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 *et al.* 2006; Field *et al.*, 2009) in which the health of young children was experimentally increased, for example, indicated that schooling outcomes were improved significantly more for females. 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.[1]

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. Another emerging fact is that in many counties 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 1990's and in China enrollment rates of girls in secondary and tertiary schools has been higher than that of boys since 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 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

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[1]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 *et al.* (2002) obtained estimates of schooling for 28 mainly developed counties 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.

supplement provided to children in the first 3 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 paper 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 twenty-five 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 U.S. study (Mathiowetz *et al.*, 1985) and our own data on the distribution of grip strength among adult men and women in rural Bangladesh, displayed in 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. 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 *et al.* (2010) construct a model in which females have an advantage in non-cognitive 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 non-cognitive 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 would yield predictions similar to both of these frameworks in a context in which the demand for skill increases. However, it can also explain 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.

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% 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 micro credit. The fraction of adult rural women who are micro credit 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.[2]

A major initiative underway in the early 1980's 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. It is not possible, of course, to infer causal effects from increased body mass to gender-specific changes in schooling from these aggregate associations.[3] Our objective is not to decompose the trends in relative schooling investments by cause in Bangladesh, but rather 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 1 of the paper 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.

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[2]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 (e.g., Ravallion and Wodon, 2000). However, these programs could not have initiated the relative rise in female schooling seen in Figure 1, as the relative trends in schooling began before any of these programs were in place.

[3]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).

In sections 4-6 of the paper 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 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 7 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 paper 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 polices on gender gaps in earnings and schooling and the gender division of labor.

1. 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:

$$W = \pi(i)v(i)(\kappa H)^{\alpha(i)}B^{(1-\alpha(i))} \quad (1)$$

where $\pi(i)$ = the equilibrium price of the output of task $i, v(i)$ = a task-specific productivity parameter, and κ = 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,

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

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

(2) $$\log(\kappa H/B) = -(\pi_i + v_i)/\alpha_i\pi(i)$$

Expression (2) has two important implications: (a) 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. (b) 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 $v_i>0$, where $\pi_i=\mathrm{d}\pi/\mathrm{d}i$ and $v_i=\mathrm{d}v/\mathrm{d}i$). 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.[4]

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

(3) $$B = B(M) + b,$$

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

[4]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 ($\pi(i)v(i)$) 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 non-tradeable output so that output prices for such tasks are lower where brawn is in plentiful supply. We test this property below.

mass. We assume that decreases in morbidity, brought about by public health interventions, increase θ. The body mass production function is:

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

where θ>0, M_1>0, M_{11}<0.

The skill production function is

(5) $$H = H(S; M),$$

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:

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

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

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

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

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

where F=parental income, p=the market price of a calorie and ρ=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.[5]

We first solve the model for the case in which γ=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 γ=0, the FONC are:

(9) $$\theta \mathrm{U}_C = \lambda p$$

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

Expressions (8) and (9) are standard, indicating that the marginal cost of a calorie is its market

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

price and schooling has a direct and opportunity cost. For men,γ>0, the FONC for schooling is the same as for women, but that for calories is different:

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

Comparing (10) 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* (γ=0) a *reduction in morbidity must increase schooling, decrease calorie consumption and increase the average skill-intensity of occupations.*

Proposition 2: *When brawn is increased by calorie consumption* (γ>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 body mass may increase or decrease schooling and the average skill-intensity of occupations.*

Proofs of these propositions are in the 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.[6] 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 appendix, the model also indicates that among males, larger

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

men may receive less schooling and be over-represented 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 only 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* $\alpha(i)\mathrm{dlog}H/\mathrm{d}S$ *will be higher for women than for men, since men will be in lower-*α *occupations.*

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

$$\mathrm{dlog}W/\mathrm{d}S = \alpha(i)\mathrm{dlog}H/\mathrm{d}S + (1 - \alpha(i))(\mathrm{dlog}B/\mathrm{d}m)\mathrm{d}m/\mathrm{d}S \quad (12)$$

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, $\mathrm{dlog}B/\mathrm{d}m>0$ but $\mathrm{d}m/\mathrm{d}S$ 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: (a) men, based on their comparative advantage, will be concentrated in brawn-intensive, low-$\alpha(i)$ occupations compared with women and (b) 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.

2. 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 provides individual-specific nutrient intakes, anthropometric measures, schooling, wages and activity choices. We use three data sets describing households in rural Bangladesh that meet these criteria. The first data set is the *Nutrition Survey of Rural Bangladesh* 1981-2 (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 *et al.* (1990) to estimate body mass endowments and to assess how these affected the allocation of nutrients among children and adults within households.

The second data set we use is from the *Nutrition Survey of Rural Bangladesh* 2001-2 (N= 9,838). This survey was a follow-up to the 1981-2 survey and includes all surviving and resident individuals surveyed in 1981-2 in fourteen of the fifteen 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 2001-2. Attrition of surviving individuals who still resided in Bangladesh at the time of the survey was less than 3%. The third data set is from the *Nutrition Survey of Rural Bangladesh* 2007-8 (N=12,244), which includes all individuals surveyed in 2001-2 and all members of their households, again regardless of residence at the time of the survey.

These data sets 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 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% 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 1981-2 and two repetitions in 2001-2 and in 2007-8. 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 2007-8 round of the survey we obtained individual-specific assessments of grip strength, pinch strength and aptitude, using Raven's Colored Progressive Matrices (CPM) tests, 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 twenty-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 1981-2 and 2001-2 surveys is consistent with the official statistics on rural school enrollment trends. As indicated in 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 2001-2 round of the survey girls' school attendance is greater than that of boys for all ages above age 6, a reversal of the differences in 1981-2. During this period both boys and girls in this age range also experienced increases in body mass. As depicted in Appendix Figure 3, 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 5 and 15; the BMI for girls is higher in the later period only for girls above 9. And, above that age the percentage increase in BMI for boys is 7.1% while that for girls is 2.2%. The data also indicate that stature has increased in the rural population. As shown in the top panel in Appendix Figure 4, the heights of respondents in the 1981-2 and 2001-2 survey rounds by the age at which the respondent reached 22 steadily increases across cohorts for both men and women.

The gains in height and body mass have not been due to increased nutrient intakes. The data indicate, as depicted in the bottom panel of Appendix Figure 4, 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.

Consistent with our model, average caloric intake is higher for men and for women in both periods, and average calories levels within gender groups, have not increased for either group. 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 1981-2 67% men aged 20-49 were engaged in "exceptionally active" or "active" occupations, based on energy expenditure levels; in 2001-2 the proportion increased to 72%. For women, only 9% were participating in such activities, and that proportion declined to 3% in 2001-2. Table A in the Appendix provides descriptive statistics for the adults age 20-59 in the 2001-2 and 2007-8 rounds of the data.

3. **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 *et al*. (1990) but applied to the 2001-2 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 *et al*. 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.[7] 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, and gender variables obtained from the 2001-2 population will be the same as those obtained from the 1981-2 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 twenty-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. Because over the period information was diffused about water purification and about the relative purity of the different sources of water, we expect that the coefficients on the water-source variables will, in contrast to those for nutrients and activities, have shifted over time. That is, a well in 1981 is not the same as a well in 2001.

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 correspond to the comparative statics of the model. That is, we estimate

(13) $$y_j = \mathbf{Z}_j\zeta + bm_j + \varepsilon_j,$$

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 ε_j=an error term, containing measurement error in the y_j. The main empirical

[7] 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 age and gender in the first stage.

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 ζ 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

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

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 *et al.*, 2003). We will refer to these estimates, which accommodate measurement error, as GLLAM M (generalized linear latent and mixed model) estimates.[8]

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 $\mathbf{Z}_j$.

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[8]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 multi-equation 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.

4. 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 *et al*. (1990), which were obtained using the 1981-82 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).[9]

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 less 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, using the same specification and econometric method. Because of the increase in sample size, the calorie and activity coefficients are measured with more precision. The point estimates, however, are not only qualitatively the same across survey rounds, but are quantitatively similar, as is to be expected if structural parameters are being identified. Indeed, we cannot reject the hypothesis that the set of calorie intake, activity, age and gender variables are identical using a standard critical-level criteria.[10] In

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[9]One concern is that age is systematically measured with error for the young, as parents with inaccurate recall report age based on the observed anthropometric attributes of a child (assuming, for example, larger children are older), which would impart bias in all of the production function estimates. To check if this is a problem we examined the correlation between the ages for children less than 15 in 1981 and their ages reported 20 years later in the 2001-2 round. Despite not having the exact month of interview for the first round, the correlation is .982 for males and .972 for females, indicating very small errors for this variable and no important difference by gender.

