American Economic Review 2012, 102(7): 3531–3560
http://dx.doi.org/10.1257/aer.102.7.3531

Human Capital Investment and the Gender Division of Labor in a Brawn-Based Economy†

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Emerging evidence suggests that returns to investments in schooling and health systematically differ across men and women across a variety of settings. In particular, investments in health augment the schooling of women relative to men but increase the earnings of men relative to women, while investments in schooling have greater returns in the labor market for women. Recent randomized field experiments in different low-income countries (Miguel and Kremer 2004; Maluccio et al. 2009; Bobonis, Miguel, and Puri-Sharma 2006; Field, Robles, and Torero 2009) in which the health of young children was experimentally increased, for example, indicated that schooling outcomes were improved significantly more for females.[1] Recent reviews of the returns to schooling also suggest that the returns to human capital investment are pervasively higher for women in the labor market (Dougherty 2005; Trostel, Walker, and Woolley 2002; Psacharopoulos and Patrinos 2004).[2]

The higher female return to schooling observed in recent data cannot simply be attributable to the scarcity of female schooling or to only women from well-off families being educated, as may have been true in the past in many countries. In many countries of the world schooling levels and attendance rates of females now exceed those of males. This phenomenon is not confined to developed countries. In Bangladesh, for example, secondary school enrollment rates for girls even in rural areas has been higher than that of boys since the late 1990s, and in China enrollment rates of girls in secondary and tertiary schools has been higher than that of boys since 2005. And the relative rise in female schooling in urban China has also been accompanied by a relative rise in the returns to female schooling (Zhang et al. 2005). There is less systematic empirical evidence on the direct labor market returns to increased health by gender. Thomas and Strauss (1997), in one of the first

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† To view additional materials, visit the article page at http://dx.doi.org/10.1257/aer.102.7.3531.

[1] Glewwe and Miguel's (2007) recent review of the literature on the impact of early nutrition on health construct a model that ignores biological differences between men and women in brawn and the effects of health improvements on the opportunity cost of schooling, as discussed here. Their model cannot account for gender differentials in health impacts on schooling, and they ignore the empirical findings of such differentials.

[2] Dougherty (2005), reviewing 27 US studies reporting estimates of rates of return to schooling, found that in 18 the schooling coefficient was higher for females, while in only one study was the estimated return higher for males. Trostel, Walker, and Woolley (2002) obtained estimates of schooling for 28 mainly developed countries and found that in 24 the schooling coefficient was higher for women. And of the estimated gender-specific returns to schooling reported for wage workers in 95 countries by Psacharopoulos and Patrinos (2004), 72 are higher for women. Of course, in many developing countries many workers, especially women, do not work for wages, so that some of these differences could be due to differential selectivity in wage work by gender.

empirical studies to account for the endogeneity of health in estimating the earnings effects of health, find that in urban Brazil, while men with greater body mass earn higher wages, the average relationship between this measure of nutritional status and wages for women was essentially zero. Consistent with this result, Hoddinott et al. (2008) found that a nutritional supplement provided to children in the first three years of life in the randomized field experiment in Guatemala increased the wage rates of men, but not those of women, although in that project, as in the other cited studies, the nutritional intervention increased only the schooling of women.

In this article we construct and empirically apply a parsimonious model of investment in human capital incorporating heterogeneity in brawn that seeks to account for all of these facts describing gender differentials in the levels and returns to human capital investments in any economy in which brawn is productive. We test the model using new panel data from rural Bangladesh covering a 25-year period when both schooling and health improved substantially in the population. Our framework departs from most standard models of human capital investment in two ways. First, we embed the model in an economy described by the Roy (1951) model. Workers are bundles of two attributes—brawn and skill—and the returns to each of these attributes differs across activities. Individuals endowed with different levels of brawn optimally invest in schooling and nutritional intake and select an occupation that maximizes a welfare function. The Roy model is a natural framework with which to examine gender differentials, given the marked differences in occupational distributions of men and women. Our model can account for the differentials in attribute returns in part as a consequence of the gender division in occupations.

Our second departure from standard models of human capital investment is that we embed in the model two biological facts about brawn. The first is that men are substantially stronger than women on average; men have a comparative advantage in brawn. Evidence from a US study (Mathiowetz et al. 1985) and our own data on the distribution of grip strength among adult men and women in rural Bangladesh (online Appendix Figure 1) indicate that, first, in both populations men are substantially stronger than women, and second, the distributions by gender across the populations are similar, consistent with these differences having biological rather than cultural or economic origins in both scale and first moments. The second biological fact we embed in the model is that increases in body mass increase strength substantially more for men than for women. This gender difference in the biological relationship between body mass and brawn has also been documented in the medical literature (e.g., Round et al. 1999).

Two recent papers have examined the relative rise in female schooling. Becker, Hubbard, and Murphy (2010) construct a model in which females have an advantage in noncognitive skills that lowers the cost of schooling. The principal causes of the relative rise in schooling are thus an overall increase in the demand for college graduates combined with differences in the distribution of these noncognitive skills within and across gender groups. More similar to our own focus, Rendall (2010) calibrates a model of the US economy incorporating gender differences in comparative advantage by brawn and skill that seeks to explain the aggregate changes in the wages, schooling, and employment of women in the United States as a consequence of skill-biased technological change. Our model yields predictions similar to both of these frameworks in a context in which the demand for skill increases. However, it can also explain, unlike in these frameworks, why girls would receive relatively more schooling than boys without any increase in demand for skill and account for (i) the larger effects of investments in health and nutrition on schooling for girls, (ii) the observed gender differences in occupational distributions, and (iii) the higher returns to female schooling even where the schooling of women exceeds that of men. And none of the prior models can explain our empirical findings that larger men, but not larger women, have lower schooling compared with their smaller counterparts, that larger men choose brawn-intensive while larger women choose skill-intensive occupations, or that the returns to schooling for women and men are lower in brawn-intensive activities.

We use data from rural Bangladesh because of the existing rich information at the individual level on anthropometrics, schooling, activities, and consumption. Rural Bangladesh is clearly a brawn-based economy. The 2004 Demographic and Health Survey for Bangladesh indicates that roughly two-thirds of the men in rural areas are engaged in activities—e.g., farming, rickshaw pulling, and other manual labor—in which brawn is presumably productive. On the other hand, less than 25 percent of women are in the labor force; there is clearly a division of labor by gender. Although it is attractive to think of economic development as raising the returns to skill relative to brawn, the rise in and overtaking of the schooling of girls relative to boys in rural areas of Bangladesh was not obviously the result of changes in technology that raised the demand for schooling. The solid line in Figure 1 shows the ratio of girl to boy secondary school enrollment rates over the period 1981–2002 from published government sources (Bangladesh Bureau of Educational Information and Statistics, 1987, 1991, 1998, 2003). As can be seen, relative schooling growth for girls has been substantial. The top discontinuous line, which plots the movement in agricultural wages over the same period, shows, however, that there has been little or no growth in real wages over this time interval. Agricultural wages are closely related to agricultural productivity (Rahman 2009), so the differential trends in schooling are evidently not the result of productivity growth or technical change. The rising relative schooling trend also cannot be explained by the growth in microcredit. The fraction of adult rural women who are microcredit clients is plotted at the bottom of the figure; as can be seen, the schooling trends began long before microcredit became an important source of loans for rural women.[3]

A major initiative under way in the early 1980s in Bangladesh was the reduction in diarrheal disease and child mortality in part through educational campaigns that provided information on the importance of clean water and through improvements in water sources. The middle discontinuous line in Figure 1 plots the increase in the fraction of the rural population with improved water sources. This line indeed parallels the trend in the relative gender-specific school enrollments and, as discussed below, the rise in height and body mass of both men and women despite the lack of any increase in the per capita caloric intake (Hels et al. 2003), consistent with a decline in morbidity, which increases the efficacy of nutritional intakes.

[3] Bangladesh has put in place a number of educational initiatives, including subsidies that favor female schooling. Studies have shown that these initiatives have been successful in increasing schooling and the relative schooling of girls (Ravallion and Wodon 2000). However, these programs could not have initiated the relative rise in female schooling, as the relative trends in schooling began before any of these programs were in place, and the estimated effects of these programs are insufficient to explain the magnitudes of the relative rise in female schooling.

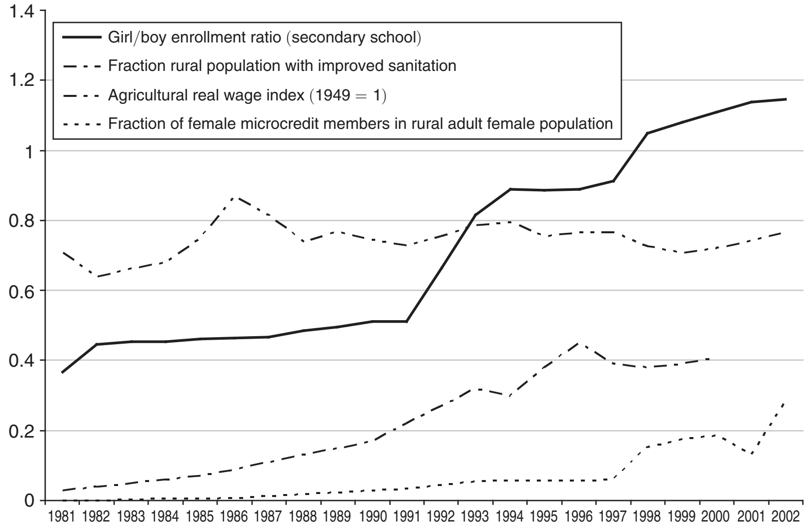

Figure 1. Trends in Rural Bangladesh: 1980–2000

It is not possible, of course, to infer causal effects from increased body mass to gender-specific changes in schooling from these aggregate associations.[4] Our objective is not to decompose the trends in relative schooling investments by cause in Bangladesh, nor to account for why in years past women received substantially less schooling than men in low-income countries. Rather we seek to estimate how changes or variation in brawn affect schooling and activity choice and the returns to schooling by gender in a framework that is consistent with these temporal changes and the observed differences by gender in schooling levels, returns, and activities in most economies.

In Section I of the article we set out the model of human capital investment incorporating the production of brawn and skill within a Roy economy. The model delivers implications for how variation in body-mass endowments, changes in the efficacy of nutritional intakes, and comparative advantage in skill and brawn affect schooling and activity choices differentially by gender when health and schooling are complements. The data are described in the next section followed by a description of the method for measuring body-mass endowments using information on body mass and individual-specific nutrients, and the strategy for estimating the effects of the estimated endowments in the presence of measurement error is described.

