Chronic Poverty
Research Centre

Working Paper

February 2010 No. 160

Mothers' human capital and the intergenerational transmission of poverty

The impact of mothers' intellectual human capital and long-run nutritional status on children's human capital Guatemala

Jere R. Behman
Alexis Murphy
Agnes R. Quisumbing
Kathryn Yount

Economics and Population Studies Center
University of Pennsylvania

Food Consumption and Nutrition Division
International Food Policy Research Institute

Global Health, Emory University

Chronic Poverty Research Centre
ISBN: 978-1-906433-62-8

What is Chronic Poverty?

The distinguishing feature of chronic poverty is extended duration in absolute poverty.

Therefore, chronically poor people always, or usually, live below a poverty line, which is normally defined in terms of a money indicator (e.g. consumption, income, etc.), but could also be defined in terms of wider or subjective aspects of deprivation.

This is different from the transitorily poor, who move in and out of poverty, or only occasionally fall below the poverty line.

www.chronicpoverty.org

Abstract

Many prior studies find significant cross-sectional positive ordinary least squares (OLS) associations between maternal human capital (usually maternal schooling attainment) and children's human capital (usually children's schooling, but in some cases children's nutritional status). This paper uses rich Guatemalan longitudinal data collected over 35 years to explore several limitations of these 'standard' estimates. The preferred estimates developed herein suggest that: (1) maternal human capital is more important than suggested by the standard estimates; (2) maternal cognitive skills have a greater impact than maternal schooling attainment on children's biological human capital; and (3) for some important indicators of children's human capital, maternal biological capital has larger effect sizes than maternal intellectual capital (schooling and cognitive skills). These results imply that breaking the intergenerational transmission of poverty, malnutrition and intellectual deprivation through investments in women's human capital may be more effective than previously suggested, but will require approaches that account for dimensions of women's human capital beyond just their schooling. Effective interventions to improve women's biological and intellectual human capital often begin in utero or in early childhood; thus, their realisation will take longer than if more schooling were the only relevant channel.

Keywords: maternal human capital, schooling, cognitive skills, nutritional status, child outcomes, intergenerational transmission of poverty, intergenerational effects, mother-child effects

Acknowledgements

This study was supported by the Chronic Poverty Research Centre (CPRC) through the Overseas Development Institute grant RES000/IGT on 'What is the impact of mothers' intellectual human capital and long-run nutritional status on child human capital in Guatemala?' and the National Institutes of Health R01 HD045627-01 grant on 'Resource flows among three generations in Guatemala'. A more technical version of this paper is available as 'Are returns to mother's human capital realized in the next generation? The impact of mothers' intellectual human capital and long-run nutritional status on children's human capital in Guatemala', IFPRI Discussion Paper 850 in Behrman *et al*. (2009b). The authors thank Kate Bird, Futoshi Yamauchi, an anonymous referee, their colleagues on the larger project of which this study is a part, participants in the session at the 2008 Population Association of America annual meetings at which this paper was presented, Elena Kuklina for sharing her knowledge of the G3 Bayley's test scores from the 1996–99 data collection, Aimee Webb for insights into the links between mothers' cognitive skills and child care practices, and Meng Wang for excellent research assistance in the preparation of the data for this paper.

Jere R. Behrman is the William R. Kenan, Jr. Professor (and former Chair) of Economics and of Sociology and Research Associate (and former Director) of the Population Studies Center at the University of Pennsylvania, where he has been on the faculty since 1965. His research interests are in empirical micro economics, economic development, labour economics, human resources (education, training, health, nutrition), economic demography, household behaviours and policy evaluation.

Alexis Murphy was formerly a Research Analyst at and a consultant to the International Food Policy Research Institute. She has conducted field work in Mexico, Guatemala, and Nicaragua

Agnes R. Quisumbing is a senior research fellow in the Poverty, Health, and Nutrition Division of the International Food Policy Research Institute. She co-leads a research program analysing the factors that enable individuals, households, and communities to move out of poverty over the long term, and has just initiated another research program on gender and assets. Her research interests include poverty, gender, property rights, and economic mobility.

Kathryn M. Yount is Associate Professor of the Hubert Department of Global Health and the Department of Sociology at Emory University. She is a family demographer with expertise in gender, intergenerational relations, and disparities in human resources across the lifecourse.

Contact: A.Quisumbing@cgiar.org

Contents

1 Introduction

There is now a voluminous body of evidence that investments in human capital, particularly in early childhood, yield returns throughout the life cycle[1]. For example, a recent study based on a unique longitudinal data set in Guatemala showed that a nutrition intervention that reached children at age zero to three had positive effects on their labour market wages in adulthood (Hoddinott *et al*., 2008). Because women participate in the labour force at lower rates than men, investments in women's human capital are often justified based on their presumed large positive effects on the next generation, rather than because of direct economic returns. In support of this, a number of influential scholars and policy makers have argued that the effect of maternal human capital on children's health and education is large and causal in poor settings (e.g., Summers, 1992, 1994; Stern, 2001; World Bank, 2001). However, several limitations in this literature prevent us from understanding fully how investment in women's human capital can be related to efforts to halt the intergenerational transmission of poverty.

First, attention has been focused almost entirely on the impact of maternal intellectual human capital, with the possible impacts of maternal biological human capital being largely ignored. This may have led to an overemphasis on schooling and a neglect of nutrition as a focus of interventions.

Second, schooling attainment is the most commonly utilised measure of women's intellectual human capital in these studies. However, schooling attainment is not equivalent to women's knowledge, but rather is an input into it, due to variations in schooling quality and the out-of-school experiences that enhance learning throughout women's lives. This may have led to an overemphasis on extending time in school, and an underemphasis on the importance of school quality and home environments.

Third, women's human capital is almost always treated as if it were randomly assigned, or, alternatively, predetermined, rather than being an outcome of behavioural decisions that often involve intergenerational interactions[2]. Not recognising that investments in human

---

1 Evidence continues to accumulate suggesting that long-run nutritional status, determined in considerable part by early-life nutrition (which in turn is affected by nutrient intake, infectious disease experience and stimulation), has a long-run impact on cognitive skills and productivities in poor societies (e.g., Behrman *et al*., 2005, 2008; Engle *et al*., 2007; Hoddinott *et al*., 2008; Maluccio *et al*., 2009; Martorell, 1997; Strauss and Thomas, 1998; Victora *et al*., 2008).

2 A small subset of articles, primarily recent studies in developed countries, have investigated what happens to estimates of impacts of maternal schooling attainment on child outcomes if maternal human capital is behaviourally determined within a life-cycle framework that accounts for unobservables, such as innate ability and health, using identical twin data (Behrman and Rosenzweig, 2002, 2005), adoption data (Plug and Vijverberg 2003; Plug 2004), and instrumental variable estimates (Black, Devereux and Salvanes 2005; Carneiro, Meghir and Parey, 2007), based on phased-in changes in compulsory schooling or local tuition fees, distance to college and local labour market variables as instruments. We are aware of only two articles for developing countries that investigate changes in the estimated impact of mothers' schooling on child schooling or health when the mothers'

capital are forms of intergenerational transfers, which may involve the correlation of 'endowments' (factors that are taken as given, such as genetics) and preferences, may misdirect attention to investment in human capital as a way of halting the intergenerational transmission of poverty.

Fourth, indicators of women's human capital are generally treated as if they are perfectly measured and not affected by random noise. This may led to underestimates of the impacts of maternal human capital because the true effects are masked somewhat by the noise due to measurement error.

Lastly, most previous studies focus on just one type of children's human-capital outcome. The largest share of prior studies focus on one or a few outcomes related to children's intellectual development (e.g., schooling enrolment or attainment), while a sizeable minority focuses only on indicators of children's biological development (e.g., birth weight and/or anthropometric measures of children's growth). This segregation of children's outcomes in the literature may mask potentially differential effects of maternal human capital on different types of children's human capital (e.g., the particularly strong effects of maternal intellectual human capital on children's intellectual human capital, and of maternal biological human capital on children's biological human capital) [3].

All of these limitations may have serious implications for the design of policies to increase investment in children's human capital because the result may be underappreciation or neglect of potentially important forms of maternal human capital that could be affected by policy, as well as of interactions among different types of human capital. In turn, this may lead us to underplay or disregard some important policy levers for intervening in the intergenerational transmission of human capital, and therefore interrupting the intergenerational transmission of poverty.

The present study uses an unusually rich longitudinal data set collected over 35 years in Guatemala to implement four innovations that address and hopefully overcome the abovementioned limitations. First, we consider the impacts of mothers' intellectual human capital and mothers' biological human capital on children's outcomes. Second, we use both

schooling is also treated as endogenous, using within-adult sister data to control for the common genetic and parental/family environments (Behrman and Wolfe, 1987a, b). All of these studies report some substantial changes, usually reductions, in the estimated impacts of maternal schooling attainment when alternative means are used to control for unobserved endowments. We are not aware of studies investigating what happens if maternal long-run nutritional status is also treated as endogenous for determining children's human capital.

3 We know of a few articles that include indicators of both types of children's human capital (e.g., Ghuman *et al*., 2005). These reports present associations that differ by type of human capital, but do not attempt to estimate causal effects that control for the behavioural determination of parental human capital when such decision making is correlated across generations.

schooling attainment and cognitive skills as measures of maternal intellectual human capital. Third, in our preferred estimates, we treat all measures of mothers' human capital as behaviourally determined and control for random measurement errors in the indicators of mothers' human capital. Fourth, we consider indicators of children's intellectual human capital and children's biological human capital as outcomes. These innovations yield important changes in our empirical understanding of the impacts of mothers' human capital on children's human capital in the studied context. Our findings suggest that the impacts are larger than found using standard methodologies, and that they vary by type of mothers' or children's human capital.

In the following, we present the conceptual framework (Section 2), the data (Section 3), alternative estimates for each of the children's human capital outcomes considered (Section 4), and then conclude (Section 5).

