Height and Cognitive Achievement of Vietnamese Children

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Summary

A longitudinal dataset that follows 1,200 Vietnamese children born in 2001–2 is used to investigate the impact of child malnutrition on cognitive development. We demonstrate that the impact of early childhood stunting on cognition can be estimated with significant bias for a majority of children if researchers omit the data on gestational age. The negative impact of the length in preterm on the cognitive achievement of pre-schoolers is statistically significant. Having controlled for the effect of the length in preterm, however, the effect of height-for-age at age one on cognitive achievement at age five is not statistically significant.

Keywords: Preterm, Height-for-age; Cognitive achievement; Instrument variables; Asia; Vietnam

1. INTRODUCTION

Governments and civil society organizations around the world run programs for reducing the incidence of undernutrition among children. The estimations of costs and benefits have always been important in approving these programs. It has become widely believed that the benefits of programs for the reduction of undernutrition include an improvement in the cognitive achievement of the participants. Research suggests that early undernutrition is one of the major factors that can affect brain structure and function, and has lasting cognitive and emotional effects (Grantham-McGregor et al. 2007: 61). According to Glewwe and Miguel, "most of the best recent studies using cross-sectional data, panel data, or data from randomized evaluations have found sizable and statistically significant positive impact of child health on education outcome" (2008: 3602). Studies such as these strengthen the rationale for nutrition interventions targeting the poor section of a population. World Bank (2005), for example, counts the impacts on cognitive development and the education outcomes for the children among the contributions of nutrition programs.

While there is no question about the desirability of nutrition programs in favor of poor children and children of poorly informed parents, there remains much to study on the effectiveness of the interventions. Most of the countries with high rates of child malnutrition are also those with low-income economies, and therefore the resources the government can mobilize to support child development programs are limited. It would make sense to inform policymakers in which stages of a child's development — in utero or else — nutrition interventions would have a greater impact. We are motivated by that question, particularly with respect to the impact of undernutrition on cognitive achievement.

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Following the literature reviewed in Glewwe and Miguel (2008), we use height-for-age as the measure of undernutrition to study its effect on cognitive achievement. We observe that even experimental studies have limitations. For instance, the experimental interventions lead to improvement not only in height, but also in other aspects of child health, and therefore, the researchers cannot separate precisely the effect of height-for-age from that of another aspect of health. The non-experimental studies in the thread under discussion have weaknesses in methodology. It is widely reported that chronic undernutrition is one of the major factors that retard linear growth and result in low height-for-age. Height-for-age, therefore, reflects the accumulated impacts of undernutrition (among other factors/events), which also affect brain function. However, some of the factors/events that lead to growth retardation may cause disproportionately greater damage to cognitive achievement than others. Moreover, some of such factors/events may be either unobserved or missing from the datasets. When these unobservable factors are left out of the equation, the effect of health on cognitive achievement may be estimated with bias. For instance, a meta-analysis by Bhutta et al. (2002:728) came to the conclusion that children who were born preterm are at risk of a reduced cognitive test score. In practice, however, the data on prematurity have rarely been used in literature on the matter.

To overcome the problem of unobserved factor, in general economists apply the method of instrument variable (IV). In fact, the most persuasive estimates in terms of conclusive results and straightforward policy implications have been produced with the application of IV. The size and the statistical significance of the estimates, however, are sensitive to the selection of instrument variables, and therefore, to the level of rigor with which the researchers accept instrument variables as valid. Unfortunately, instrument variables are never perfectly valid, as 'all

instruments arrive on the scene with a dark cloud of invalidity hanging overhead. This cloud never goes entirely away" (Murray 2006: 111).

We try to make some progress in sorting out the causal relationship between undernutrition in childhood and cognition in latter stage. For this study, the causal relationship is presented by the effect of height-for-age at age one on cognitive achievement at age five. We do so with emphasis on the validity of the instrument variables being applied in regressions. We find it is important to control for major factors/events that affect both the physical and mental development of children. For the measure of undernutrition at age one, data on prematurity should be taken into account. Our analyses demonstrate that given the same loss in height-for-age, the negative impact on cognitive achievement is more significant if the loss in height-for-age was the consequence of prematurity than that of malnutrition for a full-term born child. Having controlled for length in preterm, we find the effect of child height-for-age on cognitive achievement not statistically significant. The finding in this study implies that for the full-term born children, the impact of a difference in height-for-age made after birth, even in early childhood, on the cognitive achievement of a pre-schooler is unlikely to be important.

The paper is organized into five sections, including this introduction. Section two describes the source of the data used for estimating the effect of child health on cognition. In Section three we introduce the identification strategy. Having reviewed studies that have faced the same econometric problem dealt with in this paper, we justify our selection of instrument variable. Section four presents estimates and the argument in favor of some over others. Finally, the concluding discussions and recommendations are in Section five.

2. SAMPLE AND MEASURES

(a) The sample

We work with a dataset produced by Young Lives[1], a longitudinal study on childhood poverty conducted with the participation of Oxford University, other UK institutions, and teams in the study countries of Ethiopia, India, Peru and Vietnam. In each study country, the Young Lives surveys involve tracking 3,000 children in two cohorts. The younger cohort consists of 2,000 children who were born between January 2001 and May 2002, the so-called "millennium children". The sample used for this study consists of 1,200 millennium children from 12 commune-based clusters in Red River Delta, Mekong Delta and the city of Da Nang, which represents the urban sector and the Central Coast. All the children are ethnic Vietnamese. The sample does not include the mountainous provinces, however, which are home to all the ethnic minority children in the Young Lives sample.[2] The reasons for not considering these provinces are purely technical. Firstly, an interpretation of the test results in verbal achievement for children whose first language is not Vietnamese is beyond the framework of this study.[3] Secondly, because of the characteristics of their community, a significant number of children in the mountainous provinces lack birth weight records, which is a crucial input for our analysis. Data for Young Lives was gathered in two rounds. In 2002 (Round 1), the 1,200 children were aged around one. Four years later, 1,185 of the children were surveyed again in Round 2. Up to Round 2, none of the clusters had an attrition rate greater than 2 per cent.

