ECONOMIC GROWTH CENTER

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CENTER DISCUSSION PAPER NO. 670

THE ROLE OF EDUCATION AND HUMAN CAPITAL IN ECONOMIC DEVELOPMENT: AN EMPIRICAL ASSESSMENT

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August 1992

Note: Center Discussion Papers are preliminary materials circulated to stimulate discussions and critical comments. The original version of this paper was prepared for a conference on "Economic Growth in the World Economy," June 23-25, 1992, Institut fur Weltwirtschaft, Kiel, Germany.

Research for this paper was partially supported by the Institute for Policy Reform in Washington, D.C.

This revision benefited from the discussion with the conference participants and my colleague Gustav Ranis.

Abstract

Estimates of aggregate production functions from intercountry data have strengthened speculations that human capital is an important determinant of modern economic growth and a critical factor in explaining the convergence in growth across countries. For this macro literature to shed more empirical light on the growth contribution of education and other forms of human capital, measures of the stock of human capital must be improved and disaggregated. In particular, connections between diet, disease, height, stature and labor productivity imply that aggregate growth theories should seek to incorporate health, as well as education. Micro economic studies of individual wage differentials derived from household surveys are available from many low income countries. A host of difficult to resolve econometric problems cloud the interpretation of the partial association between the logarithm of wage rates and the years of education a worker has obtained. Nonetheless, this association between wage productivity and schooling provides a useful, if imperfect, estimate of private returns. Policymakers should take account of wage differentials by level of education as both an indicator of private payoff to educational investments in a national labor market and a criterion in setting public priorities to foster development and often to promote a more equal distribution of personal income.

KEY WORDS: Human Capital, Economic Growth, Macro-Micro comparisons

1. INTRODUCTION

Both macro and micro economists have sought to understand the role of human capital in the pace and structure of modern economic growth. Each has its own theoretical approaches, simplifying assumptions, and data for disentangling how education and analogous activities increase total factor productivity. Juxtaposing these literatures may help focus attention on the areas of agreement and areas where further research could reconcile differences of viewpoint or lead to the construction of improved data for advancing our knowledge.

2. EXOGENOUS OR ENDOGENOUS AGGREGATE GROWTH THEORY AND EVIDENCE

In the 1950s it became clear that the concept of an aggregate production function relating the input of labor hours and the services of land and capital to national output failed to account for modern economic growth in the United States since 1870 (Kuznets, 1952). Historical time series assembled by Kuznets (1966, 1971) for other industrially advanced countries reconfirmed that modern economic growth was not explained by the growth in physical units of traditional inputs. Solow (1957) made the point graphically by fitting a regression in logarithms of private nonfarm output per manhour to employed capital per manhour, and by then showing that most of the growth in output was accounted for by a linear trend in time, which he named "technical change". Possibly a more suitable name for this trend had been proposed by Abramowitz (1956), when he called it an index of our ignorance, or the more neutral term in growth accounting of "the residual" (Nelson and Phelps, 1966). Empirical and theoretical work formulating and testing hypotheses for explaining this residual stressed four factors: the quality of nonhuman capital, represented perhaps by its vintage (Solow, 1960), the quality of labor represented by human capital (T. W. Schultz, 1960), an

accumulation through research and development of a base of productive knowledge (Griliches, 1973; Nelson and Phelps, 1966), and organizational innovations possibly induced by relative factor scarcities (Hayami and Ruttan, 1971).

The recrudescence in interest in growth theory may be linked to the work of Lucas (1988) and Romer (1986) who proposed an endogenous mechanism for the generation of economic growth, a source of increasing returns associated in Lucas' view with the accumulation of human capital. A novelty of their work was the idea that in the long run output per unit of input could increase, even when inputs were exhaustively accounted for. Synergies between highly skilled workers or particular forms of capital investment were credited with producing these increasing returns, and technically advanced human capital and the growing knowledge base appear to be part of this wellspring of growth. Constant returns to scale technology at the level of the firm is retained as an approximate basis for achieving a perfectly competitive equilibrium, but at some level higher than the firm, nonappropriable increasing returns are attributed to this factor of production. Subsidization of this factor, perhaps human capital formation, might therefore be desirable.

One implication of Lucas' hypothesis was that human capital should be factored back into aggregate production functions, an empirical practice that was never fully accepted in the growth theory literature of the 1960s. Nor was much attention directed at that time to the empirical implications of growth models. A property of convergence implied by these models was then explored, in which countries moving toward a common steady state growth path would grow more rapidly the further they were from their path. Countries with low income per capita (and low capital per capita) would tend to converge to high income per capita

countries, or catch up, under suitable assumptions. But as noted by various authors (e.g. Barro, 1992), a regression of per capita growth rates among countries from 1960 to 1985 on initial levels of income per capita did not show the predicted negative relationship. But convergence conditional on initial human capital stocks, crudely approximated by literacy or contemporaneous primary and secondary enrollment rates, did suggest the expected pattern of convergence among countries.

Another approach to conditional convergence was to examine subunits in larger, more integrated, economic units, where it might be more defensible to assume that the subeconomies shared the same technological opportunities, economic institutions, savings propensities, and capital mobility. Following this approach, it was shown that convergence has occurred across the 48 states of the United States from 1888 to 1988, 46 prefectures of Japan from 1930-87, 73 administrative regions of Western Europe from 1950-85, and the OECD countries from 1960 to 1985, (Barro and Sala-i-Martin, 1992).

