic diseases (Scrimshaw, et. al. 1968). Although adult height may be largely determined many years earlier during early child development (Martorell, 1986), adult height is heterogeneous and measured with error, and consequently, the human capital effect of adult height on wages can be estimated consistently by a suitable instrumental variable technique.

Strauss (1986) first clarified how access to nutrition impacts labor productivity.<sup>11</sup> He estimated the marginal product of agricultural labor in Sierra Leone, where he hypothesized that labor might be more productive when the family workers received more calories. Rather than estimate a wage function including calories as a human capital argument, as outlined in section 4, he estimated the household agricultural production function and included in it a quadratic interaction between available supply of per capita calories in the family and the labor input to agricultural production. He thereby allowed calories to raise family labor productivity, but be subject to diminishing returns as per capita calories in the family approached satisfactory (healthy) levels. Because higher family labor productivity could also contribute to increased food consumption, Strauss used community variation in the price of food as an instrumental variable to predict family calorie consumption that in turn entered into the agricultural production function. He found calories affected the marginal product of family agricultural labor, especially at low levels of calories.

Subsequent studies replicated and extended Strauss' findings, with Deolalikar (1988) analyzing data for wage earners in India, Sahn and Alderman (1988) workers in Sri Lanka, Haddad and Bouis (1991) in the Philippines, and Foster and Rosenzweig (1993) in India and the Philippines. In Brazil, Thomas and Strauss (1997) estimated the joint effects on hourly earnings of calories, proteins, and BMI, with all three of these endogenously instrumented on local relative food prices, while also controlling for education and height, as other, presumably exogenous, forms of human capital. They found strong effects for the various endogenous nutrition/health variables, with calories again subject to diminishing returns until daily levels approached 2000 kcalories. They estimated the elasticity of earnings with respect to exogenous height for men and women in wage and self employment and found it to be significant but small.

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<sup>11</sup> This possibility of a nutrition-based wage led development economists to speculate on whether poor laborers would be able to invest efficiently in their own nutrition. If employers could not capture the full benefits of paying their workers more to have them eat better and thus be more productive workers, the poor might remain inefficiently poorly nourished (Strauss and Thomas, 1995).

An important feature of adult height is its persistence, changing relatively little from about age 20 to 55. Consequently, height can be compared across birth cohorts for 30 to 40 years in a single cross sectional survey, allowing the social statistician to ascertain whether periods of aggregate economic development are also marked by improvements in childhood nutrition and health conditions that are manifested in increased height. Economic historians constructed time series on the height of special populations, such as recruits into the military or criminals for whom height was recorded, and sought to correct for possible sources of sample selection bias. Where the military registers locally all young males at a certain age for conscription in the event of war, as in France, the records have been used to create a time series on male height at maturity by region, and it parallels closely estimates of GNP per capita about twenty years earlier when the males were infants (Weir, 1998). Fogel (1994) has consolidated estimates for a number of West European countries in which adult height is estimated for periods of one to two centuries. His estimate for the United Kingdom in the 19<sup>th</sup> and 20<sup>th</sup> Centuries suggests .45 centimeter gain in male height per decade, whereas populations in some countries that have recently prospered have reported greater increments to height over time. For example, men reaching age 20 in Japan were estimated by Shay (1994) to have added .88 cm per decade from 1892 to 1937, after which the war effort began to erode height and standards of living in Japan. Although economic historians have relied on national time series on height, BMI, and output per capita to shed light on the impact of health on productivity, the micro-estimation problems reviewed in Section 3 have not been addressed, to my knowledge.

## **6. Health and Wage Functions for Côte d'Ivoire and Ghana**

Living Standards Measurement Surveys (LSMS) coordinated by the World Bank were conducted from 1985 to 1989 in Côte d'Ivoire and Ghana (Grosch and Glewwe, 1998). These multipurpose surveys allow the joint estimation of the effects on wages of height, BMI, migration, and years of schooling for men and women (Schultz, 1995, 1999). In addition to Strauss' instruments – local relative food prices – the distance to health and school facilities, and parent education and occupation are added to the set of instruments to account for the four human capital variables. If individuals reside in a different region from their birthplace, then these migrants are attributed the average local characteristics of their region of birth for the relevant instruments that could influence early human capital investments. When Wu-Hausman (1978) specification tests are performed to judge whether the human capital variables are heterogeneous or measured with error, the IV estimates differ significantly from the OLS estimates, suggesting that the health variables are not exogenous, homogeneous and measured without error as required to accept the OLS estimates. Different combinations of these instrumental variables are considered and they suggest that the IV wage equations are reasonably robust, or pass over-identification tests (Schultz, 1996).

The OLS coefficients of these four human capital variables in the wage functions for men and women in the two countries are summarized in Table 1 in rows 1, 3, 5, and 7, whereas the IV coefficients are reported in rows 2, 4, 6, and 8. On the whole, the OLS and IV estimates are statistically similar for education and migration, whereas the wage effects of health and nutrition are sensitive to the choice of IV versus OLS estimates. As argued in the previous sections of this

paper, height and BMI are expected to be heterogeneous, and the instrumental variable estimates are designed to rely on the wage differences associated with the reproducible variation in height and BMI, rather than the genetic and random measurement error variation in these anthropometric indicators that are assumed orthogonal to food prices, health programs, and parent education. In the country with the greater child malnutrition, Ghana, the IV coefficient on height is 3.8 times larger for males than the OLS coefficient in the wage function, whereas the IV coefficient on height for women is 5.8 time larger than the OLS coefficient.<sup>12</sup> An increment of one centimeter in height is associated with a 6 to 8 percent increase in wages in Ghana, according to the preferred IV estimates. In the smaller samples (on the order of 1200- 1700 persons) from Côte d'Ivoire, the IV estimates of height on wages are not statistically significantly different from zero at the 5 percent level.

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<sup>12</sup> The World Bank estimated that 36 percent of the children under age five were malnourished in Ghana in 1990, whereas only 12 percent were in Côte d'Ivoire (World Bank, 1991). It is also documented in a variety of sources that the rate of infant and child mortality has declined rapidly in Côte d'Ivoire since 1960 as incomes per capita have risen sharply. In Ghana, which started the post Colonial era as one of the richest countries in Africa and initially had relatively high schooling rates and low infant mortality rates, growth has been slow and small farmers were taxed heavily, with little if any improvements in under five mortality during the 1970's and early 1980s (Benefo and Schultz, 1996).