In Sections IV–VI of the article reduced-form estimates of the relationships between the individual body-mass endowments and direct assessments of strength, the probabilities of attending school, completed schooling attainment, and participation in energy-intensive occupations are obtained separately for men and women. The results confirm that body mass translates into brawn for men substantially more than for women and indicate that, consistent with the model, males with

[4] Health interventions and improved nutrition also contributed to declining maternal mortality (Hogan et al. 2010), which may have also affected the relative return to female schooling (Jayachandran and Lleras-Muney 2009).

larger body-mass endowments are less likely to attend school when young, have lower completed schooling, and are more likely to be engaged in energy-intensive activities as adults compared with males with a smaller endowed body size. In contrast, larger women are marginally more likely to be in school, and have higher levels of schooling, and participate less in less energy-intensive activities compared with smaller women, consistent with health-schooling complementarity. In Section VII we consider alternative explanations for our findings on the contrasting gender-specific effects of body mass on schooling and activity choice based on relationships between body mass, cognitive ability, and, for women, age at menarche. The penultimate section of the article is devoted to estimating a wage function that is consistent with the Roy model. The estimates indicate that the log-linear wage function that assumes equality of returns across activities commonly estimated in the literature is rejected, indicating that schooling has a higher return and brawn a lower return in low energy-intensive occupations. Given that women are less represented in energy-intensive activities, on average the return to schooling is higher among women than among men. The final section contains a brief summary and considers the implications of our findings for the effects of alternative development policies on gender gaps in earnings and schooling and the gender division of labor.

I. The Roy Economy, Human Capital Production, and Activity Choice

We assume that investments in schooling and health (body mass) and the choice of activities (occupation) are made in a Roy-type economy. Specifically, there is a continuum of tasks or industries indexed by i, and each worker provides a bundle of skill H and brawn B to carry out the tasks. Firms in the economy produce outputs that are the sum of the individual outputs of workers from each task. The marginal contribution of a worker to the total output of the firm is, thus, the worker's task output. Assuming a Cobb-Douglas technology for the task function, the adult worker wage, the value of a worker's contribution to task output, is given by

$$W = \pi(i)\,\nu(i)(\kappa H)^{\alpha(i)} B^{(1-\alpha(i))}, \tag{1}$$

where $\pi(i) =$ the equilibrium price of the output of task $i, \nu(i) =$ a task-specific productivity parameter, and $\kappa =$ is a scale parameter that converts H into units of brawn.

Following Ohnsorge and Trefler (2007), we order without any loss of generality occupations/tasks by skill intensity so that $\alpha_i > 0$, where $\alpha_i = \partial\alpha/\partial i$; thus, a higher i means a more skill-intensive task by definition. That is,

$$\text{if} \quad i' > i, \quad \text{then} \quad \alpha(i') > \alpha(i).$$

For a worker with attributes B and H, (1) is maximized when occupation i is chosen such that

$$\log(\kappa H/B) = -(\pi_i + \nu_i)/\alpha(i)\,\pi(i)\,\nu(i). \tag{2}$$

Expression (2) has two important implications: (i) activity choice depends on a worker's relative amounts of brawn and skill—comparative advantage. Those persons with a comparative advantage in skill (women) will thus be in more skill-intensive (higher skill return) occupations; (ii) in an economy in which the ratio of skill to brawn is less than one (a brawn-based economy), the task price or task productivity must rise as skill intensity rises ($\pi_i > 0$ or $\nu_i > 0$, where $\pi_i = d\pi/di$ and $\nu_i = d\nu/di$). This is because for a worker for whom $\log(\kappa H/B) < 0$, a shift to a higher $\alpha(i)$ activity would lower his or her output and, thus, wage, so either the task price or task productivity must be higher to compensate a move.[5]

Brawn and skill are chosen optimally. Brawn is a function of body mass M; the production technology for brawn is given by

$$B = B(\gamma M) + b, \tag{3}$$

where $\gamma \geq 0$, $B_M > 0$, $B_{MM} < 0$. γ is a parameter that will be used to capture differences in the relationship between body mass and brawn by gender. We assume that increased body mass increases brawn for males, and not (or much less so) for females, consistent with the biomedical literature. The brawn of females is thus given by the endowment b. Each individual is also endowed with an individual-specific body mass m. Body mass can be augmented by *effective* calorie intake θC, that is, nutrients that are retained by the body, where $C =$ calorie intake and θ reflects the proportion of calories retained or the efficiency by which calories increase body mass. We assume that decreases in morbidity, brought about by public health interventions, increase θ. The body-mass production function is

$$M = M(\theta C) + m, \tag{4}$$

where $\theta > 0$, $M_1 > 0$, $M_{11} < 0$.

The skill production function is

$$H = H(S; M), \tag{5}$$

where $S =$ schooling time and $H_1 > 0$, $H_2 > 0$. We assume that a higher body mass (or, equivalently, increased nutrition) increases the return to schooling S in augmenting skill, so that $H_{12} > 0$. That is, schooling and health are complements in the production of skill, but health does not directly augment skill. Finally, the wage of a child ω is an increasing function of brawn, but not S:

$$\omega = \omega(B) \quad \text{and} \quad \omega_B > 0, \omega_{BB} < 0. \tag{6}$$

To fix ideas using the simplest optimizing model, we assume that a parent chooses schooling time and calorie consumption for a child to maximize a utility function

[5] This property of the model is true as long as the task function is CRS. Although we have not modeled the general-equilibrium properties of the economy, the condition that task value $(\pi(i)\nu(i))$ rises as the relative returns to skill increase could be due to more skill-intensive activities having higher levels of capital or due to brawn-intensive tasks producing nontradable output so that output prices for such tasks are lower where brawn is in plentiful supply. We test this property below.

that has as arguments the adult wage of the child and his or her effective calorie consumption. The optimization program is

$$(7) \qquad \max_{C,S} \quad U(\theta C, W)$$

subject to (1)–(5) and to the budget constraint

$$(8) \qquad F = pC + (1 - S)\,\omega + S\rho,$$

where $F =$ parental income, $p =$ the market price of a calorie, and $\rho =$ the direct cost of a unit of schooling time. The budget constraint reflects the fact that children work and contribute to income when not in school.[6]

We first solve the model for the case in which $\gamma = 0$, so that increases in body mass do not augment brawn. This variant of the model thus more closely describes optimal schooling and activity choices for women. For $\gamma = 0$, the first-order necessary conditions (FONC) are:

$$(9) \qquad \theta U_C = \lambda p$$

$$(10) \qquad U_w\,\alpha(i)\,H_1 W/H = \lambda\,[\omega + \rho].$$

Expressions (9) and (10) are standard, indicating that the marginal cost of a calorie is its market price and schooling has a direct and opportunity cost. For men, $\gamma > 0$, the first-order condition (FOC) for schooling is the same as for women, but that for calories is different:

$$(11) \qquad \theta\big(U_C + \gamma B_M(1 - \alpha(i))\,U_W W/H\big) = \lambda\,[\,p - \gamma(1 - S)\,\omega_B\,\theta M_1 B_M].$$

Comparing (9) and (11), we see that the returns to calorie consumption are higher for males and the net price of calories is lower, as calories augment income provided by boys. Thus, males receive more calories than females for two reasons: (a) calories increase the wage more for men, and (b) men work in more calorie (brawn)-intensive activities with a higher return to brawn than do women, as the ratio H/B is lower for men. But (10) also indicates that if men are in more brawn-intensive activities because of their higher endowed brawn, the returns to investments in schooling are also lower for men on average.

We derive from the model the following three propositions:

PROPOSITION 1: *When brawn is not affected by calorie consumption* $(\gamma = 0)$ *a reduction in morbidity must increase schooling*, *decrease calorie consumption*, *and increase the average skill intensity of occupations.*

[6] In the empirical application, we allow children to participate in three activities: schooling, work, and home time.

PROPOSITION 2: *When brawn is increased by calorie consumption* $(\gamma > 0)$, *as for males*, *a reduction in morbidity may increase or decrease schooling and the average skill intensity of occupations as long as effective calories do not change significantly.*

PROPOSITION 3: *If brawn and body mass are positively related*, *an increase in the body-mass endowment may increase or decrease schooling and the average skill intensity of occupations.*

Proofs of these propositions are in online Appendix A. As shown there, the model indicates that the reduced-form relationship between an intervention reducing morbidity (increase in θ) and schooling, as in randomized health interventions, will reflect two mechanisms in addition to the complementarity between health and schooling in skill production: the substitutability in the utility function between wages and calories and, for males, the increase in the opportunity cost of schooling that arises from increasing brawn.[7] As the latter lowers the return to schooling, the net effect on schooling of an intervention reducing morbidity for males thus may be negligible or even negative, even if schooling and health are complements, as is assumed.

Similarly, as shown in the online Appendix, the model also indicates that among males, larger men may receive less schooling and be overrepresented in brawn-intensive activities. Because larger men have more brawn, they will have higher opportunity costs of schooling and will participate in activities with lower returns to schooling. This will lower the returns to schooling; on the other hand, this is offset because health (body mass) and the adult wage are substitutes in the utility function and complements in the production of skill $(H_{12} > 0)$.

Proposition 3 has unambiguous implications for differences in the effects of augmenting nutrition for men and women and for differences in observed schooling levels and returns

LEMMA 1: *If brawn and body mass are positively related only for males*, *then increases in body mass for everyone will decrease schooling for males* relative *to females and increase the gender division of labor* (*difference in average* $\alpha(i)$).

Increasing body mass for men, but not women, raises the opportunity cost of schooling and directly lowers the relative return to schooling through occupation selection. This offsets any positive effects of reductions in morbidity on schooling investment only for males.

Finally, the model also gives rise to the following lemma:

LEMMA 2: *If men have more brawn than women and increased body mass lowers schooling for men relative to women*, *both the amounts of schooling of women and the estimated "returns" to schooling* $\alpha(i)\, d\log H/dS$ *will be higher for women than for men*, *since men will be in lower-*α *occupations.*

[7] This is the basic point that reduced-form interventions usually cannot identify technology.