2 Conceptual framework

The returns to investments in women's human capital, in terms of their children's human capital, may be realised through a number of pathways. First, mothers with more intellectual human capital may be more likely to seek health and childcare information, and may be more aware of and likely to adopt behaviours that result in better-educated and healthier children. These behaviours could be related to nutrition and the care of children, such as breastfeeding, proper diet, better hygiene and illness management (Webb *et al*., 2008a, 2008b), as well as behaviours that enhance their children's intellectual development and school performance. Second, better maternal nutritional status before and during pregnancy may lead through 'biological' pathways to better nutrition in utero and higher birth weights for the women's children, resulting in healthier children over their life cycles.[4] 'Biological' human capital is also thought to operate through the development of cognitive potential in early childhood (e.g., Engle *et al*., 2007). Third, because a higher level of maternal human capital raises the opportunity costs of the women's time, women with more maternal human capital tend to have fewer, but better-educated and healthier, children. Fourth, women with better human capital may attract spouses with better human capital; this may have positive effects on their children's human capital in addition to effects coming directly through the mothers. [5]

We take these pathways into account by viewing investment in children's human capital – as well as the human capital of their mothers – in a dynamic life-cycle framework. Within this framework, both the intellectual human capital (e.g., education, as measured by schooling attainment, or cognitive skills, such as adult reading comprehension and nonverbal skills) and biological human capital (e.g., long-run nutritional status, as measured by height) of mothers reflect behavioural choices that depend on observed and unobserved individual and family backgrounds, as well as other characteristics. Some individuals and families may have unobserved attributes that lead to greater investments in intellectual and biological human capital, such as abilities and motivations for education that are rewarded in labour markets, or better health-seeking behaviours and greater food availability. We also use estimation methods that control for the behavioural determinants of maternal human capital, so that the associations with outcomes in the children's generation will be unbiased estimates of causal effects.

Our conceptual framework for investigating the five issues noted in the Introduction considers the life cycle to have a series of stages. One of those stages is adolescence-young

4 Indeed, a recent study for the same context examined in this paper reports that better nutrition for girls when they are children results in greater birth weight and greater height in their children (Behrman *et al*. 2009a).

5 We do not attempt to identify the indirect effects of spouses' human capital from the other effects that women have on their children's human capital, to avoid including too many right-side behavioural variables in our specifications. Thus, we herein estimate the total effects of women's human capital on their children's human capital, whether such effects are direct or indirect (e.g., through the women's spouses' assets or other pathways).

adulthood, during which time (for the society under consideration) most individuals initiate first unions, parenting and child rearing. Women have a vector of human capital stock (K) that includes intellectual and biological human capital, and determines the results of their union formation in terms of spousal characteristics and children's human capital. To facilitate exposition, we denote grandparents as G1, mothers as G2, and children as G3.

Let Y be a vector of child (G3) human capital outcomes, such as health, nutrition and schooling. The basic goal of this study is to estimate how children's human capital outcomes Y depend on the intellectual and biological capital of mothers, G2 (K), measured for the ages at which women make decisions regarding first unions and parenting, in the society under study. We assume that these human capital assets are the only assets that adolescent women bring to spouse/partner acquisition, childbearing and child rearing. [6] We posit that there is a linear approximation for what determines Y, given mothers' (G2) human capital stocks (K), predetermined observed individual child (G3) characteristics (I) (such as the gender of the child and whether he/she is a twin), unobserved inherited child (G3) endowments (E0) that are correlated across generations (such as innate ability and health), and a vector of stochastic disturbance terms (V), with one element for each different outcome, as follows:

$$Y = a0 + a1\ K + a2\ I + a3\ E0 + V \qquad (1)$$

where ai represents the matrices of the coefficients to be estimated.

We seek to obtain good (consistent) estimates of the coefficients of maternal intellectual and biological human capital in relation (1); these are the components of K. However, estimation of relation (1) is a challenge because the maternal (G2) human capital that results, for example, in better child (G3) biological or intellectual capital probably reflects prior behavioural choices. As a result, OLS or similar estimates of relation (1) are likely to be inconsistent, particularly if there are intergenerationally-correlated endowments, such as genetic tendencies.

To deal with these possible estimation problems, we first assume that mothers (G2s) and their parental families (G1s) make investments in prior life-cycle stages for the mothers that determine the components of K. These investments are made within a dynamic, reduced-form demand context, given:

6 In the utilised data, almost a third of males brought household and productive assets to their unions, whereas only 13.8 and 1.3 percent of women brought household and productive assets, respectively, to their unions (Quisumbing *et al*., 2005). Thus, women mostly brought their human capital assets into unions and childbearing. Moreover, the correlations are very low between mothers' human capital and the physical assets they brought into unions; therefore, excluding the latter from our specifications does not create substantial omitted variable biases in the coefficient estimates of interest.

1) the initial conditions, which include grandparent (G1) family background (F0), initial community prices and policies (C0), genetic and other endowments (E0), and individual mothers' (G2) characteristics (I0), such as birth date;

2) the changes that occurred from the time of the births of the mothers (G2s) until they were of age to initiate partnerships and have children, such as changes in social service provision, markets and policies (ΔC), all of which are conditional on each mother's (G2's) birth date and subsequent age; and

3) unobserved idiosyncratic influences (W) on the mother's (G2s') human capital stock (e.g., random disease shocks).

It then follows that:

$$K = K(F0, C0, E0, I0, \Delta C, W). \qquad (2)$$

This expression captures the results of many decisions that the grandparents (G1s), and then increasingly the mothers themselves (G2s), make over the adolescent/young adult periods of the mothers (G2s), given initial conditions and time-varying factors outside family control. The elements in relation (2) are generally vectors of individual and community opportunities, and the constraints to which families respond. One example is genetic endowments (E0), a vector that includes innate 'ability' endowments related to learning, and 'physical' endowments related to physical growth. [7]

Many previous attempts to measure the impact of maternal human capital on child outcomes did not take into account the fact that maternal human capital is also behaviourally determined. In this study, we use instrumental variable (IV) methods in which the components of maternal human capital (K) in relation (1) are replaced by their predicted values from relation (2). [8] IV estimates also control for random measurement error, which tends to bias estimated coefficients towards zero. Because the effects of omitted variable bias due to endowments may oppose the effects of random measurement error, the IV estimates may be greater or smaller than the OLS estimates, depending on which of these potentially opposing biases is larger. In this way, IV estimates deal with both the third and

7 These various endowments may be significantly – but not necessarily positively – correlated. A recent study in the United States, for example, finds that endowments related to schooling and earnings are negatively related to physical health (Behrman and Rosenzweig, 2004). Estimates of adult cognitive skill production functions for the data utilised in the present study are consistent with such a possibility (Behrman *et al*., 2008). If this is the case, our failure to control for genetic endowments could result, for example, in overestimation of the effect of maternal intellectual human capital on child schooling, but underestimation of the effect of maternal biological human capital on child schooling.

8 The predicted values of maternal human capital are not correlated with the unobserved endowments and are therefore not correlated with the compound disturbance in relation (1).

fourth issues raised in the Introduction; however, the impact on the estimated coefficients may depend on which issue is more important if they are opposing in their effects. Second, the components of maternal human capital K are all determined at least in part by the same initial conditions (F0, C0, E0, I0), along with some common observed community changes (ΔC) and unobserved influences (W). As a consequence, mothers' (G2s') intellectual capital and biological capital are likely to be correlated, and estimates that fail to control for both components of K (as seen in most of the existing literature) are likely to suffer from omitted variable bias. In other words, if both maternal intellectual and biological human capital should be included on the right side of relation (1), but only one is actually included (e.g., maternal intellectual human capital as represented, for example, by schooling), then the coefficient estimate for that component of human capital is likely to be biased due to exclusion of the other (correlated) component of human capital.

3 Data

The relations posited in Section 2 to explore the five issues raised in the Introduction have demanding data requirements. To meet these requirements, we use an unusually rich, longitudinal data set collected over a 35-year period. The data include alternative measures of G2 intellectual and biological human capital, G3 intellectual and biological human capital, G1 family background, and exogenous 'shocks' or 'innovations' from an experimental nutritional intervention as well as market and policy changes.

3.1 General description of the data

The data used in this study are based on a supplementation trial, conducted by the Institute of Nutrition for Central America and Panama (INCAP), collected during 1969–77 for all children zero to seven years old and all pregnant and lactating women in four rural Guatemalan villages. [9,10]The females who were zero to seven years old in 1969–77 (and 26–42 years old in 2002–04) are our G2 mothers (often referred to simply as 'G2s'); their parents are our G1s; and their children are our G3s. Cohorts of newborns were included until September 1977. The birth years of G2s included in the 1969–77 longitudinal data collection thus ranged from 1962 to 1977, and their ages ranged from zero to 15 years when the intervention ended. Therefore, the length and timing of exposure to the nutritional interventions (described below) for a particular G2 depended on her birth date.

Two villages, Conacaste and San Juan, were randomly assigned to receive a high protein-energy drink, Atole, as a dietary supplement. Atole contained Incaparina (a vegetable protein mixture developed by INCAP), dry skimmed milk and sugar, and had 163kcal and 11.5g of protein per 180ml cup. This design reflected the prevailing view of the 1960s that protein was the critically limiting nutrient in most developing countries. Atole (which is the Guatemalan name for hot maize gruel) was pale grey-green and slightly gritty, but had a sweet taste. In the other two villages, Santo Domingo and Espiritu Santo, an alternative drink was provided. Fresco was a cool, clear-coloured, fruit-flavoured drink, containing no protein and only sufficient sugar and flavouring agents for palatability. It contained fewer calories per cup (59kcal/180ml) than Atole.

---

9 Three hundred villages were screened to identify those of appropriate size, compactness (so as to facilitate access to feeding stations, health centres and psychological testing sites, see below), ethnicity, diet, schooling levels, demographic characteristics, nutritional status and degree of physical isolation. From this screening, two pairs of similar villages were selected: Conacaste and Santo Domingo (relatively populous villages) and San Juan and Espíritu Santo (relatively less populous villages).

10 This population has been studied intensively, with particular emphasis on the impacts of the early-life nutritional intervention (Martorell *et al*., 2005 provide references to many of these studies).