**Table 1**  
Alternative Estimates of Human Capital Wage Returns  
for Schooling, Mobility and Nutrition-Health: Côte d'Ivoire and Ghana, 1985-1989<sup>a</sup>

	Sample Size	Years of Education	Migration from Birthplace (Migrant = 1)	Height in centimeters	Weight to Height Squared (BMI)
<b>Côte d'Ivoire: LSMS: 1985-1987</b>					
Males	1692				
1. OLS: In Wage Effects		.109 (16.4)	.715 (8.73)	.00862 (2.00)	.0451 (4.55)
2. IV: In Wage Effects		.107 (3.88)	.691 (3.09)	-.0105 (.56)	.159 <sup>b</sup> (3.00)
Females	1180				
3. OLS: In Wage Effects		.0730 (7.18)	.891 (8.26)	.00416 (.62)	.0613 (6.88)
1. IV: In Wage Effects		.0731 (3.58)	.961 (4.80)	-.0435 <sup>c</sup> (1.78)	.0950 <sup>b</sup> (2.50)
<b>Ghana: LSMS: 1987-1989</b>					
Males	3414				
2. OLS: In Wage Effects		.0437 (9.86)	.348 (6.75)	.0148 (5.02)	.0530 (6.80)
6. IV: In Wage Effects		.0445 (2.46)	.218 (2.26)	.0569 <sup>b</sup> (3.45)	.0793 (1.95)
Females	3400				
7. OLS: In Wage Effects		.0375 (7.26)	.531 (8.46)	.0129 (3.63)	.0420 (7.63)
8. IV: In Wage Effects		.0356 <sup>c</sup> (2.69)	.361 (2.98)	.0748 <sup>b</sup> (3.44)	.0981 <sup>b</sup> (4.11)

<sup>a</sup> The coefficients reported are those on the four human capital inputs in a logarithmic hourly wage function, which include dummy variables for age, regions of birth, ethnic/language group, and season. (Source: Schultz, 1996, Tables 1 and 2.)

<sup>b</sup> Hausman (1978) test of the exogeneity of this human capital input in the wage function is rejected at the 5 percent confidence level and should therefore be estimated by IV methods (<sup>c</sup> is 10 percent level).

The IV coefficients on BMI are significant in all four gender/country samples, increasing three fold from the OLS coefficients for males in Côte d'Ivoire and by one half for females, whereas in Ghana the IV coefficient on BMI increases by half for males, and more than doubles for females. An increase in BMI of one unit is associated with a 9 percent increase in wages for men in both Ghana and Côte d'Ivoire, whereas for women an increase in BMI of one unit is

associated with a 7 percent increase in wages in Ghana and a 15 percent increase in Côte d'Ivoire.

As a whole, these estimates of wage functions for two West African countries imply that the productive wage benefits associated with the reproducible variation in health human capital (i.e. height and BMI) are substantially larger than the OLS productive wage benefits associated with all of the measured variation in height and BMI. These results are consistent with the hypothesized heterogeneity in measures of nutrition and health, as reflected in these anthropometric indicators.<sup>13</sup>

## A. Height Variation Across Birth Cohorts

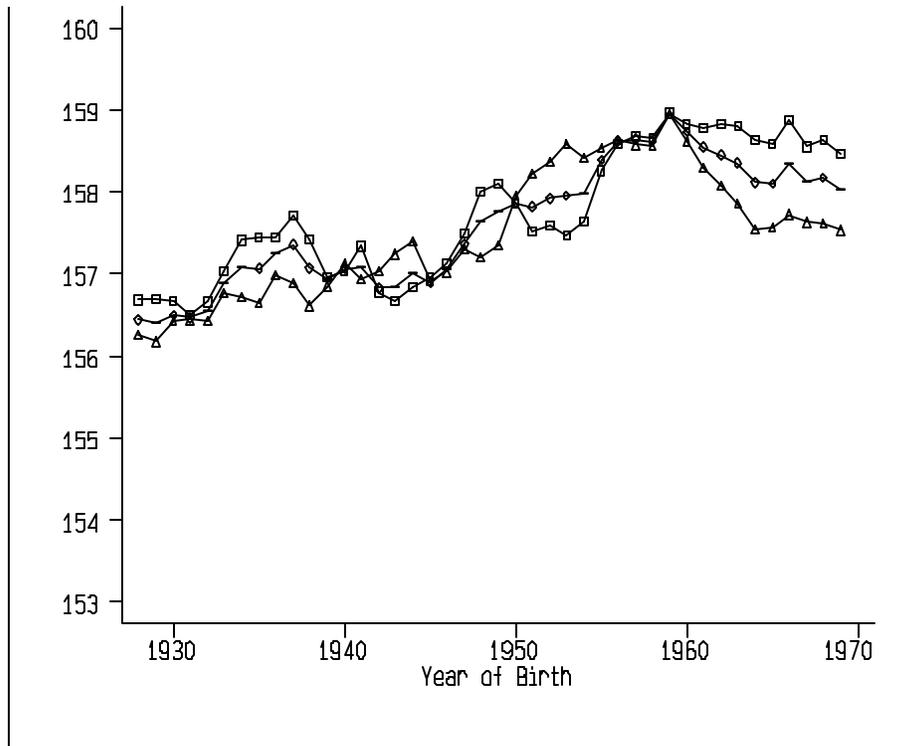
These West African LSMS surveys document the different achievements of neighboring countries. The height of adult females and males, respectively, from Ghana who were age 20 to 60 at the time of the survey, are plotted in Figures 1 and 2 as five year moving averages by date of birth, first for the entire population (circles) and then for the rural (triangles) and the urban (squares) populations separately. There are early periods of growth in height, but after independence in the 1950s the progress is slower or nonexistent, according to this dimension of health.<sup>14</sup> Males in Ghana age 20-29 report an average height of 1.70 meters, and increase of 2 cm. over Ghanaian men age 50-65, whereas in neighboring Côte d'Ivoire ( Figure 3 and 4) the height of males 20-29 years old is 1.71 meters, or an increase of 4 cm. over men age 50-65 in the same country. Estimates of GNP per capita have also increased more rapidly in Côte d'Ivoire than in Ghana during the three decades 1960-1990, 316 versus 70 percent, respectively (World Bank, 1991). For these same age groups, women increased their height in Côte d'Ivoire by 3 cm and in Ghana by 1 cm. Little research has been conducted on gender differences in height or how they respond to health or economic developments, perhaps because much of the historical evidence is from male military recruits (Steckel, 1995).

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<sup>13</sup> In Côte d'Ivoire a subset of the survey sample is reinterviewed in the following year and can be matched, allowing one to assess the random measurement error by comparing the wage estimates for this smaller group based on the average height (and more speculatively with BMI) in the two years versus that based on the individual year observations which are expected to be more noisy. As anticipated, the wage effects associated with the two-year averaged health human capital indicators are larger than those estimated from the individual-year values, but the increment in coefficients for BMI are much less than half as large as the difference between the OLS and IV estimates. Classical measurement error may be important in these health status indicators, but is not likely to account fully for the increase in the magnitude of the IV over the OLS estimates. Additional heterogeneity or endogeneity in BMI and height is probable. Nonetheless, the panel averages illustrate there can be serious problems in measuring reliably height and weight in a household survey (Schultz, 1996).

<sup>14</sup> The lack of growth in height may also be due to the selective out-migration from Ghana which is said to have led to the departure of half their professional medical staff in the 1960s and 1970s, and it might be expected that the out migrants would have been taller on average than the nonmigrants who respond in the later surveys.