To see this substitute (3), (4), and (5) into the wage equation (1), then

$$(12) \qquad d\log W/dS = \alpha(i)\, d\log H/dS + \big(1 - \alpha(i)\big)(d\log B/dm)\, dm/dS.$$

The first term in (12) is the effect of schooling on the log wage due to schooling increasing skill, the "return" to schooling. The second term arises from optimal schooling choice and from the brawn endowment being omitted from the wage equation ("brawn bias"). From (3), (4), and Proposition 3, $d\log B/dm > 0$ but dm/dS may be positive or negative for men and is zero for women. Thus there are two potential reasons that the observed relationship between schooling and wages on average is higher for women than for men: (i) men, based on their comparative advantage, will be concentrated in brawn-intensive, low-$\alpha(i)$ occupations compared with women, and (ii) the estimated average relationship between wages and schooling for men may be biased downward if brawn is not taken into account and if brawnier (larger) men obtain less schooling.

II. The Data

The principal objectives of our empirical analysis are to estimate gender-specific effects of individual body-mass endowments on schooling and occupation choice to test the model of school investment and activity choice incorporating brawn production, and to estimate a wage function that is consistent with the assumption that schooling and brawn differentially affect wages across occupations. To carry out the analysis, described below, requires at a minimum data that provide individual-specific nutrient intakes, anthropometric measures, schooling, wages, and activity choices. We use three datasets describing households in rural Bangladesh that meet these criteria. The first dataset is the *Nutrition Survey of Rural Bangladesh* 1981–1982 ($N = 4{,}107$), a probability sample of 50 households in each of 15 villages meant to be representative of the rural population of Bangladesh in the year the survey was administered. These data were used by Pitt, Rosenzweig, and Hassan (1990) to estimate body-mass endowments and to assess how these affected the allocation of nutrients among children and adults within households.

The second dataset we use is from the *Nutrition Survey of Rural Bangladesh* 2001–2002 ($N = 9{,}838$). This survey was a follow-up to the 1981–1982 survey and includes all surviving and resident individuals surveyed in 1981–1982 in 14 of the 15 original villages plus a new random sample of households in the same villages. All individuals in the original survey and all members of their households were included in the panel no matter where their residence in 2001–2002. Attrition of surviving individuals who still resided in Bangladesh at the time of the survey was less than 3 percent. The third dataset is from the *Nutrition Survey of Rural Bangladesh* 2007–2008 ($N = 12{,}244$), which includes all individuals surveyed in 2001–2002 and all members of their households, again regardless of residence at the time of the survey.[8]

These datasets have a number of important and unique features that facilitate the analysis. First, as noted, there are *individual-specific* food intakes, recorded over a 24-hour

[8] The attrition rate for this follow-up was higher, at 8 percent, due in part to increased migration outside of Bangladesh but still low by international standards.

period by observation and measurement, for all individuals in each round, except for the first survey in which this information was obtained for only a random 50 percent of households. Second, individual-specific activity schedules were obtained for the same 24-hour period, in addition to occupation information. Third, individual anthropometric information on height and weight was obtained from all individuals in all rounds. These data together enable the estimation of the body-mass production function and, thus, body-mass endowments, as described below. In addition, households in two of the villages were interviewed multiple times in the same year in each survey round. This validation subsample included four repetitions in 1981–1982 and two repetitions in 2001–2002 and in 2007–2008. The repetition subsamples will enable us to correct for measurement error in our estimates of the effects of body-mass endowments on human capital choices and wages. Fourth, in the 2007–2008 round of the survey we obtained individual-specific assessments of grip strength, pinch strength, and aptitude, using an abridged version of Raven's Colored Progressive Matrices (CPM) tests with nine questions, for every respondent meeting a minimum age requirement. Data from these instruments will enable us to directly assess whether body mass differentially affects brawn by gender and to identify any correlation between body mass and cognitive ability that may bias our estimates. Finally, the combination of long-term panel information and repeated random cross-sections will enable us both to assess the robustness of our structural (production function) estimates to environmental changes over a 20-year period as well as to assess the effects of body-mass endowments on both contemporaneous schooling investments and subsequent completed schooling and adult wages.

The activity information in the 1981–1982 and 2001–2002 surveys is consistent with the official statistics on rural school enrollment trends. As indicated in the online Appendix, Figure 2, which plots the fraction of children aged 10–15 attending school by age and gender, there has been a substantial rise in school attendance at every age for both boys and girls, but the increase has been greater for girls such that in the 2001–2002 round of the survey girls' school attendance is greater than that of boys for all ages above age six, a reversal of the differences in 1981–1982. During this period both boys and girls in this age range also experienced increases in body mass. Boys appeared to have experienced a somewhat greater increase in BMI than girls over the survey interval: for boys, BMI has increased at every age between five and 15; the BMI for girls is higher in the later period only for girls above nine. And, above that age the percentage increase in BMI for boys is 7.1 percent while that for girls is 2.2 percent. The two rounds of data also indicate that stature has steadily increased in the rural population, with height at age 22 rising about three centimeters for men and women who reached age 22 between 1952 and 2000. The gains in height and body mass have not been due to increased nutrient intakes. The data indicate that the level and allocation of calories per person, based on the individual-specific calorie information taken from comparable months across the survey years, has not significantly changed over the period.[9] Consistent with our model, average caloric intake is higher for men than for women in both 1981–1982 and 2001–2002,

[9]Our survey data showing no increase in per capita calorie consumption match closely aggregate statistics on the per capita availability of food grains for Bangladesh, based on national production and trade data for the period 1980–1981 to 1999–2000 based on statistics compiled by Begum and D'Haese (2010).

staying at approximately 3,000 calories per day for men and 2,000 calories per day for women. It is, thus, likely that the gains in stature and body mass were due to the reductions in morbidity, which increased the efficacy of nutrient intakes, as there has also not been a decrease in activity levels, at least for men. The data indicate that in 1981–1982, 67 percent of men aged 20–49 were engaged in "exceptionally active" or "active" occupations, based on energy expenditure levels; in 2001–2002 the proportion increased to 72 percent. For women, only 9 percent were participating in such activities, and that proportion declined to 3 percent in 2001–2002. The online Appendix, Table A, provides descriptive statistics for the adults age 20–59 in the 2001–2002 and 2007–2008 rounds of the data.

III. Estimation Strategy: Identifying Body-Mass Endowment Effects

To assess the effects of changes in body mass for males and females on schooling choice and occupation selection, and to estimate wage functions incorporating schooling and body mass in which the returns to skill and brawn vary across occupations consistent with the Roy model, we carry out our estimation strategy in three steps. We describe the first two steps here, deferring the discussion and estimation of the activity-specific Roy-model wage function to the final section.

The first step in our empirical analysis is to obtain estimates of body-mass endowments for the sampled respondents. To do this, we estimate the body-mass production function (4) using the same specification (Cobb-Douglas) and econometric methodology as in Pitt, Rosenzweig, and Hassan (1990) but applied to the 2001–2002 round of data, which contains many more individuals. As in that study, we generalize (4) to allow activity type to directly affect body mass, because activity type affects energy expenditure. In the earlier study weight/height was used as the body-mass measure to obtain an estimate of the body-mass endowment because it is especially sensitive to contemporaneous variations in nutrient intakes and energy expenditure. Because measures of inputs and outcomes were obtained in the same interview period, the contributions to the short-run variation in body mass from endogenous variation in inputs can be identified.

The empirical challenge to obtaining an estimate of the body-mass endowment from the production function is that, as shown in the model, the nutrient inputs and the activity type will be correlated with the unobserved endowment that is impounded in the error term. We replicate the methodology in Pitt, Rosenzweig, and Hassan and employ instrumental variables, using as instruments village-level prices interacted with an individual's age, his or her household land holdings, and the household head's characteristics—age and schooling.[10] Because we are using the same specification and estimation procedure as in the earlier study, we expect that the estimated coefficients corresponding to the work activities, nutrients, age,

[10] In the model the price of calories p, the direct cost of schooling ρ and parental income Y do not appear in the production function for body mass (4) but affect activity choice and the level of calories C. We use as determinants of Y household landholdings and head schooling and age. In the context of multiple-person households, to explain individual-specific activities and intakes there must be household- and individual-level variation in instruments, so the village-level prices and household-level income determinants are also interacted with person-specific attributes. As in the earlier study, because we have more village-level prices than villages, we replace the village-level price set by a set of complete village dummy variables.

and gender variables obtained from the 2001–2002 population will be similar to those obtained from the 1981–1982 data, despite the small overlap in the population, if the specification and estimation procedure identify structural, biological effects.

We will directly test the robustness of the estimates to the changes in environmental conditions that occurred over the 20-year interval between surveys. Among the conditions that importantly changed during the time period, aside from the relative prices of foods and nonfoods and schooling, are the reductions in morbidity (increase in θ), the sources of water used (increased availability of wells), and water use habits. Given the logarithmic form, overall morbidity θ at the time of the survey will be impounded in the intercept; individual variation in θ will be impounded in the error term. The specification will also include controls for water sources. However, because over the period information was diffused about water purification and about the relative purity of the different sources of water, by 2001 the source of drinking water for 97 percent of households was a tubewell. We thus expect that the coefficients on the water-source variables will not be important in the later period, in contrast to those for nutrients and activities.

The residuals from the estimated body-mass production function contain the body-mass endowments for each sample respondent j. We will use these to estimate the reduced-form endowment effects on schooling (attainment and attendance), activity choice, and the wage that corresponds to the comparative statics of the model. That is, we estimate

$$y_j = \mathbf{Z}_j \boldsymbol{\zeta} + b m_j + \varepsilon_j, \tag{13}$$

where $y_j = S_j, W_j, i_j$; $m_j =$ the production function residual; the $\mathbf{Z}_j =$ a vector of exogenous control variables; and $\varepsilon_j =$ an error term, containing measurement error in the y_j. The main empirical problem is that the residual m_j for individual j contains the individual's true body mass m_j^*, net of the influence of contemporaneous consumption and activities, plus measurement error η_j; i.e., $m_j = m_j^* + \eta_j$, where $m_j^* =$ the true endowment. Estimation of (13) by OLS would thus yield biased estimates of both the coefficient vector $\boldsymbol{\zeta}$ and b.

