ABSTRACT

A consensus has been forged in the last decade that recent periods of sustained growth in total factor productivity and reduced poverty are closely associated with improvements in a population's child nutrition, adult health, and schooling, particularly in low-income countries. Estimates of the productive returns from these three forms of human capital investment are nonetheless qualified by a number of limitations in our data and analytical methods. This paper reviews the problems that occupy researchers in this field and summarizes accumulating evidence of empirical regularities. Social experiments must be designed to assess how randomized policy interventions motivate families and individuals to invest in human capital, and then measure the changed wage opportunities of those who have been induced to make these investments.

Keywords: Health, Productivity, Human Capital, Schooling, Returns
JEL Classification: J24, I12, I21

I. INTRODUCTION

Child and adult survival and schooling have increased rapidly in the second half of the twentieth century. According to some measures, health and education in the low-income countries are catching up to the levels in the high-income countries (Schultz, 1993). Does convergence in these forms of human capital between the world's poorer and richer populations promise to narrow international differences in productivity and, if so, by how much? To answer such questions, the relationship between survival and schooling, on the one hand, and personal productivity, on the other hand, should be quantified in a variety of countries. Even then, difficulties remain in comparing the productive quality of schooling within and across countries, and in measuring health status as a human resource. The social return to human capital incorporate social subsidies in the production of the capital and benefits from the capital enjoyed by individuals other than the responsible family unit that is altruistic in valuing positively the enhanced productive capacities of other family members. Public investments in schooling and health should be guided by the distinct priorities implied by these social rates of return. An example where private and social returns might diverge would be the control of infectious diseases where external social benefits arise from reduced contagion.

At the level of the nation, recent periods of sustained growth in total factor productivity (i.e., growth in economic output that is not explained by increases in inputs of physical capital, land, or labor hours) are closely associated with improvements in a population's schooling, nutrition, and health (Schultz, 1961; Kuznets, 1966; Denison, 1967; Barro and Sala-i-Martin, 1995). At the level of the individual, statistical studies of random sample surveys and censuses reveal significant positive partial correlations between wages, earnings or income and a worker's schooling, nutrition, and health, stratified by sex and controlling for age or post-schooling experience (Strauss and Thomas, 1995). Macro and micro data organized according to these parallel conceptual frameworks strongly suggest that these relationships have a causal basis.

Nonetheless, estimates of the magnitude of productive returns to investments in education and health are subject to considerable uncertainty and are qualified by limitations in data and analytical methods. This paper reviews the problems that occupy researchers in this field and draws attention to the accumulating evidence of empirical regularities. Establishing the magnitude of these returns to schooling and health is a first step to concluding how much the convergence in these forms of human capital across and within countries can contribute to narrowing inter- and intra-country inequalities.

Investment of time and resources in the formation of human capital increases the productive potential of workers (and increases as well consumer benefits and leisure) that are realized over a lifetime. Measuring the internal rate of returns to human capital calls for an intertemporal analysis of costs and benefits of birth cohorts over their lifetimes. Most data pertain to cross sections, however, that describe inputs and outcomes in one period of time across different individuals grouped by age. Demographers recognize the limitations of such synthetic constructs from cross-sectional data designed to represent cohort experiences over time. Assumptions are necessary to translate cross-sectional evidence into human capital lifetime investment returns (Mincer, 1974). Whether these working assumptions are an innocuous simplification or a serious limitation on our knowledge remains to be determined. Growing examination of repeated cross sections allow statistical samples of cohorts to be followed as they grow older and long prospective panels describe individuals over time, subject to attrition bias. Both of these approaches may reduce our reliance on cross-sectional data to infer within cohorts the determinants and consequences of human capital. Sample surveys that collect information on the life histories of respondents may also alleviate the memory error problem of recall, due to asking retrospectively about the lifetime of a cohort. Time-varying conditions which are exogenous to the individual remain scarce although they can be useful for identifying in panels dynamic models of behavior.

In addition, without true social experiments designed to assess how randomized policy interventions change the motivations for families and individuals to invest in different amounts of human capital, and consequently to affect their potential earnings, statistical estimation of the relationship between wages and human capital investments may not approximate the effects that would follow from a properly designed randomized social experiment or the likely effect of a general change in policy. This paper considers several of these problems and illustrates how data and statistical methods are being used to deal with some of them.