There are also substantial differences in height between urban and rural populations, although unfortunately these figures refer to current residence and not to birthplace. The urban males are considerably taller than rural males in both countries. In Ghana, however, there was a brief period in the early 1950s when rural women were taller than urban women of the same age.<sup>15</sup> The health/nutritional levels in rural areas almost caught up to the levels in urban areas for the cohort born in 1945 in Ghana, and have since drifted apart. In Côte d'Ivoire the growth in height over time is more noticeable and the differences between rural and urban population are larger than in Ghana.

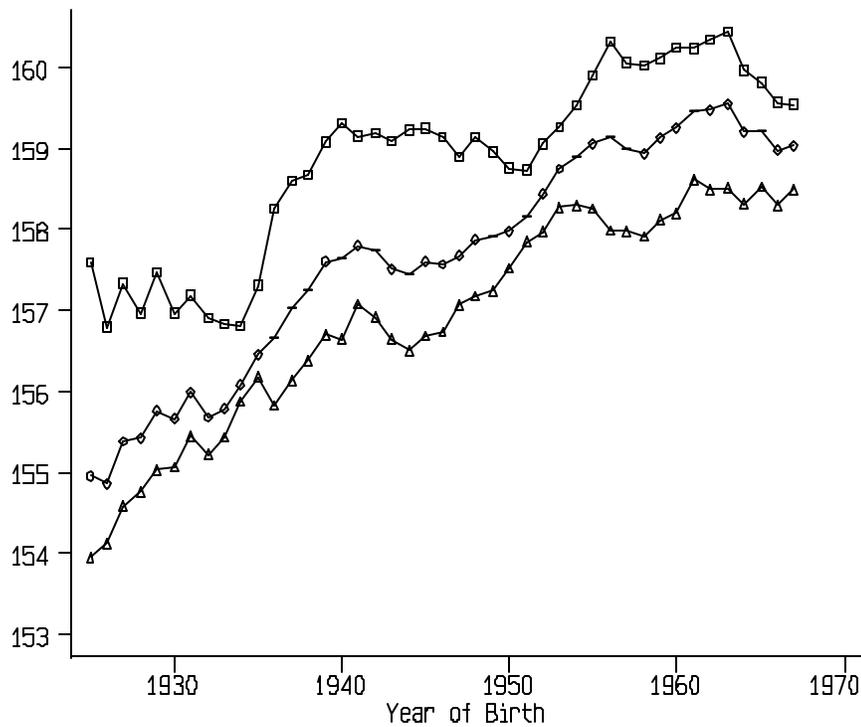


**Figure 1: Height in Centimeters of Adult Females in Ghana in 1987-1989: By year of birth, total (circle-●), rural (triangle-▲), and urban (square-◻) regions**

<sup>15</sup> This could be related to the entrepreneurial role of women as cocoa farmers, a profitable enclave in the rural sector.



**Figure 2: Height in Centimeters of Adult Males in Ghana in 1987-1989: by year of birth, total (circle-@), rural (triangle-), and urban (square-G) regions**



**Figure 3: Height in Centimeters of Adult Females in Côte d'Ivoire in 1985-1987: by year of birth, total (circle-@), rural (triangle-), and urban (square-Q) regions**



**Figure 4: Height in Centimeters of Adult Males in Côte d'Ivoire in 1985-1987: by year of birth, total (circle-@), rural (triangle- ) , and urban (square-Q) regions**

## B. Height and Wages in Brazil

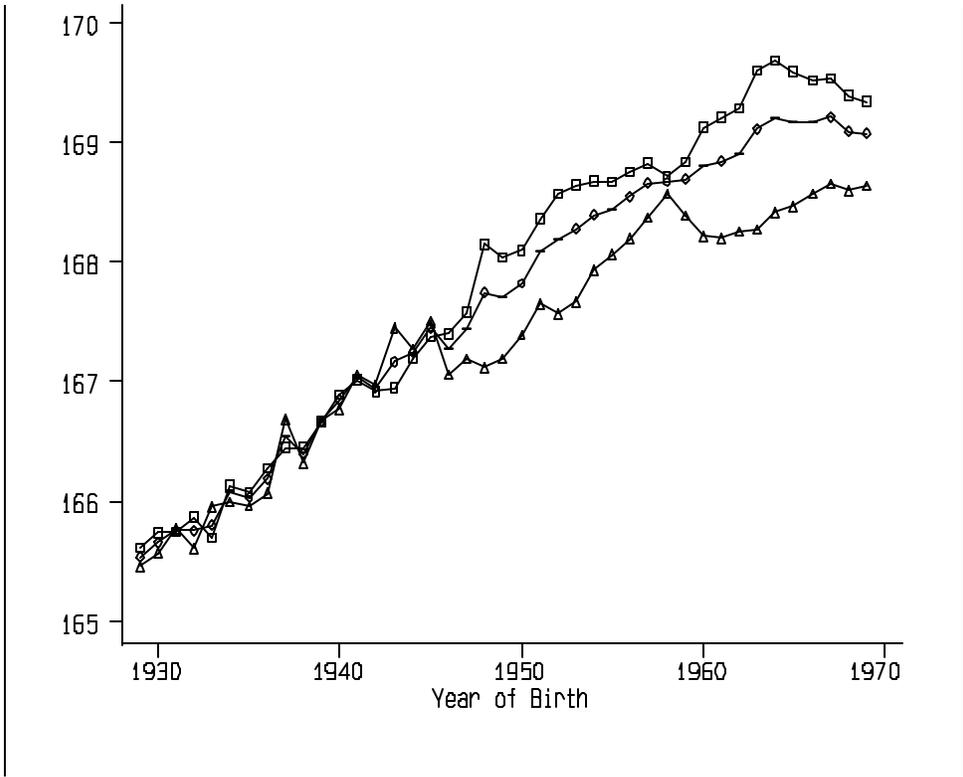
Based on the 1989 Health and Nutrition Survey (PNSN) of Brazil, comparisons of the height of individuals born from 1929 to 1969 (age 20 to 60 at the time of the survey) are plotted, using a five year moving average for women in Figures 5 and for men in Figure 6. Fitting a linear time trend to height for individual women implies that Brazilian women born a decade later were about 1.00 cm taller, and men were 0.96 cm taller on average. Among persons who were wage earners in 1989, the linear estimate of the increase in height was 1.18 cm per decade for women, and .98 cm for men, as reported in the first regression in Table 2. The second regression in Table 2 includes a quadratic terms in age, and controls for three nonwhite racial categories, and seven characteristics of local communities (i.e., municípios) as measured in the 1990 IBGE Census that were expected to affect the local public health environment and exposure to disease. Yellow and brown racial groups report distinctly lower height, whereas blacks are almost as tall as whites. Communities in which a larger fraction of the households have safe running water, more hospital beds per capita, and higher family incomes per capita have taller residents, but increased access to adequate household sanitation and higher adult education in the community is not partially associated

with greater height in the community.<sup>16</sup> The third regression in Table 2 includes 31 additional controls for climate (rainfall, temperature by quarter of the year in quadratic form, and interactions, altitude and distance to the sea in quadratic form, and interactions of population density and the eight temperature and rainfall variables) to improve predictions for height.