To deal with the measurement error problem, we use repeated measures from the validation samples of *within-round* replicates—households that were visited multiple times within the same year. For the validation subsample

$$m_{jr} = m_j^* + \eta_{jr}, \tag{14}$$

where $r =$ within-year round number. If we assume classical measurement error properties for η_j (η_j is uncorrelated with $\mathbf{Z}_j^*$, y_j^*, and ε_j) and that the repeated measures have the same mean and independent measurement errors, we have a set of "exchangeable" replicates. By jointly estimating the outcome equation (13) and the measurement equation (14), using maximum likelihood we can obtain consistent estimates of the parameters in (13) as well as appropriate standard errors that take into account that the residual measures of endowments are noisy. Owing to the conditional independence between the measurement errors and the outcome y_j given m_j^*, the likelihood is the product of the measurement model (14) and the outcome model (13), integrated over m_j^*, assuming normality for the errors

(Rabe-Hesketh, Skrondal, and Pickles 2003). We will refer to these estimates, which accommodate measurement error, as GLLAMM (generalized linear latent and mixed model) estimates.[11]

Finally, the model depicted the behavior of a pair of individuals—parent and child. In the data individuals are clustered in households with multiple members. We thus allow the allocation of resources to each individual to be a function not only of his/her own endowment but also the average endowment of other household members. We also obtain coefficient standard errors that take into account household clustering. In the empirical analysis we assume only that household landholdings, the household endowments, age, and food prices are exogenous variables that belong in the set $\mathbf{Z}_j$.

IV. Body-Mass Production Function Estimates, Body-Mass Endowments, and Brawn

The first column of Table 1 reports the two-stage least squares estimates of the body-mass production function from Table 4 in Pitt, Rosenzweig, and Hassan (1990), which were obtained using the 1981–1982 survey data. The endogenous input variables include the log of individual calorie consumption over a 24-hour period, indicator variables based on the contemporaneous reported activity of the person of whether the activity was "very active" or "exceptionally active" (the left out categories being "active" and "not very active"), whether the respondent was pregnant, and whether the respondent was lactating. Also included, but not instrumented, are the log of age and its square, gender and gender interacted with log age, and the principal source of water for the household, divided into four categories (tube well, well, and pond, the left out variable being piped water).[12]

The prior estimates indicated that net of activities, and controlling for the state of lactation and pregnancy, increased calorie consumption increased body mass while, for given calorie intake, working in energy-intensive activities depleted body mass relative to working in lower-energy activities. Body mass was also reduced if the household's principal water source was not piped water. The second column of Table 1 reports the new two-stage least squares estimates of the body-mass production function from the 2001–2002 data, estimated for the age group 3–60 and clustered at the village level, using the same specification and econometric method. Because of the increase in sample size, many of the coefficients are measured with more precision in the second round. The point estimates for calories, however, are almost identical across rounds, while the activity effects are somewhat stronger—showing again the importance of activity choice for body-mass depletion. The F-statistic indicates strong rejection of the hypothesis that the calorie intake, activities, pregnancy, and lactation variables are exogenous. As expected, the water source effects on body mass for the later round, while similar to those estimated from the

[11] The body-mass production function (4), the reduced forms (13), and the measurement error model (14) can be estimated jointly by maximum likelihood methods as a multiequation generalized least squares estimation problem with an error covariance matrix that includes both the endowments and the measurement errors. The two-step method we apply provides consistent but less efficient estimates of all of the parameters of interest.

[12] One concern is that age is measured with error for the young. However, the correlation between the ages for children less than 15 in 1981 and their ages reported 20 years later in the 2001–2002 survey round is 0.982 for males and 0.972 for females, indicating little measurement error.

Table 1—2SLS Estimates of the (Cobb-Douglas) Body-Mass Production Function, by Survey Population

Dependent variable: log *weight/height* Input/survey population	1981–1982[b]	2001–2002
log individual total calorie consumption[a]	0.136	0.129
	(3.37)	(2.70)
Very active occupation[a]	−0.0119	−0.101
	(0.23)	(2.59)
Exceptionally active occupation[a]	−0.0817	−0.272
	(1.26)	(8.01)
Pregnant[a]	0.326	0.0583
	(1.34)	(1.60)
Lactating[a]	0.513	0.0082
	(4.65)	(0.35)
log age	0.0987	0.851
	(1.90)	(12.9)
log age squared	0.0174	−0.0988
	(2.37)	(9.61)
Male	−0.0578	−0.168
	(1.81)	(9.91)
Male × log age	0.0687	0.0797
	(4.04)	(9.57)
Water drawn from tubewell	−0.0406	−0.0258
	(2.10)	(1.26)
Water drawn from well	−0.0693	−0.0193
	(3.15)	(0.63)
Water drawn from pond	−0.0649	0.00625
	(2.55)	(0.14)
Observations	1,737	6,300
H_0: calories, exceptionally active, very active, pregnancy, lactation exogenous $F(5{,}228)$ [p-value]	—	17.5 [0.000]

[a] Endogenous variable: instruments include household head's age and schooling level, land holdings, and price of all foods consumed, interacted with individual age and sex variables, land and head's schooling and age.
[b] Reproduced from Pitt, Rosenzweig, and Hassan (1990). Asymptotic t-ratios in parentheses clustered at the village level in 2001–2002 round.

Sources: "Nutrition Survey of Rural Bangladesh" 1981–1982 and 2001–2002.

first-round data, are not estimated with precision, reflecting the dominance of tubewells as the source of drinking water by 2001–2002.

We used the second-column production function estimates to compute body-mass residuals, containing the body-mass endowment, for each of the sample respondents in the 2001–2002 dataset. We use the residual-based body-mass endowment information to first estimate γ, the effect of the body-mass endowment on a measure of brawn. That is, we seek to verify a major assumption of the model in our data, and confirm findings in the medical literature, that variation in body mass is related to strength more substantially for males than for females. To obtain a measure of brawn, in the 2007–2008 round of the data we administered grip strength assessments to all adult sample respondents. Each respondent was asked to squeeze a dynometer three times with each hand and readings were recorded for all six applications. Our measure of brawn is the maximum of the per-hand average grip strength reading (in kilograms of pressure). For the sample of respondents aged 20–49, the mean

TABLE 2—THE BODY-MASS ENDOWMENT AND GRIP STRENGTH (2007–2008), BY GENDER: RESPONDENTS AGED 20–49 IN 2002

Dependent variable: Kilograms of pressure				
Group	Men		Women	
Estimation procedure	GLS (1)	GLLAMM (2)	GLS (3)	GLLAMM (4)
Endowment (γ)	7.41	8.17	1.58	1.93
	(5.89)	(6.03)	(1.69)	(1.67)
ρ	—	0.907	—	0.796
Observations	946	946	1,087	1,087

Notes: Absolute values of asymptotic *t*-ratios corrected for clustering within households in parentheses. All specifications include village fixed effects, age, age squared, landholdings, and an indicator of landlessness.

Source: "Nutrition Survey of Rural Bangladesh" 2001–2002/2007–2008 panel.

(standard deviation) grip strength for men was 37.3 (8.36) while that for women was 24.3 (5.66). Men are clearly brawnier than women on average.

Table 2 reports GLS and maximum-likelihood GLLAMM estimates of γ based on the estimated body-mass endowments and grip strength scores for men and women aged 20–49. The first column reports the GLS estimates for males and indicates that men with a greater body mass endowment are significantly stronger. The GLLAMM estimates making use of the auxiliary replicate subsample in column 2 indicate that the endowment variable, based on the residuals, is measured with error (ρ, the proportion of the total variance in the residual that is not noise, is approximately 10 percent) and the estimate of γ corrected for measurement error, in column 2, is about 10 percent higher than the corresponding GLS estimate that ignores measurement error. Men endowed with a larger body mass are indeed brawnier—a one–standard deviation increase in the body-mass endowment increases grip strength by a statistically significant 5.9 percent. The point estimate of γ for women, however, is less than one-fourth that for men, and is not statistically significantly different from zero at the 0.05 significance level. The GLLAMM estimates that exploit the replication subsample indicate that the body-mass endowment is measured with more error for women than for men, but the γ estimate corrected for measurement error (column 4) remains less than one-fourth the corresponding estimate for men. Thus, while larger women may be healthier, unlike men, they are not significantly brawnier.[13]

V. Body-Mass Endowments and Schooling

We now examine the relationship between the body mass endowment and schooling investments for children aged 10–15 based on the 2001–2002 round of data. We

[13] One possible alternative explanation for these results is that larger men select into occupations where they use brawn and, thus, develop muscle strength, while women who are in relatively sedentary occupations do not. We estimated the endowment grip strength relationship in a subsample of males and females aged 15 and over all of whom were currently attending school at the time of the assessments, and, thus, whose principal activities did not differ. The differences in the GLLAMM coefficients by gender were even stronger than those displayed in Table 2. We also verified that gender difference in the nonschool activities of the students was not biasing these results in favor of males using the detailed time-allocation data.

chose this age range because most children attend primary school, so that almost all of the school investment variation across children is occurring above age ten. We also we need to impose a low age ceiling, however, because of the young marriage age for girls—approximately 11 percent of girls in our sample aged between 15 and 25 married by age 15. Because school attendance information is available only for household members, given that most women leave the household upon marriage, a sample of in-household girls aged over 15 would be selective. Children in this age range can be engaged in one of three principal activities—schooling, work, or "home time." In 1981–1982, of the 48.3 percent of boys not attending school almost 70 percent were working; in 2001–2002, the major alternative to school for boys was also work—with over 90 percent of the 17.5 percent of boys not attending school at work. For girls, the major alternative to school is home time in both periods. Seventy-four percent of the 62.4 percent of girls not attending school were not working in 1981–1982 and 68 percent of the 12.5 percent of girls not in school were at home in 2001–2002.

To accommodate the three activity alternatives, we estimate the determinants of activity choice using multinomial (ML) logit and ML logit GLLAMM using the replication subsample to correct for endowment measurement error. In addition to the own endowment measure, we include the size of landholdings of the household, an indicator of whether or not the household owns any land, the average endowment of other household members, and the child's age. Because we have endowment measures for only half of the respondents in 1981–1982, the sample of 10–15-year olds is too small to carry out the analysis using the first-round data. The estimated marginals and their associated *t*-statistics for the probability of attending school for boys and girls in the 2001–2002 sample, derived from the ML logit and ML logit GLLAMM estimates, are provided in Table 3.

Both the ML logit and the ML logit GLLAMM estimates indicate that larger boys are significantly more likely to be working relative to attending school. In contrast, girls with larger body-mass endowments are less likely to work. The marginals for schooling in Table 3 indicate that, consistent with the model in which increased brawn lowers the net return to schooling, boys aged 10–15 with a larger body-mass endowment are significantly less likely to be attending school, while larger girls in the same age group are no less likely to be in school than smaller girls. The error-corrected point estimates indicate that a boy with a body-mass endowment one standard deviation higher than the mean is a statistically significant 6.6 percent less likely to be in school; a similar gain in body mass for girls *increases* the probability of being in school, but by a statistically insignificant 1.5 percent.