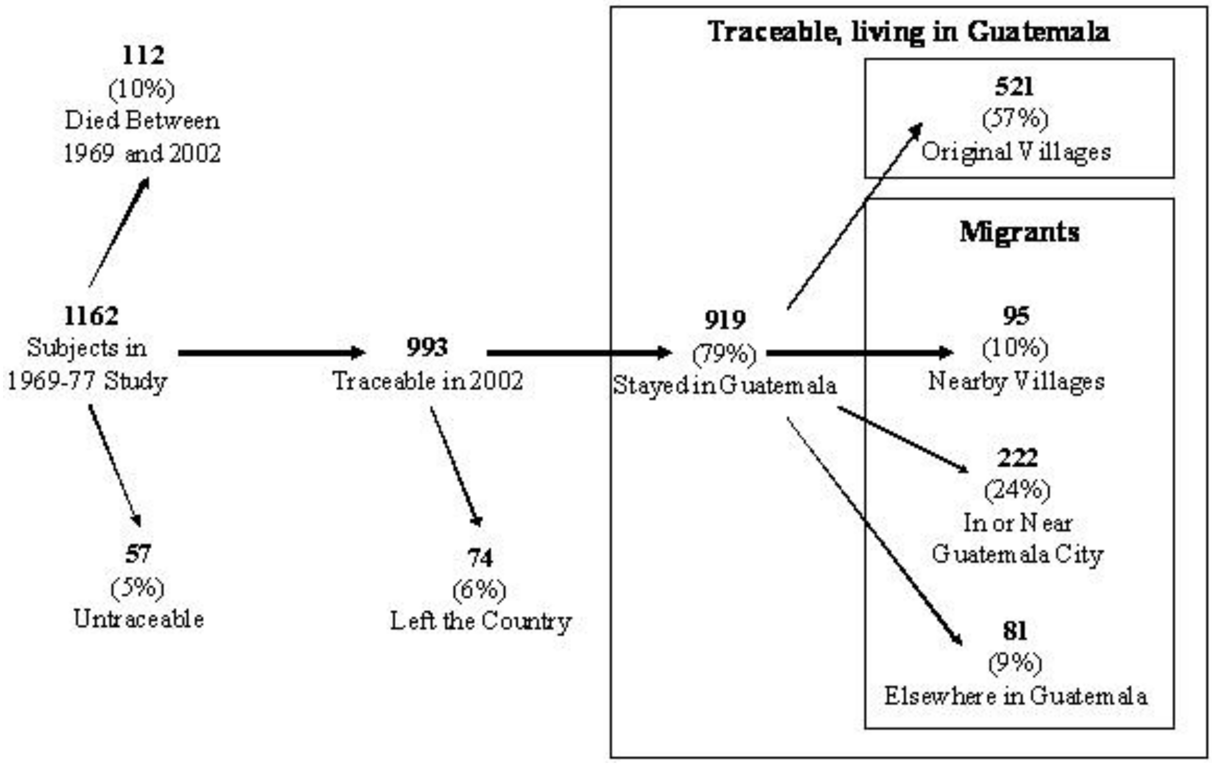
The nutritional supplements (i.e., Atole or Fresco) were distributed through supplementation centres and were available daily, on a voluntary basis, to all members of the community during times that were convenient to mothers and children, and did not interfere with usual meal times. [11] In this study, we do not directly measure the impact of the intervention, but use the differential 'intent to treat' exposure to these nutritional supplements during critical early-life periods as first-stage instruments to aid in the estimation of relation (2).

Multidisciplinary research teams conducted several follow-up rounds of data collection on G2s and their children (G3s); these are described in greater detail in the fuller version of this paper (Behrman *et al*., 2009b). The first follow-up study, conducted in 1987–88, targeted the G2s (both male and female) who were 11 to 26 years of age in 1988. Between 1991 and 1996, investigators conducted a surveillance of births (G3 offspring of the original G2 sample members) in the original villages (outmigrants were not studied). In 1996, the data collection was expanded to include a surveillance of pregnancies and to carry out longitudinal data collection on the G3 offspring. Between 1996 and 1999, information was collected on all G3s born during 1996–99, as well as G3s who were born before 1996 and were less than three years of age at the time of study onset in 1996. All of these G3s were followed to the age of three years or the study closeout, whichever came first. Finally, a multidisciplinary team of investigators, including the authors of this paper, undertook follow-up data collection in 2002–04 on all G2s from the 1969–77 data collection. In 2002–04, these individuals ranged from 25 to 42 years of age.

Figure 1 shows the distribution of the 1,162 G2 women zero to 15 years old in the original 1969–77 sample at the time of the 2002–04 data collection: 919 (79 percent) were alive and known to be living in Guatemala, while ten percent had died, six percent had migrated abroad, and five percent were not traceable. Of the 919 G2 women available for data collection, 521 lived in their original villages, 95 lived in nearby villages, 222 lived in or near Guatemala City, and 81 lived elsewhere in Guatemala. Of the total sample of 919 G2 women, 649 (71 percent) finished the complete battery of applicable interviews and measurements, and 818 (89 percent) completed at least one interview during the 2002–04 data collection (Grajeda *et al*., 2005).

11 A programme of free primary medical care was provided throughout the period of data collection. Periodic preventive health services, such as immunisation and deworming campaigns, were conducted in all four villages.

Figure 1. Sample sizes for original village residents and migrants; women only



We draw upon information on all three generations (G1, G2, G3) for our analyses. Although this enriches our analysis, it also increases the chance of missing data, including that arising through attrition. Of the 919 potential female G2s available in 2002–04, 628 (68 percent) had at least one live birth, as well as all the data necessary to be included in our analyses. The necessary data included information on schooling and fertility (from the 2002–04 data collection), data on cognitive functioning during late adolescence and late adolescent height (representing long-run nutritional status, our key indicator of G2 biological human capital) from information collected during either the 1988 or 2002–04 data collections, depending on age. As might be expected, these criteria for inclusion of G2s and G3s into our analysis reduced our sample size.

The high rates of attrition (in the broad sense of the necessary exclusion of individuals lacking all data needed for a given analysis) not only reduce our sample sizes, but may also be non-random. This is especially relevant when we consider that the mothers included in our analyses were generally non-migrant, in that they were present in the four communities during the intervention and in the 1990s, and were accessible (though not necessarily in the communities) in 2002–04. We compute attrition weights using methods parallel to those in Fitzgerald *et al*. (1998), and use them in subsequent analyses. [12] These weights are larger

12 The attrition probits can be found in Behrman *et al*. (2009b), Appendix Tables A1-A3.

for individuals for whom attrition is more likely, thus rebalancing the sample that we use for our estimates to approximate better the distributions in the original sample. All regression results presented herein thus include corrections for attrition. Similar to Behrman *et al*. (2008, 2009a), Hoddinott *et al*. (2008) and Maluccio *et al*. (2009), we do not find large impacts of attrition on the estimated coefficients. (The estimates from analyses that do not correct for attrition are available upon request.) Finally, a number of these G3s are siblings or half-siblings, so we control for mother-cluster effects in the estimation of the standard errors that are reported in Tables 3 and 4, below.

3.2 Central variables for the analysis

Table 1 presents the means and standard deviations (SD) for the G3 human capital outcome variables, as well as the percentage of the variance in outcomes that is due to village effects. We are interested in the relative importance of village vs. individual or household-level effects, because the larger are village effects in proportion to individual or household-level effects, the less likely we are to estimate individual effects of maternal human capital on children's human capital. Village effects account for a very small proportion of the variance across the different outcomes (ranging from 0.1 percent for schooling attainment to 3.7 percent for length-for-age); this suggests that most of the variance in children's outcomes is due to individual and household variability. To obtain the greatest precision in our estimates, we use all available observations for each estimate, though these vary across outcomes due to different data sources and missing information on particular variables of interest. Table 2 presents the means and SDs for the explanatory variables and instruments. Below, we briefly define the dependent variables (G3 outcomes), right side endogenous variables, right side G3 observed individual characteristics, initial conditions and observed shocks that help identify IV estimates.

3.2.1 Dependent variables: child (G3) outcomes (Y)

3.2.1.1 *Child (G3) intellectual human capital (Y)*

Schooling of children by 2002–04: difference in the grade of schooling completed by each child from the age-cohort mean, for all G3s over age seven years, taken from the 1996 and 2002–04 censuses. This indicator measures how well a child is doing relative to other children of the same age. Given the construction, the means are not significantly different from zero. However, the SD of 2.6 indicates substantial variation.[13]

---

13 We explored the possibility of including cognitive scores (Bayley's test scores) for children less than three years of age in the 1996–09 data collection. Perhaps because of limited precision resulting from the relatively small number of G3s for which this exploration was possible, the coefficient estimates for the G2 human capital components, while positive, were not statistically significant. We therefore do not include this G3 outcome measure in the present analysis.

3.2.1.2 *Child (G3) biological human capital (Y)*

Anthropometry at birth: birth weight in kilogrammes and length in centimetres, collected during 1991–99. The mean birth weight of G3s in this study is 3.0kg, which is above the standard cutoff of 2.5kg for low birth weight. However, birth weight varies considerably, and 13 percent of the birth weights are below 2.5kg. The mean birth length is 48.2cm, with a standard deviation of 2.1cm.

Nutritional status at 36 months: length-for-age (LAZ), weight-for-age (WAZ), and weight-for-length (WLZ) Z-scores from the 1996–99 data collection.[14] These scores indicate that the study population is (not surprisingly) malnourished relative to the reference population. This is particularly evident with regard to stunting (LAZ < 2.0 SD below the reference median), which is generally considered an indicator of the long-run impact of early childhood nutrition[15] on subsequent development (e.g., Victora *et al.*, 2008). Indeed, 43 percent of the children have LAZ values below -2.0.

3.2.2 ***Right-hand side endogenous variables***

3.2.2.1 *Mother's (G2) intellectual capital at or before first parenting (K)*

In addition to mothers' schooling attainment, which is the standard measure used in the literature, we use maternal cognitive skills as an alternative measure. We argue that this measure better represents mothers' knowledge, because it is affected by endowments and experiences before and after schooling, in addition to schooling itself (see Behrman *et al.*, 2008).