**Figure 5: Height in Centimeters of Adult Females in Brazil in 1989: by year of birth, total (circle-@), rural (triangle-), and urban (square-Q) regions**

<sup>16</sup> At the individual level education of the adults is strongly related to their height, but height is thought to be determined before schooling, and because both height and schooling are to some degree family choice variables, they are both likely to be affected by many shared unobserved variables. Conditioning on schooling would therefore complicate interpretation of the measures of secular trends in height.



**Figure 6: Height in Centimeters of Adult Males in Brazil in 1989: by year of birth, total (circle-@), rural (triangle-), and urban (square-G) regions**

**Table 2**  
**Ordinary Least Squares Estimates of the Determinants of Height in Brazil, 1989:**  
**Ages 20 to 60, Wage Earners<sup>a</sup>**

Explanatory Variables:	Males			Females		
	(1)	(2)	(3)	(1)	(2)	(3)
Age Years	-.098 (14.6)	.0187 (.40)	.0024 (.05)	-.118 (13.3)	-.0406 (.67)	-.0279 (.46)
Age Squared (x10 <sup>-2</sup> )	-----	-.156 (2.61)	-.137 (2.33)	-----	-.0985 (1.23)	-.114 (1.43)
<b>Race:</b>						
Black	-----	-.455 (1.33)	-.358 (1.05)	-----	.346 (.80)	.315 (.73)
Yellow	-----	-5.06 (4.37)	-4.82 (4.23)	-----	-3.99 (2.85)	-3.65 (2.62)
Brown	-----	-2.29 (14.0)	-1.56 (9.06)	-----	-1.42 (6.81)	-1.02 (4.64)
<b>Community Average Characteristic 1990:</b>						
Density Pop.	-----	-.102 (2.24)	1.57 (2.01)	-----	.053 (1.05)	-1.11 (1.14)
Density squared	-----	.0042 (2.07)	.0003 (.10)	-----	-.0023 (1.02)	-.0025 (.77)
Percent Household with Running Water	-----	.0536 (9.15)	.0149 (1.78)	-----	.0597 (7.59)	.0245 (2.10)
Percent Household with Sanitation	-----	-.0025 (.77)	.0072 (1.88)	-----	-.0054 (1.21)	-.0009 (.17)
Hospital Beds per 1000 pop.	-----	99.1 (4.59)	43.3 (1.89)	-----	103.8 (3.98)	71.3 (2.52)
Family Income per Capita	-----	.942 (3.77)	.680 (1.77)	-----	.838 (2.89)	.964 (1.94)
Years of Education Adults age 15+	-----	-.079 (.82)	.184 (1.29)	-----	-.359 (2.98)	-.262 (1.31)
31 Additional Controls Included <sup>b</sup>	No	No	Yes	No	No	Yes
Intercept	171.7 (682.)	165.6 (177.)	122.4 (3.63)	160.2 (4.97)	155.1 (130.4)	145.6 (2.90)
R <sup>2</sup> Adj. (Prob > F)	.0213 (.0001)	.1033 (.0001)	.1383 (.0001)	.0333 (.0001)	.0894 (.0001)	.1115 (.0001)
Sample Size	-----9748-----			-----5106-----		
Mean Height (standard deviation)	-----168.2----- (7.29)			-----156.1----- (6.69)		

<sup>a</sup> Beneath regression coefficients in parenthesis are the absolute values of t statistics

<sup>b</sup> Controls include for the municipio region quarterly average temperatures and rainfall in linear and squared form, interactions of quarterly temperature and rainfall, altitude and distance to seacoast in linear and quadratic form, and population density interacted with quarterly temperatures and rainfall.

**Table 3**  
**Estimates of Log Hourly Wage Functions Brazil 1989:**  
**Age 20 - 60, Wage Earners<sup>a</sup>**

Estimation Method	Males				Females			
	OLS (1)	OLS (2)	IV <sup>b</sup> (3)	IV <sup>c</sup> (4)	OLS (1)	OLS (2)	IV <sup>b</sup> (3)	IV <sup>c</sup> (4)
Height in Centimeters	.0151 (12.9)	.0131 (11.1)	.0479 (14.4)	.0394 (9.01)	.0169 (9.45)	.0153 (8.55)	.0651 (11.0)	.0564 (7.60)
Post School Experience	.0753 (26.2)	.0735 (25.7)	.0754 (26.3)	.0744 (25.9)	.0606 (16.3)	.0599 (16.3)	.0641 (17.2)	.0630 (16.9)
Experience Squared (x10 <sup>-2</sup> )	-.103 (20.2)	-.101 (20.1)	-.0973 (19.1)	-.0976 (19.2)	-.0777 (11.1)	-.0782 (11.3)	-.0727 (10.5)	-.0734 (10.6)
Education Years	.153 (59.7)	.147 (56.4)	.156 (61.7)	.152 (59.1)	.155 (45.4)	.148 (43.2)	.162 (47.9)	.157 (44.9)
Rural Resident	-.437 (23.3)	-.458 (24.5)	-.434 (23.2)	-.444 (23.7)	-.396 (12.1)	-.416 (12.9)	-.384 (11.8)	-.399 (12.3)
<b>Race:</b>								
Black	-----	-.310 (7.77)	-----	-.279 (6.97)	-----	-.367 (6.66)	-----	-.356 (6.45)
Yellow	-----	.128 (.95)	-----	.264 (1.94)	-----	.299 (1.67)	-----	.452 (2.50)
Brown	-----	-.182 (10.5)	-----	-.0879 (3.91)	-----	-.208 (8.59)	-----	-.102 (3.43)
Intercept	-4.48 (22.4)	-3.99 (19.5)	-10.1 (17.9)	-8.53 (11.4)	-4.92 (17.3)	-4.52 (15.7)	-12.6 (13.4)	-11.1 (9.36)
R <sup>2</sup> Adj (Prob > F)	.411 (.0001)	.419 (.0001)	.413 (.0001)	.417 (.0001)	.398 (.0001)	.410 (.0001)	.402 (.0001)	.408 (.0001)
Hausman t test of exogeneity of height (Prob > t)	-----	-----	8.92 (.0001)	9.17 (.0001)	-----	-----	6.67 (.0001)	6.97 (.0001)
Mean Log Wage (standard deviation)	-.297 (1.05)				-.557 (1.06)			

<sup>a</sup> Beneath regression coefficients in parentheses are the absolute values of t (OLS) and asymptotic t (IV) statistics.

<sup>b</sup> The instrumental variables included in the height regression that are not included in the wage regression are the following: three non-white race dummy variables, population density and density squared, percent of households with safe running water, sanitation, hospital beds per capita income, and average years of education completed by persons age 15 or more.

<sup>c</sup> The instrumental variables identifying the effect of height in the wage equation are the same as listed in note "b," minus the three non-white race dummy variables.