To verify that body mass also affects completed schooling attainment, we make use of the 1981–1982/2001–2002 panel data. Based on the production-function estimates from the 1981–1982 data we have body-mass endowments for one-half of respondents in 1981–1982 as well as information on their schooling attainment and wages in 2001–2002 from the second-round data. We estimate the relationship between the body-mass endowments estimated for 1981–1982 and completed schooling attainment (years) in 2001–2002 for the sample of children aged less than 16 in 1981–1982. We again include in the specification the amount of land owned in the household, an indicator of land ownership, the average household endowment

TABLE 3—ESTIMATED MARGINAL EFFECTS OF THE BODY-MASS ENDOWMENT ON THE PROBABILITY OF ATTENDING SCHOOL, BY GENDER AND ESTIMATION METHOD: CHILDREN AGES 10–15 IN 2001–2002

Estimation method	Multinomial logit[a]		ML logit−GLLAMM[b]	
Group	Boys	Girls	Boys	Girls
Endowment	−0.248	0.0600	−0.436	0.0983
	(2.37)	(0.68)	(3.60)	(1.04)
Household land owned	0.00670	0.00135	0.00674	0.00135
	(3.23)	(1.14)	(3.42)	(1.11)
No land owned	−0.0417	−0.0463	−0.0420	−0.0465
	(1.08)	(1.64)	(1.24)	(1.70)
Household average endowment of other family members	−0.0955	0.0667	−0.0927	0.0784
	(0.62)	(0.87)	(1.10)	(1.09)
Age	−0.0332	−0.0243	−0.0325	−0.0236
	(3.43)	(2.54)	(3.23)	(2.53)
Observations	410	353	410	353

[a] Asymptotic t-ratios corrected for clustering at the household level in columns.
[b] Bootstrapped t-ratios in parentheses in columns.

Source: "Nutrition Survey of Rural Bangladesh" 2001–2002 and ML estimates reported in Table 4.

TABLE 4—THE BODY-MASS ENDOWMENT IN 1981–1982 AND COMPLETED SCHOOLING IN 2001–2002, BY GENDER: RESPONDENTS AGED 0–15 IN 1982

Dependent variable: Completed education (years) in 2001–2002				
Gender	Male		Female	
Estimation procedure	GLS	GLLAMM	GLS	GLLAMM
Endowment (1981–2002)	−1.82	−2.22	1.00	0.923
	(2.05)	(1.94)	(0.86)	(0.67)
Age	−0.164	−0.161	−0.110	−0.123
	(0.76)	(0.77)	(0.49)	(0.57)
Age squared	0.00501	0.00483	−0.00908	−0.00787
	(0.36)	(0.36)	(0.60)	(0.54)
Household owned land (1981–1982)	0.00711	0.00711	0.00467	0.00468
	(5.49)	(5.66)	(3.05)	(3.17)
No land owned (1981–1982)	−1.02	−1.03	−1.05	−1.05
	(1.48)	(1.54)	(1.55)	(1.68)
Average household endowment (1981–1982)	0.261	−0.270	0.116	0.158
	(0.12)	(0.17)	(0.06)	(0.08)
ρ	—	0.838	—	0.821
Observations	311	311	273	273

Notes: Absolute values of asymptotic t-ratios corrected for clustering within households in parentheses. All specifications include village fixed effects.

Source: "Nutrition Survey of Rural Bangladesh" 1981–1982/2001–2002 panel.

of other family members, and the child's age and age squared, but here the variables refer to the origin households in 1981–1982. We use both GLS and GLLAMM, making use of the four-round replication subsample in 1981–1982.

The estimates of the effects of the body-mass endowment on schooling completed by 2001–2002 for boys and girls who were less than age 16 in 1981–1982 are reported in Table 4. The results are consistent with the estimates obtained for contemporaneous school attendance: boys with a higher body-mass endowment have fewer completed years of schooling in 2001–2002, while larger girls attained marginally higher levels of schooling. The statistically significant error-corrected point estimate indicates that boys whose body-mass endowment is one standard deviation above the mean have almost one-half a year less schooling (12 percent), while girls who are one standard deviation above the mean attain a statistically insignificant 0.2 more schooling years.

VI. Body Mass Endowments and Occupational Sorting

An important implication of the model is that not only does having an absolute advantage in brawn affect skill investment, but comparative advantage in brawn will affect the choice of tasks, with those individuals having relatively more brawn allocated to activities where brawn (schooling) has a higher (lower) relative payoff. To test this implication, we require, as for the index i in the model, a ranking of activities by their brawn or skill intensity. That is, we need to characterize the technology of tasks that is exogenous to the work force that is in them. We could obtain estimates of the task production function parameters (α_i) for each of the 34 activities/occupations in the data, taking into account optimal sorting. However, sample size, as well as tractability, precludes this approach. Instead we use information on the "energy requirements" of activities, compiled by the United Nations' Food and Agriculture Organization and the World Health Organization (2001). This metric by design characterizes the intrinsic characteristics of the jobs and not the workers participating in them. We additionally assume that activities that require more energy expenditure per unit of time have a higher relative return to brawn and a lower return to skill. While we will formally test this assumption in the next section, it seems reasonable that brawn is more valuable in activities with higher occupational energy requirements in the rural context that we are examining in which most of the activities involve physical work.[14]

The FAO defines the energy requirement of an activity as the amount of food energy that is required to maintain body size when participating in that activity. Physical activity rates (PARs) are provided for each task, defined as the average energy expenditure per unit of time needed to carry out the task divided by the basal metabolic rate (energy expenditure at rest, BMR). The PAR for pulling a rickshaw with two passengers is 7.2, for example; that for weeding is 4.0, and the PARs for sawing hardwood, bed making, and filing or reading or writing are 6.6, 3.4, and 1.3, respectively. There is, thus, significant variation in energy expenditure across the physical activities of rural workers as well as across physical and nonphysical activities. Moreover, the detailed time allocation information in the 2001–2002 survey along with the detailed activities in the FAO compilation (e.g., bed making, fetching wood) enables us to compute the "occupational" energy expenditures associated with the specific activities of women who are not in the labor force. Because the PAR depends on the basal metabolic rate, which differs by gender and age, we use

[14] One of the dominant activities is farming. Technological change in agriculture may increase the returns to schooling in farm management. However, as shown in Foster and Rosenzweig (1996), technological change does not alter the schooling returns to farm workers, who, according to the FAO data, expend more energy than do farm managers. Within agriculture there is, thus, likely to be a negative relationship between skill intensity and energy intensity.

the adult, prime age PARs and calculate energy expenditures for each of the activities in our data by multiplying the PAR by the adult male BMR (65), expressed as kilojoules per hour, for both men and women. The occupational energy expenditure variable is, thus, an occupational index and is inversely related to $\alpha(i)$ in the model.

Based on the Roy model, occupation selection is determined by comparative advantage. Because we have found that larger men have significantly more brawn and choose less schooling, in accord with Proposition 2, we would expect that men with a higher body-mass endowment would participate in higher energy expenditure (low i) tasks. Among women, however, body mass only marginally increases brawn but also appears to marginally increase skill acquisition, in accord with Proposition 1, so we should see a relatively small but negative relationship between body mass and occupational energy expenditure for females.

Table 5 reports the GLS and GLLAMM estimates of the relationships between the body-mass endowment and occupation selection for men and women aged 20–49 in 2001–2002, as measured by the occupational energy-expenditure variable. An important constraint on occupational choice in Bangladesh is land ownership. Because those not owning land are less likely to cultivate, we include the size of owned landholdings and an indicator for the absence of any owned land in the occupation choice specification, along with the average body-mass endowments for other family members to capture intrahousehold resource allocations. Consistent with the model and our earlier findings the estimates indicate that men with a higher body-mass endowment choose occupations with significantly higher average energy requirements, while women with a higher body-mass endowment are overrepresented in lower energy-expenditure activities. As expected as well, the absolute value of the coefficient for women is one-fourteenth that of men, reflecting the small effects of body mass on both brawn and schooling for women.

The coefficients on the land ownership variables are also consistent with the schooling results and with expectations for a rural setting, where, according to the FAO, energy expenditures are higher for farm worker activities than for farm management activities. The estimates indicate that for both men and women having no land is associated with activities having higher energy requirements, consistent with such individuals being primarily in wage worker activities and/or rickshaw pulling (for men). Occupational energy expenditure declines with land size, however, only for males. This is consistent with the schooling results in Tables 3 and 4, as males (but not females) from households with larger landholding are more likely to be in school and attain higher levels of schooling, for given body mass endowments. Men with larger landholdings are also more likely to be farm managers (no women are farm managers) and not farm workers. Interestingly, for given own body mass endowment, men but not women are less likely to be in higher energy-intensive activities if other household members have high endowments, suggesting within-household occupational diversification among men but not women. These findings thus suggest that both household characteristics and the endowed individual attributes of workers, in accord with their comparative advantage, sort individuals across activities.[15]

[15] In addition to influencing individual comparative advantage, household attributes also matter for occupational sorting. Their influence will be important in identifying activity-specific returns to brawn and schooling that is a key assumption of the Roy-based model, as discussed below.

TABLE 5—THE BODY-MASS ENDOWMENT AND OCCUPATION CHOICE, BY GENDER: RESPONDENTS AGED 20–49 IN 2001–2002

Dependent variable: Occupational energy expenditure				
Group	Men		Women	
Estimation procedure	GLS	GLLAMM	GLS	GLLAMM
Endowment	81.7	93.6	−5.78	−6.78
	(14.9)	(11.6)	(3.62)	(2.58)
Age	0.969	0.957	1.05	1.06
	(0.89)	(0.90)	(3.23)	(2.86)
Age squared	−0.00153	−0.000825	−0.0132	−0.0133
	(0.10)	(0.05)	(2.80)	(2.63)
Household owned land	−0.0195	−0.0212	−0.000269	−0.000262
	(3.13)	(3.42)	(0.15)	(0.18)
No land owned	6.62	6.22	2.37	2.38
	(2.87)	(2.67)	(3.64)	(3.11)
Average household endowment of others (1981–1982)	−27.0	−29.0	−2.02	−2.02
	(4.14)	(4.53)	(1.10)	(0.91)
ρ	—	0.901	—	0.828
Observations	1,236	1,236	1,338	1,338

Notes: Absolute values of asymptotic *t*-ratios corrected for clustering within households in parentheses. All specifications include village fixed effects.

