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CENTER DISCUSSION PAPER NO. 711

HUMAN CAPITAL AND ECONOMIC DEVELOPMENT

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May 1994

Note: Center Discussion Papers are preliminary materials circulated to stimulate discussions and critical comments. This paper was prepared for the 22nd International Conference of Agricultural Economists, August 22-29, 1994, Harare, Zimbabwe.

Funding for this research was provided by a grant from The Rockefeller Foundation to study gender differences in productivity in low-income countries.

This research was facilitated by the permission granted to analyze the LSMS data from Cote d'Ivoire and Ghana in preparing a conceptual survey of human resource programs for The World Bank and by the Institute for Policy Reform that encouraged me to consider methods for setting human resource priorities in Africa.

Abstract

Education, child nutrition, adult health/nutrition, and labor mobility are critical factors in achieving recent sustained growth in total factor productivity in the world. A flexible specification of labor productivity or wage function is estimated that includes as arguments these four human capital inputs measured in recent household (LSMS) surveys of Côte d'Ivoire and Ghana. Specification tests are implemented to assess whether the human capital inputs are exogenous, and instrumental variable techniques are then used to estimate Leontief-Diewert functional forms. Overall returns to these four forms of human capital realized by men and women are similar within each country, but education and migration returns are higher in the more rapidly growing Côte d'Ivoire, and nutrition and health returns are higher in the less well-nourished Ghanaian population.

KEY WORDS: Education, Productivity, Nutrition, Health, Africa

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Human Capital and Economic Development

INTRODUCTION

Many recent studies of education, nutrition, health, labor mobility, and training have sought to measure the contribution of these forms of human capital to the productivity of workers and to modern economic growth. The base of knowledge in this field is growing rapidly, but is unavoidably qualified because returns to investments in human capital are only realized over a lifetime. In addition, without true social experiments designed to assess how randomized policy interventions work through the actions of the family and individuals, statistical estimation of causal relationships may be biased. Microeconomists and other social and biological scientists have examined the economic and physical functioning of individual workers with different characteristics, while macroeconomists have analyzed aggregate output, measures of labor inputs, and the economic growth experience of nation states. A consensus has been forged that recent periods of sustained growth in total factor productivity are critically dependent on improvements in a population's nutrition, health, education, and mobility.

Analysis of these forms of human capital must now be integrated to measure with greater precision their distinct effects on economic development, because stocks of human capital acquired by individuals may not be independent, they potentially interact with each other in their impact on the productivity of the worker, and they are often subject to diminishing (or increasing) returns. Traditional semi-log-linear approximations for wage functions should, therefore, be extended to more flexible specifications that allow for returns to vary and interactions to exist among several forms of human capital.

Finally, in considering the effects of human capital on development, we are primarily interested in how state and family investments influence the formation of reproducible human capital and how it in turn impacts on labor earnings and growth. The exogenous skills and genetic endowments of workers that are largely unaffected by state and family actions are less central to our objective, except as they mask or modify measured returns to the reproducible component of human capital. Do the endogenous components of the variation in human capital exert the same "effect" on labor productivity as do the exogenous endowments? If they differ, it is the productive effects of endogenous reproducible human capital that policymakers need to know. Specifically, much of the variation in height, for example, is due to genetics. It is not clear whether differences in this genetic endowment have the same productive effect on workers as do differences caused by variation in childhood health and nutritional investments. Specification tests will be implemented to assess whether different sources of variation in human capital stocks are exogenous or endogenous, and thus whether specific forms of human capital are justifiably treated as exogenous or endogenous variables when estimating extended wage functions.

Statistical estimation of these extended human capital wage-productivity functions promises to quantify the joint productive payoff to investments in child nutrition, schooling, migration, and adult health and nutrition.[1] Are there nonlinearities in these functions that influence the optimal levels of investments, and do synergies among investments change the optimal mix? Knowledge of these connections between human capital and development may help the family invest across the full range of human capital more efficiently, and help the state set its human resource priorities more systematically. This paper outlines an empirical strategy for moving in this direction. Illustrative empirical findings are reported from an analysis of data from the 1985-89 Côte d'Ivoire and Ghana Living Standards Measurement Surveys (LSMS). The paper thus provides a general perspective on the roles of several forms of human capital in the context of West African economic development.

THE DEMAND FOR HUMAN CAPITAL AND THE WAGE-PRODUCTIVITY FUNCTION

Demand for stocks of human capital is represented as a derived demand for these productive inputs, which is a function of the prices of inputs to produce these stocks, the discounted value of their output, the income and education of parent households, and regional public services and relevant conditions. Four forms of human capital are considered as input, I_{ij} , where i refers to the individual and j to the type of human capital: H for adult height as an indicator of childhood nutritional status; E for years of education; M for whether the individual has migrated from the region of birth; and B for body-mass-index (weight in kilograms divided by height in meters squared) as an indicator of adult nutritional status and current health.

$$I_{ij} = \alpha_j Y_i + \beta_j X_i + \epsilon_{ij} \ , \ j = H, \ E, \ B, \ M \tag{1}$$

where Y refers to exogenous variables that may also affect the wage rate given human capital inputs (such as age, season of interview, and ethnic group), and X refers to exogenous variables that are not in Y but determine the demand for human capital (such as public service input prices, parent education, and local health conditions). All four human capital inputs tend to be positively correlated with each other and with wage rates in the populations analyzed here.[2]

The semi-logarithmic linear approximation of the wage-productivity function is interpreted as a household production function with arguments being human capital inputs and exogenous variables (Y) that additively affect the logarithm of wages.