2. THE DEMAND FOR HUMAN CAPITAL AND THE WAGE FUNCTION

Household demand for human capital is represented as a derived demand for the services of *n* types of capital (H). The economic determinants of these demands would include the private prices of inputs to produce these stocks, the discounted value of the increased after-tax earnings they might yield, local public services and relevant conditions that facilitate or restrict demand, and if credit markets are less than perfect, parent endowments that might also influence demands, e.g., their physical capital, human capital, and other sources of nonearned income. A linear approximation for this household demand function for human capital is as follows:

$$H_{ij} = a_j Y_i + b_j X_i + e_{ij} \quad , \quad j = 1, 2, \dots , n \; ; \; i = 1, 2, \dots , m \qquad (1)$$

where i refers to the individual, j to the form of human capital, and e the error that is assumed uncorrelated with the demand determinants, *Y* and *X*. The critical distinction is between *Y* that affects the demand for human capital partly through its impact expected on wages that motivate individual, family, and community investment in these forms of human capital, as well as through other possible channels, and *X* that affects the demand for human capital without modifying directly an individual's wage opportunities, such as the local quality of and access to schools or health care, or disease environment, and parent physical and human capital endowments. Estimates of the reduced-form parameters *a* and *b* in the demand equations (1) embody the parameters in the underlying utility function, which is responsible for behavioral demands, and the human capital production technology parameters. The utility and production technology parameters are not separately identified in most empirical work.

A standard semi-logarithmic linear approximation of the hourly wage function is expanded to include the *n* forms of human capital as inputs and the vector of *Y* variables that exogenously affect logarithmic wages and includes a fitted intercept:

$$w_i = \sum_{j=1}^{n} r_j H_{ij} + dY_i + u_i, \; j = 1, 2, ..., n, \quad i = 1, 2..., m. \tag{2}$$

The parameter *r* measures the proportional increases in wages associated with a unit increase in human capital. In the case of schooling, where a unit of capital measured is in full-time years completed, which also approximates the private opportunity cost of the capital in terms of years of earnings foregone by the student. This and additional simplifying assumptions lead to *r* being an approximation for the private internal rate of wage return on the students' time investments in schooling (Mincer, 1974). The human capital stocks are commonly assumed to be exogenous when estimating the wage function, or in other words, the error in the wage function is uncorrelated with the errors in the human capital demand functions (i.e., the covariance *of u and e* is *0* for all j types of human capital). If a Hausman (1978) specification test rejects this simplifying assumption that certain types of human capital *(*H) are exogenous in the wage equation (2), then the standard single-equation ordinary least squares (OLS) estimates of the wage function are biased and inconsistent. The wage equation might then be identified and estimated using instrumental variable (IV) methods to deal with the endogeneity of the human capital stocks, based on the working assumption that the vector of *X* variables do not enter the wage equation and provide the exclusion restriction. For *X* to be suitable instruments, they must be correlated with *H* in (1) but be uncorrelated with *u* in (2). Instrumental variable estimation of the wage function also eliminates bias due to classical random errors in the measurement of the human capital stocks, which may be a serious limitation with regard to survey measures of health human capital.

3. ARE HUMAN CAPITAL STOCKS EXOGENOUS OR ENDOGENOUS?

A number of problems in specifying the wage function can explain the correlation between the measured human capital stock and the error u. There may be a determinant of the wage that is omitted from the estimated wage equation, and if this omitted variable is itself correlated with the included human capital variable, the estimated parameter, r, on the human capital variable will be biased in proportion to the product of the partial regression coefficient on the omitted variable in the complete (true) wage equation and the partial regression coefficient on the human capital variable in an auxiliary regression predicting the omitted variable (Griliches, 1977; Lam and Schoeni, 1993). Thus, if the omitted variable is ability which increases a worker's wage, and schooling is positively correlated with ability, then the estimated coefficient on schooling in a wage function (2) when ability is omitted from Y will be an overestimate of education's true effect on wages because it has captured some of the wage effect of ability.