Table 3 reports estimates of the log hourly wage regressions for the same Brazilian samples of male and female wage earners. In the first column the standard wage function is estimated by OLS, based on the assumption that height is homogeneous, measured without error, and exogenous.<sup>16</sup> Column 3 reports the parallel IV estimates where height is predicted on the basis of the auxiliary equation reported in col 2 of Table 2, and thus identified on the basis of the race and seven health and economic community characteristics. According to this IV specification, a male worker who is one centimeter taller receives a 4.8 percent larger wage, and a female worker who is 1 centimeter taller receives a 6.5 percent larger wage. It is notable that these IV estimated effects of stature are three times larger than the OLS estimates in col. 1 of Table 3. Since it is likely that part of the differences in wages by race is due to other human capital or environmental factors and not entirely caused by genotypic differences in healthiness proxied by height, the three race dummies are also added directly to the wage specification in col. 2 of Table 3 for the OLS estimates, and in col. 4 in Table 3 for the IV estimates. The IV estimates in col. 4 for the effect of height on productivity (log wages) are, as expected, now somewhat smaller, implying a 3.9 percent wage gain per centimeter for male wage earners, and 5.6 percent wage gain per centimeter for female wage earners. But again the IV estimates are three to four times the magnitude of the OLS estimates. The Wu-Hausman (1978) specification tests confirm that the OLS and IV estimates are significantly different, strengthening the statistical argument for preferring the asymptotically unbiased IV estimates and rejecting the OLS working assumption that height is homogeneous, measured without error, and exogenous. Interpreting these results in the model outlined in Section 3 with two components of health, a human capital component and the rest, the coefficient on the human capital component is significantly larger than that on the socially unexplained residual health variation.<sup>17</sup>

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<sup>17</sup> Because height and schooling are generally positively correlated, it is anticipated that the omission of height from the traditional wage function imparts an upward bias to the standard estimates of private wage returns to schooling. This was the case in the four West African samples discussed earlier, but the magnitude of the upward bias was less than one-tenth (Schultz, 1995). In the 1989 Brazilian samples of wage earners, the inclusion of the height variable in the wage equation reduces the estimated coefficient on years of schooling only slightly, from .17 to .15 for females and from .16 to .15 for males (not reported here).

<sup>18</sup> Including 31 additional control instrumental variables for local climate and population density to improve the predictions for the regional variations in height does not greatly affect the second stage IV estimates of the impact of height on wages. The wage gains for males are then estimated to be 4.0 percent per centimeter and for females 5.6 percent (not reported). The IV estimates based only on the seven community characteristics in col 2 of Table 2 are the more suitable for capturing the payoff to reproducible health human capital, in that they might depend on interventions of public policy to improve water, health care, and incomes of communities. The specification appears to be relatively robust to changes in the subset of IV variables used to identify the effect of health human capital. The size of height's effect on wages estimated by IV appears to be substantial in Brazil, even though income levels are many times higher in Brazil than in West Africa.

### C. Simulation of Wage Changes and Inequality due to Height and Education in Brazil

To illustrate the likely contribution of advances in height and education to the growth in Brazilian wages from 1950 to 1980, the 1989 wage regressions (Col. 4, Table 3) are used to weight the changes in height and schooling reported in the third panel of Table 4, for adults born in 1930-34 and 1960-64, who might have entered the Brazilian labor force in approximately 1950 and 1980. The increase in height of 1.03 cm per decade between these birth cohorts (3.10/3 in Table 4), separated by 30 years, could account for a rise per decade in male wages of 4.1 percent ( $.0394 \times 1.03$ ), and in female wages of 5.8 percent ( $.0564 \times 1.03$ ). In contrast, the increase in years of schooling completed was 1.05 years per decade for males, schooling for females increased 1.38 years per decade, for an estimated growth in wages of constant, and suggests that improvements in nutrition and health reflected in increases between birth cohorts in height can explain somewhat less than a third of the wage growth associated with the between birth cohort increase in schooling (5 percent versus 18 percent per decade). Because there are other dimensions of health improvement that are not highly correlated with height, the inclusion of multiple dimensions of health in addition to height might be expected to account for more of the wage growth than attributed here.

Economic inequality in Brazil is among the highest in Latin America, while Latin American countries exhibits more income inequality on average than do countries in other major regions of the world (Schultz, 1998). If the variance in the logarithms of wages is adopted as a conventional measure of inequality, components of this variance in log wages can be attributed to the variance in individual endowments of the human capital stocks within age groups of the population, assuming that the covariances between age (experience), schooling, and height can be neglected as second-order effects (Becker and Chiswick, 1966; Lam, 1997). Table 4 shows that the variance in height has remained relatively stable in Brazil across these thirty years of birth cohorts, decreasing for men by 5.3 percent while increasing slightly for women by 0.9 percent, while at the same time the average height increased for both sexes by about one centimeter per decade. The variance in years of schooling increased sharply, however, by 78 percent for Brazilian males and by 127 percent for females. The growing variance in the receipt of schooling (i.e. the inequality in years of schooling within a birth cohort) has contributed to worsening wage inequality in Brazil (assuming the wage structure was constant), whereas inequality in health status represented by height, has not changed appreciably between the older and younger birth cohorts. Thus, in Brazil, there is growing economic inequality in schooling, whereas the measured inequality in height has not shown a tendency to increase.

The rural-urban disparity in height, however, may have increased in Brazil as illustrated in Figures 5 and 6. One interpretation of the rural/urban differences is that they could arise if migration were selectively drawing the taller-healthier individuals out of the rural areas and into the higher wage urban labor markets. Although trends in health have been debated in Brazil, it appears that the slowdown in economic growth during the 1980s in Brazil did not lead to an increase in child mortality or to a halt in the growth in height-for-age among young children, at least not at the national level (Monteio et al. 1992; Alves, et al. 1999). Table 4 also

**Table 4**  
**Means and Standard Deviations in Parentheses of Height and Schooling**  
**by Country, Selected Age Groups, and Sex**