[10]Specifically, this was a test of the pooling hypothesis using a likelihood ratio test. The pregnancy/lactation coefficients are also not statistically significantly different across rounds,

contrast, the water source effects on body mass are quite different, now indicating that the household's source of water does not matter. This is consistent with households increasingly purifying water in the home so that point-source water quality is no longer a good measure of the quality of individual water intake in the more recent period.

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 2001-2 data set. 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 2007-8 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 (standard deviation) grip strength for men was 37.3 (8.36) while that for women was 24.3 (5.66).[11] 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 two 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 noise, is approximately 10%) and the estimate of γ corrected for measurement error, in column two, is about 10% higher than the corresponding GLS estimate that ignores measurement error.

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although the point estimates are far apart. One possibility is that the instruments only weakly predict these variables. However, the F-statistics for all of the predicted endogenous variables are statistically significant at at least the .00001 level.

[11]Figure A in the appendix plots the distribution of test results by gender. Note that the location difference in "aptitude" is relatively trivial compared with the gender difference in strength, depicted in Appendix Figure 1. And, as discussed below, the difference in performance is almost wholly explained by the difference in schooling levels between men and women.

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%. 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 .05 significance level. The GLLAMM estimates that exploit the replication sub sample indicate that the body mass endowment is measured with more error for women than for men, but the γ estimate corrected for measurement error (fourth column) remains less than one-fourth the corresponding estimate for men. Thus, while larger women may be healthier, unlike men, they are not significantly brawnier.[12]

5. 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 2001-2 round of data. We 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 10. We also we need to impose a low age ceiling, however, because of the young marriage age for girls - approximately 11% 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 1981-2, of the 48.3% of boys not attending school almost 70% were working; in 2001-2, the major alternative

[12]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. While medical evidence suggests a biological explanation for the results that is independent of activity choice, to ascertain if the gender division of labor could cause differences in the brawn-body-mass endowment relationship by gender, 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 difference in the GLLAMM coefficients by gender were even stronger than those displayed in Table 2, with the ratio of male-female endowment effects on grip strength at 7.7 to one. The estimate of γ is statistically significant for males but not for females in this subsample as well. We also verified that gender difference in the non-school activities of the students was not biasing these results in favor of males using the detailed time-allocation data. These indicated that 63.1% of the female students were also engaged in non-sedentary activities, defined as fetching water, washing/drying clothes, or gathering firewood, while only 18 .2% of the male students were non-sedentary, principally in agricultural work.

to school for boys was also work - with over 90% of the 17.5% of boys not attending school at work. For girls, the major alternative to school is home time in both periods. 74% of the 62.4% of girls not attending school were not working in 1981-2 and 68% of the 12.5% of girls not in school were at home in 2001-2.

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 only have endowment measures for half of the respondents in 1981-82, the sample of 10-15-year olds is too small to carry out the analysis using the first-round data. Table B in the Appendix reports the ML logit and ML logit GLLAMM estimates for boys and girls in the 2001-2 sample, the left out category being school attendance. The estimated marginals and their associated t-statistics for the probability of attending school 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% 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%.

To verify that body mass also affects completed schooling attainment, we make use of the 1981-2/2001-2 panel data. Based on the production function estimates from the 1981-2 data we have body mass endowments for one-half of respondents in 1981-2 as well as information on their schooling attainment and wages in 2001-2 from the second-round data. We estimate the relationship between the body mass endowments estimated for 1981-2 and completed schooling attainment (years) in 2001-2 for the sample of children aged less than 16 in 1981-2. We again include in the specification the amount of land owned in the household, an indicator of land ownership, the average household endowment of other family members, and the child's age and age squared, but here the variables refer to the origin households in1981-2. We use both GLS and GLLAMM, making use of the four-round replication subsample in 1981-2.

The estimates of the effects of the body mass endowment on schooling completed by 2001-2 for boys and girls who were less than age 16 in 1981-2 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 2001-2 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%), while girls who are one standard deviation above the mean attain a statistically insignificant .2 more schooling years.

6. 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 workforce 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 FAO and WHO (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.[13]

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 (PAR's) 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 PAR's 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 non-physical activities. Moreover, the detailed time allocation information in the 2001-2 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 the adult, prime age PAR's 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

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[13]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 at work than do farm managers. Thus, within agriculture there is likely to be a negative relationship between skill-intensity and energy-intensity, with individuals with a comparative advantage in skill selecting into managing farms.

mass endowment and occupation selection for men and women aged 20-49 in 2001-2, 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 over-represented in lower energy-expenditure activities. As expected as well, the absolute value of the coefficient for women is 1/14th 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.[14]

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

7. 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 2001-2, boys less than 5 are indeed more likely to be ill compared with girls. While among children less than 5 or 5-9 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 5 (there is no difference above 5). However, among children aged 8-10, the performance scores on the Raven's CPM test show no statistically significant difference by gender. The lower post-primary 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 and such men are simply less smart - a one factor model is capable of explaining the results.[15] 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 2007-8 survey. Based on the performances of the respondents on the Raven's CPM, we find that body mass and this measure of aptitude is unrelated for both men and women, net and gross of schooling attainment. The details of these tests are provided in Appendix B.

A key assumption of our model is that body mass (brawn) has direct payoffs in the labor

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

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 2001-2 for males aged less than 18 in 1981-2, again controlling for household characteristics in 1981-2. 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 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%.

In columns three through six 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%, 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 under-estimated by 16%. "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.[16]

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 Ambrose (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 (Khah *et al.*, 1995), including specifically Bangladesh (Bosch *et al.*, 2008). Women were asked in the 2001-2 survey to provide their age at menarche.[17] Table D in the Appendix reports logit and logit GLLAMM estimates, respectively, of the effects of the body mass endowment for girls aged less than age 14 in 1981-2 on the probability that age at menarche occurred after age 13 (delayed menarche) as reported in 2001-2. The estimates

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[16]The Sargan overidentifying test indicates non rejection 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 endowment in constructing both the estimated residuals and the R^2 of the requisite auxiliary regression of the second-stage equation residuals on the full set of exogenous variables.

[17]Among women in the 2001-2 sample who were aged less than 13 in 1981-82 for whom we have nutritional intake information and information on parental landholdings, menarche was at age 12 or less for 21.3%, at age 13 for 54.8%, at age 14 for 21.8% and at age 15 or above for 2.0% of the sample.

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.

8. 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 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:

(15) $$W(i)_j = \pi(i)\kappa(i)(vH_j)^{\alpha(i)}B_j^{(1 - \alpha(i))}\xi_j$$

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 $\pi(i)v(i)$ varies by activity in equilibrium; accordingly we assume that $\pi(i)v(i)$ is also a function of $\varepsilon(i)$, such that $\pi(i)\kappa(i) = \varepsilon(i)^{\delta}$.[18] We also assume that the skill and brawn production functions are exponential, with both schooling and age contributing to skill, such that $H_j = e^{\beta S(j) + \varsigma \mathrm{Age(j)}}$ 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:

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

The corresponding estimating equation is:

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

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 $\log(vB/H)<0$). The model, given our assumptions, also places sign restrictions on three of the coefficients; in 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. 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

[18]Some activity prices might be related to the total ouput of the industry of which an activity may be a part. The price 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 $\pi(i)v(i)$, inclusive of technology change.

productivity, given his skill and brawn.[19] 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 v_2 and v_4 because S and m would covary perfectly within occupations. That activity choices and schooling investments are constrained by household attributes aids identification.[20]

We estimate (17) separately for males and females aged 20-49 in 2001-2. 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% 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 sub-sample 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

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[19]The body-mass endowments of other members of the household could directly affect the unobserved skill of a worker and thus his wage if there were importnat learning externalities within the household, as the endowments are correlated with schooling.

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

women in the age group reports a wage, using the same determinants that predict occupational choice, and computing the relevant Mills ratio.[21] The same set of variables is also used to estimate the gender-specific first-stage estimates. Tables E, F and G in the 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%. 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.[22]

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

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

[22]The weak performance of the body mass endowment is in accord with the findings in Behrman *et al.* (2009), who also employ a specification log-linear in schooling and health.

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 over-represented relative to men.[23] The return to body-mass, however, is positive for activities engaged in by 64% 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 the wage. The estimates from the full specification indicate that δ is negative (but not precisely estimated) and the returns to schooling are lower in the more energy-intensive activities, being positive in 22% of activities, and larger body mass is more useful in the activities requiring more energy expenditure, having a positive return in more than 80% 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.

9. 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 paper 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,

[23]That the marginal contribution of schooling is non-positive 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.

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.