Differences in the initial endowments of the individual can also induce unobserved compensatory behavior on the part of parent and child, which would impart a more complex bias to our interpretation of r as a private wage return to only the observed human capital investment in an average individual. For example, consider the endowment of health, i.e., frailty, with which a child is born which is independent of the behavior of the parents or medical care system (Rosenzweig and Schultz, 1983). This child health endowment may lead the parents and the child to make complementary (positively correlated) or more likely compensatory (negatively correlated) health care investments. As a consequence, their behavior would induce a spurious correlation between the omitted child endowment variable and the measured health input variables, X. This should bias the partial correlation between the health inputs and the observed human capital stock in eq (1), and potentially bias the wage function as well. There are two approaches to such problems. Either measure the omitted variable, e.g., genetic ability in the case of schooling or initial health in the case of health care, and include it in the input demand equation (1) or the wage equation (2), or specify a suitably exogenous instrument affecting the human capital stock. The market price of inputs to produce the human capital (e.g., school fees) or random variation in the local health infrastructure or weather shocks might be candidates for such an instrumental variable, which should impact human capital demands but not otherwise affect subsequent wage opportunities of the individual. Unobserved variables can more generally influence outcomes such as wages, and also affect the accumulation of human capital, such as credit imperfections by economic class. One approach to study investment behavior is to estimate Euler equations from the changes over time in investment and consumption as a function of relative prices and interest rates. For example, human capital investments in child health may vary (decrease) in a period of (adverse) production shocks, such as during a flood or drought. Landowners who can more readily borrow to support their long-term optimal human capital investment (and consumption) program are less affected by the weather shocks than the landless families (Foster, 1995). Similarly, the schooling of children is more likely to be interrupted by the illness of a parent or a negative weather shock, if the family has less land or physical wealth for collateral (Jacoby and Skoufias, 1997).

Another type of misspecification arises when two components of human capital are measured in the form of an aggregate, but each component has a distinct effect on wages. If there are instrumental variables to account for the variation in at least one of the two components, it may be possible to estimate the wage effect of this component of human capital and even draw some insights into the wage effect of the other residual form of human capital. For example, assume that height is primarily determined by genetic capacities or genotype of the individual that is determined at conception. But individual nutritional intakes, exposure to disease, treatment of these diseases, and variation in other environmental burdens on nutritional status may facilitate or stunt the expression of this genetic potential for height across individuals (Schultz, 2002). Height is recognized to be an objective measure encompassing a wide range of health characteristics that are otherwise difficult to quantify (Faulkner and Tanner, 1986). Changes in average height over time in a population that is closed to compositional change may be attributed to (1) reproducible human capital investments, (2) exogenous changes in disease environments, (3) advancement in health production technologies, or some combination of these interacting developments (Fogel, 1994; Steckle, 1995, Schultz, 1996). However, in cross sectional samples, the component of height that can be explained by socioeconomic investments in health may have a larger (or smaller) effect on productivity than the residual variation in height that includes the genotypic component. The Hausman (1978) specification test of height in a wage function may then reject the exogeneity of height because the socioeconomic instrumented height's effect on wages differs significantly from the effect of observed (aggregated) height. Height in the wage function may then be justifiably treated as endogenous (Schultz, 1996,2002).

Another standard problem in estimating the effect of human capital on wages is that the human capital stock may be measured with error. In the simplest model of measurement error in which wages are determined by only one human capital variable that is measured with random error, the estimated attenuation bias of the wage effect of human capital is downward in proportion to the ratio of the variance of the measurement error to the variance of the measured human capital variable (Griliches, 1977). Effort to include more wage determinants that might reduce omitted variable bias also has the consequence of increasing the measurement error bias, because the added wage determinants tend to be correlated with the true human capital variables, increasing the remaining noise-to-signal ratio. It is unclear, therefore, whether estimates of the human capital returns from a wage function are improved by the inclusion of more controls, even if the controls are exogenous and correlated with wages. One common approach for dealing with genetic endowments and other heterogeneity across individuals and families is to estimate models holding constant for the community, family, or individual. Such fixed-effect estimation strategies preclude estimating the consequences of community, family, or individual factors, which are subsumed in the fixed effect. These estimates may thus deflect analysis away from a large number of issues that originally motivated research in the field. Yet, the fixed-effect method holds the promise of estimating the effect on wages of varying human capital stocks that can be explained by the instrumental variables that are outside the family's control. Panel data offer the researcher a tradeoff, between using individual fixed-effects specifications and thus rely only on changes in variables for individuals, whereas the method is likely to magnify the relative importance of measurement error. The alternative is to rely also on the cross-sectional variation in the panel and pool the observations, which may spuriously attribute some of the effect of fixed unobservables to the observed human capital variables (Griliches and Hausman, 1986).