Vietnam went through a century of colonization and long wars that ended in 1975. A decade of unsuccessful economic development followed, so that in the 1980s Vietnam was among the poorest countries in the world. The major economic reforms of Doi Moi,[4] launched in December

1986, began to change that situation, and economic growth has been high since then. Over the period 1986–2006, the annual rate of growth of GDP averaged at 7.1 per cent. However, in spite of the high level of economic growth, Vietnam was still a low-income country in 2006. So while the children under consideration in this study are growing up in the final stage of a low-income economy, the majority of their parents lived in severe poverty for decades.

(b) The variables

We use the Peabody Picture Vocabulary Test (PPVT) as the measure of cognitive achievement (see endnote 3). This test has been widely used as a general measure of cognitive achievement in many studies, including Blau (1999), McCulloch and Joshi (2002), and Paxson and Schady (2007). Our dependent variable is raw scores on the PPVT, which henceforth will be referred to as the *outcome*.

The explanatory (and instrument) variables consist of the characteristics of the child, the household and the community. Child characteristics include gender, birth weight, length in preterm (in weeks), height-for-age z-score (HAZ) at age one, and age in months at the time the cognitive test was administered. In calculating HAZ for the one-year-old children, Young Lives used the WHO International Growth Reference in 2000. We use the following household characteristics: wealth index in Round 1, mother's education, father's education, mother's height, mother's weight in Round 1, mother's age at birth of the child, and the number of older siblings, including half-siblings, with the same mother.[5]

The wealth index was calculated in Round 1 by drawing on work undertaken by the World Bank and Macro International used to develop the wealth index cited in the UNICEF Multiple Indicator Cluster Surveys. This wealth index is the simple average of three components: first, housing quality, which is the simple average of scaled rooms per person, floor, roof and wall;

second, the value in consumer durables, which is the scaled sum of the consumer durable dummies; and finally, the value in services, which is the simple average of drinking water, electricity, sanitation facilities, and fuel, all of which are 0–1 variables.[6]

Mother's education is defined as the highest grade she completed and is measured by the number of years it usually takes to complete. If the mother completed vocational technology school or university, the variable is set 14 or 16 respectively. Father's education is defined similarly.

[Table 1 may be here]

Finally, socioeconomic and environmental shocks, as well as community characteristics, are assumed to affect children's cognition. To present shocks, we use a dummy variable called "*If-adverse-events*" that equals 1 if, and only if, an event such as a natural disaster, major loss in livestock, or being the victim of crime, which are considered to seriously affect household welfare, happened in the period since pregnancy with the child up to the date of Round 1 of the survey. The provinces inhabited by the children in the sample are vulnerable to natural disasters such as floods or typhoons, and also prone to diseases, such as bird flu or foot-and-mouth disease. Such events often lead to increased stress in mothers, food insecurity or consumption of lower-quality food, and are therefore expected to have impacts on the health of mothers and children.

The remaining variables are cluster dummies, which present community fixed effects. The cluster dummies are Mekong 1–4, Red River 1–4, and Urban 1–4. Furthermore, Mekong is defined as the sum of the dummies Mekong 1–4. Similarly, Urban is the sum of the Urban 1–4. The descriptive statistics for the variables are presented in Table 1, except the cluster dummies.

3. METHODOLOGY

(a) Model identification

We consider the following linear function of the outcome:

$$g_i = \beta_0 + \beta_1 \phi_i + \sum_{k=2}^{K} \beta_k x_i^k + \gamma_0 \theta_i + \sum_{l=1}^{L} \gamma_l y_i^l + \varepsilon_i \quad (1),$$

where g_i is raw score in the PPVT in Round 2 for the ith child; ϕ is height-for-age in Round 1;

$x_i^k, k = 2, K$ represent other observed factors (child, household and community characteristics,

and shocks) related to i^{th} child; θ is the length in preterm. We consider two models with the

equation (1). In Model 1, the length in preterm θ is treated as unobserved, but in Model 2 it is

used as an observed factor. Furthermore, y_i^l, $l = 1, L$ are unobserved exogenous factors that have

impacts on cognitive achievement. Finally, ε is assumed to be white noises. Model 1 is used for

methodological purpose. The estimates produced with the application of Model 1 will be

analysed against the estimates of the impacts of child health on education outcomes in literature.

Model 2 is to produce our preferred estimate. The observed factors are either on the list in Table

1 or among the community fixed effects.

For discussion we also consider modifications of the Models 1&2. For the modifications, two

dummy variables are introduced that are *if-preterm* and *if-term*. The former dummy equals 1 for

preterm born children, and zero for the full-term born children. On the contrary, the latter

dummy equals zero for preterm born children, and 1 for full-term born children. With these

dummy variables, we define two interactions of HAZ with each of the *if-preterm* and *if-term*

dummies. By definition, the interaction of HAZ with the dummy *if-preterm* equals HAZ for the

preterm born children, and zero for the full-term born children. The interaction of HAZ with the

dummy *if-term* equals HAZ for the full-term born children, and zero for the preterm born

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children. Furthermore, Model 1-interaction is defined as the modification of Models 1, in which HAZ is replaced by the two interactions. Similarly, these two interactions replace HAZ in Model 2 to form Model 2-interaction. Finally, Model 3 is formed from Model 2 in the following way: first, the variable on the length in preterm is replaced by the dummy *if-preterm* and secondly, the variable HAZ is replaced by the two interactions described above.