Our findings suggest how development policies will affect gender differences in earnings and schooling investment. For example, many development economists argue that investments in health are critical for development. Attention to the role of brawn suggests that health-based development, similar to the experience in Bangladesh, 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 do not disappear returns to schooling and levels of schooling will in equilibrium be higher for women than for men in almost all economies.

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

Dependent variable: log weight/height		
Input/Survey population	1981-2[b]	2001-2
Log individual total calorie consumption[a]	.136 (3.37)	.241 (3.76)
Very active occupation[a]	-.0119 (0.23)	-.0445 (3.20)
Exceptionally active occupation[a]	-.0817 (1.26)	-.125 (5.65)
Pregnant[a]	.326 (1.34)	.0273 (1.33)
Lactating[a]	.513 (4.65)	.0339 (1.39)
Log age	.0987 (1.90)	.00804 (9.02)
Log age squared	.0174 (2.37)	-.000092 (8.86)
Male	-.0578 (1.81)	-.00947 (2.89)
Male*log age	.0687 (4.04)	.00116 (3.72)
Water drawn from tube well	-.0406 (2.10)	.00551 (0.88)
Water drawn from well	-.0693 (3.15)	.00118 (0.18)
Water drawn from pond	-.0649 (2.55)	.0216 (2.36)
N	1,737	5,750
H_0: calories, age, age squared, male, exceptionally active, very active, male*age = across populations; $\chi^2(7)$ (*p*)	9.06 (.17)	

Sources: NSRB 1981-2 and 2001-2. [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 *et al.* (1990). Asymptotic *t*-ratios in parentheses.

Table 2
The Body-mass Endowment and Grip Strength (2007-8), by Gender: Respondents Aged 20-49 in 2002

Dependent variable: Kilograms of pressure				
Group	Men		Women	
Estimation procedure	GLS	GLLAMM	GLS	GLLAMM
Endowment (γ)	7.41 (5.89)	8.17 (6.03)	1.58 (1.69)	1.93 (1.67)
ρ	-	.907	-	.796
N	946	946	1,087	1,087

Source: NSRB 2001-2/2007-8 panel. 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.

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

Category	Diarrhea, Ages 0-5		Diarrhea, Ages 5-10		Fever, Ages 0-5		Fever, Ages 5-10		Raven's CPM Score, Ages 8-10	
Gender	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Incidence (%)/score	6.13	5.24	3.83	3.48	5.97	2.86	4.26	4.74	3.25	3.05
N	636	630	705	718	636	630	705	718	348	325
χ^2 [p]	.472 [.49]		.122 [.73]		7.28 [.007]		.191[.66]		-	
t [p]	-		-		-		-		1.50 [.13]	

Source: NSRB 2001-2.

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 2001-2

Estimation method	Multinomial Logit[a]		ML Logit-GLLAMM[b]	
Group	Boys	Girls	Boys	Girls
Endowment	-.248 (2.37)	.0600 (0.68)	-.436 (3.60)	.0983 (1.04)
Household land owned	.00670 (3.23)	.00135 (1.14)	.00674 (3.42)	.00135 (1.11)
No land owned	-.0417 (1.08)	-.0463 (1.64)	-.0420 (1.24)	-.0465 (1.70)
Household average endowment of other family members	-.0955 (0.62)	.0667 (0.87)	-.0927 (1.10)	.0784 (1.09)
Age	-.0332 (3.43)	-.0243 (2.54)	-.0325 (3.23)	-.0236 (2.53)
N	410	353	410	353

Source: NSRB 2001-2 and ML Estimates reported in Table 4. [a]Asymptotic *t*-ratios corrected for clustering at the household level in columns. [b]Bootstrapped *t*-ratios in parentheses in columns.

Figure 1. Ratio of Girls to Boys Enrolled in Rural Secondary Schools, Real Agricultural Wage Index, Fraction of Rural Population with Improved Sanitation, and Fraction of Adult Women Belonging to Micro-Credit Groups, 1981-2002

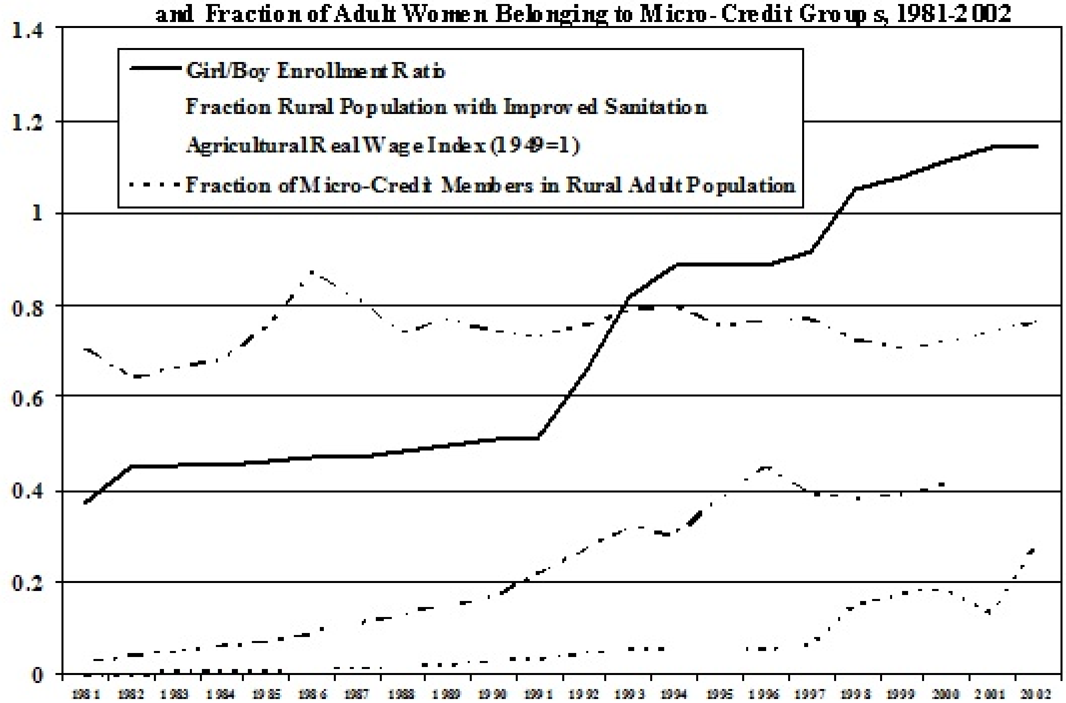


Table 4
The Body-mass Endowment in 1981-22 and Completed Schooling in 2001-2, by Gender: Respondents Aged 0-15 in 1982

Dependent variable: Completed education (years) in 2001-2				
Gender	Male		Female	
Estimation procedure	GLS	GLLAMM	GLS	GLLAMM
Endowment (1981-2)	-1.82	-2.22	1.00	.923
	(2.05)	(1.94)	(0.86)	(0.67)
Age	-.164	-.161	-.110	-.123
	(0.76)	(0.77)	(0.49)	(0.57)
Age squared	.00501	.00483	-.00908	-.00787
	(0.36)	(0.36)	(0.60)	(0.54)
Household owned land (1981-2)	.00711	.00711	.00467	.00468
	(5.49)	(5.66)	(3.05)	(3.17)
No land owned (1981-2)	-1.02	-1.03	-1.05	-1.05
	(1.48)	(1.54)	(1.55)	(1.68)
Average household endowment (1981-2)	.261	.270	.116	.158
	(0.12)	(0.17)	(0.06)	(0.08)
ρ	-	.838	-	.821
N	311	311	273	273

Source: NSRB 1981-2/2001-2 panel. Absolute values of asymptotic *t*-ratios corrected for clustering within households in parentheses. All specifications include village fixed effects.

Table 5
The Body-mass Endowment and Occupation Choice, by Gender: Respondents Aged 20-49 in 2001-2

Dependent variable: Occupational Energy Expenditure				
Group	Men		Women	
Estimation procedure	GLS	GLLAMM	GLS	GLLAMM
Endowment	81.7 (14.9)	93.6 (11.6)	-5.78 (3.62)	-6.78 (2.58)
Age	.969 (0.89)	.957 (0.90)	1.05 (3.23)	1.06 (2.86)
Age squared	-.00153 (0.10)	-.000825 (0.05)	-.0132 (2.80)	-.0133 (2.63)
Household owned land	-.0195 (3.13)	-.0212 (3.42)	-.000269 (0.15)	-.000262 (0.18)
No land owned	6.62 (2.87)	6.22 (2.67)	2.37 (3.64)	2.38 (3.11)
Average household endowment of others (1981-2)	-27.0 (4.14)	-29.0 (4.53)	-2.02 (1.10)	-2.02 (.91)
ρ	-	.901	-	.828
N	1,236	1,236	1,338	1,338

Source: NSRB 2001-2. Absolute values of asymptotic *t*-ratios corrected for clustering within households in parentheses. All specifications include village fixed effects.