Another possible source of misspecification in the wage equation (2) that could lead to bias and complicate the interpretation of estimates of the wage return to human capital stocks could arise if the return to human capital, r_j, differs across individuals and varies systematically across groups in the population affected at the margin differently by different policies or simulated treatments. This form of heterogeneity in the response of individuals to the variation in treatment captured by the instrumental variable estimates could explain the puzzling pattern of instrumental variable estimates of the private wage returns to schooling to often be larger than those estimated by ordinary least squares. One explanation for this empirical regularity is that the instruments commonly employed represent variation in the public supply of schooling, or access to schooling in the individual's region of residence, which may exert the strongest effect on educational demands among the most disadvantaged segments of the population. This segment of the population may be more responsive to the supply treatment of increased access to neighborhood schools, increase their school attainment as a consequence and experience an above average percentage wage gains from attaining an additional year of schooling, possibly because they were originally credit constrained (Card, 1999). This is a plausible hypothesis to account for growing evidence on schooling returns compiled in the United States, but in low income countries educational returns do not always change significantly between OLS and IV estimates, even when the instruments are primarily the local regional supply of schooling services (Schultz, 1995; Duflo, 2001).

There are then at least four hypothesized reasons for why the exogeneity of the human capital inputs in the wage equation might be rejected by the Durbin-Wu-Hausman specification test: (1) bias due to omitted variables, (2) bias due to the measurement of an aggregation of dissimilar sources of human capital variation, i.e., genetic and socially reproducible human capital, (3) errors in measurement of the human capital and (4) heterogeneity in the response to the treatment proxied by various instrumental variables. Because these sources of bias could be offsetting, for example, omitted variables could increase the estimated wage effect and errors in measurement might decrease it, combinations of specification errors could lead to single equation OLS estimates of the wage equation either overstating or understating the productive return from human capital.

4. THE FUNCTIONAL FORM OF THE WAGE EQUATION

Many empirical studies and economic and biological intuition suggest nonlinearities are likely to be important in the relationship between stocks of human capital and the wage. Interactions between different forms of human capital, such as positive complements or negative substitutes, have also been hypothesized and confirmed in empirical studies (Schultz,1995; Strauss and Thomas, 1995). Capturing these features of the wage equation may be crucial for accurately understanding how policy interventions will affect the productivity of specific groups and hence how interventions will affect the personal distribution of wages.

In the analysis of earnings functions, it was first noted by Mincer (1974) that years of education and post-schooling experience for U.S. males fit log earnings better than they did earnings. Statistical searches using the Box-Cox transformation by Heckman and Polachek (1974) suggested that Mincer's semi-log-linear specification was a somewhat better fit to the U.S. data than a linear approximation.

The dependent variable in equation (2) should be the (log) hourly wage rate, and not earnings. The potential productivity effect of human capital may cause workers eventually to demand more leisure and work less. Analyses focused on earnings will combine the primary productivity effect of human capital on hourly wages with the secondary labor supply decision. Labor supply choices are expected to depend not only on an individual's wage opportunities, but also on their non-earned income or educational debts and family support, for example. In the OECD countries, the average working year fell between 1913 and 1984 from about 2,600 to 1,700 hours (Maddison, 1989). If in a cross section, hours worked is lower for higher wage workers, private returns to human capital would be underestimated if based on an analysis of earnings rather than the hourly wage rate, because returns to earnings neglect returns to human capital consumed in the form of increased leisure.

The proportional effect of schooling on wages, call it r in equation (2), may also not be constant across different levels of schooling. Becker (1964) thought returns to schooling would decline for the individual with more advanced schooling, until the marginal return would fall below the opportunity cost of borrowing, at which point the individual would stop investing in (attending) school. Yet, in reality, some empirical studies find the reverse, in which private returns to schooling increase at secondary or higher education compared to the primary level. This is most common when virtually all members of a cohort complete the primary level and a bottleneck develops in the public educational system at a higher level (e.g., Côte d'Ivoire, Ghana and Thailand, Schultz, 1993). The labor market may attach more importance to graduation from a certain school level than to preceding years, or to different types of schooling such as academic versus vocational high schools. Adjustment of years of education completed to include those years repeated by a student may also improve measurement of the time-costs of schooling and hence the real returns, but retrospective data on time spent in school is rarely collected in surveys.