$$w_i = \sum_{j=1}^{4} \gamma_j I_{ij} + \delta Y_i + \nu_i \tag{2}$$

The human capital inputs in the wage function may be exogenous if the error in the wage function is uncorrelated with the errors in the human capital demand functions, in other words, the covariance$(\nu_i, \epsilon_{ij}) = 0$, for j = 1, ..., 4. If this error covariance is not zero, then that form of human capital is endogenous to the wage function, and the X variables in the human capital demand function (1) may provide a means for identifying the structural wage function (2), and permit its parameters to be estimated (Cf. the case of a health production function in Rosenzweig and Schultz, 1983). The exogeneity of the human capital inputs is tested by empirically comparing the two estimates based on the human capital inputs being assumed exogenous and endogenous. Because human capital investments are often concurrent and population heterogeneity is potentially important, there is ample reason to consider the hypothesis that the human capital inputs are endogenous in the wage function.[3] Adult nutrition has been analyzed as an endogenous input to the wage function in low-income countries starting with the study by Strauss (1986). The joint analysis of other endogenous forms of human capital in the wage function has been extended by Thomas and Strauss (1993).

Diminishing (or increasing) returns to the individual's accumulation of each form of human capital are also expected and a general specification of the wage function should allow for this possibility. For example, the effect of nutrition on physical growth and adult productivity may be subject to diminishing returns (Strauss, 1986). The proportionate increase in wages associated with a specific increase in nutrition appears to be greater for those who are especially malnourished. The proportionate increase in wages associated with an additional year of schooling tends to diminish at higher levels of schooling (Psacharopoulos, 1993), whereas the opposite pattern of increasing returns is also observed due to bottlenecks in intermediate levels of schooling.[4] This empirical feature of human capital suggests that returns to these investments may often be higher among lower income groups, with the implication for social planners that human capital investments targeted to the poor can reduce poverty without sacrificing economic growth.

Finally, human capital inputs may technically substitute or complement each other in their effect on output or labor productivity depending on the nature of tasks performed in the labor market. These potential interaction effects between human capital inputs should, therefore, be estimated in the wage function, before imposing the restriction, as in (2), that the human capital inputs only affect additively the logarithms of wage rates. Because empirical evidence on interactions between types of human capital does not generally treat the human capital inputs as endogenous, the existing literature may not serve as a reliable guide on the importance or sign of technical input interactions.[5]

In conclusion, the wage-productivity function should be estimated as a flexible second-order approximation, such as the Leontief-Diewert form (Fuss and McFadden, 1978), with the human capital inputs tested for their exogeneity (or endogeneity).[6]

$$W_i = \sum_{j=1}^{4} \gamma_j I_{ij} + \sum_{j=1}^{4} \sum_{k=j+1}^{4} \eta_{jk} I_{ij} I_{ik} + \sum_{j=1}^{3} \theta_j I_{ij}^2 + \delta Y_i + \nu_i \ . \tag{3}$$

This more flexible form of the wage-productivity function will be more difficult to estimate because 13 (compared with 4) input coefficients are now estimated from 13 variables that will be highly correlated with each other. This statistical challenge is complicated further when some of the input variables are treated as endogenous and predicted on the basis of instrumental variables (X) that do not enter the wage equation directly. Practically, it should be expected that in this context only a few of the quadratic and interaction terms will prove statistically significant in samples of only a few thousand individuals. Thus, a more parsimonious linearized specification is likely to be accepted on statistical grounds alone (Cf. Rosenzweig and Schultz, 1983). However, cumulating evidence of some significant higher-order terms in this wage-productivity function should be taken seriously, for they may be instructive on how public and private expenditures on these forms of human capital can contribute most effectively to labor productivity, and presumably, to increased economic growth.

CHARACTERISTICS OF THE SAMPLE

Table 1 reports the average levels of the four indicators of human capital stocks for men and women from Côte d'Ivoire and Ghana, by age, as estimated from the Living Standards Measurement Surveys circa 1985-1989.[7] Some individuals in the youngest age group, 15 to 19, are continuing to invest in education, and members of this age group are still growing toward their adult stature of height and BMI. Migration, because it is a cumulative measure of having ever migrated since birth, increases with age within a birth cohort, but may not increase with age groups in a cross section if mobility has been increasing over time.

Years of schooling completed began to increase sharply at least a decade earlier in Ghana than in Côte d'Ivoire. Men's education in Côte d'Ivoire increased in three decades nearly seven fold from .9 years for men age 50-65 to 6.0 among those age 20-29. In Ghana men's education more than doubled in this period from 3.6 to 8.3 years. Women age 50-65 have only one-seventh as much education as do men in Côte d'Ivoire, whereas women 50-65 in Ghana have a fourth as much education as do men. In Côte d'Ivoire women in the age group 20-29, who received their education approximately during the 1970s, have 69 percent as many years of schooling as do men, and women in Ghana have four-fifths as many years of education as do men. Women receive substantially less education than men in these two populations, and although the relative gap is

Table 1

Sample Means of Four Indicators of Human Capital Stocks by Age and Sex for Côte d'Ivoire and Ghana

	15-19	20-29	30-39	40-49	50-65	All
Côte d'Ivoire:						
Males: Sample Size	1196	1414	994	824	1034	5642
Education	5.46	6.00	5.78	2.68	.876	4.37
Migration	.289	.426	.581	.490	.300	.410
BMI	20.3	21.8	22.6	22.6	22.3	21.9
Height	1.66	1.71	1.70	1.69	1.67	1.68
Females: Sample Size	1283	1925	1287	1019	1065	6579
Education	3.77	3.20	1.80	.326	.125	2.09
Migration	.333	.430	.424	.325	.206	.357
BMI	21.8	22.8	23.2	22.8	21.8	22.5
Height	1.59	1.59	1.59	1.58	1.56	1.58
Ghana:						
Males: Sample Size	1073	1389	1075	766	731	5034
Education	7.05	8.26	7.88	6.70	3.64	7.02
Migration	.171	.258	.360	.394	.306	.289
BMI	18.4	20.7	21.1	21.0	20.5	20.3
Height	1.60	1.70	1.69	1.69	1.68	1.67
Females: Sample Size	1034	1818	1254	803	945	5854
Education	5.60	5.71	4.77	2.59	.852	4.27
Migration	.214	.296	.329	.270	.222	.273
BMI	20.4	21.5	22.8	22.7	21.6	21.8
Height	1.56	1.58	1.58	1.57	1.57	1.58

closing, it still remains substantial at the secondary school level, particularly in Côte d'Ivoire.