G2 schooling attainment: completed grades of schooling, as measured in 2002–04. The average grade completed for women included in our analyses is about 3.7 (SD 2.8) for the subsamples divided by different child outcomes. Schooling attainment, thus, was low for the G2s considered herein.

G2 *cognitive skills:* weighted average of percentile scores on the vocabulary and reading-comprehension modules of the Inter-American Reading and Comprehension Tests (IARC; see Manuel, 1967) and of nonverbal skills (Raven's Progressive Matrices; see Raven *et al.*,

---

14 Z-scores give the number of standard deviations from the median of the distribution for a reference population (we use the NCHS-CDC standards; see http://www.cdc.gov/GROWTHCHARTS/ [accessed 14 January 2010]). Not all G3s were measured at exactly 36 months. Z-scores were regressed on dummy variables for age at time of measurement for all children to obtain age-paths for the Z-scores. For children who were not measured exactly at 36 months, these estimates were used to interpolate to 36 months from the measurement nearest to 36 months.

15 Nutritional status, in turn, is thought to reflect the combined impacts of nutrients consumed, disease history and stimulation.

1984),[16] which are taken from test results obtained in 1988–09 and 2002–04 and represent maternal cognitive skills at or before first parenting. The weights are determined using coefficients on maternal IARC and Raven's scores from IV regressions in which both are included on the right side (along with maternal height) and treated as behaviourally determined. The weights imply that G2 reading-comprehension scores are the dominant indicator of mothers' cognitive skills for G3 schooling attainment (with a weight of 0.90) and for the Z-scores for weight-for-age at 36 months (0.80 for WAZ, 1.00 for WLZ). On the other hand, G2 nonverbal skills are the dominant indicator of mothers' cognitive skills for G3 anthropometry at birth (0.90 for birth weight, 0.70 for birth length) and for G3 Z-scores for length-for-age at 36 months (0.70 for LAZ). (Appendix A of Behrman *et al.* (2009b) gives more details about the construction of this variable.)

3.2.2.2 *Mother's (G2) biological capital stocks at or before first parenting (K)*

G2 long-run nutritional status: height (cm) at age 18, which is the age by which most females have attained their adult height.[17] The mean height is about 150 cm (SD 5.3), reflecting that this population is fairly short, apparently resulting from poor nutrition, particularly in early life (Schroeder *et al.*, 1995).

3.2.3 Right-side child (G3) observed individual characteristics (I)

Gender: male = 1.

Twin: whether the G3 is a twin, which may have long-run implications associated with the generally lower birth weight of twins, as well as their higher probability of prematurity (e.g., Behrman and Rosenzweig, 2004). For this population, twins are generally natural rather than the result of assisted reproductive technologies, as is relatively frequent in recent decades in higher-income populations.

3.2.4 Initial conditions (F_0, C_0, I_0) that help identify IV estimates

Grandparent (G1) characteristics and family background (F_0): G1 schooling attainments, as well as a constructed socioeconomic status score that is the first principal component of both the assets owned and the housing characteristics of the G1 households in 1975 (Maluccio *et*

16 Raven's Progressive Matrices are a common nonverbal measure of interpretative cognitive skills, whereby the respondent is given a set of shapes and patterns and asked to supply the missing piece.

17 We use a combination of the 1988 and 2002–04 data to construct this variable, taking the 1988 measure for those who were older than 18 in 1988, and the 2002–04 measures for those who were aged 11–18 years in 1988. We also use the 2002–04 measure of height for those who were older than 18 in 1988 but who were not measured at that time. About a quarter (24 percent) of women had their first live birth before age 18. While it is possible that having a pregnancy before the age at which adult height is achieved could affect achieved height, in the absence of information on height at the age of first birth, we use height at about age 18 as our measure of achieved height.

al., 2005), and a dummy variable for whether either G1 parent died before G2 was age 15 years.

Fixed community characteristics during G2's childhood (C_0): village-fixed effects to control for permanent community differences in learning and health/nutrition environments, in part because of different experiences of prior generations regarding schooling and occupational structure (Bergeron, 1992; Maluccio *et al*., 2005).

Fixed individual mother (G2) characteristics (I_0): birth year and whether the mother (G2) is a twin.

3.2.5 Observed shocks and events (ΔC) that identify IV estimates

Natural, market or policy events (ΔC): community-level time-varying variables that relate as closely as possible to the timing of key decisions in mothers' (G2s') human capital development.[18] For example, using information reported in earlier studies on infrastructure, markets and services in the four villages (Pivaral, 1972; Bergeron, 1992), along with data from a retrospective study performed in 2002 (Estudio 1360, 2002), we construct variables such as the student–teacher ratios and number of grades available (proxies for school quality) in the mothers' (G2s') villages when they were most likely to start their schooling (age seven years), as well as work in local markets when the G2s were most likely making the decision to continue schooling or join the work force (age 15 years). The variable reflecting work availability in local markets (good local job market when G2 was age 15) is equal to one if a 'boom' was occurring in any local market, such as increased *yuquilla* production in San Juan, vegetable cooperatives in Conacaste, or intensive hiring of community members at a cement factory near Conacaste and Santo Domingo (for a detailed description of the local markets, see Maluccio *et al.*, 2005). Thus, while reflecting community-level characteristics, these variables vary by single-year age cohorts within each village, as well as across villages. Because these measures more closely relate the availability and longevity of schools and markets to the periods in a woman's life when critical decisions are made (e.g., attending school, initiating working in the labour market), the use of these age-specific community data is an improvement over the more typical approach of including indicators about such factors in a given year for a population of various ages.

Experimental nutritional shocks (ΔC): whether the mother (G2) was in a birth cohort exposed to the nutritional interventions underlying the original data collection (see Section 3.1) when

18 Recent surveys of education in developing countries include references to a number of studies that provide evidence on the importance of school infrastructure and school quality and some studies that provide evidence of the importance of labour markets (Behrman, 2009; Glewwe and Kremer, 2007; Orazem *et al*., 2007). The health and nutritional literature has long stressed the importance of infectious diseases, which in turn reflect the community disease environment, water and sanitation systems, and the health sector infrastructure, in addition to family factors (Martorell, 1997; Strauss and Thomas, 1998).

she was zero to 36 months of age and, if so, whether she was in an *Atole* village. These two measures of intervention exposure, which are both included in the first-stage estimates, are based on the birth year of the G2, the dates of operation of the interventions, and where the G2 lived as a child. Thus, although the experiment was conducted at the village level, not the individual level, this measure includes substantial exogenous variation across individuals, in terms of whether they were exposed during the critical first three years of life.[19]

19 The importance of nutrition in the first three years of life in developing country populations generally is emphasised in Victoria *et al*. (2008), as well as in a number of studies of the population considered in this study (e.g., Hoddinott *et al*., 2008; Maluccio *et al*., 2009; Martorell *et al*., 1995).

4 Results

We summarise the results in this section, focusing first on child outcomes at three time points – birth, 36 months and school age – namely, birth weight, length-for-age z-score at 36 months, and grades of schooling deviation from the age-cohort mean. In Figures 2 to 4, we compare OLS estimates wherein mothers' human capital is represented only by their schooling attainment, as is common in many studies with IV estimates that control for the behavioural determination of schooling. We also report both OLS and IV estimates in regressions on both maternal schooling and height. The IV estimates control for the endogeneity of and random measurement error in biological maternal capital (mothers' height). In this first set of results, we present graphs comparing the magnitude of OLS and IV coefficients on maternal schooling and height.

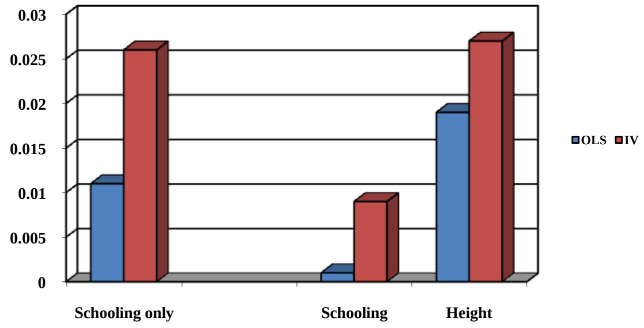
We then present results using cognitive skills as the representation of maternal intellectual capital if it is more consistent than maternal schooling attainment with regard to the variance in the children's outcome. We use the term 'preferred estimates' to refer to the specification with the representation of maternal human capital that is most consistent with the variance in the dependent variable. In describing these estimates, we use 'significant' to refer to significance at the standard 0.05 level, unless we explicitly indicate the 0.10 level. In the second set of results using cognitive skills, we use 'effect sizes' as in the biomedical literature (e.g., Engle *et al.*, 2007; Victora *et al.*, 2008) to facilitate comparison across G2-G3 human capital indicator combinations of the estimated relative effectiveness (or associations) of alternative G2 human capital measures on G3 human capital. The effect size is defined as the number of sample standard deviations in the G3 human capital variables that would be induced to change (or are associated with, in the OLS case) with a 1.0-SD change in the G2 human capital variable.

4.1 Impact of schooling and height on child outcomes

4.1.1 Anthropometry at birth

Figure 2 presents coefficient estimates from OLS and IV regressions on birth weight, first with maternal schooling only (left side of Figure 2) and with both maternal schooling and maternal height (right side of Figure 2). Results for OLS regressions on schooling only are found in Table 3. Maternal schooling is not a significant determinant of birth weight in both OLS and IV estimates, whereas maternal height is significant in both OLS and IV estimates. In all cases, the OLS coefficients are smaller than the IV estimates, suggesting that OLS estimates (those that do not take into account the behavioural determination of maternal human capital and do not control for random measurement error) tend to underestimate their impacts on child schooling.