We treat the variables on gender, age, socioeconomic and environmental shocks, mother's height, mother's weight, mother's age, the number of older half/siblings and the community fixed effects as exogenous. Furthermore, following the usual practice, we take the variables on parents' education as exogenous as well, which can be justified by the following three facts. First, an estimation of the effect of parental education on the cognition of the child is not among our aims. Second, the economic hardship experienced by the majority of parents in their childhood weakens the link, if any, between their grade attainment and their innate ability. In fact, for the dataset under study, most mothers were born around 1975, when the American war ended, and so they were poor for most of the 1980s. Poverty, credit constraints, the condition of the local infrastructure, and distances to schools were among the major factors affecting their decision on how long to stay in school. Finally, it is a matter of fact in research on child development that parental education can be considered as exogenous. For example, Behrman and Rosenzweig (2004), and Maluccio et al (2009) use mother's schooling and father's schooling in that way in their studies on the impacts of early childhood nutrition on future educational outcomes.

Spurious correlation is possible, however, if HAZ is treated as exogenous. This is because of unobserved factors, such as the preferences and abilities of parents and others that on the one hand, correlate to the outcome, and on the other hand, correlate to HAZ. For instance, we have no good measure of laziness and unresponsiveness of parents, so those factors and many others

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are treated as unobserved. These characteristics prevent parents from providing enough food *and* psychosocial stimulation for the development of their children. Such effects may result in lower HAZ and lower cognitive achievement, even in cases where there is no direct causal effect of the former on the latter.

(b) A review of literature on the impact of child health on education outcomes

The problem of endogeneity also arises in several papers that use socioeconomic behavioural data (as opposed to experimental data) to study the impact of child health on education outcomes. The problem is in large part due to unobserved factors, such as family biology and the cultural environment.

> "Both biology and culture are transmitted from parents to children, one encoded in DNA and the other in a family's culture. Much less is known about the transmission of cultural attributes than of biological ones, and even less is known about the relative contributions of biology and culture to the distinctive endowment of each family." (Becker and Tomes, 1986: S4)

This suggests that the mechanism by which the unobserved factors influence health and cognitive achievement can be very intricate.

Not all the studies that sought to estimate the impact of child health on education outcomes try to handle the problem of endogeneity. In fact, we are aware of only a handful of papers that attempt to tackle the influence of unobserved factors, and the application of instrument variables is essential in those papers.[7] Behrman and Lavy (1998) use data from the 1988–9 Ghanaian Living Standard Survey (GLSS) to estimate the effect of child health on cognitive achievement. Under certain strong assumptions, they use current prices as instrumentvariables.[8] Working with the same GLSS, Glewwe and Jacoby (1995) use the distance to nearby medical facilities and

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maternal height as the instrument variables in their study of the effect of children's HAZ on the age of school enrolment. Given that the goal is to estimate causal effect, both of these studies suffer from a serious limitation that is because of the application of a cross-sectional dataset.

Alderman et al. (2001) work with panel data collected from 1986 to 1991 for about 800 households in Pakistan. They estimate the effect of child health, which is measured by height-for-age at age five, on the probability of entering school at age seven, using food prices during the pre-school period to generate instrument variables for the variable on child health. More specifically, the instrument is the interaction of levels of parental education with the deviation in prices from long-term trends. Glewwe and Miguel (2008: 3592–3), however, pointed out some of the potential limitations of these instrument variables. Moreover, we find that the F-statistics reported in Alderman et al. (2001: 202) do not rule out the problem of weak correlation between the instruments and the endogenous variable.

Data of the Cebu (Philippine) Longitudinal Health and Nutrition Survey are used in Glewwe, Jacoby and King (2001) to study the relationship between pre-school nutritional status and subsequent academic skills, as measured by test scores. The dataset allows the authors to use within-sibling variation in their analysis and apply the height-for-age of the older sibling (at birth, 12 months and 24 months) as instrument variables. Glewwe et al., however, assume that there are no pre- or postnatal health shocks that influence both the physical and mental development of a child. With their assumption, it would rule out events such as premature delivery, which is a potentially important confounding factor, as will be demonstrated later in this paper.

Alderman, Hoddinott, and Kinsey (2006) examine the impact of pre-school malnutrition on adolescent height, the grade attained, and the age of starting school. Their data is drawn from a longitudinal survey of 400 households with 680 children in Zimbabwe. The children in the

sample were born between September 1978 and September 1986, and the surveys were carried

out in 1983/4, 1987 and 2000. Events in Zimbabwe in the late 1970s and 1980s allowed the

authors to employ unique instrument variables. These events were the final years of civil war in

late 1970 and the successive droughts in 1982–3 and 1983–4. The authors assume that children's

height from 12 to 36 months is more sensitive to nutritional deficiencies than at any other age.

The two instrument variables are exposure to civil war (number of days living in the war) and a

dummy variable on drought shock (whether the child was between 12 and 36 months old during

the two droughts). The validity of these instrument variables may be challenged by the

considerations, such as in Glewwe and Miguel (2008: 3596). All three panel data studies –

Alderman et al. (2001), Glewwe et al. (2001) and Alderman et al. (2006) – find the effect of

height-for-age on education outcomes statistically significant.