The indicator of migration peaks for women in Côte d'Ivoire in the ages 20-29 and for men at ages 30-39. In Ghana, where economic growth started earlier in this century but has been slower since the mid-1960s than in Côte d'Ivoire, migration is less frequent but more uniform across ages, peaking among persons ten years older than in Côte d'Ivoire.

Height for males in Côte d'Ivoire shows a significant increase from 1.67 among the oldest group, age 50-65, to 1.71 among those age 20-29. This three centimeter increase is larger than the two centimeter increase observed among males in Ghana. Women in Côte d'Ivoire also report a height gain of 3 centimeters between the age groups 50-65 and 20-29, whereas the gain for women in Ghana is only one centimeter. In these three decades real GNP per capita increased about 70 percent in Ghana and 316 percent in Côte d'Ivoire (World Bank, 1991), suggesting that these gains in height could be an indicator of the improved nutritional status of youth maturing during the 1970s compared with those growing up during the 1940s and 1950s.[8] As of 1990, it is estimated that 36 percent of the children under age 5 are malnourished in Ghana, whereas only 12 percent are in Côte d'Ivoire (World Bank, 1991).

Body Mass Index (BMI) peaks for men and women in the age group 30-39. It is unclear whether the differences observed in BMI by age are due to biological aging or differential health status across birth cohorts at one point in time.

Controls for age differences in these anthropometric indicators of childhood and adult nutritional status should be interpreted with caution, as they could capture both aging and changes in nutritional status. This migration measure may be distorted by the omission of emigrants. Years of education by age does not capture the large differentials in the costs of a year of primary, secondary, and tertiary schooling in these countries and the likelihood that the quality of a year of schooling has changed over time. As a measure of domestic educational investment, this indicator of schooling can also be distorted by international migration. Better educated Ghanaians emigrated in large numbers when the economy of Ghana stagnated during the 1970s and 1980s, whereas the prosperous economy of Côte d'Ivoire attracted immigrants from neighboring countries.

The demand determinants (eq. 1) and the productive consequences (eq. 2) of the four human capital stocks are estimated allowing for variation across the five age groups distinguished in Table 1, by including four dummy variables.[9] It may be difficult to distinguish the separate productive returns to height and BMI in relatively small samples, because they are by definition related measures of stature. Differences in the relative importance of height and BMI for the productivity of men and women should thus be approached with caution, for they may be genetic, or due to the physical activities men and women decide to engage in, or a statistical artifact.

ESTIMATES OF THE EXTENDED WAGE-PRODUCTIVITY FUNCTION

Table 2 reports estimates of the linear specification of the wage function for the coefficients on the human capital inputs. Columns 1 through 4 show ordinary least squares (OLS) estimates based on the working assumption that all human capital inputs are exogenous, first for only education as in

Table 2

Coefficients on Four Indicators of Human Capital Inputs in Wage Functions by Sex With Controls for Region, Ethnic Group, and Season: Côte d'Ivoire and Ghana[a]

Country Gender Variable	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) IV	(6) IV
Côte d'Ivoire Males: Sample Size 1602						
Education	.136 (20.2)	.129 (19.0)	.125 (18.5)	.124 (18.0)	.165* (4.18)	.124 (18.2)
Migration		.551 (6.90)	.527 (6.64)	.531 (6.69)	.860* (1.80)	.537 (6.74)
BMI			.0483 (4.76)	.0491 (4.83)	.0323* (.38)	.0786* (1.10)
Height				.678 (1.75)	6.68* (1.87)	9.24* (3.53)
Females: Sample Size 768						
Education	.121 (10.1)	.118 (9.97)	.116 (10.0)	.116 (9.95)	.116* (3.07)	.115 (9.47)
Migration		.652 (5.33)	.606 (5.05)	.605 (5.05)	.757* (1.11)	.643 (5.28)
BMI			.0666 (5.81)	.0662 (5.79)	.190* (2.49)	.193* (2.90)
Height				-.120 (.16)	-.0292* (.01)	.0637* (.02)
Ghana Males: Sample Size 3521						
Education	.0444 (10.1)	.0431 (9.80)	.0417 (9.15)	.0393 (8.96)	.0214* (.89)	.0407 (9.25)
Migration		.197 (4,20)	.184 (3.95)	.181 (3.91)	-.0258* (.13)	.177 (3.77)
BMI			.0585 (6.85)	.0510 (6.62)	.0867* (1.15)	.0343* (.64)
Height				1.21 (4.22)	13.8* (3.77)	13.5* (4.90
Females: Sample Size 3408						
Education	.0415 (8.11)	.0410 (8.04)	.0381 (7.52)	.359 (7.04)	.0219* (1.01)	.0320 (6.11)
Migration		.238 (4.46)	.199 (3.76)	.196 (3.70)	-.193* (.70)	.209 (3.93)
BMI			.0453 (8.27)	.0445 (8.14)	.134* (2.91)	.0870* (2.71)
Height				1.26 (3.60)	17.8* (3.37)	16.9* (5.16)

*Variable is assumed endogenous and estimated by instrumental variables, which includes parent education and occupation, local health infrastructure, and food prices.

the traditional benchmark form of the wage function, and then with the sequential addition of the migration, BMI, and height inputs. All of these estimates also control for ten regions of each country in which the individual was born, rural residence, season of interview, and age controls (See notes to Table 2 and Table A-1 for variable definitions and means in the four gender-specific country samples of wage workers).

