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Human Capital and Economic Development

INTRODUCTION

Many recent studies of education, nutrition, health, labour 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. Macroeconomists and other social and biological scientists have examined the economic and physical functioning of individual workers with different characteristics, while macroeconomists have analysed aggregate output. 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 the way state and family investments influence the formation of reproducible human capital and how it, in turn, affects labour 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 make 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 labour productivity as do the exogenous endowments? If they differ, it is the productive effects of endogenous reproducible human capital that policy makers need to understand. Specifically, much of the variation in height, for example, is due to genetics. It

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is not clear whether differences in 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 pay-off to investments in child nutrition, schooling, migration, and adult health and nutrition.[1] Are there non-linearities in these functions that influence the optimal levels of investments, and do synergies among investments change the optimal mix? Knowledge of the 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 1985–9 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 such productive inputs, which is a function of the prices of inputs needed to produce them, 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 $_j$ refers to the type of human capital, which include: 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 the body mass index (weight in kilograms divided by the square of height in metres) as an indicator of adult nutritional status and current health:

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

Here 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 heath conditions). All four human capital inputs tend to be positively correlated with each other and with wage rates in the populations analysed 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:

$$w_j = \sum_{j=1}^{4} \gamma_j I_{ij} + \delta Y_i + \nu_i \quad (2)$$

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 $(\nu_i, \varepsilon_{ij}) = 0$, for $j = 1,\ldots,4$. If this error covariance is not zero, then that for human capital is endogenous to the wage function, and the X variables in the human capital demand function (1) may provide a mans for identifying the structural wage function and (2) permit its parameters to be estimated (compare 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 on the assumption that the human capital inputs are 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 analysed as an endogenous input to the wage function in low-income countries since 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 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 resulting from bottlenecks in intermediate levels of schooling.[4] This empirical feature of human capital suggests that returns to investments may often be higher among lower-income groups, with the implication for social planners that human capital investments aimed at the poor can reduce poverty without sacrificing economic growth.

Finally, human capital inputs may technically substitute for or complement each other in their effect on output or labour productivity, depending on the nature of tasks performed in the labour market. These potential interaction effects between human capital inputs should, therefore, be estimated in the wage function, before imposing the restriction, as in equation (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 to 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 four) 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 (compare 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 labour 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 undertaken in 1985–9.[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 towards their adult stature of height and BMI (Body Mass Index). 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 sevenfold, from 0.9 years for men aged 50–65, to 6.0 among those aged 20–29. In Ghana, men's education more than doubled in this period from 3.6 to 8.3 years. Women aged 50–65 have only one-seventh as much education as do men in Côte d'Ivoire, whereas women of 50–65 in Ghana have a quarter 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 per cent 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 closing, it still remains substantial at the secondary school level, particularly in Côte d'Ivoire.

The indicator of migration culminates for women in Côte d'Ivoire during 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, culminating among people 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, ages 50–65, to 1.71 among those aged 20–29. This four-centimetre increase is larger than the two-centimetre increase observed among males in Ghana. Women in Côte d'Ivoire also report a height gain of three centimetres between the age groups 50–65 and 20–29, whereas the gain for women in Ghana is only one centimetre. In these three decades real GNP per capita increased about 70 per cent in Ghana and 316 per cent in Côte d'Ivoire (World Bank, 1992), 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

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	5462
Education	5.46	6.00	5.78	2.68	0.876	4.37
Migration	0.289	0.426	0.581	0.490	0.300	0.410
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	0.326	0.125	2.09
Migration	0.333	0.430	0.424	0.325	0.206	0.357
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	631	4934
Education	7.05	8.26	7.88	6.70	3.64	7.02
Migration	0.171	0.258	0.360	0.394	0.306	0.289
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	0.852	4.27
Migration	0.214	0.296	0.329	0.270	0.222	0.273
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

during the 1940s and 1950s.[8] As of 1990, it is estimated that 36 per cent of the children under age five are malnourished in Ghana, whereas only 12 per cent are in Côte d'Ivoire (World Bank, 1992).

Body Mass Index (BMI) reaches its peak 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 anthropometric indicators of childhood and adult nutritional status should be interpreted with caution, as they could capture both aging and changes in nutritional status. The migration measure may also 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, the 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 neighbouring countries.