(c) The birth weight and the length of preterm

Birth weight is among the most important measures an infant's health. We find birth weight

strongly correlated with height-for-age at age one. That means the variable on birth weight

satisfies the *relevance condition* for being a valid instrument variable (see Glewwe and Miguel,

2008: 3585, for the relevance condition, exogeneity condition and the exclusion condition). The

exclusion restriction is satisfied automatically, as this variable is not included as explanatory

variable in equation (1). It remains to justify for the exogeneity of the variable on the birth

weight, which we will do over the course of this section, starting with some of the issues that are

most likely to cause concerns about the possibility of estimates being biased.

One of these issues is the potential selection bias. Following Strauss and Thomas (2008: 3434),

the low socioeconomic-status mothers are more likely to give birth at home and the birth weight

record is usually missing for children born at home. For the dataset under this study, however,

we find that problem unlikely to be serious. Our calculation reveals that only one cluster has five observations (or 5 per cent) missing birth weight data. Three other clusters each have three observations lacking that information. In total, only 1.4 per cent of the observations lack a birthweight record.

Correlation to unobserved factor is another important reason for the estimates being biased. We may have a problem with spurious correlation if there are unobserved factors that on the one hand, link to birth weight, and on the other hand, link to the outcome in some other way that is independent from birth weight and all the observed exogenous factors in the equation (1). In the remainder of this section, we are going to justify that, for the data under study the spurious correlation can be ignored.

According to Kramer (1987), child birth weight is governed by two major processes: duration of gestation and intra-uterine growth rate. Low birth weight (LBW) is thus caused either by premature birth or intra-uterine growth retardation (IUGR). Villar and Belizan (1982) examined data from diverse countries and found that in developing countries, most LBW is due to IUGR, whereas in developed countries (especially those with the lowest LBW rates), most is due to preterm birth. For the data used in this study, the cases with birth weight lower than 2,500g make up 4.3 percent of the total observations with records on birth weight. Slightly less than half of the LBW cases (2.0 percent) were born more than two weeks prematurely, and another 0.8 percent (of the total observations with records on both birth weight and the length in preterm) were born one or two weeks in preterm. On the other hand, 11 percent of the sample were born preterm, but not with LBW. These statistics need not be interpreted as contradicting the finding in Villar and Belizan (1982), given that the number of the LBW cases is relatively small.

(d) A justification for the length in preterm being used as exogenous variable

The events leading to preterm birth are still not completely understood, and recent literature describes the causes of preterm birth as multifactorial and complex (see Goldenberg et al., 2008). However, there is no evidence to support the argument that the inclusion of the variable on length in preterm would definitely cause spurious correlation for equation (1). On the contrary, we find facts that suggest that the incidence of prematurity and the length in preterm can be treated as random to the socioeconomic and other household characteristics that are relevant to the cognitive development of the child.

Worldwide, according to Beck et al. (2010: 31), "[A]pproximately 45–50% of preterm births are idiopathic, 30% are related to preterm rupture of membranes (PROM) and another 15-20% are attributed to medically indicated or elective preterm deliveries." In southern Brazil, Barros et al., who studied a cohort of 5,914 liveborns in Pelotas, found that risk factors for IUGR differ from those for preterm births.

> "Intrauterine growth retardation was strongly associated with a number of socioeconomic and biological variables ... Children of mothers who smoked during pregnancy were at greater risk of IUGR. Risk of preterm birth, on the other hand, did not appear to be influenced by maternal height or education or by birth interval. It also appeared less influenced by smoking than IUGR, and indeed the association with this factor was not quite significant." (Barros et al, 1992: 239-40)

For the dataset in this study, we find that the variable on the length in preterm has little association with the other factors in equation that are reasonably thought to be relevant to infant nutrition. In Table 2 we present the results of OLS regression of the length in preterm on a group of relevant factors, such as gender, birth order, wealth index, mother's characteristics, father's education, the adverse events, and the 11 dummy variables for community fixed effects. It demonstrates that none of the variables on wealth index, mother's height, and parents' education

have any significant explanatory power for the variation of the length in preterm. Apart from one of the community fixed effects, only the variable called *If-adverse-events* is found with coefficient to be statistically significant at five per cent. Other than that, the coefficients of the variable on mother's age and that on the squared age of mother are statistically significant at ten per cent, but not at five per cent. The meaning of the last fact is that prematurity is slightly more likely for either too-young or too-old mothers. [Table 2 may be here]

One may say that the variable on the length in preterm is almost random with respect to the factors mentioned in the previous paragraph. In fact, our analysis shows that only a small fraction (less than 2.5 per cent) of the variation in the length in preterm is explained by the above-mentioned factors. Moreover, the variables with the statistically significant coefficients, the dummy *If-adverse-events*, and a community fixed effect, have nothing to do with the innate abilities of any member in the household.

The assumption that there is no spurious correlation caused by the length in preterm θ can be justified in the following way. Let us consider the unobserved characteristics that enable the child to do well in the cognitive test. For instance, the supposedly being smart, or having good vocabulary, or else if any that is important for the child's performance on the test. Spurious correlation exists if the unobserved characteristics have been there in the unborn infant and had significant impact on θ. These unobserved characteristics can be reasonably considered as inherited from one of the parents. The environmental impacts and random interventions do not cause spurious correlation. Thus, most likely the characteristics are shared by the child and one of the parents.