All four human capital indicators are significantly positively associated with wages in the four samples, with the single exception of height among women in Côte d'Ivoire, for which the sample is smallest, 768. Wage increases of 14 to 21 percent are associated with each additional year of schooling of men and women in Côte d'Ivoire and increases of 4.4 and 4.2 percent in wages in Ghana, respectively. These country differences might be attributed to aggregate demand or supply factors, namely, the lower level and growth of income in Ghana, and the larger fraction of adult Ghanaians with schooling. If region, ethnic group and season are not included as controls in the wage function, the returns to schooling increase between 2 and 4 percentage points in both countries (not reported). Adding controls for migration, BMI, and height reduces the initially estimated returns on education (col. 1 to col. 4) by about one-tenth, but leaves the statistical significance of these estimates of the wage effects of schooling essentially unchanged. Although all of the four human capital inputs are positively correlated with each other and with wages, the omission of migration, BMI, and height from the wage function does not have a dramatic effect of biasing upward the traditional univariate estimate of schooling's effect on wages in Col. 1 of Table 2 (Cf. Griliches, 1977).

The effect of migration is larger in Côte d'Ivoire than in Ghana, 55-65 percent versus 20 to 24 percent, which is consistent with the more integrated labor market and superior transportation system in Ghana compared with Côte d'Ivoire. A standard deviation in BMI in the male and female samples is roughly 2.5 and 4.5, respectively (See Appendix Table A-1). A unit increase in BMI is associated with a 5 and 7 percent increase in wages for men and women in Côte d'Ivoire and with a 6 and 5 percent increase in wages in Ghana. The standard deviation in height in the samples is about 6 centimeters, and an increment of one centimeter to height is associated with a 1.2 to 1.3 percent increase in wages in Ghana and a smaller .7 percent increment for men in Côte d'Ivoire.

ENDOGENOUS DEMANDS FOR HUMAN CAPITAL INPUTS

Hausman (1978)-Wu (1973) have proposed a procedure to test the null hypothesis that a regressor is exogenous. In the case of height it is rejected at the 5 percent level of confidence in three out of four samples, among men and women in Ghana and women in Côte d'Ivoire (Appendix Table A-2). Moreover, BMI is rejected as being exogenous among women in both country samples. Migration is rejected as being exogenous only for women in Ghana. The exogeneity of education is never rejected. Lacking complete agreement in these tests across samples, I have first treated all four variables as endogenous in the instrumental variable (IV) estimates reported in Column 5 in Table 2. The standard errors are corrected for the fact that the human capital variables are now predicted.

When all human capital inputs are treated as endogenous, returns on education increase fractionally for men and decline for women in Côte d'Ivoire and decline for both sexes in Ghana. The estimates of endogenous migration are also larger in Côte d'Ivoire than when they are estimated as exogenous, but cease to play a role in wage determination in Ghana. BMI is a more important factor in determining female wages when endogenized, and the effect of height on wages increase markedly for men and women in Ghana and for men in Côte d'Ivoire when estimated as an endogenous variable.

The mixed estimates in column 6 of Table 2 are preferred, because they rely on the more efficient OLS estimates of education and migration, based on their apparent exogeneity, and use IV techniques to correct for the potential endogeneity of the anthropometric indicators of childhood and current nutrition and health, namely, height and BMI. Returns to education and migration are about what they were when estimated in Col. 4, but the estimated effects of an increase in height by one centimeter is now to increase men's wages by 9.2 percent in Côte d'Ivoire and 13.5 percent in Ghana, and women's wages by 16.9 percent in Ghana. Weight for height, measured by BMI, is related to wages of women more strongly than of men and could represent the greater ratio of fat to muscle tissue for women as a store of energy for frequent childbearing. A unit increase in BMI is associated with an increase in women's wages in Côte d'Ivoire of 19.3 percent and women's wages in Ghana by 8.7 percent. The productivity of these two related anthropometric indicators of stature should be cautiously assessed together, as noted earlier.

To combine these four estimates of the wage effects of human capital across the four samples, I first simulate the effect of a sample standard deviation (Table A-1) increases in all four input variables together. This increment in all human capital stocks is associated with men's and women's wages being 179 and 174 percent higher in Côte d'Ivoire, respectively, and men's and women's wages in Ghana being both 134 percent higher. Education among males and females in Côte d'Ivoire is a major factor, because the wage-returns to education are several times larger in this country than in Ghana. In the poorer country, Ghana, three-quarters of these simulated gains in wages are attributed to childhood health and nutritional investments. The combined contribution of BMI and height is one-half or more of the wage gains in Côte d'Ivoire as well. Clearly, if there were a low cost means to increase these anthropometric indicators of health and nutrition by a standard deviation, there would be large economic benefits in terms of enhanced labor productivity in both countries; but at lower income and nutrition levels in Ghana, the wage benefits are proportionately greater.[10]

Migration returns are higher in Côte d'Ivoire than Ghana, suggesting that labor markets in Côte d'Ivoire are not as well integrated as in Ghana. Although this could be due to natural barriers to migration, such as language groupings or physical terrain, investments in roads and transportation infrastructure could be partially justified in Côte d'Ivoire to enhance labor mobility. The greater early investment in primary education in Ghana may have also fostered more mobility and eroded regional income differences in that country. In contrast, the more rapid recent pace of development in Côte d'Ivoire, and its particular concentration around Abidjan, may have fostered and sustained the large regional wage differences, which benefit (predominantly) migrants today in Côte d'Ivoire.