Source: "Nutrition Survey of Rural Bangladesh" 2001–2002.

VII. Alternative Interpretations and Threats to Identification

We consider first an alternative biological explanation for why girls receive more schooling than boys, and then consider two alternative explanations for why we find that males with larger body-mass endowments obtain less schooling and enter into occupations where brawn is important, while larger women obtain slightly more schooling and allocate themselves to less brawn-intensive activities. With respect to the level difference in schooling favoring girls, one alternative possibility is that the higher morbidity of young boys relative to girls slows their brain development. Table 6 shows that in our sample in 2001–2002, boys less than five are indeed more likely to be ill compared with girls. While among children less than five or five to nine, boys are no more likely than girls to exhibit diarrheal symptoms, they are more than twice as likely to experience fever than girls among children aged less than five (there is no difference above five). However, among children aged eight to ten, the performance scores on the abridged Raven's CPM test show no statistically significant difference by gender. The lower postprimary school attainment of boys is, thus, evidently not due to their entering secondary school at a skill disadvantage relative to girls.

A. *Are Big Men Dumber?*

One alternative explanation to the productivity of brawn influencing allocation decisions is that body mass or brawn in fact has little productive value but is negatively correlated with "ability"—thus larger (less able) men attend school less and enter brawn-intensive activities not because they have a comparative advantage in brawn but because the only attribute that matters in the economy is cognitive ability

Table 6—Are Young Boys Sicker and thus Less Smart than Girls? Children's Morbidity Symptoms and Raven's CPM Scores, by Age and Gender

Age	Ages 0–5		Ages 5–10		Ages 8–10	
Gender	Male	Female	Male	Female	Male	Female
Diarrhea						
Incidence	6.13	5.24	3.83	3.48	—	—
Observations	636	630	705	718	—	—
χ^2 [p]	0.472	[0.49]	0.122	[0.73]	—	—
Fever						
Incidence	5.97	2.86	4.26	4.74	—	—
Observations	636	630	705	718	—	—
χ^2 [p]	7.28	[0.007]	0.191	[0.66]	—	—
Raven's CPM Score						
Score	—	—	—	—	3.25	3.05
Observations	—	—	—	—	348	325
t [p]	—	—	—	—	1.50	[0.13]

Source: "Nutrition Survey of Rural Bangladesh" 2007–2008.

and such men are simply less smart—a one factor model is capable of explaining the results.[16] We assess this alternative explanation in two ways. We first directly tested whether cognitive ability and body mass are correlated, by looking at the relationship between the body-mass endowment and performance measures from the cognitive ability assessments carried out in the 2007–2008 survey. Based on the performances of the respondents on the abridged Raven's CPM, we find that body mass and this measure of aptitude are unrelated for both men and women, net and gross of schooling attainment. The details of these tests are provided in online Appendix B.

A key assumption of our model is that body mass (brawn) has direct payoffs in the labor market for men. If body mass and ability are negatively correlated and brawn is unproductive, then the reduced-form relationship for men between the body-mass endowment and wages should unambiguously be negative—we have seen that brawnier men have less schooling and by this hypothesis they are also less able. On the other hand, if brawn is productive, as assumed, and independent of cognitive ability, then it must be true that men who are endowed with more brawn will have higher lifetime earnings than men with lower brawn, despite lower schooling, if schooling is chosen optimally. It is possible that wages are lower for brawnier men (who have a longer work span), but if it is found that such men earn higher wages then we can reject the hypothesis that brawn is just an inverse measure of ability.

The first two columns of Table 7 report the GLS and GLLAMM reduced-form estimates, respectively, of the relationship between the body-mass endowment and the log daily wage in 2001–2002 for males aged less than 18 in 1981–1982, again controlling for household characteristics in 1981–1982. Consistent with the assumption of the model that brawn is productive and not just a negative correlate of ability, men with higher body-mass endowments, once measurement error is taken

[16] Of course this cannot explain why females who have larger body masses do not reduce their schooling.

Table 7—The Body-Mass Endowment in 1981–1982 and Log Wages in 2001–2002: Males Aged 0–17 in 1981–1982

Dependent variable: log daily wage in 2002 (tk.)						
Estimation procedure	GLS (1)	GLLAMM (2)	GLS (3)	GLS (4)	GLLAMM (5)	GLLAMM-IV (6)
Schooling (2002)	—	—	0.0261	0.0277	0.0311	0.0432
			(2.27)	(2.41)	(3.01)	(1.86)
Endowment (1982)	0.252	0.327	—	0.303	0.370	0.387
	(1.21)	(2.16)		(1.46)	(2.49)	(1.16)
Age	0.100	0.106	0.0750	0.0994	0.103	0.100
	(2.30)	(2.73)	(1.90)	(2.33)	(2.66)	(2.43)
Age squared	−0.0052	−0.0054	−0.0036	−0.0051	−0.0053	−0.0052
	(2.08)	(2.34)	(1.61)	(2.08)	(2.30)	(2.16)
Household owned land (1982)	0.00040	0.00041	—	—	—	—
	(2.03)	(2.51)				
No land owned (1982)	0.0528	0.0607	—	—	—	—
	(0.44)	(0.68)				
Average household endowment of others (1982)	−0.115	−0.147	—	—	—	—
	(0.27)	(0.45)				
ρ	—	0.838	—	—	0.838	0.838
Sargan overidentification $\chi^2(2)$	—	—	—	—	—	0.00129
[p]						[0.99]
Observations	225	225	225	225	225	225

Notes: Absolute values of asymptotic *t*-ratios corrected for clustering within households in parentheses in columns 2–6. Bootstrapped *t*-values in column 6. All specifications include village fixed effects. Instruments for the IV estimates include household owned land, no owned land, and the average household endowment of other household members.

Source: "Nutrition Survey of Rural Bangladesh" 1981–1982/2001–2002 panel.

into account, earn significantly higher wages, despite, as seen in Table 4, having lower schooling attainment. The error-corrected point estimate indicates that a one–standard deviation increase in the body-mass endowment increases the adult wage by 7.1 percent.

In columns 3 through 6 we also explore the sensitivity of the schooling "return" estimates to the exclusion of brawn, using the conventional Mincer wage specification that is pervasive in the literature. The log-linear wage function estimate of the schooling return, with the body-mass endowment excluded, is reported in the third column. The return is low at 2.6 percent but is measured with precision. In the fourth and fifth columns the body-mass endowment is also included in the log wage specification, estimated using GLS and GLLAMM, respectively. With or without measurement correction the inclusion of the brawn measure increases the estimated return to schooling, consistent with the finding that schooling and brawn are negatively correlated for men. The fifth column results, which correct for measurement error, indicate that brawn net of schooling positively affects the wage. The estimates also suggest that by not considering how heterogeneity in brawn affects schooling attainment and wages, the estimated Mincer return to schooling is underestimated by 16 percent. "Brawn bias," thus, can explain at least part of the gap in the estimated returns to schooling between men and women (when occupational sorting is ignored), given that body mass and schooling are not negatively correlated for women. In the last column we also allow for "ability" bias in schooling by instrumenting schooling, using the family background variables landholdings, land ownership, and the household average endowment in 1982 (estimates available from the authors). The resulting GLLAMM-IV schooling coefficient is marginally higher than the GLLAMM coefficient, indicating some positive ability bias. However, the positive body-mass coefficient and its statistical significance are unchanged.[17]

B. *Age at Menarche and the Body-Mass Endowment*

The second alternative explanation we consider for the difference in findings between males and females for the effects of the body mass endowment on schooling is that body mass affects age at menarche for women, which is an important and unique determinant of girls' marriage age and schooling. Field and Ambrus (2008) show that age at menarche is a strong predictor of completed schooling for women in Bangladesh because it affects when they marry. If age at menarche is higher for women with a larger body-mass endowment, this could explain the sign reversal, relative to men, for the estimated body-mass effects on schooling.

The medical literature, however, suggests that age at menarche is negatively related to body mass in poor countries (Khan et al. 1995), including specifically Bangladesh (Bosch et al. 2008). Women were asked in the 2001–2002 survey to provide their age at menarche.[18] We estimated using logit GLLAMM the effects of the body-mass endowment for girls aged less than age 14 in 1981–1982 on the probability that age at menarche occurred after age 13 (delayed menarche) as reported in 2001–2002. The estimates (available from the authors) strongly reject, consistent with the medical literature, that girls with a larger body mass are less likely to have a delayed age at menarche. These results indicate that the relationship between body mass and menarche cannot be the reason for the positive association between schooling and body mass among women. Indeed, the estimates indicate that menarche is at a lower age for larger girls, suggesting that the positive effect of body mass on schooling for women may be underestimated given the marriage practices tied to age at menarche in Bangladesh.

VIII. Estimating the "Roy" Wage Function

The finding that the body mass endowment differentially affects the choice of activities for women and men is consistent with the assumption of the Roy model that occupations reward worker attributes differently, but it could also reflect other factors such as discrimination and/or tradition. In this section we directly test the assumption that high–energy expenditure occupations reward brawn relative to skill by estimating a wage function that is consistent with, and derived from, the Roy-based model in which workers have two productive attributes, brawn and skill, the returns to the attributes differ across tasks, and there are optimal investments in skill

[17] The Sargan overidentifying test indicates nonrejection of the hypothesis that the excluded instruments are conditionally uncorrelated with the log wage. In implementing the test we used quadrature methods to compute posterior means in order to net out the covariate measurement error in the body-mass endowments.

[18] Among women in the 2001–2002 sample who were aged less than 13 in 1981–1982 for whom we have nutritional intake information and information on parental landholdings, menarche was at age 14 for 21.8 percent and at age 15 or above for 2.0 percent of the sample.

via schooling. The wage function for a worker j in activity i from the model, with an appended individual worker productivity error term ξ, from (1), is

$$W(i)_j = \pi(i)\,\kappa(i)(\nu H_j)^{\alpha(i)}B_j^{(1-\alpha(i))}\xi_j. \tag{15}$$

There are a number of challenges in estimating the parameters describing (15). First, brawn and skill are not directly observed, so we need to express these attributes in terms of the observables schooling and the body-mass endowment. That is, we need to incorporate in (15) the production functions (3), (4), and (5) that relate brawn to the body-mass endowment m and skill to schooling S. Second, returns $(\alpha(i))$ differ by activity. Third, both schooling and activity i are optimally chosen so that they may be related to the unobservable component of productivity ξ_j, which may contain the unobservable ability of the worker. And fourth, the body mass endowment contains measurement error. To estimate (15) we therefore need to impose additional structure. We now formally assume that skill intensity $\alpha(i)$ is inversely related to the energy expenditure $\varepsilon(i)$ of an occupation by assuming that $\alpha(i) = \alpha_0 + \alpha_1\varepsilon(i)$, with $\alpha_0 > 0$ and $\alpha_1 < 0$. In the model the duple $\pi(i)\nu(i)$ varies by activity in equilibrium; accordingly we assume that $\pi(i)\nu(i)$ is also a function of $\varepsilon(i)$, such that $\pi(i)\kappa(i) = \varepsilon(i)^{\delta}$.[19] We also assume that the skill and brawn production functions are exponential, with both schooling and age contributing to skill, such that $H_j = e^{\beta S(j)+\varsigma Age(j)}$ and $B_j = e^{\gamma m(j)}$, where $\beta > 0$ and $\gamma > 0$.