5. SURVEY INDICATORS OF HEALTH STATUS AND ESTIMATING WAGE RETURNS TO HEALTH HUMAN CAPITAL

There is a large literature on indicators of health status, which may contribute to assessments of the productive benefits of health, if the indicators can be measured at the individual level without bias for a sufficiently large random sample, and these indicators of health are significantly explained by reasonable instrumental variables, such as the prices of or access to health inputs. Mortality has been studied by demographers at the aggregate level in life-tables, but mortality is difficult to introduce into estimates of individual wage functions, for the obvious reason that the counterfactual is not observed, i.e. the dead are not in the sample of wage earners, although some means of predicting mortality in a panel survey might be useful.

Self-reported specific morbidities are more likely to be identified by the respondent in a survey if these morbidities have been already diagnosed by the medical care system. However, in most societies access to the medical system varies by region and across socioeconomic classes, introducing systematic reporting bias. For example, self-reported “hypertension” in a survey may not be closely related to survey administered tests of blood pressure designed to measure hypertension, but may be diagnosed and reported more often among educated urban elites. Functional limitations on activities of daily living are therefore viewed as more reliable evidence of functional limitations imposed by health status which could reduce the ability of respondents to work, or raise the disutility of their engaging in physical labor (Strauss, et al, 1995). Asking directly whether an individual has a health disability, however, may be subjectively affected by the individual's preferences for leisure and opportunities to work, and thus not capture an unbiased indication of restrictions on work due to health status alone. In high-income countries, moreover, social disability insurance may also encourage an individual who plans to retire from the labor force with the aid of such insurance to report a more serious disability than would be the case if such a social welfare program did not exist.

Anthropometric indicators have a long history of tracking health and nutritional status, starting with infancy onward, from birthweight, gestational age at birth, and derived measures of uterine rates of growth. However, the attractiveness of measuring health status from the "start of life" before it is affected by unobserved variations in behavior does not escape the endogeneity of the fetal environment or the pregnant mother's health and prenatal behavior which can be shown to affect these birth indicators of health (Rosenzweig and Schultz, 1983). Fixed effects for identical or fraternal twins, or for siblings within a family, or within a community to capture environmental health conditions, all have been used to assess the determinants of health and the productive consequences of such health variation, while controlling for certain confounding factors, such as genetic potential, family endowments, and community health conditions, respectively. A wide variety of other anthropometric indicators of growth and nutritional development warrant study from this human capital perspective. But they cannot be simply added as exogenous conditioning variables to the wage function. For example, it may be possible to elicit informative responses from women on their age at menarche, which is partially inversely correlated with their childhood nutrition and health status (Knaul, 2000).

Retrospective information on childhood health conditions, location, and family characteristics may provide instrumental variables which will help to predict age at menarche, as they would account for birth height, and adult height (Schultz, 2002).

A second approach to assessing health human capital effects on productivity is to design and conduct randomized experiments in order to estimate without bias the effect of the intention to treat on health status outcomes and on subsequent productivity compared with a control, ideally surveyed before and after the treatment is administered. Because of the long time lag of a decade or more between health interventions directed toward mothers, infants and children and the subsequent measurement of the children's school achievement and productivity as adults, this social experimental approach often requires costly panel surveys. Even in these panel studies there is attrition in following up the original survey respondents, which may lead to biased estimates from an analysis of only those who can be reinterviewed. Nonetheless, situations arise where the benefits of the panel randomized treatment strategy justifies the costs and lead time for their collection and analysis (e.g. Gertler, 2000; Glewwe, et al. 2001; Miguel and Kremer, 2002).

A third approach is sometimes called quasi-experimental exploiting for identification specific situations where control and treatment populations may be distinguishable in the survey, typically because of some administrative variation in access to the program by region, sex, birth cohort, etc. which the researcher contends does not otherwise affect the health status or adult productivity. Because these quasi-experiments are not random social experiments, they represent a version of the methodology presented at the outset, in which an instrumental variable, X, is assumed to be a factor determining health status in equation (1), and X is also assumed uncorrelated with the residual, u, in the wage equation (2).

Multiple differencing of the data according to the critical features defined by the instrumental variables – timing of program (before/after), location, eligibility for treatment, and other possible characteristics such as the respondent's age and sex – can provide an alternative identification and estimation strategy. These difference in differences estimators generally hypothesize that all of the persons who are treated respond by the same amount to treatment, although this assumption can be relaxed by allowing for the estimation of interactions between the treatment and the characteristics of the treated and control populations.