Table 7
The Body-mass Endowment in 1981-2 and Log Wages in 2001-2: Males Aged 0-17 in 1981-2

Dependent variable: Log daily wage in 2002 (*tk.*)						
Estimation procedure	GLS	GLLAMM	GLS	GLS	GLLAMM	GLLAMM-IV
Schooling (2002)	-	-	.0261 (2.27)	.0277 (2.41)	.0311 (3.01)	.0432 (2.18)
Endowment (1982)	.252 (1.21)	.327 (2.16)	-	.303 (1.46)	.370 (2.49)	.387 (2.39)
Age	.100 (2.30)	.106 (2.73)	.0750 (1.90)	.0994 (2.33)	.103 (2.66)	.100 (2.57)
Age squared	-.00517 (2.08)	-.00536 (2.34)	-.00356 (1.61)	-.00510 (2.08)	-.00527 (2.30)	-.00518 (2.26)
Household owned land (1982)	.000404 (2.03)	.000412 (2.51)	-	-	-	-
No land owned (1982)	.0528 (0.44)	.0607 (0.68)	-	-	-	-
Average household endowment of others (1982)	-.115 (0.27)	-.147 (0.45)	-	-	-	-
ρ	-	.838	-	-	.838	.838
Sargan overid. $\chi^2(2)$ [*p*]	-	-	-	-	-	0.00129 [.99]
N	225	225	225	225	225	225

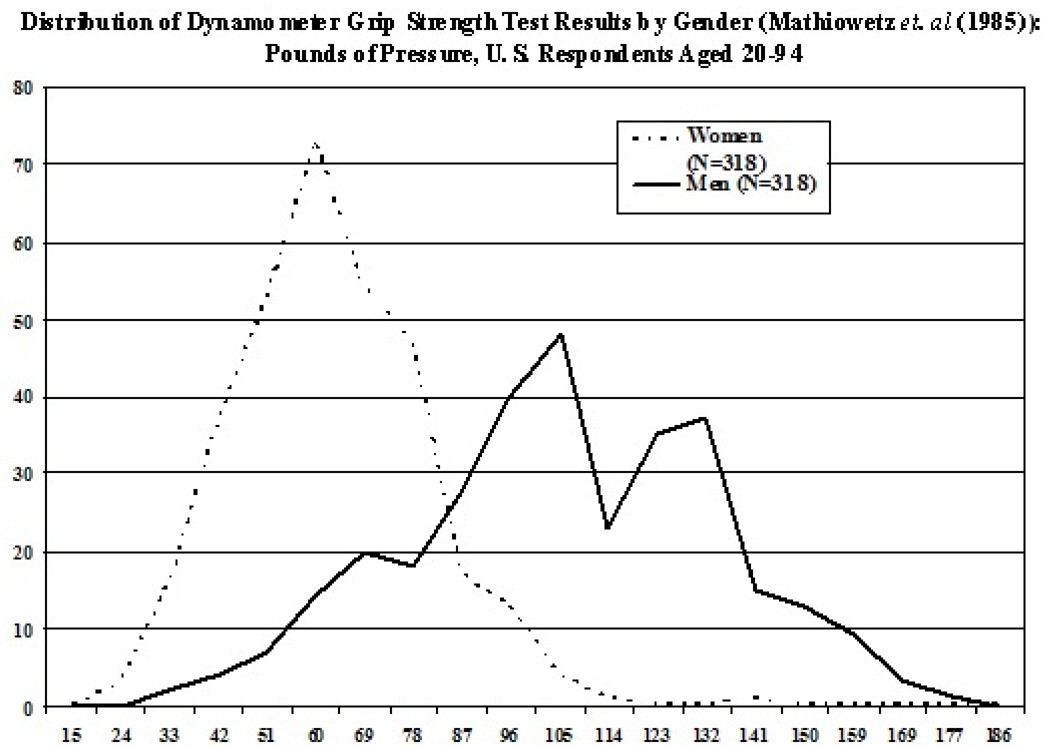
Source: NSRB 1981-2/2001-2 panel. Absolute values of asymptotic *t*-ratios corrected for clustering within households in parentheses in columns 2-6. Bootstrapped *t*-values in column 7. All specifications include village fixed effects. Instruments for the IV estimates include household owned land, no owned land and the average household endowment of other household members.

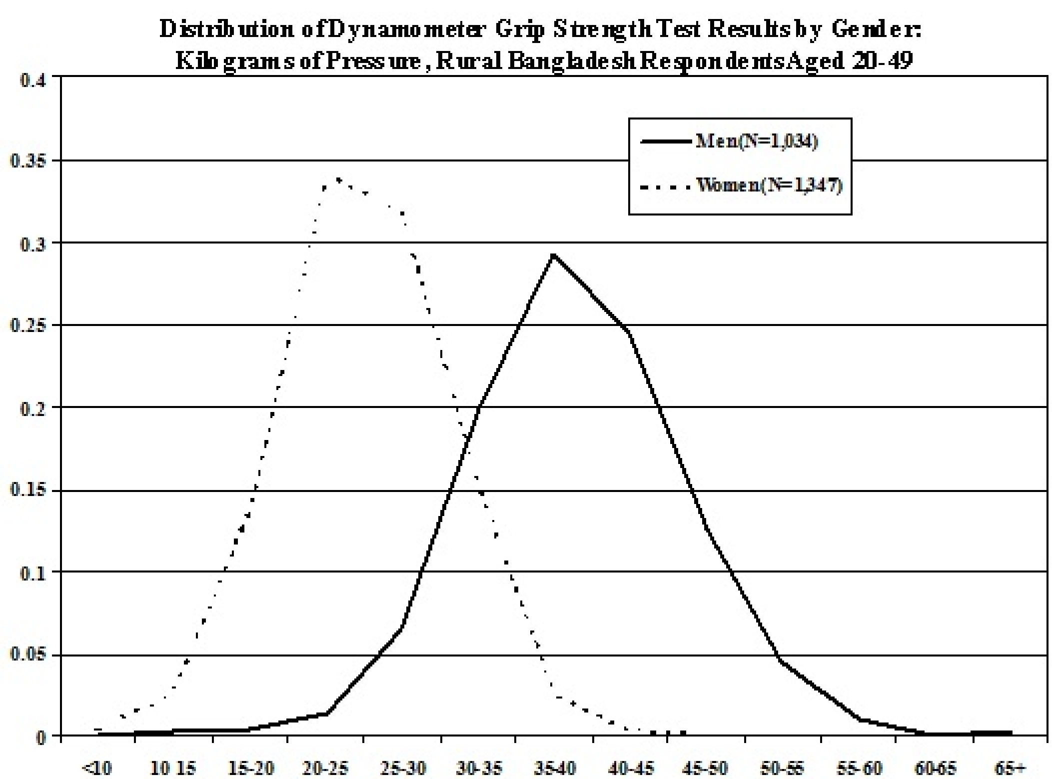
Table 8
Occupation-Specific Wage Function Estimates, by Gender: Adults Aged 20-49 in 2001-2

Gender	Male			Female		
Estimation procedure	GLS[a]	GLLAM[a]	GLLAM-IV[b]	GLS[a]	GLLAM[a]	GLLAM-IV[b]
Schooling	.0409 (11.6)	.0417 (10.1)	.334 (2.75)	.0487 (2.38)	.0467 (2.41)	1.14 (2.05)
Schooling x occupation energy expenditure	-	-	-.00256 (2.87)	-	-	-.007 (2.03)
Endowment	-	.0765 (0.84)	-1.46 (2.34)	-	.0895 (0.22)	-4.53 (1.28)
Endowment x occupation energy expenditure	-	-	.0115 (2.85)	-	-	.0254 (1.52)
Age x occupation energy expenditure	-	-	.000401 (1.16)	-	-	.00204 (1.09)
δ	-	-	-3.36 (1.67)	-	-	-4.37 (0.44)
λ	-	-	-	11.7 (1.46)	12.7 (1.49)	10.3 (0.78)
ρ	-	.889	.867	-	.904	.900
Sargan overidentification χ^2 [*p*]	-	-	11.09 [.436]	-	-	0.0033 [.999]
N	1,094	1,094	1,094	79	79	79