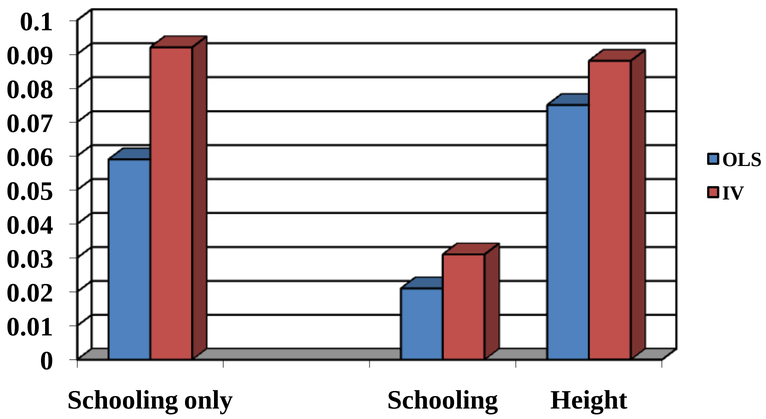
Figure 2. Impact of maternal schooling and height on birthweight,
coefficients from OLS and IV regressions



4.1.2 Anthropometry at 36 months

We estimated regressions on length-for-age z-scores (LAZ), weight-for-age z-scores (WAZ), and weight-for-height z-scores (WHZ) at 36 months, first with maternal schooling only, and then with both maternal schooling and maternal height. Coefficient estimates from OLS and IV regressions on length-for-age z-scores (LAZ) at 36 months are presented in Figure 3, with estimates with maternal schooling only on the left side of the figure, and those with both maternal schooling and maternal height on the right.[20] Similar to the results for birth weight, OLS estimates are smaller in magnitude than the IV estimates. However, maternal schooling is significant only when it enters without maternal height; when maternal height is included as an indicator of maternal human capital, maternal schooling loses its significance. In contrast, maternal height – our measure of maternal biological human capital – is significant in both OLS and IV specifications.

Figure 3. Impact of maternal schooling and height on length for age z-scores (LAZ) at 36 months, coefficients from OLS and IV regressions

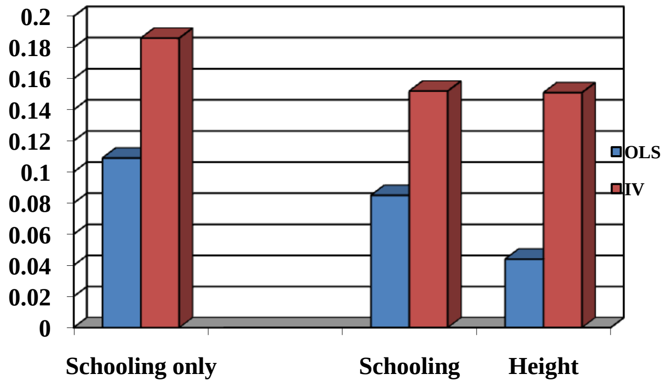


20 Results for WAZ and WHZ are found in Behrman *et al*. (2009b), Tables 3 and 4.

4.1.3 *Child schooling deviation from cohort mean*

Finally, our school-age outcome is the deviation of the child's completed grades of schooling from the cohort mean. In contrast to the earlier measures of child biological human capital, maternal schooling is significant, even when maternal height is included as a regressor. Both maternal schooling and maternal height are significant at one percent in the OLS specification.

Figure 4. Impact of maternal schooling and height on child schooling deviation from age cohort mean, coefficients from OLS and IV regressions



4.1.4 *Preliminary conclusions with maternal schooling and maternal height only*

These preliminary explorations suggest that using maternal schooling as the only measure of mother's human capital tends to overestimate the impact of maternal schooling. Including maternal height, our measure of biological human capital, decreases coefficient estimates on maternal schooling. OLS estimates that do not take into account the behavioural determination of maternal height and random measurement error also tend to underestimate their impact – IV estimates of maternal height are larger than the OLS estimates. Finally, the magnitude and significance of the coefficients on maternal height in the birth weight and LAZ regressions suggest that maternal biological capital (height) may be more important than maternal schooling in determining child health and anthropometric outcomes. Maternal schooling, however, is an important determinant of child schooling outcomes.

4.2 Impact of maternal cognitive skills and maternal height on child outcomes

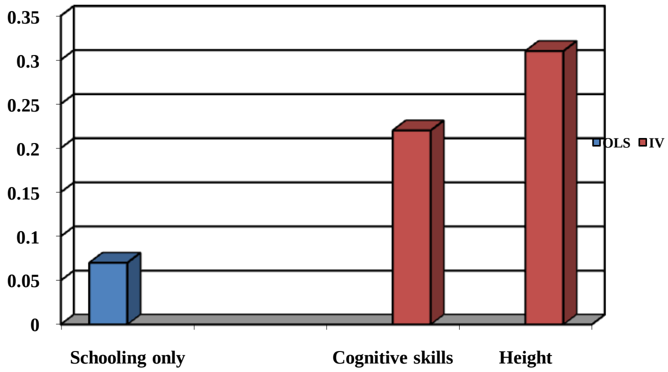
As discussed in the introduction, maternal schooling is an imperfect measure of mother's cognitive skills because it does not capture variations in schooling quality as well as the out-of-school experiences from which women learn throughout their lives. Fortunately, we have rich data on cognitive skills, consisting of reading scores, math scores, and Raven's progressive matrices tests.

The index of cognitive skills that we use in this paper is based on reading scores and Raven's scores for ages prior to, or at the age of first birth (details on the construction of this variable are found in Behrman *et al.*, 2009b). We do not use math scores in our index of maternal cognitive skills because they were not assessed in 2002–04; consequently, we cannot use the same methods of imputation for missing variables as we did for the other two measures. In order to visualise the relative impact of increasing maternal human capital by one standard deviation, Figures 5 to 8 present effect sizes. In addition, Figures 5 to 8 contrast the 'standard' OLS results for maternal schooling (Table 3) only with our 'preferred' estimates in which we use the representation of maternal human capital that is most consistent with the variance in the dependent variable (Table 4).

4.2.1 *Anthropometry at birth*

Figure 5 presents the impact of a one SD increase in various measures of maternal human capital on birth weight. Standard OLS estimates suggest that a one SD increase in maternal schooling will increase birth weight by 0.07 SD; however, this increase is not significant (Table 3). IV estimates suggest a much bigger, and significant, impact of maternal height and maternal cognitive skills (Table 4). A one SD increase in maternal height increases birth weight by 0.31 SD (significant at one percent), and a one SD increase in maternal cognitive skills increases birth weight by 0.22 SD (also significant at one percent). The standard OLS estimates, however, indicate that maternal schooling has no significant impact, even at the 0.10 level, on either birth weight or birth length. IV estimates indicate less impact on birth length: a one SD in maternal cognitive skills increases birth length by 0.19 SD; this is only weakly significant at ten percent, and maternal height does not have a significant effect (Table 4).

Figure 5. Change in birthweight from one standard deviation increase in mother's human capital (in SDs), effect sizes from OLS and IV regressions



4.2.2 Anthropometry at 36 months

Figures 6 and 7 present OLS and 'preferred' estimates of the impact of maternal human capital on length-for-age z-scores (LAZ) and weight-for-age z scores (WAZ). The effect size of maternal schooling from the 'standard' OLS estimate is 0.17 for LAZ and 0.10 for WAZ; these are significant at one percent and ten percent, respectively (Table 3). In contrast, in the preferred estimates, maternal schooling is not significant for LAZ, but maternal cognitive skills are significant for WAZ (at one percent) with an effect size of 0.27 (Table 4). Maternal cognitive skills are also significant for weight-for-length (WLZ), with an effect size of 0.20. That is, a one SD increase in maternal cognitive skills will increase LAZ by 0.27 SD and WLZ by 0.20 SD. Maternal height is significant only in the LAZ regression, with a relatively large effect size of 0.46. That is, a one SD increase in maternal height increases LAZ by almost half a standard deviation.

Figure 6. Change in length for age z-scores at 36 months from one standard deviation increase in mother's human capital (in SDs), effect sizes from OLS and IV regressions

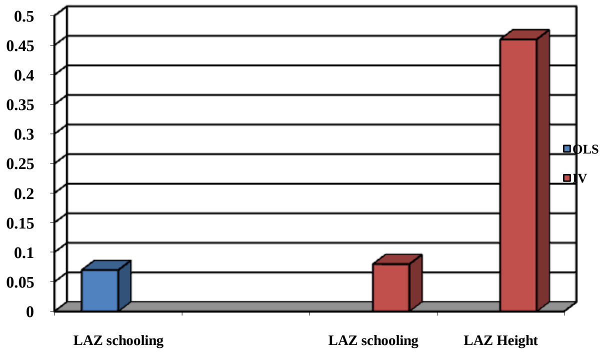
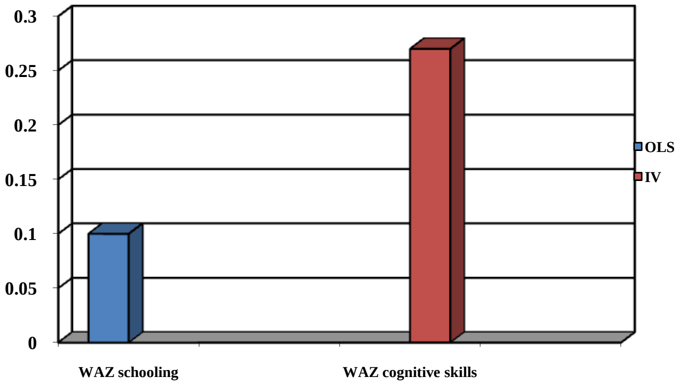
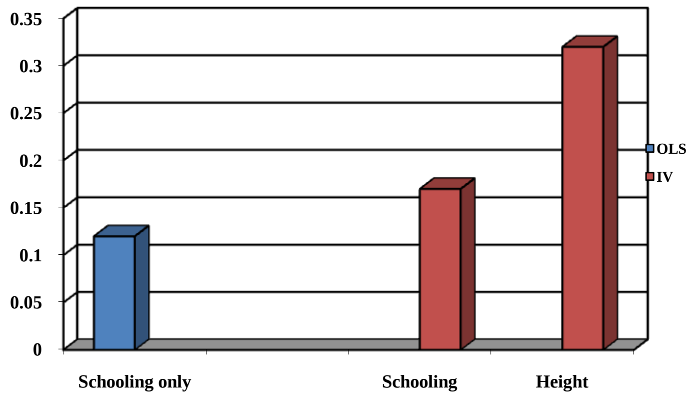


Figure 7. Change in weight for age z-scores at 36 months from one standard deviation increase in mother's human capital (in SDs), effect sizes from OLS and IV regressions



Child schooling deviation from cohort mean. Finally, we present effect sizes for the child schooling deviation from his or her cohort mean (Figure 8). Maternal schooling is the preferred measure of mother's intellectual capital; a one SD in mother's grades of completed schooling increases the child schooling deviation by 0.12 SD in the OLS estimates (Table 3) and by 0.17 SD in the IV estimates. These estimates are significant at one percent and five percent in the OLS and IV estimates, respectively. Maternal height is also an important determinant of how well a child does in school; a one SD increase in maternal height increases the child schooling deviation by 0.32 SD. This is significant at one percent.