However, a standard deviation in human capital inputs across a population is generated by two components: one the variation due to investments of individuals, families and states, and another the variation in genetic endowments that are not appreciably affected by reproducible human capital investments. In the case of height and weight-for-height, the genetic component may be relatively large. It would seem more realistic, therefore, when simulating the wage effects of "equally likely" changes in the human capital inputs, to vary those inputs only by the share of their variation in the population that can be "explained" by socioeconomic development. Ideally that explanation would be of changes over time, but that is not possible here where the database is cross-sectional. Assuming that all instrumental variables (X and Y) represent socioeconomic factors, which is probably an overstatement in the case of ethnic, age and region variables, I have weighted the standard deviation of each human capital input by the R^2 obtained in the instrumental variable auxiliary regression of equation (1). Since the proportion of the variance explained of education and migration ranges from .5 to .3, and that of BMI and height from .1 to .2, this scheme reduces the relative weight attributed to the estimated wage effects of the anthropometric indicators of nutrition and health. These calculations are summarized in Table 3.

The educational input variation accounts for about 40 to 50 percent of the wage gain in Ghana and Côte d'Ivoire, respectively. Migration contributes from 11-16 to 24 percent of the wage gain in the two countries, parallel to

Table 3

Percentage Changes in Wages Associated with Simulated Changes in Human Capital Inputs: Côte d'Ivoire and Ghana[a]
(Percent of Total Change in Parentheses)

Human Capital Input	Côte d'Ivoire		Ghana	
	Males	Females	Males	Females
Education	31.3 (56)	29.4 (49)	9.1 (40)	6.7 (42)
Migration	13.4 (24)	14.6 (24)	2.5 (11)	2.6 (16)
BMI	2.6 (5)	16.3 (27)	1.2 (5)	.6 (4)
Height	8.1 (15)	.1 (0)	10.1 (44)	6.0 (38)
Total	55.4 (100)	60.1 (100)	22.9 (100)	15.9 (100)

[a] The simulated change in log wages is based on the product of the coefficients, β_j (col. 6, Table 2), the standard deviation of the j^{th} in human capital input (Table A-1), SD_j, the coefficient of determination of the input demand equation $R^2_{I_j, xy}$, (coefficient of determination of inputs on all instruments), and 100.

the results discussed earlier. Height and BMI together contribute 42-47 percent of the simulated wage gain in Ghana and 20-27 percent in Côte d'Ivoire. Overall, these reweighted wage gains confirm again that the levels of wage returns to human capital are not dissimilar from women and men (Schultz, 1993). But the overall level of wage returns to human capital is higher in Côte d'Ivoire than in Ghana, presumably because of the different macroeconomic success of these two economies in the last 25 years. Another finding from this two-country comparison is that the optimal mix of human capital investments may differ between countries, perhaps by level of income and prevalence of malnutrition. The health and nutritional status of the population are more salient constraints on labor productivity in Ghana than they are in Côte d'Ivoire in the late 1980s. Many replications and refinement studies are needed to increase confidence in these types of generalizations, but they are of the form that social planners of human resource development should examine closely.

ESTIMATES OF INTERACTIONS BETWEEN FORMS OF HUMAN CAPITAL

It is often hypothesized that in the long run various forms of human capital, such as health, education, and migration, are thought to exhibit a common pattern of diminishing returns that equilibrates individual demands for any one form of human capital, as more of it is supplied by the aggregate population. There are also reasons to think human capital investments might reinforce or complement each other, as it has been noted that increased longevity should generally raise returns to other longer-lived human capital investments (Ram and Schultz, 1979). To consider what evidence these data can generate on returns to scale of investment and interactions between human capital inputs, the full Leontief-Diewert second-order approximation of the wage function is estimated in Table 4, treating as endogenous all human capital inputs that embody either height or BMI. Thus, in comparison with Col. 6 in Table 2 where two variable are endogenous, in Table 4 there are 9 endogenous variables to estimate by instrumental variable techniques. Since migration is a binary variable, it does not have a quadratic form, although it does have a full range of interactions. In three out of four samples, the F test reported in the bottom row of Table 4 indicates that the additional 9 parameters estimated in Table 4 are jointly statistically significant at the 5 percent level (compared with Col. 6, Table 2), and for males in Côte d'Ivoire the F is near that threshold level at 1.79. ($P<.05$, if $F>1.88$).

In both countries and for both sexes there is evidence that returns to education increase at more advanced levels, as others have found in analyses of these data (Schultz and Tansel, 1993; Vijverberg, 1993). This is presumably a disequilibrium condition that implies public investments in schooling might favor a further expansion in the secondary school system where wage returns are relatively large. Among men in Côte d'Ivoire there is a statistically significant tendency for education and migration to substitute for each other, with the return to education being 2.7 percentage points lower among migrants than among nonmigrants. The significant positive correlation between education and migration in these four samples is eliminated by conditioning on the instrumental variables. This evidence is consistent with there being heterogeneity among families leading them to invest more or less in the human capital of their children, but this heterogeneity is associated

Table 4

Coefficients on Human Capital Inputs, Squared Inputs and Interactions between Inputs in the Wage Function by Sex for Côte d'Ivoire and Ghana