To evaluate whether instruments satisfy the working assumptions or whether the identification exclusion restrictions appear to be justified, statistical specification and overidentification tests can be reported to diagnose common problems (Bound, et al., 1995). For example, the first-stage instrumental equations predicting the health status (Equation 1) should have "explanatory power", or in other words, the joint test of the instruments having zero coefficients in this first stage equation (1) should be confidently rejected. Otherwise, one confronts the problem of weak instruments, and then if the instrumental variable estimate of health status in the wage equation (2) are insignificantly different from zero, this can lead to the Durbin-Wu-Hausman (1987) specification test not rejecting the exogeneity of the health status human capital variable in the wage equation. Weak instruments erode the power of the Hausman test, and this specification check is then not reliable. This may often be the case with health status variables where the access to and local health input price variables (X) are regional and will not explain a large fraction of the cross individual variation in health status (Schultz and Tansel, 1997).

6. EFFECTS OF HEALTH ON PRODUCTIVITY

Health, nutrition, and productivity are closely interrelated, but less empirical study has documented the form of the relationships between household and individual characteristics, nutritional status, and adult productivity than is the case for schooling and wages. The availability of calories, proteins and certain micronutrients allow a child to grow and fight off infections and perform various energy-demanding tasks. Birth weight and gestational age at birth, height for age, weight for age, and weight for height (BMI), are all anthropometric indicators of net nutritional status that proxy health, because they predict survival, reduced chronic illnesses, and seem to be correlated with later school and labor market performance. Child height by age four is a particularly good predictor of adult height (Martorell and Habicht, 1986), which has led to the assumption that adult height may be treated as predetermined from early childhood and enhances subsequent adult labor productivity in much the same way as does schooling. Consequently, many researchers assume that height is an exogenous argument in a wage function, although growing empirical evidence suggests the need to consider height as endogenous or at least measured with substantial error (Schultz, 2002).

If long-run net nutritional status is measured by height, then weight-relative to height is a shorter-run measure of current health and nutritional status and physical work capacity (Komlos, 1994; Steckle, 1995). Waaler (1984) has shown in a large sample from Norway that when the body mass index (BMI=height in meters/weight in kilograms squared) is less than 21 or more than 29, age-specific mortality from a variety of causes increases for both men and women. Fogel (1994) has documented in a sample of U.S. Civil War veterans that height is inversely related to chronic health problems in middle age, and BMI exhibits a U shaped relationship with the relative risk of morbidity similar to that found by Waaler. Costa (1996) accounts for nonparticipation in the labor force (i.e., disability) by BMI in the Civil War Veteran's sample aged 50 to 64 and again among males in the same ages in the US National Health Interview Survey in 1985-1991. The nonlinear relationships she estimates are remarkably similar to those reported by Waaler in his analysis of mortality in these age groups.

Assessments of the effect of height and BMI on economic functioning, productivity, and time allocation are only beginning to occur. Until recently there was no consensus on how to measure adult health and the problems of endogeneity and measurement error emphasized in this paper were not extensively addressed. To estimate with much precision the differential incidence of mortality and clinically confirmed morbidity among the elderly requires large samples and costly data collection programs in which thus far only a few high-income countries have invested. Among working-aged adults, health status cannot be reliably appraised by following mortality, because it is too rare and it is often related to special forms of consumption that are not always directly related to low productivity or diminished welfare while alive, for example, automobile accidents, alcohol abuse, smoking, other drugs, or HIV/AIDS. Structural models must distinguish between the demand for health human capital in eq. (1) in the form of height, BMI, etc., and their consequences on labor productivity due to the formation of health human capital in eq. (2). Establishing the reliability of anthropometric and other new measures of adult health status, and documentation of suitable two-stage econometric methods for evaluating the productive benefits of health human capital formation could change our assessment of the private and social returns to such health human capital, as it has for schooling human capital (Card, 1999). These advances in measurement of the biological indicators of health status and their economic analysis could also reduce omitted variable bias in parallel studies which seek to establish the cost-effectiveness of private household health-related behavior and public health expenditures and program interventions.