Other implications of the growth process follow from the reestimated parameters of this human capital augmented, but nonetheless neoclassical, constant returns to scale, Solow growth model. The share of income attributed to nonhuman capital is awkwardly large, on the order of 60 percent, in the simple Solow model, whereas the human capital, nonhuman capital and labor shares of income appear to be more reasonably estimated as about one-third each in the augmented Solow model (Mankiw, Romer and Weil, 1992). The elasticity of income per worker with respect to population growth increases from -1/2 to -2, with the augmentation of the growth model to include human capital measured approximately as secondary school enrollments as a share of population (Mankiw, Romer and Weil,

1992). Although population continues to be treated as exogenous, it becomes quantitatively more important in the augmented model. The next step is to incorporate fertility as endogenous to the human capital formation process (Becker, et al, 1990) and eventually it may be made responsive to the gender composition of that human capital as noted in section 6 below (Schultz, 1973, 1981). Similarly, the elasticity of the income per worker with respect to the physical savings rate is substantially larger, increasing in one set of regressions from +1/2 to 1. The convergence among countries with the same population growth, technologies, and capital accumulation propensities is also slower and more nearly compatible with the slow conditional convergence previously estimated (Mankiw, Romer and Weil, 1992).

However, none of these plausible empirical patterns seems to depend on an externality or source of increasing returns as postulated by Lucas/Romer. Indeed, there is little concrete guidance in this literature on where precisely to look for this externality, if it exists. Should it occur across production units in a city (Jacobs, 1984), or an industry (Jaffe, 1992), or nation state. Without a more empirically tractable description of the mechanism and the relevant unit of observation, it may be some time before a convincing empirical test is mounted for the notion of an aggregate externality caused by human capital. But even if the externality associated with human capital is not confirmed, we can expect to see more study of international time series for clues on their determinants. Casual empiricism had previously explained the resurgence of Western Europe and Japan after the Second World War as due to the highly skilled and disciplined labor forces of these countries. The mobility of physical capital quickly returned these war-damaged economies to their steady state growth paths once

institutional stability was reestablished and property rights clarified. The establishment of property rights and institutions to achieve capital mobility appear to be more serious problems today ahead of Eastern Europe, although again countries in this region start relatively well-endowed with human capital.

This economic growth literature may now begin to go beyond intercountry regression coefficients on educational enrollment and literacy rates. Growth models call for a variable representing the level of, or increments to, the stock of human capital. These are not provided by any existing international agencies, such as UNESCO.[1] Capital stocks can be constructed in terms of the historical (or replacement) cost of production, or according to their current productive value. These two measures may diverge substantially in a long-lived human capital stock, producing quasi rents for the owners of human capital. A distinctive feature of human capital is that it is not bought or sold, but only hired from workers in exchange for wages. Consequently, most analysis of human capital is based on wage structures for individuals with different amounts of human capital, and these micro economic differences in wages are interpreted as due to the workers having invested in observable skills, training, or health. How these inferences may be biased is discussed in the next section of this paper. However, it may be useful to consider here how human capital stock series might be constructed and used in future empirical work in this reinvigorated field of economic growth studies (Cf. Jorgenson, Gallop and Fraumeni, 1989;

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[1] In the World Bank Development Report for 1991 human capital stocks were created by backward projecting enrollment rates to the start of this century. The stock of labor force educational attainment was than constructed for intermediate years. Where these figures can be checked against Census cross tabulations of the population by educational attainment, it seems clear that the trend extrapolation of enrollments may need to be revised and refined.

Eisner, 1989).

From the social cost accounting side, the stock of human capital investment made during a year in country j, I_j, might be defined as follows:

$$I_j = \sum_{i=7}^{n} S_{ji}\, C_{ji}\, P_{ji}$$

where S_{ji} is the enrollment rate of individual students in a specific i^{th} age cohort for a given number of days each year, C_{ji} is the social cost of educating them, and P_{ji} is the population in that i^{th} age group. The social cost of education has three components: the opportunity cost of the student's time or the foregone production which is approximated by the market wage for comparable individuals who do not attend school for a year, W_i; the private direct costs borne by the family, such as books, transportation, and school fees, P_i; and the public expenditures for a student-year of education, G_i. Gross domestic product as conventionally measured must then be augmented by the opportunity cost of the time of students. The investment share of this augmented income invested in human capital can then be properly calculated (Eisner, 1989).

Because the dominant cost of most public education is the foregone wages of students, the percentage increase in the market wage resulting from an additional year of schooling is approximately equal to the private internal rate of return to these schooling investments by families (Becker, 1964; T.W. Schultz, 1967; Mincer, 1974). Few studies include estimates of the private direct costs of education to families, P_i, for even consumer expenditure surveys rarely relate family expenditures on education to the amounts spent on each particular individual in the family who attends school. Calculations of social returns to schooling vary a great deal in methodology, but generally include public

expenditure on each level of schooling, at least at the central governmental level.

The majority of micro economic studies of wage structures find that private returns to schooling vary by level whereas aggregate growth studies assume returns are constant across levels of schooling. Although the predominant tendency may be for the social returns to schooling to be higher in low income countries than in high income countries, and to decrease at more advanced levels of schooling within either class of country (Psacharopoulos and Woodhall, 1985), there is no shortage of short run exceptions.[2] In linking macro economic studies to micro evidence, it would be useful to compare how a particular country compares to other countries. Are those countries with relatively low levels of human capital investment in macro models the same countries that exhibit lower than average private or social rates of return to schooling as measured from independent micro wage studies? If not, then are other institutions dissimilar across these countries? Does effective protection of an economy from competitive

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[2] When about 95 percent of a birth cohort has completed a given level of education, it may prove difficult to estimate the return with any reasonable confidence. Comparisons of the wage received for persons with only that level of education compared to the wage received by the fewer than five percent with less education may be volatile, and frequently not statistically different from zero. Hypotheses regarding the self selection process can be used to explain this pattern, but this finding is probably better viewed as a clue about the limitations of the approach. For this reason estimates of the private returns to primary education in high income countries where virtually all persons (except immigrants) have completed primary schooling are not meaningful. It is also often the case that where national economies have grown rapidly, a bottleneck may emerge at the secondary level and for some years the private returns to secondary schooling will exceed those at the primary level (e.g. Thailand, Cf. Schultz, 1992). Or where the tertiary level of education is controlled by the public sector and entry is rationed by national entrance examinations, returns to tertiary schooling may be exceptionally high until private colleges are permitted to enter the market or public universities expand (Cf. Taiwan and Korea in the 1980s).

pressures of foreign trade or the domination of sectors by public and private monopolies or unions lead to less demand for educated workers and hence lower private returns to schooling? There are surprisingly few studies that combine macro and micro evidence of this form on human capital and growth. But to integrate the two approaches and plausibly identify these macro economic models is a difficult challenge.