The demand determinants (equation 1) and the productive consequences (equation 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 decided 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 to 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 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 3, 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 at 768. Wage increases of 14 to 21 per cent are associated with each additional year of schooling of men and women in Côte d'Ivoire and increases of 4.4 and 4.2 per cent in wages in Ghana, respectively. These country differences might be attributed to aggregate demand

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*

Country Gender Variable	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) IV	(6) IV
CÔTE D'IVOIRE						
Males[1]						
Education	0.136	0.129	0.125	0.124	0.165*	0.124
	(20.2)	(19.0)	(18.5)	(18.0)	(4.18)	(18.2)
Migration		0.551	5.27	0.51	0.860*	0.537
		(6.90)	(6.64)	(6.69)	(1.80)	(7.74)
BMI			0.0483	0.0491	0.0323*	0.0786*
			(4.76)	(4.83)	(0.38)	(1.10)
Height				0.678	6.68*	9.24*
				(1.75)	(1.87)	(3.53)
Females[2]						
Education	0.121	0.118	0.116	0.116	0.116*	0.115
	(10.1)	(9.97)	(10.0)	(9.95)	(3.07)	(0.47)
Migration		0.652	0.606	0.605	7.57*	0.643
		(5.33)	(5.05)	(5.05)	(1.11)	(5.28)
BMI			0.0666	0.662	0.190*	0.193*
			(5.81)	(5.79)	(2.49)	(2.90)
Height				–0.120	–.0292*	0.0637*
				(0.16)	(0.01)	(0.02)
GHANA						
Males[3]						
Education	0.0444	0.0431	0.0417	0.0393	0.0214*	0.0407
	(10.1)	(9.80)	(9.15)	(8.96)	(0.89)	(9.25)
Migration		0.197	0.184	0.181	–0.0258*	0.177
		(4.20)	(3.95)	(3.91)	(0.13)	(3.77)
BMI			0.0585	0.0510	0.0867*	0.0343*
			(6.85)	(6.62)	(1.15)	(0.64)
Height				1.21	13.8*	13.5*
				(4.22)	(3.77)	(4.90)
Females[4]						
Education	0.0415	0.0410	0.0381	0.359	0.0219*	0.0320
	(8.11)	(8.04)	(7.52)	(7.04)	(1.01)	(6.11)
Migration		0.238	0.199	0.196	–0.193*	0.209
		(4.46)	(3.76)	(3.70)	(0.70)	(3.93)
BMI			0.0453	0.0445	0.134*	0.0870*
			(8.27)	(8.14)	(2.91)	(2.71)
Height				1.26	17.8*	16.9*
				(3.60)	(3.37)	(5.16)

Notes: [1]Sample size 1602.
[2]Sample size 768.
[3]Sample size 3521.
[4]Sample size 3408
*Variable is assumed endogenous and estimated by instrumental variables, which included parent education and occupation, local health infrastructure and food prices.

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 two and four percentage points in both countries (this is not reported in detail). 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 (compare Griliches, 1977).

The effect of migration is larger in Côte d'Ivoire than in Ghana, which is consistent with the more integrated labour market and superior transport system in Ghana compared with Côte d'Ivoire. The standard deviation in BMI in the male and female samples is roughly 2.5 and 4.5, respectively (see Table 3). A unit increase in BMI is associated with a 5 and 7 per cent increase in wages for men and women in Côte d'Ivoire and with a 6 and 5 per cent increase in Ghana. The standard deviation in height in the samples is about 6 centimetres, and an increment of one centimetre to height is associated with a 1.2 to 1.3 per cent increase in wages in Ghana and a smaller 0.7 per cent increment for men in Côte d'Ivoire.

TABLE 3 *Means and standard deviations of variables for wage function samples*

	Côte d'Ivoire		Ghana	
	Males	Females	Males	Females
Education	5.67	3.61	6.89	4.24
	(5.47)	(5.00)	(5.48)	(5.00)
Migration	0.607	0.465	0.318	0.283
	(0.489)	(0.499)	(0.466)	(0.450)
BMI	22.7	23.7	2.07	22.2
	(2.88)	(4.36)	(2.62)	(4.21)
Height	170	1.58	1.69	1.58
	(0.0672)	(0.0592)	(0.0700)	(0.0623)
Log wage rate	5.66	4.82	3.34	3.17
	(1.42)	(1.72)	(1.26)	(1.36)
Age	38.7	36.5	36.2	35.6
	(11.5)	(11.9)	(12.4)	(12.7)

ENDOGENOUS DEMANDS FOR HUMAN CAPITAL INPUTS

Hausman (1978) and Wu (1972) 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 per cent level of confidence in three out of four samples, among men and women in Ghana and women in Côte d'Ivoire (Table 4). Moreover, BMI 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, all four variables have been treated as endogenous in the instrumental variable (IV) estimates reported in col. 5 in Table 2. The standard errors are corrected for the fact that the human capital variables are now predicted.