One problem in measuring the effect of health on productivity is that productivity contributes to income, which allows expenditures to increase on food and other health-related inputs that may themselves improve health. In other words, nutrition may increase productivity, but productivity also leads to an increased consumption of nutritional-health inputs. To estimate without simultaneous equation (upward) bias the one-way effect of nutrition and health on labor productivity, some exclusion restriction must be specified to identify the effect of nutrition on productivity, namely, a variable that is hypothesized to affect nutrition (or the use of other health related inputs) but which does not otherwise affect individual productivity. Errors in measurement of nutrition and health status are also likely to bias (downward) direct estimates of health status on labor productivity, as they do with schooling. Indeed, height and BMI were found to be subject to relatively larger measurement errors in a Côte d'Ivoire panel survey than schooling. Self-reported measures of health might be subject to an even greater measurement noise to signal ratio. Fortunately, instrumental variable estimation methods have the potential to also correct for bias due to classical sources of random measurement error (Schultz, 1996).

Strauss (1986) first described in econometric terms this problem, and proposed that variation in the community level price of food is suitably correlated (inversely) with food consumption and can serve as an instrument for nutrition in the family farm labor productivity function. He showed that in Sierra Leone in very low-income farm households the predicted availability of nutrition is related to increased output per family farm worker, and the nonlinear effect of nutrition on productivity is substantially larger at the lowest levels of calories. Similar estimates for wage earners in India (Deolalikar, 1988) and Sri Lanka (Sahn and Alderman, 1988) were subsequently reported. In Brazil, Thomas and Strauss (1996) estimated the effect on wages of height and education, both treated as exogenous wage determinants, while BMI, calories, and proteins were treated as endogenous and identified by local relative food prices. According to their estimates, a one per cent increase in height is associated with a three per cent increase in wages for males and a two per cent increase of females. Calories exert a quadratic effect on wages, subject to the anticipated pattern of biologically diminishing productivity benefits as calories approach levels of near-normal 2,000 calories per day (Thomas and Strauss, 1996).

Adult health is also measured by general morbidity (poor/fair/good/excellent health). Measures of adult morbidity in a household survey are self reported and subjective and possibly culturally affected, and they are therefore regarded by some as unreliable (Johansson, 1991). One approach to diminish this potential source of subjective bias and unreliability is to ask a series of questions on limitations of activity of daily living (ADL), e.g., unable to walk up stairs without assistance or feed oneself, which have recently become an accepted tool for evaluating the health functioning status of the elderly in high-income countries and should be associated with productivity and physical capacity to work (Steward and Ware, 1992; Strauss et al., 1995). Another measure of adult morbidity for the non elderly is self-reported functional activity limitations (days of work missed) due to illness, during a specified recall period of say a month. Although this indicator is also subjective, it may be a more reliable indicator of productive health for wage earners who are paid by their time at work, than it is for self-employed and home-production workers who can more often modify their work routines and adapt them to their current health status. In the case of most wage earners who are paid by the time they work, it may be assumed that employers would not want to pay them at a regular rate if they were sick and their productivity impaired. This implicit constraint of the labor contract should discipline workers to not report for work when they are ill, and might improve the reliability of morbidity information on disabled days as reported by wage earners. Because this health indicator is also potentially simultaneous determined with expenditures on food and health care, it should be treated as endogenous and instrumented by such variables as the local availability or prices of health care and inputs, unanticipated health risks, or the relative prices of nutrition. Using these local area instruments to predict the frequency of disabled-days, estimates for male wage workers in Côte d'Ivoire and Ghana imply that one more disabled-day per month is expected to reduce a worker's wage by 10 per cent, and reduce his monthly hours worked by 3 per cent (Schultz and Tansel, 1997; Savedoff and Schultz, 2000).

In Côte d'Ivoire and Ghana education, height, BMI and migration have all been included as joint determinants of the wage for men and women from 1985 to 1989. Local food prices, health and schooling services, along with parent education and occupation, are specified as instruments to account for an individual's four human capital stocks. The exogeneity of all four human capital stocks are then tested according to Hausman specification tests. In this study education and migration cannot be rejected as being exogenous, because their OLS and instrumental variable estimates are not statistically different, although this could be due to weak instruments in the case of migration. But the wage effects of height and BMI are generally substantially larger when they are treated as endogenous and estimated by the same set of community and parental instrumental variables, compared with OLS estimates of their wage effects. The returns to schooling are larger in Côte d'Ivoire (8-11 per cent) than in Ghana (3-4 per cent) due perhaps to the more rapid and sustained economic growth since independence in Côte d'Ivoire than in Ghana (i.e., aggregate derived demand for skilled labor), and the greater proportion of educated workers initially in Ghana than in Côte d'Ivoire (i.e., relative supply of schooling). Migration of the worker from their province of birth is associated in both countries with workers receiving higher wages. An increment of one centimeter in height is associated with a 6-8 per cent increase in wages in Ghana, but not in Côte d'Ivoire. This is consistent with other evidence that for several decades child malnutrition has been more common in Ghana than in Côte d'Ivoire, and infant mortality has improved more rapidly in Cote d'Ivoire than Ghana. A unit gain in BMI is associated with a 9 per cent increase in wages for men in both countries, but for women the wage gain is 15 per cent in Côte d'Ivoire and 7 per cent in Ghana. Holding constant for migration, height and BMI, the estimated wage return to education is diminished by one-tenth, as is expected due to omitted variable bias and the reported positive inter-correlation of these four human capital stocks in both countries (Schultz, 1996).