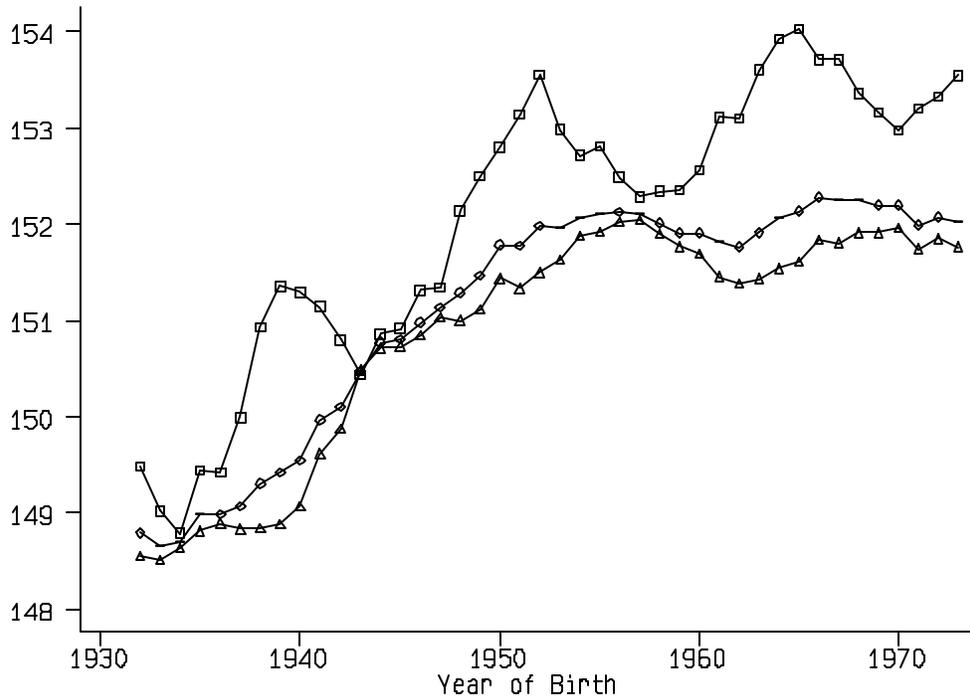
Country	Height (cm.)		Schooling (yrs.)	
	Female	Male	Female	Male
<b>Ghana: 1987-89</b>				
Age 25-29	158.53	169.46	5.29	8.29
Age 55-59	156.93 (5.96)	169.00 (6.51)	2.12 (4.29)	5.68 (5.97)
Change	+1.60 (+0.29)	+0.46 (+0.12)	+3.17 (+0.68)	+2.61 (-0.88)
<b>Côte d' Ivoire: 1985-87</b>				
Age 25-29	159.11 (5.67)	170.11 (6.70)	2.78 (3.99)	6.12 (5.07)
Age 55-59	157.57 (6.11)	168.48 (6.88)	0.23 (1.32)	2.30 (3.98)
Change	+1.54 (-0.44)	1.63 (-0.18)	+2.55 (+2.67)	+3.82 (+1.09)
<b>Brazil: 1989</b>				
Age 25-29	156.27 (6.62)	168.90 (7.27)	6.36 (4.31)	5.66 (4.22)
Age 55-59	153.16 (6.59)	165.79 (7.47)	2.21 (2.86)	2.52 (3.16)
Change	+3.10 (+0.03)	+3.10 (-0.20)	+4.15 (+1.45)	+3.14 (+1.04)
<b>Vietnam: 1992-93</b>				
Age 25-29	152.16 (5.39)	162.10 (5.39)	7.90 (3.21)	8.35 (3.38)
Age 55-59	148.73 (5.64)	159.19 (5.93)	3.74 (2.59)	6.48 (3.82)
Change	+3.43 (-0.25)	+2.91 (-0.54)	+4.16 (+0.62)	+1.87 (-0.44)

reports the comparable data on cohort differences in levels and standard deviations of schooling and height for Ghana, Côte d'Ivoire and Viet Nam. In all of these four countries there are gains in the levels of these human capital stocks, little change in the variances in adult height, but substantial increases in the variances in education, except for Ghanaian and Vietnamese males. Unless the returns to schooling decline over time, these developments are likely to generate increasing within age group wage inequality due to the growing disparities in educational attainments (Schultz, 1998).

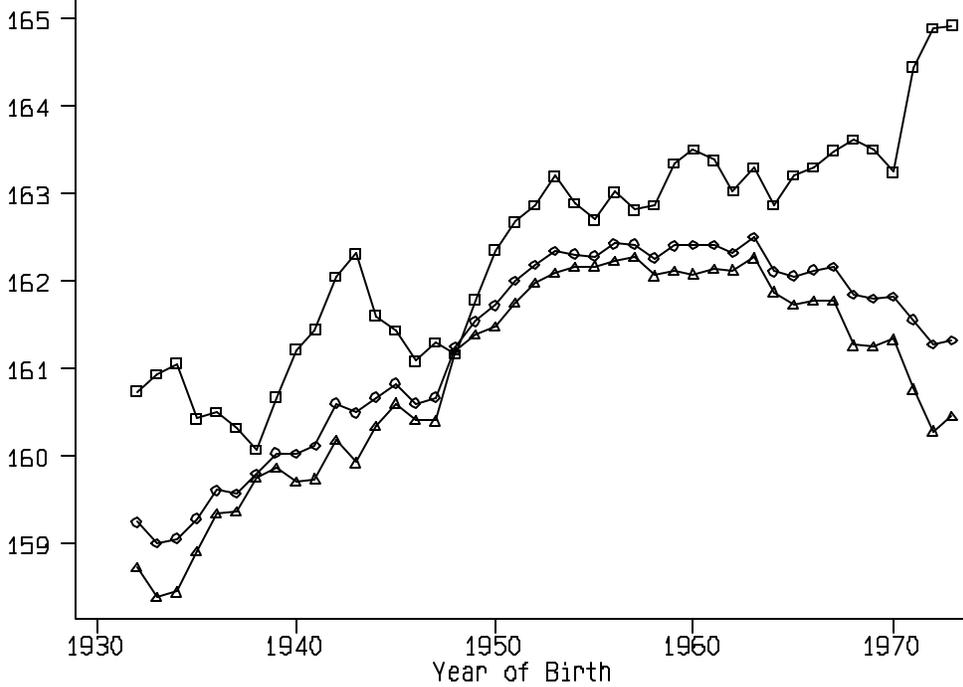
## D. Evidence from China and Viet Nam

Dislocations of markets, political incompetence, wars, and famines can reverse these positive trends in nutrition and health associated generally with development and reflected in anthropometric indicators of health status such as adult height (Sen, 1981; Fogel, 1991). China witnessed a severe famine from 1959 to 1961 which led to excess mortality of tens of millions. Such large swings in mortality related to famine and epidemics tend to have their most severe impact on infant and child mortality and on death rates among the elderly. Two offsetting effects of the famine may impact the average height of birth cohorts. First, infants and very young children subjected to malnutrition during a famine physically grow more slowly and many may not be able to catch-up to their normal adult potential height, leading to a shortfall in average adult height for those born during or immediately before a famine. A second expected consequence is that more frail individuals would be most likely to die from the famine and ensuing epidemics, and those with elevated risks of mortality are likely to be shorter on average (Waahler, 1984; Vaupel, 1990). If this heterogeneity in health endowments in the population are individually persistent over the life cycle, the surviving members of a cohort diminished by a famine would tend to be taller and healthier than the surviving adults from birth cohorts that preceded or followed the famine (Cf. Alters and Riley, 1989). There is insufficient time series evidence on mortality and health status indicators to know under what conditions one empirical force (i.e. stunting or selection by mortality) would dominate. An analysis by Yan (1999) of the Health and Nutrition Survey from 8 of 30 provinces in China, collected in 1991 and 1993, found that for persons born after the Second World War (and surviving to 1993) that adult height increased by roughly 1 cm per decade, with a dip, at least for males, associated with the 1959-61 famine.

The 1992-93 Living Standard's Measurement Survey of Viet Nam also provides evidence of time series changes in adult height across birth cohorts. Figure 7 and 8 plot the five year moving averages for height from this survey, which rises until the era of the Viet Nam War, after which male heights grew much less than female, and probably declined in rural areas, perhaps as the military mobilization exposed the taller males to increased mortality risks. Large swings in both male and female heights in the urban areas are evident for cohorts born in the 1940s, followed by a widening gap between urban and rural males as the war reversed earlier advances. I know of no analysis of China or Viet Nam that uses survey information in the fashion outlined here to jointly account for adult height and also treats adult height as a determinant of wages and labor productivity.