Replacing the unobservable price, brawn, and skill terms by the observables $\varepsilon(i)$, m_j, and S_j using the production-function relationships and taking logs yields the estimable wage function in terms of the structural parameters:

$$\log W(i)_j = \delta\log\varepsilon(i) + \alpha_0\beta S_j + \alpha_1\varepsilon(i)\beta S_j + (1-\alpha_0)\gamma m_j - \alpha_1\varepsilon(i)\gamma m_j + \alpha_0\varsigma Age_j + \alpha_1\varepsilon(i)\varsigma Age_j + \log\xi_j. \tag{16}$$

The corresponding estimating equation is

$$\log W(i)_j = \delta\log\varepsilon(i) + \upsilon_1 S_j + \upsilon_2\varepsilon(i)S_j + \upsilon_3 m_j - \upsilon_4\varepsilon(i)m_j + \upsilon_5 Age_j + \upsilon_6\varepsilon(i)Age_j + \log\xi_j, \tag{17}$$

where the υ are coefficients. The only structural parameter that is identified from the estimation of (17) is δ, although we cannot distinguish between changes in product prices π and changes in overall activity productivity with brawn intensity. Recall, however, that the sign of δ, from (2), indicates whether workers in the economy have a comparative advantage in brawn (e.g., $\delta < 0$ if $\log(\nu B/H) < 0$). The model, given our assumptions, also places sign restrictions on three of the coefficients; in

[19] Some activity prices might be related to the total output of the industry of which an activity may be a part. The prices of products from agriculture, the key industry of our rural sample, are likely to be internationally determined and thus exogenous to production levels. With time series data it might be possible to identify a richer specification of the determinants of $\pi(i)\,\nu(i)$, inclusive of technology change.

particular, $\upsilon_1 > 0$, $\upsilon_2 < 0$, and $\upsilon_4 > 0$—the "return" to schooling, $\upsilon_1 + \upsilon_2\varepsilon(i)$, should be lower in energy (brawn)-intensive activities, and the return to brawn should be higher in energy-intensive activities. Note that the log-linear wage function, which imposes the restrictions that $\upsilon_2 = 0$ and $\upsilon_4 = 0$, is nested in (17).

To take into account that the body-mass endowment is measured with error and that schooling and activity choice may be related to ξ, we use GLLAMM-IV to estimate (17), making use of the repeated measures of m_j from the replication subsamples and using the household characteristics landholdings and the body-mass endowments of other family members as identifying instruments.[20] The estimates of schooling attainment and choice of activity, in Tables 4 and 5, suggest that household variables affect schooling and activity choices in addition to the body-mass endowment. These variables should not importantly directly affect a worker's productivity, given his skill and brawn.[21] Note that if activity choice was strictly based on individual comparative advantage, and schooling investment depended only on m_j, it would not be possible to estimate ν_2 and ν_4 because S and m would covary perfectly within occupations. That activity choices and schooling investments are constrained by household attributes aids identification.

We estimate (17) separately for males and females aged 20–49 in 2001–2002. Note that the model assumes that the parameters of the wage equation (15) are the same for men and women—average "returns" to schooling reported in the literature obtained from log linear wage functions differ by gender because of the different occupational mixes of men and women resulting from the operation of comparative advantage. However, estimating wage equation (17) separately by gender will not yield identical parameters from our data. First, because we are using the body-mass endowment rather than a brawn endowment the coefficients associated with the body-mass endowments υ_3 and υ_4 in estimating equation (17) will differ by gender because, as seen in (16), these coefficients contain the brawn production-function parameter γ, which is smaller for women than men. Second, the sets, not just the distributions, of occupations chosen by the men and women in our sample and who work for wages are quite different. Male wage workers appear in 33 occupations in our sample, of which 19 have no sample women wage workers represented (among the most important are farmer, rickshaw driver, mason, fisherman), and of the limited set of 15 occupations where there are female wage workers, the two most important ones have no men represented—housemaid and livestock tender. The wage functions by gender thus characterize different sets of occupations. For both sets of activities, however, we should find that $\delta < 0$ and that the returns to schooling are lower in energy-intensive occupations.

While less than 17 percent of males in the 20–49 age group do not report wage earnings, only 79 women in this age group work for wages in our sample, a small fraction of the female labor force. The subsample of women with wages is, thus, likely to be selective, and we therefore employ a control function approach to deal with selectivity bias, estimating the probability that a woman in the age group

[20] We derive second-stage coefficient standard errors using bootstrapping.

[21] We are assuming that the body-mass endowments of other members of the household (which affect their schooling) do not directly affect the unobserved skill of a worker and, thus, his wage due to learning externalities within the household.

reports a wage, using the same determinants that predict occupational choice, and computing the relevant Mills ratio.[22] The same set of variables is also used to estimate the gender-specific first-stage estimates. Tables in the online Appendix report the estimates of the determinants of the probability of wage work for women and the gender-specific activity choice (occupational energy expenditure), schooling and interaction variables of schooling, age, the body-mass endowment, and occupational energy expenditure. In all cases the *F*-statistics indicate that the set of instruments contribute significantly to accounting for the variation in the endogenous variables, consistent with our earlier findings, and the probability that a woman engages in wage work.

Table 8 reports the estimates of the log wage coefficients. We first discuss the estimates from the sample of male wage workers, which are not dependent on the specification of a selection model and cover a broad spectrum of activities. In the first column, the estimate of the schooling coefficient using the standard Mincer specification, in which only schooling and age and age squared are included, is reported. The Mincer schooling return is 4.1 percent. The second column reports estimates from a log-linear specification which includes both schooling and the (error-corrected) body mass endowment. The endowment has a positive but statistically insignificant effect on the log wage, and the schooling coefficient rises by only a small amount.

The third column of Table 8 reports the estimated coefficients from the full, Roy-model consistent specification that allows returns to differ by occupation using IV and correcting for measurement error in the body-mass endowment. The coefficient patterns are in conformity with the model—the schooling return is lower and the endowment return higher in the energy-intensive activities. The set of schooling and body-mass endowment coefficients are now statistically significant; in contrast to the linear specification estimates, body mass matters for productivity. The specification also passes the Sargan overidentification test. The point estimates from the full specification indicate that the returns to schooling are positive only in the least energy-intensive activities, those associated with relatively sedentary activities engaged in by clerks and tailors. These activities make up a small proportion of total activities in the rural setting, but they are occupations in which women are overrepresented relative to men.[23] The return to body mass, however, is positive for activities engaged in by 64 percent of male workers. Consistent with these findings, the estimate of δ is negative and statistically significant—high energy-intensive activities are valued less than low energy-intensive activities, implying that male workers in rural Bangladesh have a comparative advantage in brawn.

The estimates for the wage functions obtained from the sample of female wage workers, and their limited set of activities, exhibit the same sign patterns as the estimates for the males, although the estimates are less precise. The coefficients on the Mills ratio (λ) indicate that female wage workers are marginally positively selective with respect to unmeasured attributes net of the body-mass endowment that increase

[22] The details are reported in online Appendix C. The estimates indicate that women with higher body-mass endowments from lower landholding households are more likely to work for a wage.

[23] That the marginal contribution of schooling is nonpositive in some activities suggests that the flexible specification, based on the Cobb-Douglas form, may not be wholly suitable to describe the technologies of the complete set of activities in Bangladesh and should be considered an approximation.

TABLE 8—OCCUPATION-SPECIFIC WAGE FUNCTION ESTIMATES, BY GENDER: ADULTS AGED 20–49 IN 2001–2002

Gender	Male			Female		
Estimation procedure	GLS[a]	GLLAM[a]	GLLAM-IV[b]	GLS[a]	GLLAM[a]	GLLAM-IV[b]
Schooling	0.0409	0.0417	0.281	0.047	0.047	1.14
	(11.6)	(10.1)	(2.14)	(2.38)	(2.41)	(2.05)
Schooling × occupation energy expenditure	—	—	−0.00225	—	—	−0.007
			(2.20)			(2.03)
Endowment	—	0.0765	−2.01	—	0.0895	−4.53
		(0.84)	(1.88)		(0.22)	(1.28)
Endowment × occupation energy expenditure	—	—	0.0164	—	—	0.0254
			(2.50)			(1.52)
Age × occupation energy expenditure	—	—	0.00096	—	—	0.00204
			(2.54)			(1.09)
δ	—	—	−6.97	—	—	−4.37
			(3.03)			(0.44)
λ	—	—	—	12.7	12.7	10.3
				(1.46)	(1.49)	(0.78)
ρ	—	0.889	0.888	—	0.904	0.900
Sargan overidentification χ^2 [p]	—	—	11.09	—	—	0.0033
			[0.436]			[0.999]
Observations	1,094	1,094	1,094	79	79	79

Notes: All specifications include age and age squared.
[a]Absolute values of asymptotic *t*-ratios corrected for clustering within households in parentheses in column.
[b]Bootstrapped *t*-ratios in parentheses in column.

Source: "Nutrition Survey of Rural Bangladesh" 2001–2002.

the wage. The estimates from the full specification indicate that δ is negative and the returns to schooling are lower in the more energy-intensive activities, being positive in 22 percent of activities, and larger body mass is more useful in the activities requiring more energy expenditure, having a positive return in more than 80 percent of activities. The estimates from both the male and female samples and the distribution of workers among activities are thus consistent with rural Bangladesh being a brawn-based economy.