3. MICRO EVIDENCE OF THE PRODUCTIVITY EFFECT OF EDUCATION

With the routinization of labor force surveys and censuses, that collect information on the earnings and hours worked by employees, it is possible to compare wage differentials by educational attainment at several points in time in an increasing number of countries from Latin America, Asia and Africa. The common pattern is for these indicators of private returns to education to increase as the national economy grows rapidly and become more integrated into the world economy, and then, only after a lag of one or two decades, does the expansion of the educational system begin to catch up to the derived demands for educated labor. Only then do very high educational returns, in excess say of 10-15 percent, begin to diminish.

In Brazil the 1960s and 1970s witnessed a sharp increase in the relative wage gap between secondary and primary educated workers and between those with university training and secondary school graduates (Lagoni, 1977). Although public education in Brazil may have in retrospect lagged behind these demands for educated workers, private returns to education have begun to decline in Brazil in the 1980s, from about 20 to 15 percent, but they remain about constant at all levels of schooling (Lam and Levison, 1989; Lam and Schoeni, 1991; Strauss and Thomas, 1991). Within Brazil, the higher income regions, such as Sao Paulo and

Rio de Janeiro, report the smallest educational wage differentials and the best educated workforce, whereas the low income Northeastern region reports the highest educational wage differentials (Reis and Barros, 1991). Regional and educational wage inequality is larger in Brazil than observed in all high income countries and in most low income ones. Simple Mincerian earnings functions account for as much as half of the variance in the log of wages in Brazil, whereas these specifications of wage functions account for only a quarter of the variance in the United States (Mincer, 1974, 1981). These educational differentials are not apparently caused by segmentation of the labor force into formal/informal sectors (Barros, et al. 1992), and are not reduced more than a few percent by controlling for parent education and region (Lam and Schoeni, 1991).

From 1937 to 1951 educational wage differentials widened in Colombia, continuing to expand during the 1960s and then declining slowly thereafter. The recent decline in schooling returns from 20 to 12 percent can be seen from a series of national household surveys (Londoño, 1990), while rural-urban wage differentials have closed and migration to the cities diminished. As in Brazil, regional differentials in wages are largest for the least educated, and a substantial fraction of the returns to obtaining an education is recouped through migration, if the student is born in a rural area or a low income region (Schultz, 1982, 1988). Because the labor market for college educated workers tends to be more nearly national in scope, relative differences in wage rates across regions for these more highly educated workers tend to be narrower than the relative differences in wage rates across regions for the least educated. The same pattern of educational-wage differentials by region is noted in 1961 in

Venezuela as occurs in Brazil or Colombia, and is consistent with the greater likelihood of interregional migration among the more educated (Schultz, 1982; Schwartz, 1971).

Countries that have protected their domestic economy from competitive pressures of international trade have tended to have slower growth and lower returns to education (Harrison, 1991; World Bank, 1991). Peru, for example, as the military managed the economy during the 1970s and aggressively pursued import substitution policies, recorded a decline in its social returns to secondary schooling from nearly 20 to about 7 percent (Schultz, 1988).

Korea, which has sustained perhaps the most rapid expansion of its educational system in the last thirty years, experienced a marked increase in returns in the late 1960s as export led growth in light industry developed. Returns to college education have only begun to decline markedly at the end of the 1980s, despite the several fold increase in number of college graduates (Choi, 1991; Topel and Kim, 1992). Korean estimates of returns to schooling may, however, be somewhat distorted, because the primary source of data is the Occupational-Wage Survey collected only from nonagricultural private firms with at least ten employees. Taiwan has also reported stable high returns to schooling throughout the 1970s and 1980s, and as with Korea, for some time rationed excess demand for tertiary education with university entry level examinations, and thereby undoubtedly raised the wage returns to higher education (Deaton and Paxson, 1992).

Wage differentials associated with education are monitored in Thailand since the early 1970s. They evidence some decline in returns at the primary level, as virtually all Thais completed primary school by the 1960s. A

relatively slow expansion of secondary education, particularly for girls, is partly responsible for the rise in private returns associated with secondary schooling to 30 percent per year for females and 20 percent for males during the period 1975 to 1985. Returns to higher education appear to be more moderate in Thailand, and the corresponding proportion of the population studying at this level is also relatively large compared to neighboring countries with similar levels of income per capita (Schultz, 1991, 1992).

Africa also provides a number of comparisons of different educational policies and growth experiences, but less in the way of time series on wage differentials. Kenya expanded rapidly its public and private secondary school systems in the 1960s and 1970s in response to popular demands, using school fees to finance part of the growth. Tanzania, in contrast, relied upon an entrance exam to ration excess demand for relatively fewer places in its fully subsidized public secondary school system. On the demand side, the Kenyan economy has been more open to trade and investment, and growth has proceeded more rapidly than it has in the state-dominated Tanzanian economy. Growth in per capita GDP has been 1.7 percent per year in Kenya from 1965 to 1987, while it has been negative in Tanzania. Private wage returns in Kenya to secondary education have declined. In the stagnant Tanzanian setting, the relative returns to secondary schooling have also decreased, but so has the absolute level of wages (Knight and Sabot, 1987).

Ghana followed Kenya in its educational laissez-faire policy, achieving shortly after independence in 1965 enrollments of about 70 percent at the primary school level, and by 1975 enrollment of 36 percent at the secondary level. But the subsequent declines in national output that occurred during the 1970s halted

*any further expansion of schools in Ghana and probably contributed to a decline in educational returns. By 1985, as the economy began to again revive, private returns to primary education were nil and an additional year of middle or secondary schooling earned a ten percent premium in wage employment (Schultz, 1992).