7. CONCLUSIONS

Extensive historical and contemporary studies in low- and high-income countries document that health and nutritional status, measured in terms of a long-run indicator such as height and as a shorter-run indicator such as BMI (weight for height), influence labor productivity per unit time worked, and labor supplied per adult year to market work, and longevity (Fogel, 1994, Strauss and Thomas, 1995, Schultz and Tansel, 1997). At levels of real income when nutrition is very low, these effects of health and nutrition on productivity and survival are reported to be substantial, but there is not yet agreement on the precise magnitudes of the health productivity effects or how costly they are to achieve by private expenditures or public regulations or outlays. Consequently, internal rates of return to particular interventions, policies, or institutional investments are not yet known. There are suggestions from many studies that BMI and nutritional intake should be treated as endogenous. Even adult height that is molded during uterine development and early childhood is modified by household and community resource allocations, is subject to measurement error, and consequently is appropriately viewed as an endogenous human capital variable in the adult wage function over a lifecycle, even if most of the human capital investments reflected in adult height are undertaken by parents and not the adult worker. The statistical methods outlined in this paper promise in the next generation of health and economic studies to define with increasing precision the contribution of the health transition to modern economic growth in the low-income world since the second world war. This work will complement the extensive work on today's high-income countries which has documented the evolution and cross sectional differentials in anthropometric indicators of health during the early phases of industrialization and economic development (Komlos, 1994).

Evidence on the wage returns to education has evolved much further than that on health, where analyses have been replicated from hundreds of labor force and integrated demographic household surveys in countries at all levels of development (Schultz, 1993). As in the cases cited of Ghana and Côte d'Ivoire, private wage returns to education are affected by both the relative supply of educated workers to the economy, and the derived demand for educated workers, which depends on the composition and growth of the aggregate economic output. Although most of the evidence of returns to education is potentially subject to multiple sources of statistical bias (e.g., omitted variables, errors in measurement, endogeneity, heterogeneity in productive response to treatment) these sources of bias are not all in one direction, and do not appear to distort seriously the simple pattern that emerges when one documents how workers wages increase proportionally with their schooling. There is a biological basis for expecting the economic productive returns to nutrition to exhibit diminishing returns as nutrition and health improve, but there is less reason to expect that the pattern of returns to schooling will be uniform in all settings, or even subject to a common pattern of diminishing returns. Indeed there are many reasons for different distributions of the *supply* of education in the population and aggregate economy-wide differences in the derived *demand* for skills to generate notably different rates of return to schooling at various levels of schooling. Moreover, even within a country, the pattern of returns can change abruptly, as in the United States where returns to college education declined during the 1970s and increased sharply after 1980. Neither change in the supply of workers by age, education or sex, nor macroeconomic imbalances, nor increasing penetration of international trade, can adequately explain these far reaching changes in wage structures in the United States that are now found in a growing number of high and low-income countries. Thus, wage structures for education may change unexpectedly and should be periodically monitored by surveys to provide guidance as to where to expand public educational systems.

Evidence is accumulating that health and schooling contribute to higher labor productivity in most countries. Yet, it is not clear when education first became a critical factor enhancing labor productivity. There are few representative surveys that provide information on education and wages before the 1940 US Census. It seems unlikely that education was an important productive characteristic for most workers in the 19th century, when apprenticeships, on-the-job experience, and family training transmitted most productive skills. Why in the twentieth century did the opening up of the world economy to trade, capital mobility, and the diffusion of technology create extensive opportunities for better educated workers to outperform their peers in a widening range of jobs? With a better answer to this question, it may be possible to forecast the future evolution of returns to education, and begin to formulate testable hypotheses which might help to account for the growing evidence of substantial returns to health human capital, measured imperfectly along many diverse dimensions.

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