IX. Conclusion

An emerging set of studies suggests that the returns to investments in schooling and health differ across males and females in a variety of settings. In particular, health investments augment the schooling of women relative to men but increase the earnings of men relative to women, while schooling has greater labor-market returns for women. Moreover, in an increasing number of countries, both developed and low-income, women acquire greater amounts of schooling than do men. In this article we have used a simple model of human capital investment and activity choice to explain these findings. The model incorporates biological gender differences in the level and responsiveness of brawn to nutritional intakes in a setting in which activities reward skill and brawn differentially. Empirical evidence from rural Bangladesh, where brawn plays a prominent role in economic activities, appears to support the model and the importance of the distribution of brawn in explaining gender differences in human capital investments and returns.

The estimates indicate that, consistent with the Roy model, returns to schooling and brawn differ significantly by occupation, with brawn-intensive activities rewarding skill less, and occupational selection is explained in part by individual comparative advantage in brawn. We find that because men have a comparative advantage in brawn, men obtain less schooling and sort into activities with lower returns to skill (and higher rewards for brawn) than do women. Our estimates also indicate that nutritional investments, because they augment the brawn of men, directly raise the wages of men. This increases the opportunity cost of schooling and makes it less profitable for men to enter into activities where schooling has high payoffs, so that despite schooling and health being complements in a technical sense, optimal schooling for men either does not increase or actually falls, as in our setting, when there are interventions that augment health. Among women, however, because strength does not increase significantly when there are improvements in health, schooling is positively affected by health gains because of this complementarity.

Our findings also suggest that log wage equations linear in human capital variables can hide important effects of health variation and cannot account for gender differences in returns. The estimated average return to schooling in an economy will importantly depend on the composition of activities and also on the correlation between health and schooling, which we show differs by gender. In brawn-based economies, for example, the average payoffs to schooling will be low but will be higher for women, who specialize in skill-intensive activities, while returns to health may be high for men but not women depending also on the mix of activities in the economy.

While our model and findings contribute to the understanding of the differential returns to and levels of human capital investments based on the substantial differences in brawn between men and women and the operation of comparative advantage, we have ignored another salient biological difference between men and women—childbearing. While this difference alone cannot account for the higher level of schooling of women compared with men, it is probably no coincidence that the recent worldwide upward trends in female schooling have been accompanied by declines in fertility. Future work incorporating fertility choice in a model with realistic relationships between health and schooling investments would appear to be productive.

Finally, our findings suggest how development policies will affect gender differences in earnings and schooling investment. Attention to the role of brawn suggests that health-based development policies similar to the experience in Bangladesh, for example, will, in the absence of any other changes, increase the schooling of women relative to men, increase occupational differentiation by gender and, thus, differences in returns to schooling by gender, but increase the gap in earnings between men and women. Similarly, a policy that favors agricultural development—a sector in which brawn has relatively high payoffs—will augment the earnings of men, who have an absolute advantage in brawn, relative to women, and increase the gender division of labor across activities. In contrast, a policy promoting openness to trade and foreign investment that changes the occupational mix in favor of jobs that are skill-intensive will augment the earnings of women relative to men, increase schooling investments by women relative to men, and lower the gap in schooling returns. Given the distribution in brawn between men and women, however, to the extent that brawn-intensive occupations (e.g., construction) do not disappear, returns to schooling and levels of schooling will in equilibrium be higher for women than for men in almost all economies.

REFERENCES

Bangladesh Bureau of Educational Information and Statistics (BANBEIS). 1987, 1991, 1998, 2003. Bangladesh Educational Statistics 1987, 1991, 1997, 2003.

Becker, Gary S., William H. J. Hubbard, and Kevin M. Murphy. 2010. "Explaining the Worldwide Boom in Higher Education of Women." *Journal of Human Capital* 4 (3): 203–41.

Begum, M.E.A., and Luc D'Haese. 2010. "Supply and Demand Situations for Major Crops and Food Items in Bangladesh." *Journal of the Bangladesh Agricultural University* 8 (1): 91–102.

Bobonis, Gustavo J., Edward Miguel, and Charu Puri-Sharma. 2006. "Anemia and School Participation." *Journal of Human Resources* 41 (4): 692–721.

Bosch, Alinda M., Frans J. Willekens, Abdullah H. Baqui, Jeroen K. S. Van Ginneken, and Inge Hutter. 2008. "Association between Age at Menarche and Early-Life Nutritional Status in Rural Bangladesh." *Journal of Biosocial Science* (40) 2: 223–37.

Dougherty, Christopher. 2005. "Why Are the Returns to Schooling Higher for Women than for Men?" *Journal of Human Resources* 40 (4): 969–88.

Field, Erica, and Attila Ambrus. 2008. "Early Marriage, Age of Menarche, and Female Schooling Attainment in Bangladesh." *Journal of Political Economy* 116 (5): 881–930.

Field, Erica, Omar Robles, and Maximo Torero. 2009. "Iodine Deficiency and Schooling Attainment in Tanzania." *American Economic Journal: Applied Economics* 1 (4): 140–69.

Food and Agriculture Organization of the United Nations (FAO). 2001. *Human Energy Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation*, Rome, October 17–24. Food and Nutrition Technical Report Series 1: 1–96.

Foster, Andrew D., and Mark R. Rosenzweig. 1996. "Technical Change and Human-Capital Returns and Investments: Evidence from the Green Revolution." *American Economic Review* 86 (4): 931–53.

Glewwe, Paul, and Edward A. Miguel. 2007. "The Impact of Child Health and Nutrition on Education in Less Developed Countries." In *Handbook of Development Economics*. Vol. 4, edited by T. Paul Schultz and John Strauss, 3561–606. Amsterdam: Elsevier Science, North-Holland.

Hels, O., N. Hassan, I. Tetens, and S. Haraksingh Thilsted. 2003. "Food Consumption, Energy and Nutrient Intake and Nutritional Status in Rural Bangladesh: Changes from 1981–1982 to 1995–1996." *European Journal of Clinical Nutrition* 57 (4): 586–94.

Hoddinott, James, John A. Maluccio, Jere R. Behrman, Rafael Flores, and Reynaldo Martorell. 2008. "Effect of a Nutrition Intervention during Early Childhood on Economic Productivity in Guatemalan Adults." *The Lancet* 371 (9610): 411–16.

Hogan, Margaret C., Kyle J. Foreman, Mohsen Naghavi, Stephanie Y. Ahn, Mengru Wang, Susanna M. Makela, Alan D. Lopez, Rafael Lozano, and Christopher J. L. Murray. 2010. "Maternal Mortality for 181 Countries, 1980–2008: A Systematic Analysis of Progress Towards Millennium Development Goal 5." *The Lancet* 375 (9726): 1609–23.

Institute of Nutrition and Food Science, Dhaka University. 1984, 2004, 2010. "Nutrition Survey of Rural Bangladesh." 1981–1982, 2001–2002, 2007–2008. Contact nhassan@bangla.net.

Jayachandran, Seema, and Adriana Lleras-Muney. 2009. "Life Expectancy and Human Capital Investments: Evidence from Maternal Mortality Declines." *Quarterly Journal of Economics* 124 (1): 349–97.

Khan, Awal D., Dirk G. Schroeder, Reynoldo Martorell, and Juan A. Rivera. 1995. "Age at Menarche and Nutritional Supplementation." *Journal of Nutrition* 125 (4 Supplement): 1090S–1096S.

Maluccio, John A., John Hoddinott, Jere R. Behrman, Reynaldo Martorell, Agnes R. Quisumbing, and Aryeh D. Stein. 2009. "The Impact of Improving Nutrition during Early Childhood on Education among Guatemalan Adults." *Economic Journal* 119 (537): 734–63.

Mathiowetz, Virgil, Nancy Kashman, Gloria Volland, Karen Weber, Mary Dowe, and Sandra Rogers. 1985. "Grip and Pinch Strength: Normative Data for Adults." *Archives of Physical Medicine and Rehabilitation* 66 (2): 69–74.

Miguel, Edward, and Michael Kremer. 2004. "Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities." *Econometrica* 72 (1): 159–217.

Ohnsorge, Franziska, and Daniel Trefler. 2007. "Sorting It Out: International Trade with Heterogeneous Workers." *Journal of Political Economy* 115 (5): 868–92.

Pitt, Mark M., Mark R. Rosenzweig, and Md. Nazmul Hassan. 1990. "Productivity, Health, and Inequality in the Intrahousehold Distribution of Food in Low-Income Countries." *American Economic Review* 80 (5): 1139–56.

Pitt, Mark M., Mark R. Rosenzweig, and Mohammad Nazmul Hassan. 2012. "Human Capital Investment and the Gender Division of Labor in a Brawn-Based Economy: Dataset." *American Economic Review*. http://dx.doi.org/10.1257/aer.102.7.3531.

Psacharopoulos, George, and Harry Anthony Patrinos. 2004. "Returns to Investment in Education: A Further Update." *Education Economics* 12 (2): 111–34.

Rabe-Hesketh, Sophia, Anders Skrondal, and Andrew Pickles. 2003. "Maximum Likelihood Estimation of Generalized Linear Models with Covariate Measurement Error." *The Stata Journal* 3 (4): 386–411.

Rahman, Rushidan Islam. 2009. "An Analysis of Real Wage in Bangladesh and Its Implications for Underemployment and Poverty." Unpublished.

Ravallion, Martin, and Quentin Wodon. 2000. "Does Child Labour Displace Schooling? Evidence on Behavioural Responses to an Enrollment Subsidy." *Economic Journal* 110 (462): C158–75.

Rendall, Michelle. 2010. "Brain versus Brawn: The Realization of Women's Comparative Advantage." Unpublished.

Round, J. M., D. A. Jones, J. W. Honour, and A. M. Nevill. 1999. "Hormonal Factors in the Development of Differences in Strength between Boys and Girls during Adolescence: A Longitudinal Study." *Annals of Human Biology* 26 (1): 49–62.

Roy, A. D. 1951. "Some Thoughts on the Distribution of Earnings." *Oxford Economic Papers New Series* 3: 135–46.

Thomas, Duncan, and John Strauss. 1997. "Health and Wages: Evidence on Men and Women in Urban Brazil." *Journal of Econometrics* 77 (1): 159–85.

Trostel, Philip, Ian Walker, and Paul Woolley. 2002. "Estimates of the Economic Return to Schooling for 28 Countries." *Labour Economics* 9 (1): 1–16.

Zhang, Junsen, Yaohui Zhao, Albert Park, and Xiaoqing Song. 2005. "Economic Returns to Schooling in Urban China, 1988 to 2001." *Journal of Comparative Economics* 33 (4): 730–52.