In comparison, Côte d'Ivoire grew many times faster than Ghana from 1960 to 1980 and expanded its primary school system to Ghana's level by 1975, but restricted the enrollment rate at the secondary level to about 20 percent, and maintained its French Lysee type examination system. Although it is not clear whether the demand or supply conditions are responsible, private returns to primary schooling in Côte d'Ivoire were by 1987 about 10 percent, whereas at the middle and secondary school levels they exceeded 20 percent (Vijverberg, 1992; Schultz, 1992; Tansel, 1992).

Private wage returns should be accounted for within a model that combines evidence on population growth and capital investment that determines the derived demands for educated labor with evidence on the expanding supply of educated labor. However, only ad hoc case studies such as those cited have been undertaken, or simulations of computable general equilibrium models are based on unconfirmed assumptions regarding critical elasticities of substitution among the factors of productions, including educated and uneducated labor (Londoño, 1990). This is another instance where macro economic evidence of the role of human capital in growth and educational policies of price versus quantity rationing could better inform policymakers about the trade-off between different forms of public investment, growth, and the resulting personal distribution of income.

4. MEASUREMENT OF RETURNS TO SCHOOLING AND OTHER FORMS OF HUMAN CAPITAL: ISSUES OF MODEL SPECIFICATION AND ESTIMATION

Limitations in our capacity to measure the economic returns to education and other forms of human capital arise from two basic sources: omitted variable bias and errors in measurement. Comparative studies of worker productivity cannot, in most cases, be based on experimentally controlled variation in human capital investments across people. Thus, those who acquire more education than others may differ in many ways that could influence their productivity, whether or not they are educated (Griliches, 1977). Controls for these omitted variables, such as ability or parental wealth, that could directly influence the individual's productivity or earnings, does not necessarily reduce the bias in estimates of schooling returns. In some cases ability, if suitably measured in the preschool aged child before these measures are themselves affected by education, do not appear to exert a large effect on wages, or to introduce substantial bias in the estimate of educational returns. Moreover, the more correlates of education that are held constant, such as ability, the larger is the offsetting bias due to the errors in measurement of education (Griliches, 1977; Lam and Schoeni, 1991). There is a large literature scattered over the last thirty years proposing methods for estimating wage functions to deal with one or another source of omitted variable bias, but no consensus has emerged that any one general approach is superior (Dougherty and Jimenez, 1991).[3]

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[3]Obvious differences in the "quality" of a year's education across countries encourage researchers to construct more comparable measures of the output of educational investments. It is, however, necessary to recall that one does not automatically prefer a standardized test score, such as are frequently reported across countries for a particular grade level and subject. Unless increments to the score for a worker are also calibrated from the wage setting process and are associated with workers being offered the same percentage

A second potential source of bias arises because the productivity of labor is generally inferred from only workers who receive a wage or salary. It is substantially more complex to measure the product of an individual who is self employed or works without a wage in a family enterprise. But analyses of self employed men and women in a variety of countries, including the United States, Thailand, Colombia, and Israel, have not detected major differences in returns to schooling associated with working in wage and nonwage sectors (Schultz, 1988). What (unobserved) variables influence an individual to work for wages rather than as self employed or in the home must be modeled as a sample selection decision rule (Heckman, 1979). I have adopted the identification strategy of assuming that land ownership, other assets and nonearned income are associated with individuals being able to enter self employment rather than work for wages, or withdraw from the labor force entirely. If these wealth variables are exogenous to the wage function or the individual's market productivity, and yet raise her or his reservation wage these variables can be used as instruments to identify the sample selection correction model. Dealing with the sample selection bias problem using this basis for statistical correction, a number of studies have not found large biases in our estimates of schooling returns in high income countries. However, this source of bias may be more important for women than for

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increment to their wages in all countries, the score need not be an improvement on seemingly cruder indicators such as "years of education". Having higher physics or geography scores may or may not purchase for workers higher wages in all of the world's labor markets. However, in hundreds of studies of national labor markets, years of education are statistically associated with workers receiving higher wages. Standardized test scores might eventually show themselves to be a superior indicator of educational investments compared to years of education. Initial efforts to combine substantive test scores with years of education in the analysis of adult productivity, however, have not suggested the omission of test scores is a serious source of bias in inferences concerned with estimating the market returns to "years of education" (Boissiere, et al., 1985).

men, because women participate less frequently in wage employment in most parts of the world (Schultz, 1990; 1992).

Without experimental variation in educational investments there is no perfect method for disentangling the social conditions and characteristics of persons who receive education from their labor productivity. There are special circumstance, however, when random variation in education is induced in a population and the resulting variation in educational attainment can then be analyzed to obtain an estimate of the returns to education that is free of both omitted variable bias and errors in measurement bias. Two recent papers illustrate the approach, and find that the simple direct correlation implied by the Mincerian (1974) earnings function is not necessarily misleading. In the first paper, the variation in birth dates and state compulsory school attendance laws in the United States are used to predict variation in how much schooling individuals receive by state and birth cohort, as measured in several population censuses. Using these state-of-residence and birth dates as instrumental variables to estimate returns to schooling, it is shown that these "experimental" estimates are generally not statistically different from the ordinary least squares estimates (Angrist and Krueger, 1991a). In the second paper, the lottery of birth dates that was used to select individuals for induction into the Armed Forces during the Vietnam War are used as instruments to explain who among the relevant cohort of U.S. males continued their education and thereby avoided the draft. The threat of a high lottery number was associated with continued education, and that extra education earned the individual about the same wage gains as education did for the entire population (Angrist and Krueger, 1991b). Although two studies of the United States do not generalize widely, the viewpoint

is becoming more widespread that the simple partial correlation between schooling and wage productivity is a reasonable, if not perfect, approximation for the productive returns to marginal expansions of schooling.