For the parents, the shared characteristics that enable the child do well in the cognitive test should have enabled at least one the parents do well in either schooling and/or economic

activities, which have impact on wealth index. For the data under this study, about 99 percent of

the mothers are the biological mothers. The corresponding figure for fathers is 96 percent. Thus,

the assumption about there being of the spurious correlation would imply that θ would have had

statistically significant correlation with at least one of the variables on mother's schooling,

father's schooling, and wealth index. This implication from there being of the spurious

correlation contradicts to the fact that none of the factors related to parents' innate ability, such

as mother's schooling, father's schooling, and wealth index, has any significant explanatory

power regarding to the variation in θ. In sum, the results of the OLS regression in Table 2 justify

for the spurious correlation being ignored.

(e) Birth weight controlled for the length in preterm: a presentation of IUGR

The evidence presented in the previous subsection justifies our assumption that the variable on

length in preterm can be taken as an exogenous variable for equation (1). Conditional on the

exogeneity of this variable, we now work on the exogeneity of another component of birth

weight to be defined as the following. We first run an OLS regression of birth weight on the

length in preterm θ:

$$birthweight = Constant + a\theta + residual,$$

and a proxy δ of IUGR is defined as:

$$\delta = birthweight - a\theta = Constant + residual$$

Unlike the length in preterm, the proxy δ of IUGR correlated strongly with a number of

variables on child and household characteristics, such as sex, mother weight, birth order, wealth

index, mother's education, and others.

To investigate the existence of any unobserved factor that correlates on the one hand to cognitive

achievement, and on the other hand to the proxy δ of IUGR in some pathway that is independent

of the observed exogenous factors in Model 2, we will create another variable to be called

residual ξ. The residual ξ is defined as the residual of the OLS regression of the proxy δ on the

observed exogenous factors x^k, $k = 2, K$, of Model 2, excluding the variable on child's age

(months old), which is, by nature, irrelevant to birth weight.

$$\delta = b + \sum_{k=2}^{K} a_k x^k + \xi \ (2)$$

We propose the following testable null-hypothesis: *The residual ξ is uncorrelated with the*

outcome g: $Cov(g, \xi) = 0$. Essentially, the null-hypothesis says that any part of the variation

in birth weight, if it cannot be explained by the characteristics of the child, the mother, the

household, and other factors in equation (2), then it has no correlation with the outcome. An

acceptance of this null-hypothesis would rule out the existence of an unobserved factor that is

independent of the observed exogenous factors x^k, $k = 2, K$, in equation (2) but correlates to

both the outcome g and the proxy δ. To test the null-hypothesis, our calculation shows that the

p-value of significance for the correlation between cognitive achievement g and the residual ξ

equals 61 per cent, which is too high to reject the null-hypothesis: $Cov(g, \xi) = 0$.[9] Failure to

reject the null-hypothesis justifies ignoring the spurious correlation caused by the proxy δ. Given

the condition on the exogeneity of the length in preterm, it equivalently justifies ignoring the

spurious correlation caused by the variable on birth weight.

In the next section, in addition to the OLS estimations, we also run 2SLS regressions with two

options on the instrument variables. In the first option, our 2SLS preferred estimate is produced

with the variable on birth weight being the only instrument variable. In the second option, two

alternative 2SLS estimates are produced with the application of two instrument variables - birth

weight and mother's height. The purpose of the alternative estimate is to safeguard against a claim that there is a risk of the sole instrument variable of birth weight not capturing enough variation in the endogenous variable, and for that reason, some of the explanatory power of endogenous variable being lost in the estimating process.

There is some reason to use the variable on mother's height as another instrument variable for the endogenous variable of height-for-age (see endnote 5). "A recent review of the literature concludes that, in Western countries, approximately 80 per cent of variation in [adults'] body height is genetic and 20 per cent is due to environmental factors", say Case and Paxson (2008: 504). For the one-year-old children in the developing country under study here, even though the percentage shares in the variation of height may differ from what is quoted above, the role of genetic characteristics is certainly important, in addition to birth weight, which is one measure of the quality of the uterine environment. The pair-wise correlations of HAZ and mother's height, HAZ and birth weight, and mother's height and birth weight are 0.31, 0.30, and 0.13 respectively. The p-values of the pair-wise correlations are all below 0.0001, meaning they are all strongly statistically significant. The inclusion of the variable on the mother's height in, as the additional instrument variable, does no harm if it does not lead to the problem of over-identification. In the next section, we will find there is no such over-identification problem for this set of instrument variables.

4. ESTIMATION

To make presentation clearer, we label the set of estimates with an indication of the model, the method used in estimations. They are the following:

    M1-OLS: Model 1, OLS regression;

    M1-2SLS: Model 1, 2SLS regression;

2SLS-full-term: Model 1, 2SLS, estimated for the full-term born children only;

M1-interaction: Model 1-interaction, OLS regression (see subsection (*a*) in Section 3 for

definitions of Model 1-interaction, Model 2-interaction, and Model 3);

M2-interaction: Model 2-interaction, OLS regression;

M3: Model 3, OLS regression; and

M2-2SLS: Model 2, 2SLS regression.

Furthermore, aM2-2SLS, and a2SLS-full-term are the alternative estimations corresponding to

M2-2SLS, and 2SLS-full-term. We use two instrument variables (birth weight and mother's

height) in the 2SLS regressions for the alternative estimates.

Table 3 presents the M1-OLS, M1-2SLS and 2SLS-full-term estimates. With the application of

the simplest identification strategy, the impact of HAZ at age one on the outcome is estimated

statistically significant at ten per cent, but not at five per cent. Let us recall from Section 3 that

there is an issue about endogeneity of HAZ. One may assume that the impact of HAZ might have

been underestimated in this case because of the endogeneity of HAZ.