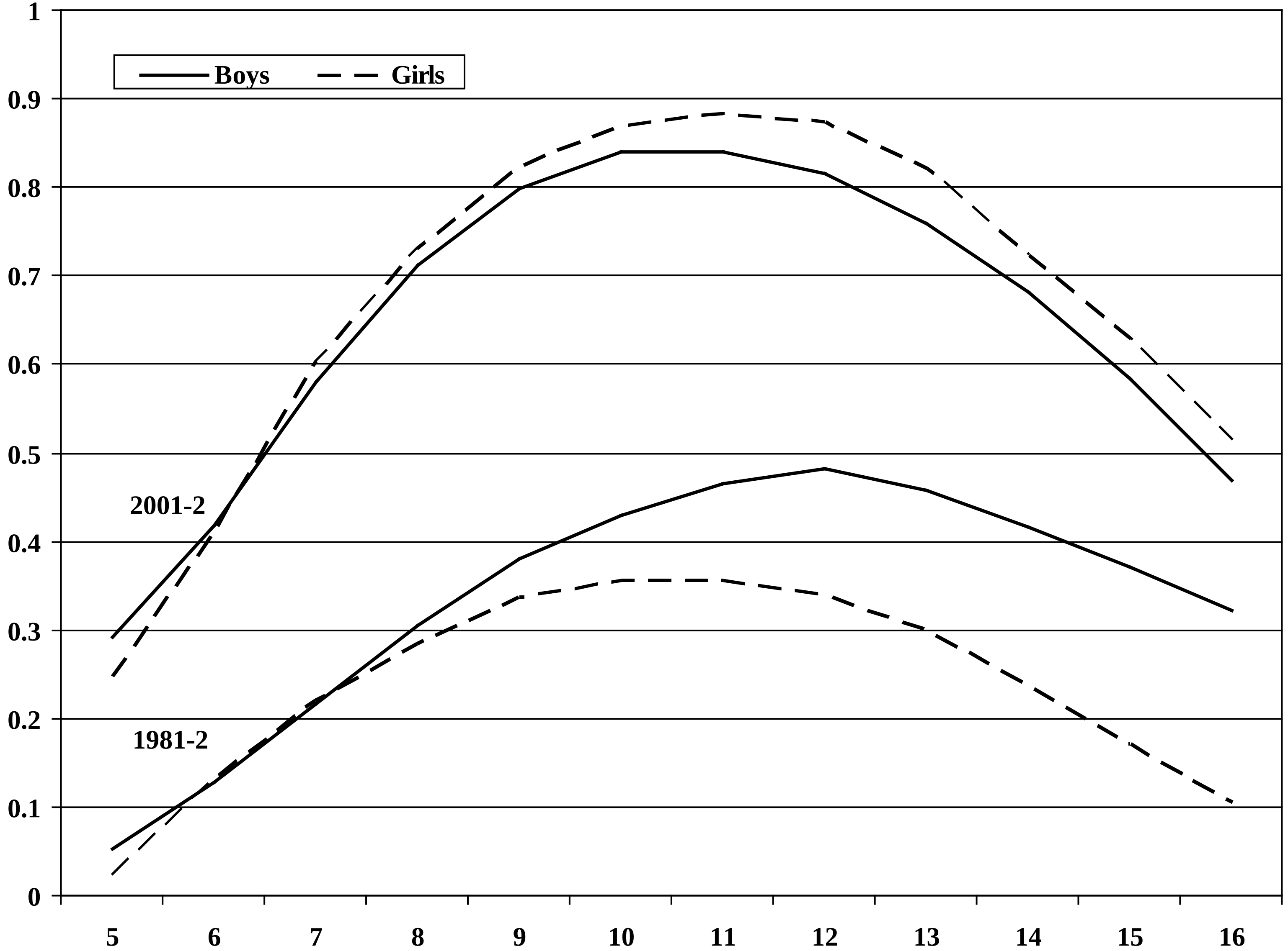
Source: NSRB 2001-2. All specifications include age age and age squared. [a]Absolute values of asymptotic *t*-ratios corrected for clustering within households in parentheses in column. [b]Bootstrapped *t*-ratios in parentheses in column.