If the standard measures of private and social returns to education are of a reasonable magnitude, of approximately 15 and 10 percent respectively, then how has the share of income invested in education changed? Based on government expenditures on education at all three levels of schooling for 47 countries during the 1960s and 1970s, I estimated a real growth in public expenditures on education of 5.4 percent per year per school-aged child (Schultz, 1992). This calculation assumed that the domestic GDP price deflator is applicable to educational inputs, and that foreign exchange rates are a satisfactory basis for translating domestic currencies into a common unit of value, 1970 dollars.

Because of rapid population growth in that period, these public expenditures on education in this sample have increased about 8 percent per year. This is considerably faster than the growth of GDP that increased at about 6 percent for this sample of countries. If one were able to include also the foregone earnings of students and the private costs of education paid by families, the share of national income allocated to total educational investments would also appear to have increased. More refined and representative estimates are required to judge more precisely the contribution of education to economic growth in this period. These are not, to my knowledge, available.

5. RETURNS TO HEALTH AND NUTRITION

Productive benefits from health and nutrition can be estimated by including health characteristics of the worker in the wage function, just as education and potential job experience are currently included (Mincer, 1974). The task of

estimating returns is no different than with education, if the health investment is predetermined before labor productivity or the wage is determined. In the case of current health status, acute illnesses, or current nutritional intakes, the health indicator is probably not predetermined. If earnings are used partly to improve health or nutrition, then the impact of nutrition and health on wage rates must be estimated by simultaneous equation methods to capture only the one-way effect of health on labor productivity. As with education, the problem of measurement errors in nutrition and health status may be as serious a source of bias as the simultaneous feedback effect. To obtain unbiased estimates of the effect of nutrition and current health status on wages then requires the specification of a suitable instrumental variable that will identify the model. Local food prices and health programs may be excluded from the wage function, but assumed to influence the household demand for nutrition and health inputs, and hence be a valid identifying instrumental variable for this model.

This approach was first used by Strauss (1986) in a study of family farm labor productivity as a function of predicted calorie availability in Sierra Leone, and his methodology has now been replicated and extended in several other low income settings. These estimates of the benefits of calories, weight and a reduction in morbidity have not yet been combined with the costs of making these nutritional and health investments, to derive commensurable internal rates of return to these investment activities (Thomas and Strauss, 1992; Schultz and Tansel, 1992). Such private productive returns to health and nutrition may also differ for men and women. A study of nutrition, time allocation and productivity in Bangladesh provides a broader family context in which to analyze these interrelated decisions and the productive efficiency of calories used by

different members of the household (Pitt, et. al. 1990).[4]

Height may be approached in the same econometric fashion as education. Many studies suggest that adult height is an inverse measure of chronic childhood malnutrition that causes stunting, and this effect occurs primarily before the child reaches five years of age (Falkner and Tanner, 1986). Consequently, height is not strictly simultaneously determined with labor productivity. Nonetheless, unobserved or omitted factors may still affect both height and adult productivity, and therefore, the simple partial association between height and wage rates or earnings may be a biased indicator of the causal effect of height on labor productivity.

Much historical analysis of the level and change in height in Western European populations in recent centuries has documented a remarkable growth in the stature of 'man'. Fogel (1990) argues that the improvement in diet that contributed to this increase in adult height is responsible for a third of the growth in labor productivity in Western Europe from 1750 to 1990. Recent studies

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[4]But education and health are themselves interdependent. The connections between education and health are not yet clearly documented, in part because mortality or morbidity rates are not often available for analysis by educational attainment. Recent research has linked mother's education to the survival of her children in low income countries (Cochrane et al., 1982), whereas other studies have suggested that nutrition and health of children can affect their school achievement (Moock and Leslie, 1986). Height is believed to be largely determined by nutritional status of the individual before reaching age four (Fogel, 1990). Height can then be viewed as an indicator of long-run nutritional status that is essentially fixed in early childhood and may therefore be treated as exogenous in an adult's wage function in the same way that education is. Weight or a body-mass-index or current caloric intake or acute illness, on the other hand, is more reasonably viewed as simultaneously determined with current productivity and income. Calorie consumption as an indicator of short run nutritional status can be estimated as a determinant of productivity by instrumental variable methods but may only be a quantitatively important determinant of labor productivity and wages at very low levels of income or calorie intake (Strauss, 1986).

of low income countries also confirm a strong relationship between wages and height, even after controlling by instrumental variable methods for current calorie and protein consumption and a body-mass-index (a ratio of weight to height squared that is associated with adult relative risk of mortality) (Thomas and Strauss, 1992). There is also evidence that intergenerational gains accrue to improvements in health that are only evident in panel data (Rozensweig and Wolpin, 1992). The gains in stature and longevity that have occurred widely in the last century are responsible for some portion of modern economic growth, but research on this source of growth is not yet in a form to permit us to assign it a precise quantitative role.

6. HUMAN CAPITAL INVESTMENTS IN MEN AND WOMEN

Human capital investments in women have increased relative to those made in men in most countries during this century, as proxied by both years of education and years of longevity. The shift in the gender composition of human capital formation has occurred at about the same time as women have entered more frequently into the market labor force, particularly in employment outside of the family for wages (Schultz, 1990). The coincidence of these trends in female labor force participation and their schooling may have contributed to Becker's (1964) conjecture that individuals only realize the returns to college education through their work in the market labor force, but this view must be critically reappraised (Schultz, 1991).

Most studies of labor force participation of women confirm that women with more education supply more of their time to market work, and more specifically to wage employment. The release of time from childbearing and childrearing activities is also associated with women leaving home for market employment.

Which comes first, the market labor force commitment, the decline in fertility, or the educational attainment of women? Economists usually analyze education as being determined first, based on expected individual returns to education and on parents endowments, both educational and financial, that allow parents to promote their children's schooling (Schultz, 1981). By this reasoning, fertility and specialization between home and market labor force skills are modified by prior educational attainment. What is needed to disentangle such lifecycle causal chains is a suitable source of variation in schooling that is exogenous or independent of the child's (or parent's) preferences for adult careers of childbearing or market employment. Measures of this source of variation in schooling may then be used to identify the effect of education on individual productivity and behavior (Cf. Card and Krueger, 1992). It should then be possible to infer how variation in women's education affects their wage opportunities, as well as fertility and labor force behavior.