To deal with the problem of endogeneity, we apply the method of 2SLS with the variable on

birth weight being the instrument variable. The effect of HAZ estimated in the second column of

Table 3 is statistically significant at five per cent and is three-and-a-half times as large as that in

the first column. This fact makes the estimate of M1-2SLS consistent with the implication from

the panel studies reviewed in Section 3. There are many studies – not only ones within economic

literature – that document the significance of the association between early childhood

undernutrition and cognition in the later stages of development. For example, Richards et al.

analyse the data on cognitive function in a British 1946 birth cohort and find that birth weight

was significantly and positively associated with cognitive ability at age eight (2001: 199). It is

important, however, to note that many of the studies lack data on gestational age, which turns out to be essential for the study at hand. [Table 3 may be here]

To show that gestational age can be a confounding factor, we conduct the estimation on the sample of only full-term born children (zero length in preterm). The result of the 2SLS with birth weight being the sole instrument variable is presented in the last column of Table 3. It indicates that the impact of HAZ is not statistically significant. This is inconsistent with the estimate in the second column. The difference between the estimates in M1-2SLS and 2SLS-full-term can be interpreted in the following way. Having controlled for the exogenous explanatory factors of Model 1, the effect of HAZ on the outcome is larger for the preterm born children than that for the full-term born ones.

So, for Model 1, in addition to the risk of endogeneity, there could be another problem. The inconsistency between the results in Table 3 suggests that the problem might be dealt with by one of the following methods. First is to replace the variable on HAZ in equation (1) by the interactions of HAZ with the dummy variables *if-preterm* and *if-term* (see subsection (a) in Section 3 for definitions of interactions of HAZ). Second is to include some dummy variable that distinguishes the preterm born children from the full-term born ones. By the first method, we apply Model 1-interaction and by the second method we may come up with either Model 3 or Model 2-interaction (see subsection (a) in Section 3 for definitions of these models). The results of these estimations are presented in Table 4. [Table 4 may be here]

Let's first look at the first column (under the heading M1-interaction). For this estimation, where the variable *if-preterm* and that on the length in preterm are treated as unobserved, we find the impact of HAZ is statistically significant for the preterm born children, but is not for the full-term born children. Next, when the dummy *if-preterm* is included, we find in the second column

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of Table 4 that the impact of HAZ in M3 is largely the same as in the M1-interaction. It is statistically significant for one group of children and not for the other. More importantly, the coefficient for the dummy *if-preterm* is not found to be statistically significant, and for that reason, the justification for the inclusion of the dummy *if-preterm* is not conclusive.

The application of Model 2-interaction reveals the important role of the variable on length in preterm. The figures in the last column of Table 4 demonstrate that when the effect of the length in preterm is controlled for, the effect of HAZ is found to be statistically significant for neither group of children. It is important that the effect of HAZ in M2-interaction is found consistent to that of the 2SLS-full-term in Table 3, in the sense that they all not statistically significant. Thus, the results in Table 4 suggest that the omission of the variable on length in preterm (not that of the dummy *if-preterm*) might have been the reason for the inconsistency between the estimates related to Model 1.

Further pursuing the idea of the importance of the variable on length in preterm, we now consider Model 2. Moreover, the problem of endogeneity of HAZ, which was not addressed for estimates in Table 4, is now dealt with. If we apply only one instrument variable, it results in the estimate for M2-2SLS. The effect of the length in preterm in the first column of Table 5 is consistent to that for M2-interaction in Table 4. The effect of HAZ is found not statistically significant, and for that reason, it is consistent to the corresponding estimates in M2-interaction in Table 4 and 2SLS-full-term in Table 3.

Let us recall from Section 3 that panel data studies in other countries find statistically significant impact of height-for-age at age five on education outcomes in later stages. That means the preferred estimate of this study is not quite in accordance with those in the panel studies, even though not directly contradicting. Let us try to figure if there is a possibility that M2-2SLS

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underestimates the true impact of HAZ on the outcome. If the estimated impact of HAZ in the first column of Table 5 is indeed biased toward zero, then it is most likely because of the instrument variable. Some part of the explanatory power of the endogenous variable may be lost in the estimating process because of weak correlation between the instrument variables and the endogenous variable. However, the test statistics from the 2SLS regression of Model 2 are strong enough to work against such a claim. In fact, the statistics for the first-stage regression for M2-2SLS are strong against a hypothesis of weak instruments. Specifically, the results of the first-stage regression show that F-statistics equals 17.4, which is well above the threshold by rule of thumb (see Stock and Yogo, 2005:101); R-squared equals 0.32; and the t-statistic for the variable on birth weight is as high as 8.3. [Table 5 may be here]

To safeguard against potential claim that limitations in the instrument variable may lead to some loss in the explanatory power of HAZ, we try two alternative 2SLS estimators, as shown in the second and third column of Table 5. For the alternative 2SLS estimators, we use the variable on mother's height and that on birth weight as two instrument variables. As argued at the end of Section 3, the combination of these two instrument variables captures more variation of HAZ than the lone instrument variable does. The estimates for the effect of HAZ in aM2-2SLS and a2SLS-full-term can be considered as consistent to that in M2-2SLS in the sense that none of them is statistically significant.

The effect of the length in preterm is estimated consistently across regressions of the models that contain this variable. The estimated impact of the length for preterm in the second column of Table 5 is close to that in the first column, and they are all statistically significant at five per cent. Moreover, these estimates are fairly close to that in the estimate for the length in preterm in M2-iteraction in Table 4.