	Côte d'Ivoire		Ghana	
	Males	Females	Males	Females
Education (in years)	.104 (5.93)	.0839 (2.67)	-.0214 (1.92)	-.0164 (1.23)
Education²	.00218 (2.11)	.00311 (1.74)	.00461 (7.14)	.00393 (4.19)
Migration (not in birthplace)	.632 (5.63)	.750 (4.96)	.416 (5.09)	.230 (3.25)
BMI (weight kg/height mt.²)	2.85* (.95)	2.84* (1.42)	-2.35* (1.38)	-8.12* (2.86)
BMI²	4.31* (1.53)	-.132* (.14)	.114* (.08)	1.53* (1.45)
Height (meters)	318.* (2.52)	-85.0* (.47)	-209. (2.13)	-52.0* (.40)
Height²	-91.2* (2.47)	34.9* (.60)	61.3* (2.03)	-9.58* (.23)
Educ.* Mig.	-.0182 (1.33)	-.0223 (1.08)	-.0267 (3.19)	.00457 (.48)
Educ.* BMI	.0216* (.98)	-.0330* (2.70)	.0504* (3.09)	-.0141* (1.27)
Educ.* HT	-.208* (.72)	.477* (2.59)	-.688* (3.26)	.186* (1.12)
Mig.* BMI	-.412* (2.09)	-.179* (1.37)	-.172* (1.13)	-.266* (1.49)
Mig.* HT	5.24* (2.06)	2.78* (1.45)	1.98* (1.06)	3.54* (1.37)
BMI* HT	-.430* (.29)	-1.43* (1.16)	1.13* (1.03)	4.80* (2.84)
That interaction and quadratic parameters are jointly tested by F (degrees of freedom)	1.79 (9, 1561)	3.42 (9, 736)	9.65 (9, 3479)	4.51 (9, 3366)

* endogenous variable estimated by instrumental variables: parental education and occupation, rural residence, and local health infrastructure and food prices.

[a] Other control variables include region of birth, ethnic group, age and season of interview. Beneath regression coefficient is the absolute value of the t statistic in parentheses.

with observable conditions of parents and child. The tendency toward substitution of education for migration is also evident among men and women from Côte d'Ivoire, although it is not statistically significant. The predominant pattern observed here challenges the existing literature that concludes that because more educated individuals migrate more often, the two forms of human capital must be complementary (Schultz, 1982a,b).

Education and height, which proxies childhood nutritional status, appear to be complements for women in Côte d'Ivoire and substitutes for men in Ghana. It has been hypothesized that improved nutrition and health status of school children help them concentrate their abilities and perform better in school (Moock and Leslie, 1986; Behrman, 1993). Again the positive correlation between these human capital traits, even after controlling for the instrumental variables examined here, suggests unobserved background characteristics of families may favor both forms of human capital investment, and that the simple or conditional correlation between inputs does not necessarily represent a technical complementarity. Height does however contribute to increased returns to migration, although this complementarity is only statistically significant among men in Côte d'Ivoire.

Weight for height (i.e., BMI) appears in all four samples to be a substitute for migration, although the interaction effect is statistically significant at the 5 percent level only for males in Côte d'Ivoire. Migration is often from rural to urban labor markets, and the wage returns to physical labor that heavier persons have a comparative advantage in performing are a more common feature of the rural labor markets than the urban ones. In this case, we might find less motivation to migrate among high BMI individuals who are relatively more productive in physically demanding jobs in their rural birthplace. Finally, height and BMI are complements for women in Ghana and exhibit a weak tendency in this direction for men in Ghana, but appear to operate as substitutes for men and women in Côte d'Ivoire.

These estimates of the full second-order approximation of the extended wage-productivity function do not offer a single set of empirical regularities across the four country and gender samples. Hypotheses for why these human capital inputs might exert different effects for men and women, and what characteristics of the two countries explain differences in levels of returns, such as in education and migration, must await more research. There are nonetheless hints of some plausible tradeoffs that warrant further study. As a more adequate understanding emerges of the factors affecting the demand for the four human capital inputs emphasized here, and larger samples of wage workers can be analyzed, a firmer basis should develop for measuring both the nonlinear and interactive returns to human capital. Thomas and Strauss (1993) have made a start based on an unusually large and detailed survey from Brazil. Collecting intergenerational data, with anthropometric indicators of nutrition, combined with labor market information on wages, should open the field to comparative studies. Analysis of multiple human capital inputs to enhance labor productivity in developing countries is an expanding research frontier from which we can expect to learn much in the next decade.

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NOTES

1. Another human resource program that should be analyzed as an argument in the wage function is family planning. Family planning performs several functions, one of which helps women avoid unwanted births by reducing the cost of effective birth control. Unwanted births may be associated with women sacrificing their career objectives, if that career is imperfectly compatible with childbearing. In studies of Malaysia and the United States, an unanticipated or unwanted birth is associated with women receiving a wage in the labor market that is 10 percent lower (Schultz, 1992: Table 5.1).

2. There are several hypotheses for the input correlations which involve heterogeneity and technology: (1) exogenous family wealth relaxes the budget constraint allowing more wealthy families to invest more in all forms of human capital in their children, driving down the marginal returns to these investments to the family's lower than average opportunity cost of capital; (2) an individual endowment raises the returns to all forms of human capital, as for example, it is hypothesized that ability increases the returns to education (Becker, 1967; Griliches, 1977); (3) heterogeneity in preferences of families could also lead to differences across individuals in amounts of all human capital investments; and finally (4) particular types of human capital may complement (or substitute) for each other, leading individuals who maximize their joint returns on all human capital investments to concentrate them in complementary inputs and specialize between substitute inputs.