The returns to education and health investments may interact and partially account for the shifting emphasis toward women's human capital. The argument that medical knowledge contributed little to the decline in mortality before the twentieth century is increasingly accepted, and yet the creation and spread of public health and medical technologies in this century have been important factors in the demographic transition that may have recently given educated persons a new survival advantage. And in the case of a woman, that health advantage due to education is apparently extended to her children. If this is a relatively recent phenomenon, then it might help explain the recent shift of resources toward women's education, even when women are still primarily engaged in traditional household production tasks within the family in many low income

countries.

It also seems likely that the increased nutrition and health status of populations is contributing to the rising productivity of more educated workers. If this is true, the estimated contribution of education to labor productivity in a wage function could be overstated by the failure to hold constant nutritional status. At a minimum, to understand the causal pathways from lifetime and current nutritional investments to adult productivity requires more empirical study of nutritional status in combination with educational investments in societies at various stages in the development process where males and females are explicitly distinguished.

At this stage we can only speculate what motivated families and society to invest more human capital in women in this century relative to men. Whatever this force was, it seems to have been present in Europe, populations of European Settlement, and Latin America, Japan, and finally in East and South East Asia. Where data on individual characteristics and wages are available to standardize for the observed heterogeneity of labor skills, there appear to be similar private returns to the education of men and women. Indeed, frequently when women have received a small fraction of the secondary or higher education in a society, women with these more scarce skills receive a larger relative wage premium than do men (Schultz, 1992). Although the relative wage returns to schooling for women and men may be of a similar magnitude, this does not necessarily imply that the level of women's wages is equal to men's. Private returns are approximated by the ratio of the wage of the more educated worker to that of a worker with less education, divided by the years a student must forego employment to acquire this extra education (Mincer, 1974). Both the wage gains and opportunity costs

of schooling are generally lower for women than for men, but roughly in the same proportion, implying comparable private rates of return for both genders.

Beyond the market productivity of workers that should be captured by private individual returns flowing efficiently to those who might invest in their own schooling, there are external benefits to society such as are exhibited through reduced child mortality, improved child nutrition and schooling, and decreased fertility and population growth. These measurable social externalities of education are primarily associated with educating women, not men. Thus, there may be a persuasive case for society to subsidize investments in women's schooling by a greater amount than men's (Schultz, 1992).

Why then does the shortfall in female education and health relative to male education and health persist in South and West Asia and with respect to female education in much of Africa? The answer probably lies in the family decision making process and in parent's own interests that traditionally attach less value to the future productivity of daughters than to that of sons. Parental claims on the adult productivity of boys may be more secure in some family-cultural systems than their claims on girls. Researchers have only begun to tease out empirical implications from such culture-based hypotheses for gender differences that can be tested statistically (Foster and Rosenzweig, 1992; Pitt, et al, 1990).

7. CONCLUSIONS

Estimates of aggregate production functions from intercountry data and indications of convergence across countries and regions in economic growth have contributed to speculations that human capital is an important determinant in modern economic growth and a central factor in explaining differences in per

capita income across countries. For this literature to shed more empirical light on the growth contribution of education and other forms of human capital, measures of the stock of human capital must be improved and disaggregated. A year of educational attainment or enrollment in a school does not generally cost the same amount to produce or have the same productive value for the labor force (and home workers) at the primary, secondary and tertiary levels. More refined and disaggregated national series on the cost of human capital formation and the market rental value of that capital (valued at current or fixed wage relatives) may be expected to yield new insight into the contribution of education to aggregate economic development.

Micro economic studies of wage differentials of individuals have multiplied in the last several decades as household surveys in most countries began to collect routinely information on each individual's sources of income, hours of work, and productive characteristics, such as education. A host of difficult to resolve econometric problems cloud the interpretation of the partial association between the logarithm of wage rates and the years of a particular form of educational attainment. This indicator of the scarcity of schooling provides, nonetheless, a rough estimate of private returns to various levels and types of education and training. From this large empirical literature it appears that returns to education are often substantial at both the private individual and social levels. The increase in the share of national income invested in education that is associated with these relatively high return activities must play a major part in the rapid pace of modern economic growth and its spread in the second half of the twentieth century.

Both years of education of adults and current enrollment years have

increased more rapidly in low income countries than in high income countries (Schultz, 1992). If relative returns were of a similar magnitude in both groups of countries, the closing of the gap in investments in education would help to close the relative income gap between high and low income countries, as hypothesized in the convergence literature (Barro and Sala-i-Martin, 1992). Although far less well understood at this time, the convergence in life expectation at birth between the high and low income countries is also a factor relevant to the convergence in national incomes. Increased adequacy of diet at the lowest income levels improves nutritional status and productivity of adults markedly. As these connections between diet, disease, height, stature and labor productivity become better defined as a series of empirical regularities, aggregate growth theories should seek to incorporate health, as well as education and job training, into their human capital models of economic and demographic growth (Meltzer, 1989).

REFERENCES

Abramovitz, M., 1956, Resources and Output Trends in the United States since 1870, Occasional paper 52, National Bureau of Economic Research, New York.

Angrist, J.D. and A.B. Krueger, 1991a, "Does Compulsory Schooling Affect Schooling and Earnings?", Quarterly Journal of Economics, 105(4):979-1014.

_____, and _____, 1991b, "Estimating the Payoff to Schooling Using the Vietnam-era Draft Lottery", Industrial Relations Section, Princeton, N.J.: Princeton University Press.

Barro, R.J., 1992, "Economic Growth in a Cross-Section of Countries", Quarterly Journal of Economics, 106(2):407-443.