We also observe that the effect of age is found to be consistently statistically significant in all the regressions considered in this study. The figures in the last column (under M2-interaction) of Table 4 and in the first two columns (under M2-2SLS and aM2-2SLS) of Table 5 show that the negative impact of one week in preterm is about 80 per cent of the effect of one month of age for a normal child. Thus, if all time intervals are converted into weeks, the results suggest that by magnitude, the negative impact of the length in preterm is stronger than the effect of age.

Parental education is an important aspect of household socioeconomic status. The figures in Tables 3, 4 and 5 indicate that the schoolings of the mother and that of the father have statistically significant effects on the child's cognitive achievement. Furthermore, living in an urban area is another important factor in cognitive development. The advantage of the urban children is multidimensional so that without the community dummy variables, the observed factors in Model 2 cannot capture enough variation in the cognitive achievement of children. One of the advantages of the urban sector is that it provides an enabling environment for learning and playing. The urban children's caregivers have better access to diverse reading materials than their counterparts in rural areas. The urban–rural gap also includes other factors that matter for cognitive development, such as seeing more things and meeting more people who possess a richer vocabulary. Finally, it is widely reported that rural children have less access to entertainment than children in cities.

5. DISCUSSIONS AND RECOMMENDATIONS

It is well documented that undernutrition in childhood has an important impact on cognitive achievement/education outcomes in later stages of the person's development. Economic literature has confirmed the statistically significant positive effect of height-for-age on education outcomes. Our analysis shows, however, that if the data on gestational age is missing, the effect

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of stunting (low height-for-age) can be estimated with significant bias for full-term born children. Having controlled for the length in preterm, we find that the effect of height-for-age at age one on cognitive achievement at age five is not significantly significant. On the other hand, the results in this study consistently show statistically significant negative impact of the length in preterm. For this reason, policymakers may think of shifting the focus of attention to the interventions in prenatal period. "Unfortunately, [however] there are currently no effective diagnostic measures for preterm labour resulting in preterm birth, and no effective early interventions for prevention" (Beck et al. 2010: 37).

The implications of the outcomes of this study need not be interpreted as undermining the value of early childhood nutritional interventions. We cannot rule out the possibility that only a part of the impact of nutritional interventions on cognition works through height-for-age, while the total effect is more significant. There is in fact evidence that improving the nutrient intake of very young children can have a substantial, long-term impact on education outcomes (see for example Maluccio et al. 2009). This evidence is not necessarily against our finding.

More efforts to revise the estimation of the effect of childhood undernutrition on cognitive achievement are needed before recommendations can be made to policymakers. For future studies on this matter, we recommend that the researchers control for gestational age, or other factors that carry data on the mother's health in the prenatal period. Furthermore, the limitation in the use height-for-age to represent a child's health needs to be addressed.

Endnotes

[1] Young Lives is an innovative longitudinal study investigating the changing nature of childhood poverty. Young Lives is tracking 12,000 children in Ethiopia, India (Andhra Pradesh), Peru and Vietnam over 15 years through a quantitative survey and participatory qualitative research, linked to policy analysis.

[2] The Young Lives sample also includes clusters in a province of Northern Uplands and another province of the Central Coast. All the Young Lives ethnic minority children live in these two provinces.

[3] Verbal skill and achievement were measured by scores in the standardized Peabody Picture Vocabulary Test. Bias may arise when using the same instruments to test children with different mother tongues. However, the sample used in this study consists of ethnic Vietnamese children only.

[4] "Doi Moi" is the name of the 1986 economic reforms in Vietnam. It can be considered as the start of the country's "socialist-oriented" market economy.

[5] Young Lives has not collected data on the height and weight of fathers.

[6] See "Young Lives: An international study of childhood poverty: Rounds 1 and 2, 2002–2006", *Data Archive Study*, *5307* at http://www.esds.ac.uk/doc/5307/mrdoc/pdf/5307methodology_r1.pdf , pp. 50–2.

[7] Since the methodological issue under consideration is irrelevant for studies on randomized evaluations, we limit our discussion on the literature of retrospective estimation.

[8] Following Alderman et al. (2001:186), Behrman and Lavy assume "that (i) child health reflects behavioral decisions of households in the presence of unobserved individual, family and community predetermined variables (for example, genetic endowments and general learning environments that are not observed by analysts) but (ii) there are no unobserved inputs to child cognitive development that reflect choices of households".

[9] The value of the correlation between cognitive achievement g and the residual ξ is 0.0165.

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Tables

Table 1: Descriptive statistics of main variables used in the analysis

Variable	Mean	Std. Dev.
PPVT score	42.0	18.2
Birth weight	3117	438
Height-for-age z-score at age one	-0.27	1.1
Length in preterm (weeks)	0.35	1.1
Male	0.51	0.50
Months old	63.9	3.8
Wealth index Round 1	0.52	0.24
Number of older half/siblings	0.69	0.82
Mother's height (cm)	152.9	6.0
Mother's weight (kg)	48.9	13.2
Mother age's at birth of the child	26.8	5.7
Mother's education (years)	8.2	3.6
Father's education (years)	8.8	3.7
If-adverse-events	0.06	0.23
Mekong	0.34	0.47
Urban	0.35	0.48