3. See footnote 2, where the first three hypotheses of the intercorrelation of human capital inputs conditional on household and region variables could also be used to justify the specification of these inputs as endogenous to the

wage function, if some of these unobserved wealth, endowment, and preference variables also affect wage rates.

4. Unobserved heterogeneity in individuals may also explain why those who invest more in any particular form of human capital may earn lower (or higher) returns at the margin. As noted above, these sources of heterogeneity bias in input demands would be corrected when the inputs are treated as endogenous to the wage function.

5. For example, it has been noted that children who are taller for their age (or of greater weight for age) perform better in school (Moock and Leslie, 1986). More educated individuals are more likely to migrate, even when controlling for wage and unemployment rates at origin and destination (Schultz, 1982a,b). If either migration or education is determined endogenously, then a positive effect of the human capital interaction variable based on the assumption they are exogenous in the wage function may not be a valid indication of their technological interactions.

6. This production function would, however, retain the logarithmic transformation of the dependent variable, the wage rate. In the case of the translog function, which is the other commonly used second-order approximation, all inputs must take on positive values, which education does not generally satisfy (Fuss and McFadden, 1978). The translog specification was not superior to the estimates reported here, with the minimum value of education assumed to be one. It might also be useful to explore the interactions between age and the human capital inputs, which could reflect the different productive value of that human capital input at different biological ages, or it could reflect the different quality of that input produced at different times embodied in different birth cohorts.

7. For the Côte d'Ivoire, the three years 1985-87 are combined for a total sample of about 40,000 persons. For wage earners and self-employed who reported labor earnings and hours worked in that activity, a wage rate is derived. This group of wage earners between the ages of 15 and 65 is comprised of 1602 men out of 5642 and 768 women out of 6579. Ainsworth and Muñoz (1986) describe the design of these surveys. For Ghana, two years of surveys are combined from 1987-88 and 1988-89 with a sample of about 30,000 persons. The wage-earner sample yielded 3521 men out of 5034 between the ages of 15 and 65, and 3408 females out of 5834. The anthropometric variables (i.e., height and BMI) were not collected for all individuals, which also restricted the size of these working samples.

8. If the difference in male height in the Côte d'Ivoire LSMS of 3 cm. between those age 20-29 and 50-59 is a difference in adult height of these birth cohorts, this gain of.10 cm. per year for this thirty-year period exceeds Fogel's (1994) estimates of growth in height for six European countries from the end of the 18th to the end of the 20th centuries. Fogel concludes that the increase in height in this two-century period for England of .045 cm. per year accounts for 30 percent of the improvement in labor productivity in this period. It may be assumed that a similar accounting for

Cote d'Ivoire would imply a substantial amount of the growth in labor productivity from 1955 to 1985 would also be attributable to improvements in nutritional status as reflected in adult height. The smaller increase for males in Ghana, about .067 cm. per year, still exceeds the annual rates of growth in height in the majority of Fogel's six countries.

9. Another specification of the age controls introduced a quadratic in age plus a linear adjustment in age for the ages 15-19 when maturation is still rapid. The results reported here were not notably changed. Further study of suitable age controls and function forms is needed in this field (Cf. Thomas and Strauss, 1993). To assess the consequences in this study of the unavoidable restriction of the estimation sample to workers (who report earnings and hours), joint maximum likelihood estimates of the probit equation for being in the worker sample and the wage equation were calculated, based on the identifying exclusion of all observed business, land, financial wealth and nonearned income variables from the wage equation, and their inclusion in the worker probit equation. The estimated correlation between the errors in the worker probit and wage equations was not statistically significant, suggesting that sample selection bias is not a serious problem.

10. Individuals may not have an efficient incentive to invest in their own nutrition because employers in day-labor markets do not observe and reward nutritional investments (although they can see height and weight). Thus, the efficiency wage hypothesis could account for a suboptimal stable equilibrium among the very poor, undernourished workers who can not reach another more desirable efficient equilibrium by capturing the productive returns from improving their nutrition. This might occur if they worked under a longer term contract, were paid by a piece rate, or had the capital and skills to work in self-employment. See some evidence by Rosenzweig and Foster (1993), and an early formulation of the hypothesis by Bliss and Stern (1978).

Table A-1

Means and Standard Deviations of Variables for Wage Function Samples

	Côte d'Ivoire		Ghana	
	Males	Females	Males	Females
Education	5.67 (5.47)	3.61 (5.00)	6.89 (5.48)	4.24 (5.00)
Migration	.607 (.489)	.465 (.499)	.318 (.466)	.283 (.450)
BMI	22.7 (2.88)	23.7 (4.36)	20.7 (2.62)	22.2 (4.21)
Height	1.70 (.0672)	1.58 (.0592)	1.69 (.0700)	1.58 (.0623)
Log Wage Rate	5.66 (1.42)	4.83 (1.72)	3.34 (1.26)	3.17 (1.36)
Age	38.7 (11.5)	36.5 (11.9)	36.2 (12.4)	35.6 (12.7)

Table A-2

Specification Tests of Exogeneity of Human Capital Inputs in the Wage Function (t ratio and beneath it in parentheses is the confidence level for rejecting the null of exogeneity)

Human Capital Input	Côte d'Ivoire		Ghana	
Schooling	-	-	-	-
Migration	-	-	-	-2.79 (.005)
Height	2.30 (.021)	-	4.88 (.000)	4.55 (.000)
BMI	-	1.96 (.048)	-	2.44 (.014)

- not significant at 5 percent level

Table A-3a

Human Capital Demand Equations Used to Instrument Inputs in Wage Function[a] in Côte d'Ivoire