TABLE 4 *Specification tests of exogeneity of human capital inputs in the wage function*

Human capital input	Côte d'Ivoire		Ghana	
	Males	Females	Males	Females
Schooling	n.s.	n.s.	n.s.	n.s.
Migration	n.s.	n.s.	n.s.	–2.79 (0.005)
BMI	n.s.	1.96 (0.048)	n.s.	2.44 (0.14)
Height	2.30 (0.21)	n.s.	4.88 (0.000)	4.55 (0.000)

Notes: n.s. = not significant as 5 per cent level.
Table shows *t* ratio and confidence level (in parentheses) for rejecting the null of exogeneity.

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 increases markedly for men and women in Ghana and for men in Côte d'Ivoire when estimated as an endogenous variable.

The mixed estimates in col. 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 on an increase in height by one centimetre is now to increase men's wages by 9.2

per cent in Côte d'Ivoire and 13.5 per cent in Ghana, and women's wages by 16.9 per cent in Ghana. Weight for height, measured by BMI, is related to wages of women more strongly than those 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 for women's wages in Côte d'Ivoire of 19.3 per cent and for women's wages in Ghana by 8.7 per cent. 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, the first step is to simulate the effect of a sample standard deviation (Table 3) increase 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 per cent higher in Côte d'Ivoire, respectively, and men's and women's wages in Ghana being 134 per cent higher. Education among males and females in Côte d'Ivoire is a major factor, because the wage returns to education are several times larger there 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 larger economic benefits in terms of enhanced labour productivity in both countries; but at lower income and nutrition levels in Ghana, the wage benefits are proportionately higher.[10]

Migration returns are higher in Côte d'Ivoire than Ghana, suggesting that labour 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 transport infrastructure could be partially justified in Côte d'Ivoire to enhance labour 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: the variation due to investments of individuals, families and states, and 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 larger. 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 data base 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, the standard deviation of each human capital input has been weighted by the R^2 obtained in the instrumental variable auxiliary regression of equation (1). Since the proportion of the variance explained by education and migration ranges from 0.5 to 0.3, and that of BMI and height from 0.1 to 0.2, 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 5.

The educational input variation accounts for about 40 to 50 per cent of the wage gain in Ghana and Côte d'Ivoire, respectively. Migration contributes from 11–16 to 24 per cent of the wage gain in the two countries, parallel to the results discussed earlier. Height and BMI together contribute 42–47 per cent of the simulated wage gain in Ghana and 20–27 per cent in Côte d'Ivoire. Overall, these reweighted wage gains confirm again that the levels of wage returns to human capital are not dissimilar for women and men (Schultz, 1993). However, 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 the 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 were more salient constraints on labour productivity in Ghana than they were in Côte d'Ivoire in the late 1980s. Many replications and refinement of the studies are needed to increase confidence in these types of generalizations, but they are of

TABLE 5 *Percentage changes in wages associated with simulated changes in human capital inputs: Côte d'Ivoire and Ghana*[1] *(percentage of total change in parentheses)*

Human capital input	Côte d'Ivoire		Ghana	
	Males	Females	Males	Females
Education	31.3	29.4	9.1	6.7
	(56)	(49)	(40)	(42)
Migration	13.4	14.6	2.5	2.6
	(24)	(24)	(11)	(16)
BMI	2.6	16.3	1.2	0.6
	(5)	(27)	(5)	(4)
Height	8.1	0.1	10.1	6.0
	(15)	(0)	(44)	(38)
Total	55.4	60.1	22.9	15.9
	(100)	(100)	(100)	(100)

Note: [1]The simulated change in log wages is based on the product of the coefficients, β_j (Table 2, col. 6), the standard deviation of the j^{th} in human capital input (Table 3), SD_j, the coefficient of determination of the input demand equation $R^2_{ij,xy}$ (coefficient of determination of inputs on all instruments) and 100.

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 demand for any one form of human capital, as more of it is supplied by the aggregate population. There are also reasons to think that 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 6, treating as endogenous all human capital inputs that embody either height or BMI. Thus, in comparison with col. 6 in Table 2, where two variables are endogenous, in Table 6 there are nine endogenous variables to be estimated 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 6 indicates that the additional 9 parameters estimated in Table 6 are jointly statistically significant at the 5 per cent levels (compared with col. 6, Table 2) and for males in Côte d'Ivoire the F is near that threshold level at 1.79 ($P < 0.05$, 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 analysis of the material (Schultz and Tansel, 1993; Vijberberg, 1993). This is presumably a disequilibrium condition that implies public investments in schooling might favour a further expansion in the secondary school system where wage returns are relatively larger. 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 non-migrants. 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 with observable conditions of parent and child. The tendency towards 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, 1982b).

Education and height, which proxies childhood nutritional status, appear to be complements for women in Côte d'Ivoire and substitutes for men in Ghana.