**Figure 7: Height in Centimeters of Adult Females in Viet Nam in 1992-1993: by year of birth, total (circle-@), rural (triangle-), and urban (square-G) regions**



**Figure 8: Height in Centimeters of Adult Males in Viet Nam in 1992-1993: by year of birth, total (circle-@), rural (triangle-), and urban (square-G) regions**

## E. Morbidity and Wages: West Africa and Latin America

Self-reported morbidity has been tabulated in sample surveys to describe health differences among groups, but until recently these data have not often been analyzed at the individual level to understand the determinants and consequences of health status. Analyses of the two West African LSMS surveys from the late 1980s confirm that the number of days sick and unable to engage in regular wage-earning activity follows conventional patterns in mortality, i.e., increasing with age after the 20s, higher in rural compared with urban areas, and decreasing generally with education of the respondent, although not in all instances. The average level for adults age 15 to 65 is about two days per month sick and unable to work for either men or women in both Ghana and Côte d'Ivoire (Schultz and Tansel, 1997).

Measures of community health conditions at birthplace or current residence for nonmigrants are exploited as factors potentially affecting the health human capital formation of individuals. These instrumental variable predictions of the number of days ill and unable to work in the last four weeks and also a binary indicator as to whether the person had any days thus disabled in the recall period are used to account for variation in wages among adult workers. The list of instruments employed to predict the self-assessed morbidity variables included access locally to health services and facilities, development infrastructure that should improve access to health care, climate and local malaria problems, parent education and occupation, region of birth, and local relative food prices. Although the reported days disabled is only weakly related to wages based on OLS estimates of the wage function by sex, the IV coefficients on this measure of days disabled are larger and statistically significant for men and women in Ghana and Côte d'Ivoire (Schultz and Tansel, 1997). According to the IV estimates, an increase of one more day disabled in the last four weeks is associated with a reduction in hourly wages of at least 10 percent, and an additional three percent reduction in hours worked. The labor supply response to expected morbidity could reflect the impact of poor health on capacity to work and a negative labor supply response to the lower wage of the sicker individual, i.e. income uncompensated hours response to the wage rate. However, these large reductions in earnings associated with the predicted frequency of illness do not provide consistent evidence as to which local health services or infrastructure have had the largest effect on improving health.

The Inter American Development Bank coordinated a series of health and productivity studies based on recent Latin American household surveys (Savedoff and Schultz, 2000). They found that self-reported morbidity was associated with lower wage rates when evaluated using the framework outlined in this paper. Murrugarra and Valdivia (2000) analyzed hourly earnings in an urban sample of Peru collected in 1994 and found using instrumental variables that both male self employed and wage earners received significantly lower earnings per hour if they were predicted to experience a larger number of days ill in the previous four weeks. They then investigated in which groups of the labor force these health effects were more pronounced and found these effects on labor productivity were larger for older persons, older than age 26. Using quantile regressions they also find larger effects on hourly earnings for the lower quantiles of the residuals in the wage distribution. In other words, workers who were relatively poor for no observable reason tended to have the larger proportionate gain in their productivity by residing in a relatively healthy local environment. The empirical regularities in hourly earnings were less stable and significant for female workers in Peru than for male workers, but of generally the same sign and approximate magnitude.

In an analysis of elderly workers in Mexico based on a survey collected in 1995, Parker (2000) observed that males reporting no days ill, injured or hospitalized in the last 180 days received wages that were 96 percent larger than those who experienced some morbidity, when wages were estimated by instrumental variables. The much smaller sized samples of elderly female wage earners did not display a significant wage relationship with this indicator of illness. Parker (2000) also examined in the same survey functional limitations of daily living as a measure of health status, and found significant results for males. Using instruments related to the health services in the locality, the IV estimates implied that one additional functional limitation out of four queried in the survey was associated with a 58 percent reduction in hourly wage rates among the sample.

Ribero and Nuñez (2000) found in Colombia that reporting any days disabled in the last month was associated with a significant reduction in hourly wage rates, from 13 to 33 percent, when this binary health status indicator was estimated using instrumental variables representing local health services, housing infrastructure, and coverage by social security. The effect of this measure of morbidity on wage rates was somewhat larger for men and women in the rural than in the urban sector, consistent with the evidence from Peru (Murrugarra and Valdivia, 2000) that the productive returns to reducing morbidities are larger for the poor, or that the payoff to health is subject to diminishing returns. Adult height was reported only for the Urban segment of a 1993 household survey of Colombia (Ribero and Nuñez, 2000). Using a variety of indicators of the health infrastructure and the adequacy of the housing stock in the urban areas as instruments to predict height, they found the coefficient on height in the wage function increased many fold when IV estimates were compared with OLS estimates of the wage function. The preferred IV estimate implied an increase of one centimeter in height was associated with 8 percent higher wages for urban males, and 7 percent higher wages for urban females, parallel to the estimates for Ghana and Côte d'Ivoire.

In 1995 the representative National Family Planning Survey of Mexico collected information on the age at menarche. Women age 18 to 54 reported their first menstruation occurred on average at age 13.1 years, and fitting these responses to a linear time trend to year of birth, but controlling for the one available indicator of ethnicity (proportion of community that does not speak Spanish), Knaul (2000) noted that age at menarche occurred on average .11 years later ( $t = 8.54$ ) if the woman was born 10 years earlier. Age at menarche occurred later for Mexican women residing in rural than in urban areas, and for women who had completed fewer years of schooling, controlling for age. Knaul interprets this variable as an indicator of the timing of the adolescent growth spurt in Mexican women that is thought to occur earlier when childhood nutrition/health status improves (Wyshak and Frisch, 1982; Faulkner and Tanner, 1986). When age at menarche is added to the wage equation for these women, and instrumented, because of its measurement error, by local public health, schooling, and housing variables, a highly significant partial relationship with wages is obtained, controlling for the ethnicity variable and a variety of other locality characteristics that might affect both nutrition/health and wages. Experimenting with a variety of functional forms to fit the nonlinear relationship between age at menarche and the wage, a one month decrease in age at menarche is associated with a 1.9 to 2.3 percent increase in female wage rates at the sample mean, and in all functional forms the coefficient on this early nutritional indicator is statistically significant.

There are plausible biological and behavioral reasons to expect to find nonlinearities in the effects of health on productivity, as emphasized by Strauss (1986) in his analysis of calories, but to include polynomial approximations for health effects in the wage equation requires unusually strong instruments, because the predictions of the linear and higher powers of the health variable will be, by definition, plagued by multicollinearity. Cortez (2000) argued the need to transform the self reported days ill variable into a new health indicator that embodied the diminishing returns before it was estimated jointly with the wage function. His data from the 1995 Peruvian Household Survey suggested that one day less illness in the last 15 days was associated with 3.4 percent lower wages for urban women, 6.4 percent lower for rural women, 4.7 percent lower for urban men, and 14.2 percent lower for rural men. These IV estimates are many times larger than the OLS coefficients on the health variable, and both IV and OLS coefficients are statistically significant.