Barro, R.J., and X. Sala-i-Martin, 1992, "Convergence", Journal of Political Economy, 100(2):223-251.

Barro, R.J., N.G. Mankiw, and X. Sala-i-Martin, 1992, "Capital Mobility in Neoclassical Models of Growth", Economic Growth Center Discussion Paper No. 655, Yale University, New Haven, CT.

Barros, R., R. Mello, V. Pero and L. Ramos, 1992, "Informal Labor Contracts: A Solution or a Problem", processed, Yale University, New Haven, CT.

Becker, G.S., 1964, Human Capital, New York: Columbia University Press.

Becker, G.S., K.M. Murphy and R. Tamura, 1990, "Human Capital, Fertility and Economic Growth", Journal of Political Economy, 98(5)part 2:S12-S36.

Boissiere, M., J.B. Knight, R.H. Sabot, 1985, "Earnings, Schooling, Ability and Cognitive Skills", American Economic Review, 75:6, 1016-1030.

Bowles, S. 1969, Planning Educational Systems for Economic Growth, Cambridge MA: Harvard University Press.

Card, D. and A.B. Krueger, 1992, "Does School Quality Matter?", Journal of Political Economy, 100(1):1-40.

Choi, K.S., 1991, "Changes in Wage Profiles in Korea during the 1980s", processed, Yale University, New Haven, CT.

Cochrane, S.H., J. Leslie and D.J. O'Hara, 1982, "Parental Education and Child Health", Health Policy and Education, 2:213-250.

Deaton, A. and C. Paxson, 1992, "Savings, Growth and Aging in Taiwan", processed, Princeton University, Princeton, N.J.

Dougherty, C.R.S. and E. Jimenez, 1991, "The Specification of Earnings Functions: Tests and Implications", Economics of Education Review, 10(1):85-98.

Eisner, R., 1989, The Total Incomes System of Accounts, Chicago: University of Chicago Press.

Falkner, F. and J.M. Tanner, 1986, Human Growth, Vol. 3, 2nd Ed., New York, Plenum Press.

Fogel, R.W., 1990, "The Conquest of High Mortality and Hunger in Europe and America", NBER Working Paper No. 16, Cambridge, MA.

Foster, A. and M. Rosenzweig, 1992, "Information, Learning and Wage Rates in Low Income Rural Areas", paper presented at conference on Women's Human Capital and Development, Bellagio, Italy.

Gomes-Neto, J.B., E.A. Hanushek, R.H. Leite, and R.C. Frota-Bezzera, 1992, "Health and Schooling Evidence and Policy Implications for Developing Countries", Rochester Center for Economic Research Working Papers No. 306, University of Rochester.

Griffen, P. and A. Cox-Edwards, 1992, "Rates of Return to Education in Brazil: Do Labor Market Conditions Matter?", processed, California State University, Long Beach.

Griliches, Z., 1973, "Research Expenditures and Growth Accounting", in Science and Technology in Economic Growth, (ed.), B.R. Williams. New York: Wiley.

_____ 1977, "Estimating the Returns to Schooling: Some Econometric Problems", Econometrica, 45(13):1-22.

Harrison, A., 1991, "Openness and Growth: A Time Series, Cross Country Analysis for Developing Countries", Working Paper Series 809, The World Bank, Washington, D.C.

Hayami, Y. and V.W. Ruttan, 1971, Agricultural Development: An International Perspective, Baltimore, MD: Johns Hopkins University Press.

Heckman, J.J., 1979, "Sample Bias as a Specification Error", Econometrica, 47(1):153-162.

Inkeles, A. and D.H. Smith, 1974, Becoming Modern: Individual Change in Six Developing Countries," Cambridge, MA: Harvard University Press.

Jacobs, J., 1984, Cities and the Wealth of Nations, New York: Random House Vintage Books.

Jaffe, A.B., M. Trajtenberg, and R. Henderson, 1992, "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations", processed, Harvard University, Cambridge, MA.

Jamison, D.T. and L.T. Lau, 1982, Farmer Education and Farm Efficiency, Baltimore, MD: Johns Hopkins University Press.

Jorgenson, D., F. Gollop and B. Fraumeni, 1989, Productivity and U.S. Economic Growth, Cambridge, MA: Harvard University Press.

Kim, J.I. and L. Lau, 1992, "Sources of Economic Growth of the Newly Industrialized Countries on the Pacific Rim", processed, Stanford University, Stanford, CA.

Knight, J.B. and R.H. Sabot, 1987, "The Rate of Return on Educational Expansion", Economics of Educational Review, 6(3):255-262.

Kuznets, S., 1952, "Long Term Changes in National Income of the United States of America since 1870", in (ed.) S. Kuznets, Income and Wealth, Series II, Cambridge, Bowes and Bowes.

_____, 1966, Modern Economic Growth: Rate, Structure, and Spread, New Haven, CT: Yale University Press.

_____, 1971, Economic Growth of Nations, Cambridge, MA: Harvard University Press.

Lam, D. and D. Levison, 1989, "Declining Inequality in Schooling in Brazil and Its Effects on Inequality in Earnings", processed, University of Michigan, Ann Arbor, MI.

Lam, D. and R. F. Schoeni, 1991, "Effects of Family Background on Earnings and Returns to Schooling", processed, University of Michigan, Ann Arbor, MI.

Langoni, C.G., 1977, "Income Distribution and Economic Development: The Brazilian Case", in M. Intrilligator (ed.), Frontiers of Quantitative Economics, Vol. II, 587-606, Amsterdam: North Holland Publishing Co.

Lau, L.J., D.T. Jamison and F.F. Louat, 1990, "Education and Productivity in Developing Countries", Working Paper WPS 612, The World Bank, Washington, D.C.

Lichtenberg, F.R., 1992, "Have International Differences in Educational Attainment Levels Narrowed?", paper presented at New York University workshop on "Historical Perspective on the International Convergence of Productivity".