Figure 8. Change in child's schooling deviation from cohort mean from one standard deviation increase in mother's human capital (in SDs), effect sizes from OLS and IV regressions



4.2.3 Summary of results from 'preferred' estimates

These estimates (discussed in detail in Behrman *et al*., 2009b) indicate that G2 maternal human capital has significant impacts on all of our indicators of the children's (G3s') intellectual and biological human capital (though significant only at the 0.10 level for children's birth length). With the exception of the impact on LAZ at 36 months, the effect sizes for the G2 intellectual human capital in our IV estimates, which range from 0.17 to 0.27, are larger than those in the OLS estimates. The preferred indicator of G2 intellectual human capital is maternal schooling for children's schooling and LAZ (though not significant even at the 0.10 level in the latter case). However, maternal cognitive skills are preferred for the other four indicators of children's human capital. G2 biological human capital has significant effects on three G3 human capital outcomes, namely schooling attainment relative to cohort means, birth weight and LAZ. The effect sizes of G2 biological human capital in these cases are 0.31 to 0.46, which are larger than the effect sizes of G2 intellectual human capital for each of these three G3 human capital outcomes.

In short, compared with the OLS estimates, our IV estimates show that: (1) maternal human capital has larger estimated coefficients; (2) maternal cognitive skills tend to be more predictive than maternal schooling attainment when examining children's biological human capital; and (3) maternal biological capital is significant and has larger effect sizes than maternal intellectual capital for half of the G3 outcomes.

5 Discussion and conclusions

Most previous estimates of the impacts of maternal human capital on children's human capital are OLS estimates for the effects of maternal schooling attainment on children's schooling or, less commonly, children's nutrition as measured by anthropometric indicators. In this paper, we use unusually rich longitudinal data collected over 35 years in rural Guatemala to explore five limitations of these 'standard' estimates. In the following, we first summarise what is suggested by our estimates regarding these five limitations in the literature, and then we summarise the substantive implications of our estimates.

5.1 Implications of dealing with the five limitations affecting previous literature

First, most of the previous literature considers only mothers' intellectual human capital. We consider the impact on children's outcomes of not only mothers' intellectual human capital, but also mothers' biological human capital (in the form of maternal height, a measure of long-run nutritional status). We find that mothers' biological capital is a significant factor in three of the IV estimates; indeed, these three indicators of child human capital – schooling attainment, birth weight and length-for-age at age three – are probably are the most-emphasised children's human capital development indicators among the six considered herein. In these three cases, the estimated effect sizes are larger for maternal biological human capital than for maternal intellectual capital (Table 5, Panel 4). Moreover, if maternal height is not included in the regressions, the coefficient of maternal intellectual capital is overestimated by 18 percent to 66 percent (Table 5, Panel 1), because maternal intellectual capital is proxying in part for maternal biological capital, as discussed as a possibility in the model presented in Section 2.

Second, most of the previous literature represents mothers' intellectual human capital only by schooling attainment. Here, we examine both schooling attainment and maternal cognitive skills as measures of maternal intellectual human capital. We find that maternal cognitive skills are more consistent with the sample variation in four of the five indicators of children's biological human capital examined herein; where maternal intellectual human capital is significant, child schooling attainment relative to peers from the same birth cohort was the sole indicator more consistent with maternal schooling. We also find (with the sole exception of LAZ at 36 months, for which neither of our maternal intellectual human capital indicators is significant) that the estimated effects sizes are, if anything, larger for maternal cognitive skills than for maternal schooling attainment (Table 5, Panel 2). This suggests that schooling is a limited proxy for 'what mothers know'.

Third and fourth, most of the previous literature considers mothers' human capital to be taken as given, and to be accurately measured. Here, we treat all measures of mothers' human capital as behaviourally determined and measured with random errors. When IV methods are employed to control for these two possibilities, the estimated impacts of the indicators of women's human capital are systematically higher (from 15 percent to 86 percent) than those based on OLS methods (Table 5, Panel 3). Not taking into account the behavioural determination of and measurement error in maternal human capital underestimates the potential impact of investing in women's human capital for the next generation.

Fifth, among our child (G3) outcomes, we consider indicators of both children's intellectual human capital and children's biological human capital in order to examine variation in the effects of different types of maternal human capital on child human capital development. The estimates suggest variation among the children's outcomes; only maternal intellectual human capital is significant for birth length, WAZ and WLZ; only maternal biological human capital is significant for LAZ; and both maternal intellectual and biological human capital are significant for the two most emphasised indicators of children's human capital in the literature, namely schooling attainment and birth weight (Table 5, Panel 4). Due to such variation in the importance of different types of maternal human capital across the children's outcomes, generalisations made from the impacts on only one or two children's outcomes are likely to be misleading. However, our results do not reveal a pattern suggesting that for the children's intellectual (biological) human capital outcomes, maternal intellectual (biological) human capital dominates.

There are, however, some patterns with regard to which of the two indicators of G2 intellectual human capital is most predictive of different G3 outcomes. Only for children's schooling attainment is maternal schooling attainment more predictive; in all of the other cases in which maternal intellectual human capital is significant, maternal cognitive skills are more predictive of the children's outcomes than is maternal schooling attainment. This finding suggests that for most children's outcomes, maternal cognitive skills may better capture maternal intellectual human capital, whereas maternal schooling attainment is more predictive for children's schooling, perhaps because it relates more directly to this specific investment in children. Better-schooled mothers, for example, may be more cognizant of school requirements, such as attendance and homework. Finally, there is also some variance in the weights of reading comprehension versus nonverbal skills when examining the children's outcomes for which maternal cognitive skills appear to be the preferred representation of maternal intellectual human capital. For example, maternal reading comprehension dominates for the children's weight-related measures at 36 months (WAZ, WLZ), but nonverbal skills dominate for birth anthropometry and LAZ at 36 months. These findings are consistent with recent work on the same study population showing that maternal schooling and acquired cognitive skills are associated with better hygiene practices (Webb *et al*., 2008a) and better maternal care during episodes of diarrhoea (Webb *et al.*, 2008b). Thus, it appears that the most relevant maternal human capital indicators vary across children's human capital outcomes.

Future research on maternal–children human capital links would benefit from the adoption of strategies aimed at dealing with the five noted limitations of the previous literature, thereby moving beyond the standard methodology for understanding these relationships. Our doing so has importantly affected our understanding of impacts of mothers' human capital on children's human capital in the studied context.

5.2 Policy implications of the estimates of the impacts of maternal human capital on children's human capital

Our preferred IV estimates, which included multiple dimensions of maternal and child human capital, suggest that: (1) maternal human capital is more important than suggested by the OLS estimates; (2) maternal cognitive skills tend to be more predictive than does maternal schooling attainment for many child outcomes; and (3) for some important child human capital indicators [e.g., children's schooling attainment, birth weight and length-for-age (LAZ) at age 36 months] maternal biological capital is significant and has larger effect sizes than maternal intellectual capital.

Thus, our results suggest that the intergenerational links between maternal and child's human capital are stronger and more multi-dimensional than typically thought on the basis of standard estimates. This strengthens the case for investing in women's human capital, particularly its biological component, through nutrition and health interventions. This conclusion also implies that there will be a greater challenge in breaking the intergenerational transmission of poverty, malnutrition and intellectual deprivations, not only because of the strength and multidimensionality of the estimated maternal–child human capital effects, but also because effective interventions to improve women's biological and intellectual human capital often begin *in utero* or in early childhood, and thus will require a longer period before the returns in the investment are realised (compared to the case if more schooling were the only channel).[21]

Nevertheless, in comparison with estimates calculated using the approaches dominant in the previous literature, our results support a stronger argument for improving women's human capital in terms of impacts on the human capital of the next generation. In particular, our estimated effects are 15–86 percent larger in our preferred IV estimates compared to our OLS estimates. It is important to note, however, that such support should recognise that women's human capital has both biological and intellectual components, and that the intellectual components reflect not just school attendance, but also the quality of schooling and the nature of pre- and post-schooling experiences. The importance of post-schooling

21 Though some assume that schooling is the only determinant of cognitive skills, estimates of cognitive skill production functions for this same sample with pre-school-age and post-school-age experiences included along with schooling, and with all these experience treated as endogenous, find that both pre- and post-school-age experiences are quite important relative to schooling (Behrman *et al*., 2008).

experience suggests that opportunities to invest in human capital exist at different stages of the life cycle. Adopting a life-cycle framework helps highlight different opportunities for investment in human capital, as well as different vulnerabilities. Public policies should therefore ensure that the appropriate investments are made at each stage, and that these are pro-poor.

References

Behrman, J. R. (2009). 'Investment in education – inputs and incentives'. In D. Rodrik and M. R. Rosenzweig (eds.), *Handbook of Development Economics: The Economics of Development Policy,* Vol. 5. Amsterdam: North-Holland Publishing Co.

Behrman, J. R., Calderon, M. C., Preston, S., Hoddinott, J., Martorell, R. and Stein, A. D. (2009a). 'Nutritional supplementation of girls influences the growth of their children: prospective study in Guatemala'. Mimeo. Philadelphia, PA: University of Pennsylvania.