Appendix Figure 1

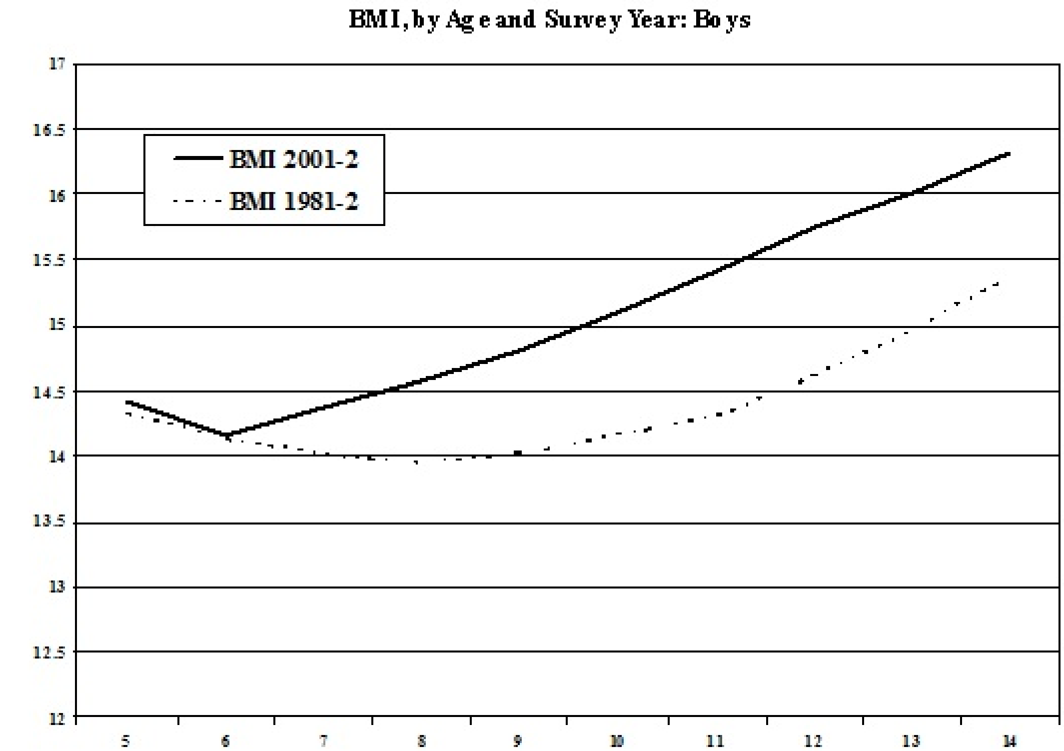


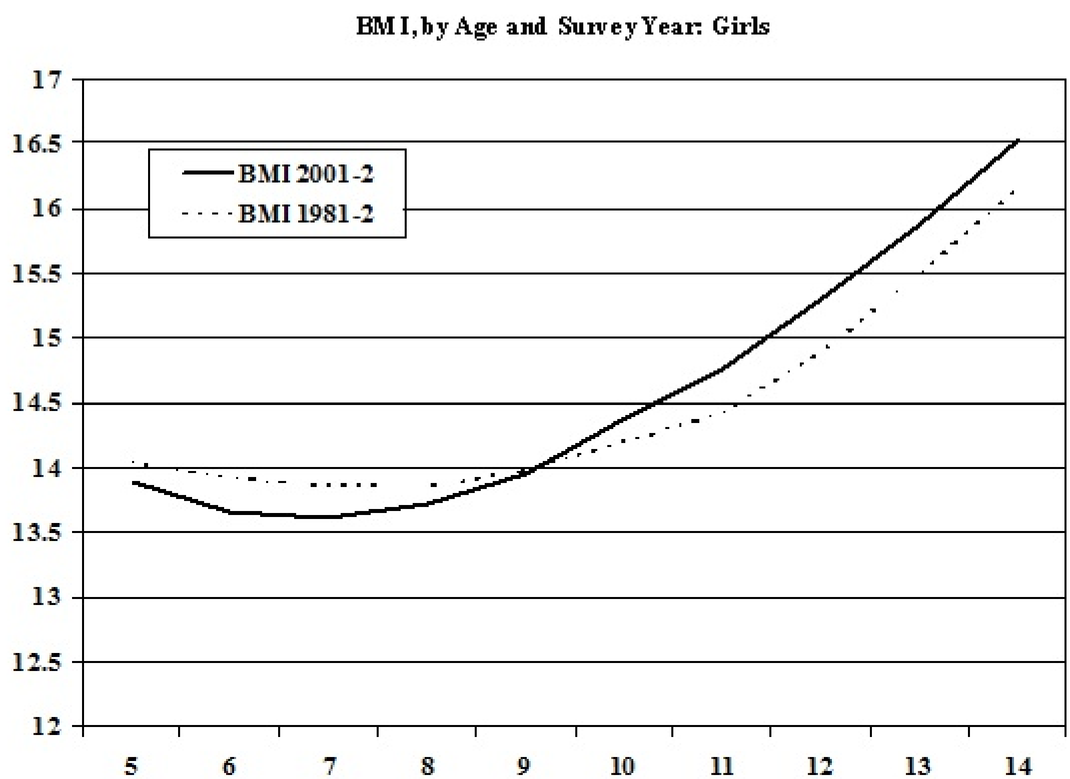


Appendix Figure 2. School Attendance, by Age, Gender and Survey Year

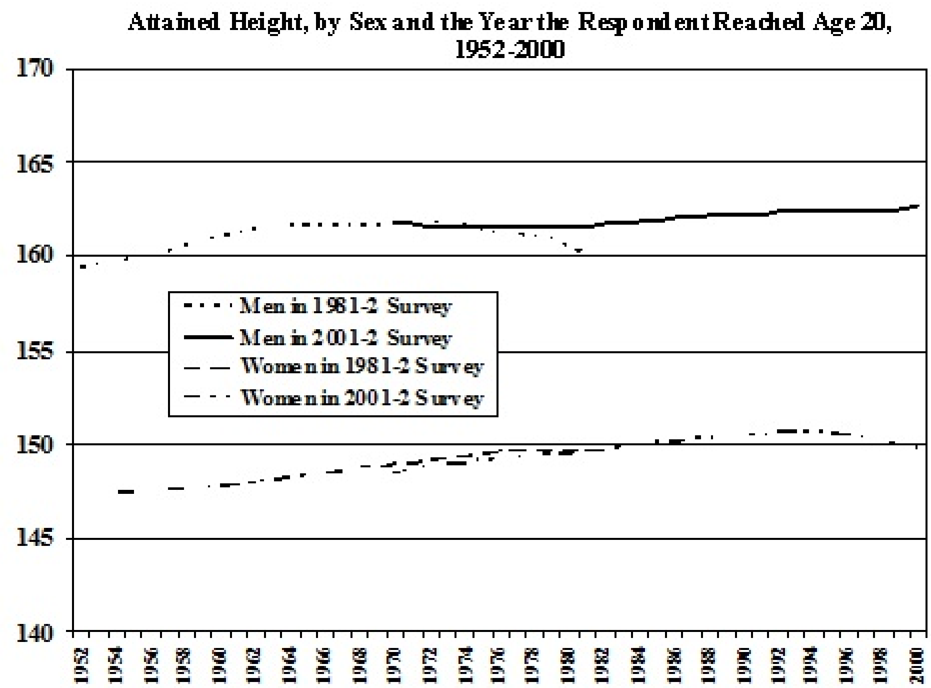


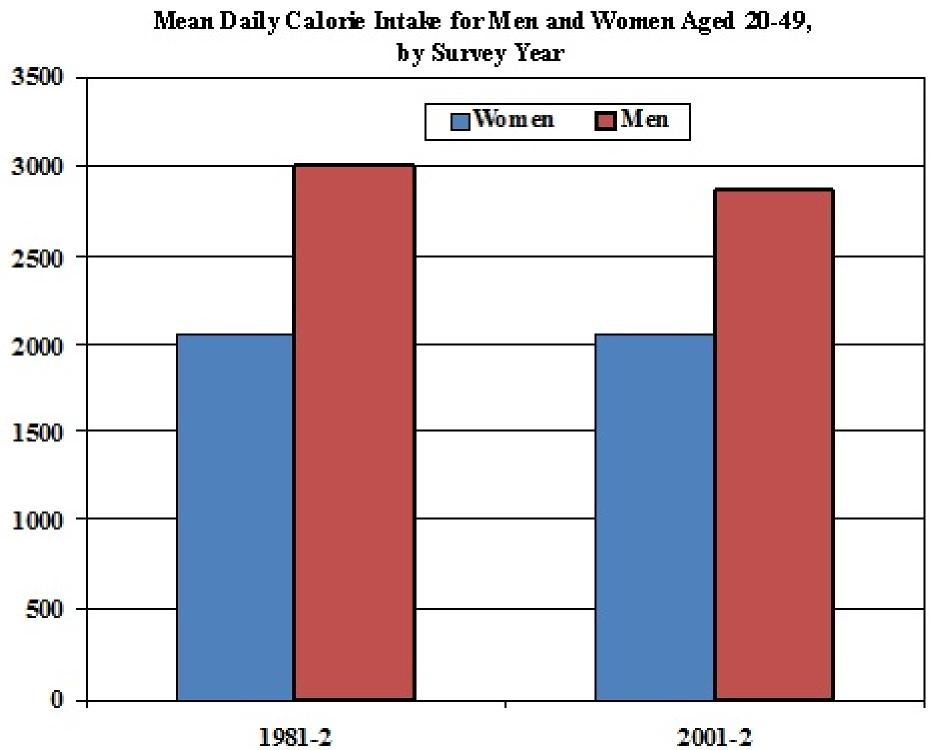
Appendix Figure 3



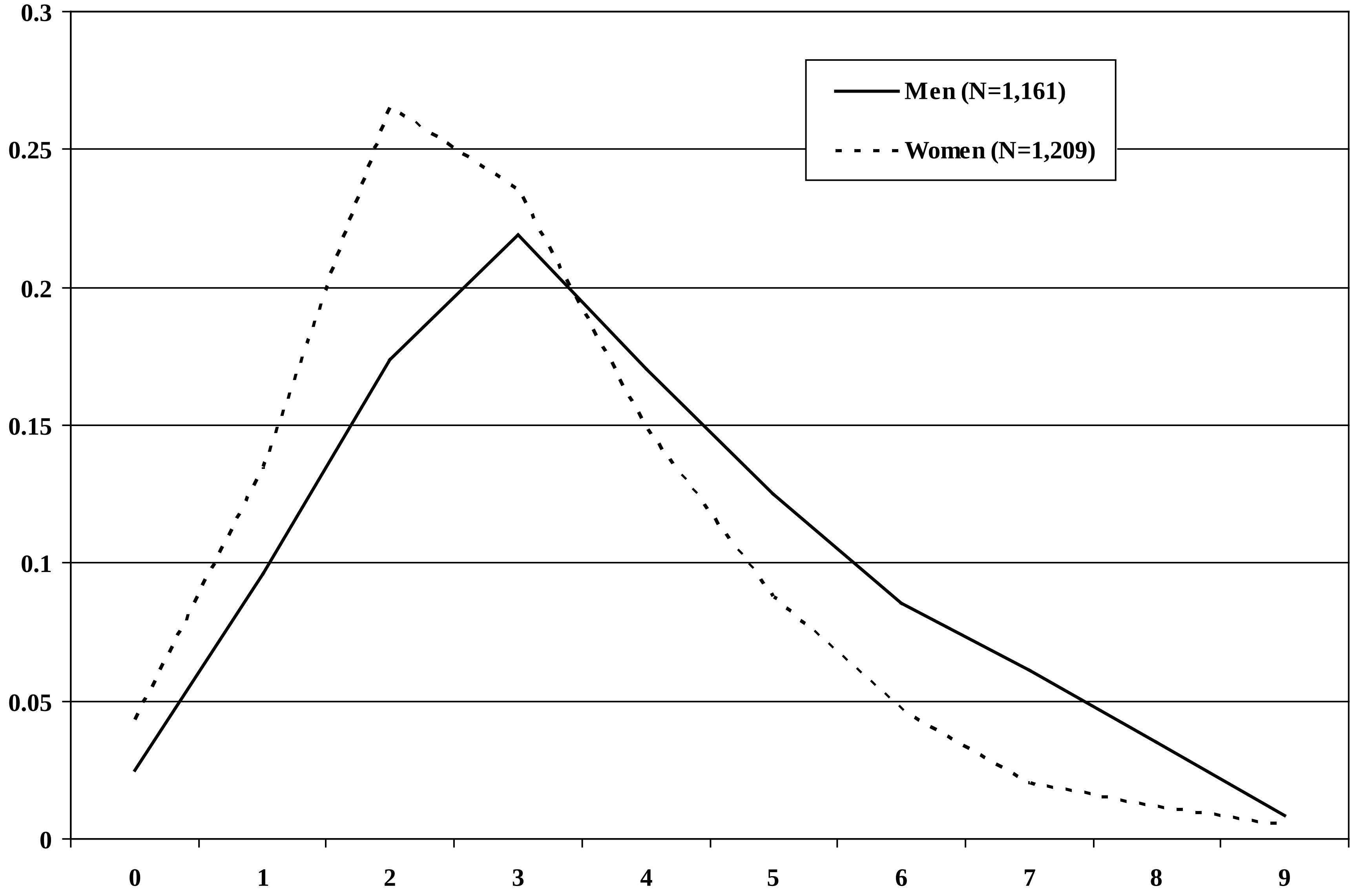


Appendix Figure 4





Appendix Figure A. Distribution of Raven's CPM Test Results by Gender: Number of Correct Answers, Respondents Aged 20-49