Table 5 summarizes the magnitudes across investigations of the instrumental variable estimates of the relationships between the different indicators of adult health status and the wage rate. Because the units of the various health indicators differ, those associated with morbidity are expressed as an elasticity, and when health improves as the indicator decreases in magnitude the sign of the elasticity is reversed to standardize comparisons across health indicators. The responsiveness of wages with respect to the health indicator, summarized by the elasticity, appears to be greater when the measure of morbidity is days unable to work rather than merely days sick. The percentage wage effects associated with an comparable increment to height or BMI are roughly the same order of magnitude in the few available studies.

## **5. Conclusions and Directions for Further Research and Improved Data Collection**

A range of survey indicators of adult nutritional and health status have recently been studied as potential determinants of individual wages and labor productivity in low-income countries. Several investigations have analyzed adult height as a proxy for uterine and early childhood nutritional/health status that is widely thought to be an important determinants of adult chronic health problems, particularly cardiovascular, and ultimately a determinant of longevity (Barker, 1992; Fogel, 1999). Estimates of wage functions at the individual level from representative household surveys that include adult height find that height is partially associated with modest increments to wages, confirming the relevance of height to health and productivity, as long emphasized from aggregate data analyzed by physical anthropologists and economic historians. But when wage functions are estimated by instrumental variable methods at the individual level, as outlined in section 3 of this paper, with such instruments as food prices, community health services, and parental family resources to predict the adult health indicators, the estimated wage effect of these health human capital variables, are increased and generally become more statistically significant. An additional centimeter in height is associated with a gain in wage rates of roughly 5-10 percent, and rapidly growing countries can add a centimeter to the height of a birth cohort with the passage of a decade. The interpretation offered in this paper is that these much larger effects of predicted variation in adult health status on labor productivity are due to the estimation approach focusing on the socially reproducible component of adult health status that is akin to the human capital part of the measured variation in health. The statistical interpretation is that the socially predictable component in the observed variation in height ( and perhaps other health status indicators) exerts a stronger influence on wages and presumably on

adult health than does the remainder of measured health which has been interpreted here as attributable largely to genetic diversity and measurement error.

Although self reported morbidity exhibits virtually no partial (OLS) correlation with wages in several studies in Africa and Latin America, the community health instrumental variable estimates of these health status effects on wages tend to be statistically significant and substantial in magnitude. Functional limitations of daily living are found to be similarly powerful in IV estimates of wage functions for elderly male workers in Mexico (Parker, 2000). Finally, age at menarche may prove to be a useful survey indicator of individual child health inputs which exhibits an inverse relationship with later adult female wages (Knaul, 2000).

These recent studies of wages and health human capital are only beginning to define the most suitable functional forms to fit for these relationships, which if they have some biological generality, could then be approximately replicated across different populations. Diminishing returns to nutritional inputs are expected, and a similar pattern may emerge with physical growth indicators of health. Because of the discrete and unusual distributions of such variables as number of days ill or disabled in a reference period, the estimation of ordered Probit models might shed light on more suitable transformations of the scale of such variables that would fit the data better than linear models.

It should be emphasized that all of these studies have relied on concurrent community and family health-related conditions as instruments to predict health human capital. The health conditioning variables should be ideally measured over the individual's entire lifetime, weighted in some fashion for the sensitivity of adult health to inputs at each stage in the individual's prior lifetime. Current clinical and panel studies conclude the critical nature of the early uterine environment and early childhood, suggesting that the community and family health conditions should be measured for the individual prenatally, as well as during the first few years of life. If individual migration histories were collected retrospectively by household surveys, the individual could then be matched to regional records on locality-specific health programs at residence when the adult respondent was an infant. The resulting instrumental variable estimates would then become a more satisfactory basis for evaluating of community health policy. The empirical problems of relating health programs and policies to productive outcomes would be greatly simplified if community health programs were implemented in a staggered and randomized manner, to assure that the local allocations of program resources would be statistically independent of unobserved heterogeneity across localities.

The connection between the accumulation of health human capital and labor productivity is a starting point for appraising priorities in health programs and policies. The complexity posed by health that is less of a problem with education is that the indicators that represent health are multifaceted and are not always adequately justified by their correspondence with mortality, morbidity, and quality of life. Many of these health indicators may encompass essential components that function as a type of human capital, consuming current social resources and yielding over the life cycle of the individual increased production potential. In the case of years of schooling, the measured variable appears to be largely reproduced by the application of private family and school resources and effort, though of course the survey variable may include errors in measurement and neglects dimensions of educational quality, resource intensity, or cost

effectiveness of the schooling process. With the health indicators it is more likely that current measures mix together an exogenous (or genetic) and an endogenous (or human capital) component. This distinction is perhaps most evident in the case of adult height where the tendency is for family and community socioeconomic characteristics to account for only 2-10 percent of the variation in height in the population, and one suspects, therefore, that much of the remaining “unexplained” variation in height is due to genotypic variation across individuals.<sup>18</sup>

The weakest link in the conceptual and empirical methodology outlined in this paper is in measuring satisfactory instrumental variables at the level of the formative family and childhood community. Different instruments should be relevant to different health indicators, whether birth weight, child anthropometrics, timing of puberty, adult height, BMI, acute and chronic morbidities, disabilities, days disabled, and functional limitations ( e.g. ADLs). The choice of these instruments should also be informed by the medical literature on what are likely to be cost-effective interventions to improve these outcomes, since the basis for identification with instrumental variables should be replicable as policy variations if the estimates are to be useful in guiding policy choices.

Finally, heterogeneity in a population in its response to health treatments is commonplace, and this should lead to estimation of the impact of different policy interventions on wages for different socioeconomic groups. Quantifying these distributional consequences of different policy interventions is an important challenge to policy evaluation methods. The convenient assumption of homogeneity in treatment response that is implicit in most program evaluation studies needs to be reappraised. With the analysis of individual data collected in household-matched community surveys, there is nothing to stand in the way of such a reappraisal. First, interactions can be directly estimated between the treatment (instrument, or health outcome) effect and different socioeconomic group characteristics in either the health reduced form or wage equation. Second, the analysis should specify instrumental variables that capture distinctive program strategies that promise to yield special benefits for disadvantaged groups. The choice of these program characteristics may be informed by the most persuasive theories generated by biomedical sciences, sociology, anthropology, political science, or economics. Third, quantile wage regressions, using instrument variable methods, may help clarify what improvements in health have particularly large productive benefits for unaccountably poor persons or those in the lowest quantiles of the wage residual distribution. In other words, health policies which benefit disproportionately those whose wages are low relative to their observed productive characteristics (e.g., Murrugarra and Valdivia, 2000).

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<sup>19</sup> More explicit analysis of matched siblings, and the exploitation of fixed effect estimation, might illuminate the relative importance of family and sibling fixed effects. It would not be clear, however, whether the sibling/ family effects were only genetic in origin, even after many observed socioeconomic characteristics of the family had already been controlled. Nonetheless, such estimates should provide another way to identifying how changes over time in the community public programs work their effect on height and correspondingly affect adult wages of persons who benefitted from these local programs because they came into a specific family before or after the program started.

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