TABLE 6 *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)	0.104	0.0839	–0.0214	–0.0164
	(5.93)	(2.67)	(1.92)	(1.23)
Education (squared)	0.00218	0.00311	0.00461	0.00393
	(2.11)	(1.74)	(7.14)	(4.19)
Migration	0.632	0.750	0.416	0.230
	(5.63)	(4.96)	(5.09)	(3.25)
BMI (weight kg/height mt.^{2})	2.85*	2.84*	–2.35*	–8.12*
	(0.95)	(1.42)	(1.38)	(2.86)
BMI (squared)	4.31*	–0.132*	0.114*	1.53*
	(1.53)	(0.14)	(0.09)	(1.45)
Height (metres)	318.0*	–85.0*	–209.0	–52.0*
	(2.42)	(0.47)	(2.13)	(0.40)
Height (squared)	–91.2	34.9*	61.3*	–9.58*
	(2.47)	(0.60)	(2.03)	(0.23)
Educ. and Mig.	–0.182	–0.0223	–0.0267	0.00457
	(1.33)	(1.08)	(3.19)	(0.48)
Educ. and BMI	0.0216*	–0.0330*	0.0504*	–0.0141*
	(0.98)	(2.70)	(3.09)	(1.27)
Educ. and HT	–0.208*	0.477*	–0.688*	0.186*
	(0.72)	(2.59)	(3.26)	(1.12)
MIG. and BMI	–0.412*	–0.179*	–0.172*	–0.266*
	(2.09)	(1.37)	(1.13)	(1.49)
MIG. and HT	5.24*	2.78*	1.98*	3.54*
	(2.06)	(1.45)	(1.06)	(1.37)
BMI and HT	–4.30*	–1.43*	1.13*	4.80*
	(0.20)	(1.16)	(1.03)	(2.84)
Interaction and quadratic parameters jointly tested by *F* (degrees of freedom)	1.79 (9,1561)	3.42 (9,736)	9.67 (9,3479)	4.51 (9,3366)

Notes: Endogenous variable (*) estimated by instrumental variables: parental education and occupation, rural residence and local health infrastructure and food prices. 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 parenthesis.

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 that unobserved background characteristics of families may favour 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 (BMI) appears in all four samples to be a substitute for migration, although the interaction effect is statistically significant from rural to urban labour markets, and the wage returns to physical labour which heavier persons have a comparative advantage in performing are a more common feature of the rural labour 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 as to 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 return, such as education and migration, must await more research. There are nonetheless hints of some plausible trade-offs which 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 analysed, a firmer basis should develop for measuring both the non-linear and interactive returns to human capital. Thomas and Strauss (1993) have made a start based on unusually large and detailed survey from Brazil. Collecting intergenerational data, with anthropometric indicators of nutrition, combined with labour market information on wages, should open the field to comparative studies. Analysis of multiple human capital inputs to enhance labour productivity in developing countries is an expanding research frontier from which we can expect to learn much in the next decade.

NOTES

[1]Another human resource programme that should be analysed 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 labour market that is 10 per cent lower (Schultz, 1992).

[2]There are several hypotheses concerning 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 such 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: 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 (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 their complementary inputs and specialize between substitute inputs.

[3]See note 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 correct when the inputs were 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 their 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, 1982b). If either migration or education is determined endogenously, a positive effect of the human capital interaction variable based on the assumption that 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 1985–7 are combined for a total sample of about 40 000 people. For wage earners and self-employed who report labour 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 7579. Ainsworth and Muñoz (1986) describe the design of these surveys. For Ghana, two years of surveys are combined from 1987–8 and 1988–9 with a sample of about 30 000 people. 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 (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 4 cm between those aged 20–29 and 50–59 is a difference in adult height of these birth cohorts, the annual gain of 0.10 cm over the 30-year period exceeds Fogel's (1994) estimates of growth in height for six European countries from the end of the eighteenth to the end of the twentieth centuries. Fogel concludes that the increase in height in this two-century period for England of 0.45 cm. per year accounts for 30 per cent of the improvement in labour productivity for the period. It may be assumed that a similar accounting for Côte d'Ivoire would imply that a substantial amount of the growth in labour 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 0.067 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 functional forms is needed in this field (compare 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 non-earned income variables from the wage equation, and their inclusion in the worker probit equation. The estimate 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 labour markets do not observe and reward nutritional investments (although they can see height and weight). Thus the efficiency wage hypothesis could account for a sub-optimal stable equilibrium among the very poor, undernourished workers who cannot 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 Foster and Rosenzweig (1993), and an early formulation of the hypothesis by Bliss and Stern (1978).

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