Appendix A

Proof of Proposition 1:

Assume that $U_C + \theta C U_{CC} \leq 0$, then

(A1) $dS/d\theta = -(\alpha(i)CH_{12}U_w W/H)\Phi_{22} + (U_C + \theta C U_{CC})\Phi_{21} > 0$

(A2) $dC/d\theta = (\alpha(i)CH_{12}U_w W/H)\Phi_{21} - (U_C + \theta C U_{CC})\Phi_{11} < 0$

(A3) $di/d\theta = (\alpha(i)CH_{12}U_w W/H)\Phi_{32} - (U_C + \theta C U_{CC})\Phi_{31} > 0$

where $\Phi_{22} = -p^2(\pi_{ii}/\alpha(i)\pi(i) - \pi_i/(\alpha_{ii})^2\pi(i) - 1/\alpha_i\pi_i)/\Delta<0$

$\Phi_{21} = -p(\omega + \rho)(\pi_{ii}/\alpha(i)\pi(i) - \pi_i/(\alpha_{ii})^2\pi(i) - 1/\alpha_i\pi_i)/\Delta<0$

$\Phi_{11} = -(\omega + \rho)^2(\pi_{ii}/\alpha(i)\pi(i) - \pi_i/(\alpha_{ii})^2\pi(i) - 1/\alpha_i\pi_i)/\Delta<0$

$\Phi_{32} = -p^2(H_1/H)/\Delta>0$

$\Phi_{31} = -p(\omega + \rho)(H_1/H)/\Delta>0$ by second-order conditions

Proof of Proposition 2:

Assume that effective calories do not change, so that $U_C + \theta C U_{CC}=0$, then:

(A4) $dS/d\theta = -(\alpha(i)CH_{12}U_w W/H + \gamma CH_1 W^2 U_{WW}(1 - \alpha(i))\alpha(i)/HB - \lambda\gamma\omega_B B_1)\Phi_{22}$
$- (\gamma CB_1M_1/B)\Phi_{32}$

(A5) $di/d\theta = -[\alpha(i)CH_{12}U_w W/H + \gamma CH_1 W^2 U_{WW}(1 - \alpha(i))\alpha(i)/HB - \lambda\gamma\omega_B B_1]\Phi_{32}$
$+ (\gamma CB_1M_1/B)\Phi_{33}$

where $\Phi_{22} = -[p - \gamma S\omega_B\theta M_1B_M]^2(\pi_{ii}/\alpha(i)\pi(i) - \pi_i/(\alpha_{ii})^2\pi(i) - 1/\alpha_i\pi_i)/\Delta<0$

$\Phi_{32} = [p - \gamma S\omega_B\theta M_1B_M][\gamma B_M\alpha_i U_W M_1\theta W(\omega + \rho)/B$
$+ \alpha_i U_W H_1 W(p - \gamma S\omega_B\theta M_1B_M)/H]/\Delta>0$

$\Phi_{33}<0$, by second-order conditions

Proof of Proposition 3:

(A6) $dS/dm = (-\gamma B_1\alpha(i)H_1[(1 - \alpha(i))W/HB + U_{WW}W/H] + \lambda\gamma\omega_B B_1)\Phi_{22} - (\gamma B_1/B)\Phi_{32}$

(A7) $di/dm = (-\gamma B_1\alpha(i)H_1[(1 - \alpha(i))W/HB + U_{WW}W/H] + \lambda\gamma\omega_B B_1)\Phi_{32} + (\gamma B_1/B)\Phi_{33}$

Table A
Characteristics and Performance Scores of Respondents Aged 20-49 in 2001-2 and 2007-8, by Gender

Group	Men		Women	
Statistic	Mean (SD)	N	Mean (SD)	N
	Characteristics in 2001-2			
Schooling (years)	3.99 (4.48)	1,264	2.40 (3.57)	1,355
Age	33.7 (8.10)	1,264	32.9 (8.23)	1,355
BMI	19.1 (2.66)	1,264	18.8 (2.79)	1,355
Height (cm)	162.1 (7.89)	1,264	150.3 (6.97)	1,355
Occupation energy expenditure	159.2 (38.2)	1,251	143.6 (7.92)	1,346
Household owned land (hectares x 10^{-2})	91.5 (193.0)	1,264	81.1 (166.7)	1,355
No land owned (%)	48.3 (49.9)	1,264	48.4 (49.9)	1,355
Daily wage (*tk.*)	94.5 (90.0)	1,094	40.1 (32.5)	79
	Assessments in 2007-8			
Grip strength (kilograms of pressure)	37.3 (8.36)	946	24.3 (5.66)	1,087
Number of correct answers, Raven's Matrices	3.66 (1.96)	1,038	2.94 (1.73)	1,200

Source: NSRB 2001-2 and 2007-8

Table B
Multinomial Logit and Logit-GLLAMM Estimates of the Determinants of Children's Activities: Children Ages 10-15 in 2001-2 (Left out activity = Schooling)

Estimation method	Multinomial Logit[a]		ML Logit-GLLAMM[b]	
Activity	Work	Home Time	Work	Home Time
		Boys		
Endowment	2.33 (2.42)	.284 (0.15)	4.09 (3.41)	.426 (0.13)
Household land owned	-.0599 (2.93)	-.0515 (1.01)	-.0603 (2.94)	-.0515 (0.55)
No land owned	.356 (1.09)	.348 (0.45)	.359 (1.19)	.344 (0.04)
Household average endowment	.817 (0.57)	1.38 (0.58)	.784 (0.58)	1.39 (0.34)
Age	.261 (2.82)	.799 (2.52)	.254 (2.53)	.800 (0.16)
N	410		410	
		Girls		
Endowment	-5.66 (2.62)	1.46 (0.89)	-6.87 (2.84)	1.72 (0.93)
Household land owned	.0174 (0.84)	-.0386 (1.38)	.0157 (0.54)	-.0389 (1.09)
No land owned	.705 (1.08)	.607 (1.41)	.632 (0.88)	.605 (1.21)
Household average endowment of other family members	-1.61 (0.90)	-.691 (0.47)	-1.94 (1.14)	-.642 (0.42)
Age	-.0178 (0.07)	.550 (3.18)	-.0994 (0.36)	.581 (3.06)
N	353		353	

Source: NSRB 2001-2. [a]Asymptotic *t*-ratios corrected for clustering at the household level in columns. [b]Bootstrapped *t*-ratios in parentheses in columns.

Appendix B

Are body mass and "ability" negatively correlated?

To directly assess whether body mass and ability are significantly correlated we estimated the association between a respondent's body mass endowment and his or her performance on the Raven's CPM tests that were administered to all adult respondents in 2007-8. Table A reports the GLS and GLLAMM estimates, by gender, of the effects of the body mass endowment on the total number of correct answers (out of nine) for respondents aged 20-49 in 2001-2. As reported in Table A of the Appendix the mean (standard deviation) number of correct answers was 3.66 (1.96) for men and 2.94 (1.73) for women, with the complete distribution of test scores by gender depicted in Figure A in the Appendix. The first two columns of Table C indicate that while larger men perform less well than smaller men, the point estimate is very small - a one standard deviation increase in the body mass endowment reduces the test score (total correct answers) by less than 3 percent (one tenth of a question). It is well recognized, however, that performance on the Raven's test, despite neither requiring literacy nor numeracy, is affected by schooling, and larger men have less schooling. When schooling attainment is included in the specification in column 3 its coefficient is indeed highly statistically significant and positive. Moreover, the coefficient on the body mass endowment is reduced by more than an order of magnitude to essentially zero. Evidently, larger men, net of schooling, are no less able to carry out mental tasks than are men with less brawn.

For women, the reduced-form relationship between the body mass endowment and test score performance is positive and marginally statistically significant when measurement error is taken into account (column 5). However, as for men, schooling and test scores are strongly positively correlated (column 6) and the effect of body mass on the test score is not statistically significant when schooling attainment is included in the specification. Although still positive, the point estimate is also small - a one-standard deviation increase in body mass for women, net of schooling, increases the number of correct answers by less than a tenth (3.1%). Interestingly, when schooling is included in the specification, the association between landholdings and test performance is also eliminated for both men and women - larger landowners do not perform better on the test once their higher level of schooling is taken into account.