Country, Sex Explanatory Variable[b]	Males				Females			
	Education	Migration	BMI	Height	Education	Migration	BMI	Height
Mother's Education	.301 (1.71)	.0512 (3.37)	.106 (.89)	.00043 (.16)	.355 (2.95)	-.0327 (2.58)	-.356 (2.65)	.00475 (2.55)
Father's Education	.242 (4.25)	.0041 (.83)	.0567 (1.48)	.00164 (1.84)	.248 (4.40)	-.00047 (.08)	.0958 (1.52)	-.00058 (.66)
Mother Employed in Agriculture	-.953 (3.79)	-.0359 (1.66)	-.165 (.97)	-.00645 (1.64)	-.868 (2.40)	-.0538 (1.41)	.159 (.39)	-.00700 (1.10)
Father Employed in Agriculture	-.174 (.56)	.0765 (2.86)	.363 (1.73)	-.00692 (1.43)	-1.97 (4.63)	.0660 (1.47)	-.664 (1.40)	-.0106 (1.60)
Rural Resident	-3.81 (8.12)	-.415 (10.3)	-1.13 (3.57)	-.0166 (2.27)	-2.48 (3.65)	-.255 (3.56)	-.777 (1.02)	-.00546 (.52)
Rainfall	.0165 (1.94)	.0030 (3.13)	.00564 (.98)	.00026 (1.93)	.0244 (1.98)	.00499 (3.83)	.0311 (2.27)	.0000 (.01)
Health Problems: Malaria	.141 (.13)	-.109 (1.14)	-.659 (.88)	-.0480 (2.58)	-.169 (.14)	-.222 (1.69)	-2.77 (1.99)	-.0202 (1.04)
Diarrhea	-.067 (.13)	-.115 (2.48)	-.660 (1.82)	-.00562 (.67)	.412 (.60)	-.144 (1.98)	-.932 (1.21)	-.0035 (.33)
Infectious Parasites	1.16 (1.97)	-.0691 (1.36)	-.479 (1.20)	.00736 (.80)	-.0299 (.04)	-.0436 (.50)	-1.03 (1.12)	-.0282 (2.21)
Sanitary/Water	1.46 (2.18)	.0589 (1.02)	.175 (.39)	.0158 (1.51)	.510 (.53)	-.0736 (.72)	-.438 (.41)	.0032 (.22)
Distance to Clinic or Hospital	.0013 (.85)	.0003 (.29)	-.0107 (1.19)	.00017 (.81)	-.0087 (.27)	-.00057 (.17)	-.0264 (.73)	-.00073 (1.46)
R^2	.4620	.5000	.1142	.1304	.5122	.4539	.1942	.1613

[a] Beneath regression coefficient in parentheses is absolute value of t.
[b] Other control variables include 4 age dummies, 5 ethnic groups, 11 regions, 8 local food prices, 5 rainy season malaria interactions.

Table A-3b

Human Capital Demand Equations Used to Instrument Inputs in Wage Function[a] in Ghana

Country, Sex Explanatory Variable[b]	Males				Females			
	Education	Migration	BMI	Height	Education	Migration	BMI	Height
Mother's Education	.134 (3.75)	-.0024 (.74)	-.0281 (1.35)	.00023 (.41)	.214 (7.57)	-.0058 (2.04)	-.0124 (.44)	.0001 (.17)
Father's Education	.187 (9.41)	.0035 (1.92)	.0434 (3.77)	.00022 (.71)	.268 (16.2)	.0037 (2.23)	.0249 (1.50)	.0009 (3.50)
Mother Employed in Agriculture	1.16 (.70)	.130 (.86)	.868 (.91)	.0214 (.83)	2.13 (2.02)	.151 (1.42)	-.804 (.76)	.0036 (.21)
Father Employed in Agriculture	.0807 (.15)	-.0441 (.91)	.553 (1.79)	.00157 (.19)	.366 (.90)	.0050 (.12)	-.159 (.37)	.0102 (1.59)
Rural Resident	-1.93 (8.02)	.0866 (3.91)	-.115 (.82)	.00340 (.90)	-1.28 (5.71)	.0572 (2.54)	-.754 (3.36)	-.00225 (.63)
Rainfall	-.0075 (.85)	-.0026 (3.27)	.0015 (.30)	-.00629 (2.11)	.00305 (.36)	-.0046 (5.37)	-.0047 (.55)	-.00022 (1.64)
Health Problems: Malaria	-.186 (.53)	.0208 (.65)	-.460 (2.27)	-.0078 (1.42)	-.0227 (.08)	-.0233 (.76)	-.0539 (.18)	.0051 (1.05)
Diarrhea	.541 (2.21)	-.123 (5.43)	-.161 (1.13)	.0092 (2.40)	.0315 (.14)	-.0948 (4.09)	.0471 (.20)	.0051 (1.40)
Infections Parasites	.0518 (.24)	.0421 (2.09)	.0248 (.20)	-.0008 (.23)	.182 (.89)	.0519 (2.53)	-.318 (1.56)	.0043 (1.33)
Sanitary/Water	.0060 (.27)	.0126 (.63)	.0350 (.27)	.0046 (1.34)	-.0177 (.08)	-.0128 (.58)	-.382 (1.75)	-.0061 (1.75)
Immunization Campaign in 5 yrs.	-.578 (2.02)	.255 (9.67)	-.229 (1.38)	-.00226 (.50)	-.784 (2.95)	-.228 (8.54)	-1.14 (4.30)	-.0069 (1.65)
R^2	.4071	.3059	.1300	.1071	.4170	.2721	.1741	.0571

[a] Beneath regression coefficient in parentheses is absolute value of t.
[b] Other control variables include 4 age dummies, 5 ethnic groups, 11 regions, 8 local food prices, 5 rainy season malaria interactions.