Behrman, J. R., Hoddinott, J., Maluccio, J. A. and Martorell, R. (2005). 'Does it pay to become taller? Or is what you know all that really matters?' Mimeo. Philadelphia, PA: University of Pennsylvania.

Behrman, J. R., Hoddinott, J., Maluccio, J. A., Soler-Hampejsek, E., Behrman, E. L., Martorell, R., Ramirez, M. and Stein, A. D. (2008). 'What determines adult skills? Impacts of pre-school, school-years and post-school experiences in Guatemala'. Mimeo. Philadelphia, PA: University of Pennsylvania.

Behrman, J. R., Murphy, A., Quisumbing, A. and Yount, K. (2009b). 'Are returns to mother's human capital realized in the next generation? The impact of mothers' intellectual human capital and long-run nutritional status on children's human capital in Guatemala'. IFPRI Discussion Paper 850. Washington, DC: International Food Policy Research Institute.

Behrman, J.R. and Rosenzweig, M. R. (2002). 'Does increasing women's schooling raise the schooling of the next generation?' *American Economic Review,* 92 (1), 323–34.

Behrman, J. R. and Rosenzweig, M. R. (2004). 'Returns to birthweight'. *Review of Economics and Statistics,* 86 (2), 586–601.

Behrman, J. R. and Rosenzweig, M. R. (2005). 'Does increasing women's schooling raise the schooling of the next generation? – Reply'. *American Economic Review,* 95 (5), 1745–51.

Behrman, J. R., Rosenzweig, M. R. and Taubman, P. (1996). 'College choice and wages: estimates using data on female twins'. *Review of Economics and Statistics,* 73 (4), 672–85.

Behrman, J. R. and Wolfe, B. L. (1987a). 'How does mother's schooling affect the family's health, nutrition, medical care usage, and household sanitation?'. *Journal of Econometrics,* 36, 185–204.

Behrman, J. R. and Wolfe, B. L. (1987b). 'Investments in schooling in two generations in pre-revolutionary Nicaragua: the roles of family background and school supply'. *Journal of Development Economics,* 27 (1–2), 395–420 [reprinted in P. Bardhan, J. R. Behrman and A. Fishlow (eds.), *International Trade, Investment, Macro Policies and History: Essays in Memory of Carlos F. Diaz-Alejandro.* Amsterdam: North-Holland.

Bergeron, G. (1992). 'Social and economic development in four latino communities of Eastern Guatemala: a comparative description'. *Food and Nutrition Bulletin,* 14 (3), 221–36.

Black, S. E., Devereux, P. J. and Salvanes, K. G. (2005). 'Why the apple doesn't fall far: understanding intergenerational transmission of human capital'. *American Economic Review,* 95 (1), 437–49.

Brooks-Gunn, J., Klebanov, P. K. and Duncan, G. J. (1996). 'Ethnic differences in child's intelligence test scores: role of economic deprivation, home environment, and maternal characteristics'. *Child Development,* 67, 396–408.

Carneiro, P., Meghir, C. and Parey, M. (2007). 'Maternal education, home environments and the development of children and adolescents'. London: Institute for Fiscal Studies WP15/07.

Cleland, J. and Van Ginneken, J.K. (1988). 'Maternal education and child survival in developing countries: the search for pathways of influence'. *Social Science and Medicine,* 27, 1357–68.

Engle, P. L., Black, M. M., Behrman, J. R., Mello, M. C. de, Gertler, P. J., Kapiriri, L., Martorell, R. and Young, M. E., Lancet Child Development Series Steering Committee (2007). 'Strategies to avoid the loss of potential among 240 million children in the developing world'. *Lancet,* 369, 229–42.

Estudio 1360 (2002). *Changes in the Socioeconomic and Cultural Conditions that Affect the Formation of Human Capital and Economic Productivity.* Final report presented to INCAP, 13 May.

Fitzgerald, J., Gottschalk, P. and Moffitt, R. (1998). 'An analysis of sample attrition in panel data'. *The Journal of Human Resources,* 33 (2), 251–99.

Ghuman, S., Behrman, J. Borja, J. B., Gultiano, S. and. King, E. M. (2005). 'Family background, service providers, and early childhood development in the Philippines: proxies and interactions'. *Economic Development and Cultural Change,* 54 (1), 129–64.

Glewwe, P. and Kremer, M. (2007). 'Schools, teachers, and education outcomes in developing countries'. In: E. A. Hanushek and F. Welch (eds.), *Handbook of the Economics of Education*. Amsterdam: North-Holland.

Grajeda, R., Behrman, J. R., Flores, R., Maluccio, J. A., Martorell, R. and Stein, A. D. (2005). 'The human capital study 2002–04: tracking, data collection, coverage, and attrition'. *Food and Nutrition Bulletin* 26 (2) (Supplement 1), S15–S24.

Hoddinott, J., Maluccio, J. A., Behrman, J. R., Flores, R. and Martorell, R. (2008). 'The impact of nutrition during early childhood on income, hours worked, and wages of Guatemalan adults'. *Lancet,* 371, 411–16.

Islam, M. and Hoddinott, J. (2008). 'Evidence of intra-household flypaper effects from a nutrition intervention in rural Guatemala'. *Economic Development and Cultural Change,* 57 (2), 215–38.

Maluccio, J. A., Hoddinott, J., Behrman, J. R., Quisumbing, A., Martorell, R. and Stein, A. D. (2009). 'The impact of nutrition during early childhood on education among Guatemalan adults'. *Economic Journal,* 119(537), 734-63.

Maluccio, J. A., Melgar, P., Méndez, H., Murphy, A. and Yount, K. M. (2005). 'Social and economic development and change in four Guatemalan villages: demographics, schooling, occupation, and assets'. *Food and Nutrition Bulletin* 26 (2) (Supplement 1), S25–S45.

Maluccio, J. A., Murphy, A. and Yount, K. M. (2005). 'Research note: a socioeconomic index for the INCAP longitudinal study 1969–-77'. *Food and Nutrition Bulletin,* 26 (2) (Supplement 1), S120–S124.

Manuel, H. T. (1967). *Technical Reports, Tests of General Ability and Tests of Reading, Interamerican Series*. San Antonio, TX: Guidance Testing Associates.

Martorell, R. (1997). 'Undernutrition during pregnancy and early childhood and its consequences for cognitive and behavioral development'. In M.E. Young (ed.), *Early Child Development: Investing in Our Children's Future.* Amsterdam, The Netherlands: Elsevier.

Martorell, R., Behrman, J. R., Flores, R. and Stein, A. D. (2005). 'Rationale for a follow-up focusing on economic productivity'. *Food and Nutrition Bulletin,* 26(2) (Supplement 1), S5–S14.

Martorell, R., Habicht, J.-P. and Rivera, J. A. (1995). 'History and design of the INCAP longitudinal study (1969–77) and its follow up (1988–89)'. *Journal of Nutrition,* 125 (4S), 1027S–1041S.

Orazem, P. F., King, E. M. and Duryea, S. (2007). 'Schooling in developing countries: the roles of supply, demand and government policy'. In T. P. Schultz (ed.), *Handbook of Development Economics*, *5*. Amsterdam: North Holland.

Pivaral, V.M. (1972). *Características Económicas y Socioculturales de Cuatro Aldeas Ladinas de Guatemala*. Guatemala: Ministerio de Educación Pública, Instituto Indigenista Nacional.

Plug, E. (2004). 'Estimating the effect of mother's schooling on children's schooling using a sample of adoptees'. *American Economic Review,* 94 (1), 358–68.

Plug, E. and Vijverberg, W. P. M. (2003). 'Schooling, family background and adoption: is it nature or nurture?' *Journal of Political Economy,* 111, 611–41.

Quisumbing, A. R., Behrman, J. R., Maluccio, J. A., Murphy, A. and Yount, K. M. (2005). 'Levels, correlates and differences in human, physical, and financial assets brought into marriages by young Guatemalan adults'. *Food and Nutrition Bulletin,* 26 (2) (Supplement 1), S55–S67.

Raven, J. C., Court, J. H. and Raven, J. (1984). *Manual for Raven's Progressive Matrices and Vocabulary Scales. Section 2: Coloured Progressive Matrices*. London: H. K. Lewis.

Stern, N. (2001). 'Investing for growth and poverty reduction: institutions and people'. Speech delivered in Islamabad, Pakistan 29 March as the Senior Vice President and Chief Economist of the World Bank.

Schroeder, D. G., R. Martorell, J. A. Rivera, M. T. Ruel, and J.-P. Habicht. (1995). 'Age differences in the impact of nutritional supplementation on growth'. *Journal of Nutrition,* 125 (4S): 1051S–1059S.

Strauss, J. and Thomas, D. (1998). 'Health, nutrition and economic development'. *Journal of Economic Literature,* 36 (2), 766–817.

Summers, L. H. (1992). 'Investing in all the people'. *Pakistan Development Review,* 31 (4), 367–406.

Summers, L. H. (1994). 'Investing in all the people: educating women in developing countries'. Washington, DC: World Bank, Economic Development Institute Seminar Paper 45.

Victora, C. G., Adair, L., Fall, C., Hallal, P. C., Martorell, R., Richter, L. and Sachdev, H. S. on behalf of the Maternal and Child Undernutrition Study Group (2008). 'Undernutrition 2 – Maternal and child undernutrition: consequences for adult health and human capital'. *The Lancet,* 371(9609): 340-57.

Webb, A., Stein, A. D., Ramakrishnan, U. and Martorell, R. (2008a). 'Schooling and cognitive skills are associated with improved hygiene practices among rural Guatemalan mothers'. Unpublished manuscript. Department of Anthropology, University of Toronto.

Webb, A., Ramakrishnan, U., Stein, A. D., Sellen, D. W. and Martorell, R. (2008b). 'Maternal schooling and cognitive skills are independently associated with improved management of child diarrhea by rural Guatemalan mothers'. Unpublished manuscript. Department of Anthropology, University of Toronto.

World Bank (2001). *Engendering Development: Gender Equality in Rights, Resources, and Voice*. New York: Oxford University Press for the World Bank.