Table C

The Body-mass Endowment and Raven's Matrices Test Performance (2007-8), by Gender: Respondents Aged 20-49 in 2002

Dependent variable: Number of correct answers						
Group	Men			Women		
Estimation procedure	GLS	GLLAMM	GLLAMM	GLS	GLLAMM	GLLAMM
Endowment	-.355	-.371	-.0251	.605	.724	.347
	(1.05)	(0.96)	(0.07)	(2.14)	(1.86)	(0.96)
Schooling	-	-	.151	-	-	.180
			(9.92)			(9.18)
Household owned land	.000905	.000896	.0000958	.000561	.000561	-.000127
	(2.52)	(2.55)	(0.26)	(1.67)	(1.73)	(0.38)
No land owned	-.365	-.380	-.168	-.328	-.329	-.128
	(2.63)	(2.77)	(1.31)	(2.83)	(2.80)	(1.13)
Age	-.0502	-.0475	-.0316	-.0671	-.0682	-.0265
	(0.73)	(0.67)	(0.47)	(1.16)	(1.15)	(0.48)
Age squared	.000110	.000069	-.000031	.000429	.000561	.000112
	(0.11)	(0.07)	(0.03)	(0.51)	(0.52)	(0.14)
ρ	-	.872	.872	-	.805	.805
N	1,038	1,038	1,038	1,200	1,200	1,200

Source: NSRB 2002-2007 panel. Absolute values of asymptotic *t*-ratios corrected for clustering within households in parentheses. All specifications include village fixed effects.

Table D
The Body-mass Endowment in 1982 and Age at Menarche Reported in 2001-2,
Girls Aged 0-13 in 1982

Dependent variable: Whether age at menarche occurred after age 13, as reported in 2002

Specification	(1)		(2)	
Estimation procedure	Logit	GLLAMM-Logit	Logit	GLLAMM-Logit
Endowment (1982)	-2.23 (2.11)	-2.81 (1.97)	-2.22 (2.00)	-2.72 (1.85)
Age	-	-	-.132 (0.69)	-.119 (0.62)
Age squared	-	-	.00710 (0.48)	.00586 (0.39)
Household owned land (1982)	-	-	-.000785 (0.87)	-.000784 (0.87)
No land owned (1982)	-	-	.0966 (0.20)	.107 (0.23)
ρ	-	.740	-	.740
N	216	216	216	216

Source: NSRB 1981-2/2001-2 panel. Absolute values of asymptotic *t*-ratios corrected for clustering within households in parentheses. All specifications include village fixed effects.

Appendix C

Procedure and Estimates for Correcting for Selectivity in the Female Wage Equation

The estimates of the wage equation (17) for the sample of women are selectivity corrected using the approach of Lee (1982). The specification of the selection equation is the same as that for the occupational choice equation (13), reproduced below,

$$y_j = \mathbf{Z}_j\zeta + bm_j + \varepsilon_j,$$

where now y_j is a binary indicator of whether or not a women is working for a wage, m_j = the production function residual; the $\mathbf{Z}_j$ = a vector of exogenous control variables; and ε_j=an error term. We estimate the selection equation by logit GLLAMM that corrects for measurement error in the endowments with the replication sub-sample. The Logit and GLLAMM estimates are reported in Appendix Table E.

The distributions ε_j and ξ_j , the error of the wage equation, are allowed to be correlated. As Lee points out, only the marginal disturbances of ε_j and ξ_j needs to be specified, and not their joint bivariate distribution. Let $\Phi(\cdot)$ be the standard normal distribution function, and $\Phi^{-1}(\cdot)$ be its inverse function. With the completely specified marginal distributions $G(\xi_j)$ and $F(\varepsilon_j)$ of ε_j and ξ_j, respectively, each of these errors can be transformed into a standard normal random variable N(0, 1). Let

$$\varepsilon^*_j = J_1(\varepsilon_j) = \Phi^{-1}(F(\varepsilon_j))$$

and

$$\xi^*_j = J_2(\xi_j) = \Phi^{-1}(G(\xi_j)).$$

Both the transformed random variables ε^*_j and ξ^*_j are standard normal variables with zero means and unit variances. If $F(\cdot)$ and $G(\cdot)$ are standard normal distributions, then the term to add to the censored wage equation to correct for selection is the well-known inverse Mills ratio, $\varphi(\mathbf{Z}_j\zeta + bm_j)/\Phi(\mathbf{Z}_j\zeta + bm_j)$, evaluated at the estimated values of ζ and b. If $G(\cdot)$ is normal and $F(\cdot)$ is logistic, the selection correction term becomes

(A1) $$\varphi(J_1(\mathbf{Z}_j\zeta + bm_j)/\Phi(J_1(\mathbf{Z}_j\zeta + bm_j)).$$

The implementation of this selection correction method is complicated by the presence of measurement error in the endowments m_j. We use quadrature methods to compute posterior means in order to net out covariate measurement error in constructing the estimated $(\mathbf{Z}_j\zeta + bm_j)$ obtained using GLLAMM. Finally we include the selection correction term (A1), net of covariate measurement error, in the estimation of the wage equation (15) for women reported in the last three columns of Table 8. Standard errors are constructed by bootstrapping.

Table E
Determinants of Working for a Wage, Women Aged 20-49 in 2001-2

Estimation procedure	Logit	GLLAMM Logit
Household owned land	-.00437 (2.32)	-.00441 (2.33)
No land owned	.283 (0.86)	.278 (0.84)
Endowment	2.27 (4.30)	2.79 (4.32)
Household average endowment of other family members	.0533 (0.06)	.0186 (0.02)
Age	.288 (2.02)	.290 (2.04)
Age squared	-.00392 (1.88)	-.00393 (1.88)
ρ	-	.829
N	1,348	1,348

Source: NSRB 2001-2. Absolute values of asymptotic *t*-ratios corrected for clustering within households in parentheses in column. All specifications include village fixed-effects.

Table F
First-Stage Estimates for the Occupation-Specific Wage Function: Men Aged 20-49 in 2001-2

Dependent variable:	Schooling (years)	Schooling x occupational energy expenditure	Endowment x occupational energy expenditure	Age x occupational energy expenditure	Log occupational energy expenditure
Household owned land	.00779	.943	-.00568	-1.32	-.000237
	(8.98)	(7.93)	(2.87)	(4.07)	(4.76)
No land owned	-.815	-92.6	2.54	226.9	.0373
	(2.89)	(2.40)	(3.82)	(2.52)	(2.29)
Endowment	-1.57	-105.4	174.6	3028	.534
	(2.48)	(1.22)	(113.5)	(12.8)	(14.6)
Household average endowment of other family members	2.39 (3.08)	208.8 (1.96)	-7.27 (3.93)	-876.2 (3.53)	-.140 (3.12)
F(19, 1022)	15.3	13.0	176.2	82.6	20.6
F(3,1022): land, no land, average household endowment	33.1	27.0	18.4	20.1	17.0
F(16,1022): land, no land, average household endowment + village fe	15.3	14.0	6.35	8.00	7.83
N	1,094	1,094	1,094	1,094	1,094

Source: NSRB 2001-2. Absolute values of asymptotic *t*-ratios corrected for clustering within households in parentheses in column. All specifications include village fixed-effects, age and age squared.

Table G
First-Stage Estimates for the Occupation-Specific Wage Function: Women Aged 20-49 in 2001-2

Dependent variable:	Schooling (years)	Schooling x occupational energy expenditure	Endowment x occupational energy expenditure	Age x occupational energy expenditure	Log occupational energy expenditure
Household owned land	.0207 (1.96)	1.99 (1.22)	-.0352 (1.65)	-5.37 (3.11)	-.00116 (3.66)
No land owned	-.0163 (0.01)	-111.7 (0.54)	-3.77 (1.87)	-349.4 (1.79)	.0781 (1.97)
Endowment	1.58 (0.54)	-199.9 (0.47)	167.9 (25.9)	317.7 (0.89)	.0588 (0.70)
Household average endowment of other family members	-146.0 (1.53)	-12595 (0.90)	-52.8 (0.69)	36107 (3.24)	8.08 (3.71)
λ	2964 (1.58)	2602.4 (0.94)	926.5 (0.63)	-72269 (3.38)	-161.6 (3.86)
F(19, 75)	7.90	6.25	860.4	1161	136.7
F(3,75): land, no land, average household endowment	4.02	2.42	1.44	7.21	9.26
F(16,75): land, no land, average household endowment + village fe	5.00	3.83	1.99	6.78	14.9
N	79	79	79	79	79

Source: NSRB 2001-2. Absolute values of asymptotic *t*-ratios corrected for clustering within households in parentheses in column. All specifications include village fixed-effects, age and age squared.