Londoño de la Cuesta, J.L., 1990, "Income Distribution during the Structural Transformation: Colombia 1938-88", unpublished Ph.D. dissertation, Harvard University.

Lucas, Jr., R.E., 1988, "On the Mechanics of Economic Development", Journal of Monetary Economics, 22(3):3-42.

_____, 1990, "Why Doesn't Capital Flow from Rich to Poor Countries?", processed, University of Chicago, Chicago, IL.

Mankiw, N.G., D. Romer and D.N. Weil, 1992, "A Contribution to the Empirics of Economic Growth", Quarterly Journal of Economics, 107(2):407-437.

Meltzer, D., 1989, "Length of Life, Human Capital and Economic Growth", paper for Conference on the Family, Gender Differences and Development, Economic Growth Center, Yale University, New Haven, CT.

Mincer, J., 1974, Schooling Experience and Earnings, New York: Columbia University Press.

_____, 1981, "Human Capital and Economic Growth", NBER Working Paper No. 803, Cambridge, MA.

Moock, P. and J. Leslie, 1986, "Childhood Malnutrition and Schooling in the Terai Region of Nepal", Journal of Development Economics, 120:33-52.

Nelson, R.R. and E.S. Phelps, 1966, "Investment in Humans, Technological Diffusion and Economic Growth", American Economic Review, 56(1):69-75.

Pitt, M., M. Rosenzweig and M.D.N. Hassan, 1990, "Productivity, Health and Inequality in the Intrahousehold Allocation of Food", American Economics Review, 80(5):1139-1156.

Psacharopolos, G., 1985, "Returns to Education", Journal of Human Resources, 20(4):583-604.

Psacharopolos, G. and M. Woodhall, 1985, Education for Development, New York: Oxford University.

Reis, J.G. Almeida dos and R. Paes de Barros, 1991, "Wage Inequality and the Distribution of Education", Journal of Development Economics, 36:117-143.

Romer, P., 1986, "Increasing Returns and Long Run Growth", Journal of Political Economy, 94(3):1002-37.

_____, 1989, "Human Capital and Growth: Theory and Evidence", NBER Working Paper No. 3173, Cambridge, MA.

Rosenzweig, M.R. and K.I. Wolpin, 1992, "Are There Increasing Returns to the Intergenerational Production of Human Capital?", processed, University of Pennsylvania, Philadelphia, PA.

Sala-i-Martin, X., 1990, "Lecture Notes on Economic Growth," Economic Growth Center Discussion Paper No. 622, Yale University, New Haven, CT.

Schultz, T.P., 1973, "A Preliminary Survey of Economic Analyses of Fertility", American Economic Review, 63(2): 71-78.

_____, 1981, Economics of Population, Reading, MA: Addison-Wesley.

_____, 1982, "Notes on the Estimation of Migration Decision Functions", in (ed.) R.H. Sabot, Migration and the Labor Market in Developing Countries, Boulder, CO: Westview Press.

_____, 1987, "School Expenditures and Enrollments, 1960-1980", in National Academy of Sciences Background Papers, (eds.), D.G. Johnson and R. Lee, Population Growth and Economic Development, Madison, WI: University of Wisconsin Press.

_____, 1988, "Education Investments and Returns", in (eds.) H. Chenery and T.N. Srinivasan, Handbook of Development Economics, Vol. 1, Chap. 13, Amsterdam: North Holland Publishing Co.

_____, 1990, "Women's Changing Participation in the Labor Force", Economic Development and Cultural Change, 38(3): 457-488.

_____, 1991, "Returns to Women's Education", in (eds.) M.A. Hill and E.M. King, Women's Education in Developing Countries, New York: Oxford University Press.

_____, 1992, "Investments in the Schooling and Health of Women and Men: Quantities and Returns", presented at Conference on Women's Human Capital and Development, Bellagio, Italy.

Schultz, T.P. and A. Tansel, 1992, "Measurement of Returns to Adult Health: Morbidity Effects on Wage Rates in Côte d'Ivoire and Ghana", processed, Yale University, New Haven, CT.

Schultz, T.W., 1960, "Capital Formation in Education", Journal of Political Economy, 68(4):571-83.

_____, 1961, "Investments in Human Capital", American Economic Review, 51(1):1-17.

_____, 1967, "The Rate of Return in Allocating Investments to Education", Journal of Human Resources, 2(3):293-309.

Schwartz, A., 1971, "Interpreting the Effect of Distance on Migration", Journal of Political Economy, 6(2):193-205.

Solow, R.M., 1957, "Technical Change and the Aggregate Production Function", Review of Economics and Statistics, 39(3):312-320.

_____, 1960, "Investment and Technical Progress", in (eds.) K.J. Arrow, S. Karlin and P. Suppes, Mathematical Methods in the Social Sciences 1959, Stanford: Stanford University Press.

Strauss, J., 1986, "Does Better Nutrition Raise Farm Productivity?", Journal of Political Economy, 94(2):297-320.

Strauss, J. and D. Thomas, 1991, "Wages, Schooling and Background: Investments in Men and Women in Urban Brazil", Economic Growth Center Discussion Paper No. 649, Yale University, New Haven, CT.

Tansel, A., 1992, "School Attainment and Parental Education in Côte d'Ivoire and Ghana", processed, Yale University, New Haven, CT.

Thomas, D. and J. Strauss, 1992, "Health, Wealth and Labor Market Outcomes of Men and Women: Evidence from Brazil", presented at Conference on Women's Capital and Development, Bellagio, Italy.

Topel, R. and Dae-Il Kim, 1992, "Labor Markets and Economic Growth: Lessons from Korea's Industrialization, 1970-1990", National Bureau of Economic Research Conference, April 10-11.

Vijverberg, W.P.M., 1992, "Educational Investments and Returns for Women and Men in Côte d'Ivoire", presented at Conference on Women's Capital and Development, Bellagio, Italy.

World Bank Staff, 1991, World Development Report for 1991, Washington, D.C.