Tables

Table 1. Summary of G3 human capital outcomes

	Mean	SD	% Variance due to village effects	n	Clusters[1]
Child intellectual human capital					
Schooling attainment[2]	0.02	2.64	0.1	1,175	484
Child biological human capital					
Anthropometry at birth					
Birth weight (kg)	2.98	0.46	1.5	576	327
Birth length (cm)	48.24	2.13	0.5	556	320
36-month anthropometric Z-scores					
Length-for-age (LAZ)	-1.79	1.02	3.7	459	296
Weight-for-age (WAZ)	-1.26	1.09	1.8	459	296
Weight-for-length (WLZ)	-0.26	0.96	2.0	459	296

Notes:
[1] *The number of clusters indicates the number of mothers of G3 subjects.*
[2] *Difference in schooling grades completed from age-cohort mean (positive if grades schooled > cohort mean).*

Table 2. Summary of explanatory variables and instruments by G3 human capital outcomes[1]

	G3 Schooling attainment sample		G3 Anthropometry at birth[2] sample		G3 36-month anthropometric Z-scores sample	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Explanatory variables						
G2 Intellectual capital						
Grades of schooling	3.7	2.9	3.6	2.8	3.6	2.8
Cognitive skills[3] (percentiles, %)	50.2	26.5	53.7	25.4	51.4	23.3
G2 Biological human capital						
Height (cm) at age 18	150.3	5.6	150.3	5.3	150.0	5.3
Other controls						
G3 Gender (1=male)	0.51	0.50	0.50	0.50	0.52	0.50
G3 Twin	0.01	0.11	0.01	0.12	0.01	0.10
Instruments						
G2 community characteristics and shocks						
G2 Lived in communities when zero to 36 months of age	0.35	0.48	0.35	0.48	0.37	0.48
G2 Exposed to *Atole* when zero to 36 months of age	0.21	0.41	0.21	0.41	0.21	0.41
G2 Born in San Juan	0.24	0.42	0.17	0.38	0.18	0.38
G2 Born in Conacaste	0.33	0.47	0.36	0.48	0.33	0.47
G2 Born in Espíritu Santo	0.17	0.38	0.19	0.39	0.21	0.41
Student–teacher ratio in community when G2 was age seven	41.6	10.1	40.8	10.3	40.5	10.4
Number of grades available in community when G2 was age seven	5.7	0.6	5.8	0.6	5.8	0.5
Good local job market when G2 was age 15	0.68	0.47	0.69	0.46	0.68	0.47

G2 Family and individual characteristics						
G1 Mothers' schooling	1.1	1.5	1.1	1.5	1.2	1.5
G1 Fathers' schooling[4]			1.6	2.0	1.6	2.0
G1 Household wealth index in 1975	-2.84	0.90	-2.90	0.89	-2.91	0.86
Missing G1 mothers' schooling	0.01	0.12	0.01	0.08	0.01	0.08
Missing G1 fathers' schooling			0.03	0.16	0.03	0.16
Missing G1 household wealth index in 1975	0.15	0.36	0.06	0.25	0.08	0.27
Death of G1 mother or father before G2 reached age 15	0.06	0.25	0.07	0.26	0.07	0.26
Birth year	1,968.4	4.0	1,969.7	4.3	1,970.2	4.2
G2 is a twin	0.02	0.13	0.02	0.13	0.03	0.16

Notes: [1] These summary statistics are at the level of G2 mother (except for G3 gender and twin). Table 1 gives the sample sizes (e.g., n = 1,175 for G3 children and 484 for G2 mothers for G3 schooling, n = 576 (556) for G3 children and 327 (320) for G2 mothers for anthropometry at birth, and n = 459 for G3 children and 296 for G2 mothers for G3 36-month anthropometric Z-scores).

[2] Summary statistics for anthropometry at birth are based on mothers in birth weight regression. Birth length sample is slightly smaller (see note 1).

[3] Cognitive skills are weighted percentiles for reading-comprehension scores and nonverbal scores, with weights for G3 schooling estimates of 0.90 and 0.10; for birth weight estimates of 0.10 and 0.90; for birth length estimates of 0.30 and 0.70; for 36-month LAZ estimates of 0.30 and 0.70; for 36-month WAZ estimates of 0.80 and 0.20; for 36-month WLZ estimates of 1.00 and 0.00. For anthropometry at birth, the mean and SD in the table is for birth weight [those for birth length are 52.2 (22.9)]. For 36-month anthropometric Z scores, the mean (SD) in the table is for LAZ [those for WAZ are 48.4 (24.4) and those for WLZ are 47.2 (27.4)].

[4] Overidentification tests suggest that G1 fathers' schooling should not be included in instruments set for G3 schooling.

Table 3. OLS 'standard' estimates of the impact of G2 maternal human capital (as represented by maternal schooling attainment) on G3 child human capital outcomes[1]

	Coeff	t	Effect size
G3 Child intellectual human capital			
Schooling attainment[2]	0.109	3.45***	0.12
G3 Child biological human capital			
Anthropometry at birth			
Birth weight (kg)	0.011	1.46	0.07
Birth length (cm)	0.046	1.24	0.06
36-month anthropometric Z-scores			
Length-for-age (LAZ)	0.059	2.76***	0.17
Weight-for-age (WAZ)	0.039	1.87*	0.10
Weight-for-length (WLZ)	-0.003	-0.17	-0.01

Notes: [1] Details of full estimates are found in Panel 1 of Tables A4–A6 in Behrman et al. (2009b).
The effect size is the change in number of SDs in the dependent child human capital outcome estimated to occur due to a one-SD increase in maternal human capital.
[2] Difference in schooling grades completed from age-cohort mean (positive if grades schooled > cohort mean).
**** significance at 0.01 level, ** at 0.05 level, * at 0.10 level.*

Table 4. Preferred IV estimates of the impact of G2 human capital on G3 human capital outcomes[1]

	G2 Intellectual human capital				G2 Biological human capital		
	Coeff	t	Effect size	Indicator	Coeff	t	Effect size
G3 Intellectual human capital							
Schooling attainment²	0.152	2.3**	0.17	Schooling	0.151	2.61***	0.32
G3 Biological human capital							
Anthropometry at birth							
Birth weight (kg)	0.004	2.35**	0.22	Cog skills	0.027	2.64***	0.31
Birth length (cm)	0.018	1.92*	0.19	Cog skills			
36-month anthropometric Z-scores							
Length-for-age (LAZ)	0.031	0.79	0.08	Schooling	0.088	3.21***	0.46
Weight-for-age (WAZ)	0.012	2.68***	0.27	Cog skills			
Weight-for-length (WLZ)	0.007	1.98**	0.20	Cog skills			

Notes: 1 Details of full estimates are given in Panel 4 of Tables A4-A6 in Behrman et al. (2009b) except for birth length (shown in Panel 3 of Table A5) and WAZ and WLZ (shown in Panel 3 of Table A6). The effect sizes are the change in number of SDs in the dependent child human capital outcome estimated to occur due to a one-SD increase in the specific maternal human capital indicator
2 Difference in schooling grades completed from age-cohort mean (positive if grades schooled > cohort mean).
**** significance at 0.01 level, ** at 0.05 level, * at 0.10 level.*

Table 5. Summary of the implications of the alternative estimates for the five issues raised in the introduction[1]

Dependent Variables	Panel 1. % change in coefficient estimate of preferred G2 intellectual human capital when G2 biological human capital added to relation and found to be significant	Panel 2. Effect sizes of maternal schooling attainment vs. maternal cognitive skills, preferred G2 human capital indicator in bold		Panel 3. % Change in coefficient estimate of preferred G2 human capital indicator if IV estimation instead of OLS (relative to IV estimate)		Panel 4. Effect sizes of G2 intellectual human capital and biological human capital	
		Schooling attainment	Cognitive skills	Intellectual human capital	Biological human capital	Intellectual human capital	Biological human capital
G3 Intellectual human capital							
Schooling attainment2 (grades)	-18%	0.17	0.20	44%	71%	0.17	0.32
G3 Biological human capital							
Anthropometry at birth							
Birth weight (kg)	-22%	0.06	0.22	46%	30%	0.22	0.31
Birth length (cm)		0.15	0.19	47%		0.19	
36-month anthropometric Z-scores							
Length-for-age (LAZ)	-66%	0.08	-0.11	32%	15%	0.08	0.46
Weight-for-age (WAZ)		0.23	0.27	42%		0.27	
Weight-for-length (WLZ)		0.15	0.20	86%		0.20	

Notes: [1] Panel 1 in this table is based on Panels 3 and 4 in Tables A4–A6 (Behrman et al., 2009b) when Panel 4 gives preferred estimates (the only three cases in which this information is relevant); Panel 2 in this table is based on Tables A4–A6 (Panel 3 for birth length, WAZ and WLZ and otherwise Panel 4); Panel 3 in this table is based on Tables A4–A6 (Panel 3 vs. Panel 1 for birth length, WAZ and WLZ and otherwise Panel 4 vs. Panel 2); Panel 4 in this table is based on Tables A4–A6 (Panel 3 for birth length, WAZ and WLZ and otherwise Panel 4).

[2] G3 difference in schooling grades completed from age-cohort mean (positive if grades schooled > cohort mean)

Chronic Poverty Research Centre

www.chronicpoverty.org

The **Chronic Poverty Research Centre** (CPRC) is an international partnership of universities, research institutes and NGOs, with the central aim of creating knowledge that contributes to both the speed and quality of poverty reduction, and a focus on assisting those who are trapped in poverty, particularly in sub-Saharan Africa and South Asia.

Partners:

Bangladesh Institute of Development Studies (BIDS), Bangladesh

Development Initiatives, UK

Development Research and Training, Uganda

Economic Policy Research Center, Uganda

FIDESPRA, Benin

HelpAge International, UK

Indian Institute of Public Administration, India

IED Afrique, Senegal

Institute of Development Studies, UK

Overseas Development Institute, UK

Programme for Land and Agrarian Studies, South Africa

University of Legon, Ghana

University of Manchester, UK

University of Sussex, UK

Contact:
cprc@manchester.ac.uk