Table 2: Results of OLS robust regressions

Dependent variable: Length in preterm

	Coef. (Std.Err.)
Wealth index Round 1	0.252 (0.26)
Male	0.105 (0.065)
Mother's age at birth (of child)	-0.088*(0.05)
Squared mother's age at birth	0.002*(0.001)
Number of older half/siblings	-0.067 (0.05)
Mother's height	0.00005 (0.006)
Mother's weight	-0.001 (0.005)
Mother's schooling (years)	0.019 (0.013)
Father's schooling (years)	0.004 (0.012)
If-adverse-events	0.285**(0.142)
Red River 2	0.252 (0.158)
Red River 3	0.422***(0.158)
Red River 4	0.196 (0.158)
Urban 1	0.142 (0.167)
Urban 2	0.204 (0.171)
Urban 3	0.056 (0.18)
Urban 4	0.234 (0.16)
Mekong 1	0.166 (0.166)
Mekong 2	0.236 (0.167)
Mekong 3	0.15 (0.171)
Mekong 4	0.238 (0.162)
Constant	1.03 (1.09)

Notes: 1.Number of observations =1135; R-squared = 0.0245.
2. *** denotes statistical significance at 1%, ** at 5%, and * at 10%.
3. Standard errors in parentheses.

Table 3: Results of Model 1' robust regressions

Dependent variable: PPVT raw score at age five

	M1-OLS	M1-2SLS	2SLS-full-term
Height-for-age z-score at age one	0.818* (0.448)	2.87** (1.41)	1.71 (1.56)
Wealth index Round 1	3.57 (3.55)	3.23 (3.68)	1.98 (3.98)
Male	1.12 (0.936)	1.44 (0.957)	1.53 (1.04)
Months old	1.03*** (0.144)	1.19*** (0.179)	1.17*** (0.197)
Mother's height	-0.002 (0.086)	-0.105 (0.105)	-0.042 (0.113)
Mother's weight	-0.008 (0.068)	-0.008 (0.072)	0.049 (0.080)
Mother's age at birth of child	-0.041 (0.784)	-0.188 (0.806)	-0.492 (0.938)
Squared mother's age	-0.0001 (0.014)	0.003 (0.015)	0.008 (0.017)
Number of older half/siblings	-0.707 (0.714)	-0.717 (0.727)	-1001 (0.796)
Mother's schooling (years)	0.67*** (0.197)	0.589*** (0.2)	0.479** (0.218)
Father's schooling (years)	0.68*** (0.175)	0.630*** (0.179)	0.668*** (0.197)
If-adverse-events	-1.667 (1.692)	-1.26 (1.77)	-0.291 (1.98)
Mekong	1.46 (2.0)	1.07 (2.08)	0.022 (2.18)
Urban	15.7*** (2.1)	14.9*** (2.048)	14.91*** (2.32)
Number of observations	963	950	806
R^2/First stage's R^2	0.39	0.31	0.31
First stage's F-statistics		18.1	14.8
Second stage's centered R^2		0.37	0.37
Under-identification p-value		0.000	0.000
Cragg-Donald F-statistic		89.2	73.4

Notes: 1. *** denotes statistical significance at 1%, ** at 5%, and * at 10%.
2. Standard errors in parentheses.
3. Test statistics for over-identification all instruments for the 2SLS: 0.0 (equation exactly identified).
4. Community fixed effects for nine clusters are not displayed.

Table 4: OLS robust regressions with application of height-for-age z-score's interactions

Dependent variable: PPVT raw score at age five

	M1-interaction	M3	M2-interaction
HAZ interacted with term	0.563 (0.488)	0.579 (0.49)	0.582 (0.488)
HAZ interacted with preterm	2.12** (0.87)	1.88**(0.947)	1.47 (0.897)
If preterm		-0.965 (1.34)	
Length in preterm (week)			-0.824** (0.398)
Wealth index Round 1	3.53 (3.55)	3.52 (3.55)	3.86 (3.55)
Male	1.12 (0.936)	1.15 (0.941)	1.20 (0.941)
Months old	1.03***(0.144)	1.02***(0.143)	1.02***(0.144)
Mother's height	-0.001 (0.086)	0 (0.086)	0.003 (0.086)
Mother's weight	-0.006 (0.068)	-0.007 (0.068)	-0.004 (0.068)
Mother's age at birth of child	-0.092 (0.782)	-0.095 (0.781)	-0.163 (0.780)
Squared mother's age	0.001 (0.014)	0.001 (0.014)	0.002 (0.014)
Number of older half/siblings	-0.712 (0.713)	-0.743 (0.715)	-0.784 (0.712)
Mother's schooling (years)	0.668*** (0.196)	0.681***(0.195)	0.693*** (0.196)
Father's schooling (years)	0.696*** (0.176)	0.698***(0.176)	0.697*** (0.176)
If-adverse-events	-1.53 (1.68)	-1.52 (1.68)	-1.32 (1.68)
Mekong	1.43 (2.02)	1.4 (2.04)	1.61 (2.05)
Urban	15.70*** (2.07)	15.74***(2.09)	15.80*** (2.09)
Number of observations	963	963	963
R^2	0.39	0.39	0.39

Notes: 1. HAZ stands for height-for-age z-score
2. *** denotes statistical significance at 1%, and ** at 5%.
3. Standard errors in parentheses.
4. Community fixed effects for nine clusters are not displayed.

Table 5: The preferred estimate and alternative 2SLS robust regressions

Dependent variable: PPVT raw score at age five

	M2-2SLS	aM2-2SLS	a2SLS-full-term
Height-for-age z-score at age one	1.62 (1.51)	1.18 (1.21)	1.33 (1.27)
Length in preterm (week)	-0.874** (0.407)	-0.914** (0.395)	
Wealth index Round 1	3.88 (3.61)	4.04 (3.57)	2.12 (3.93)
Male	1.35 (0.941)	1.29 (0.939)	1.47 (1.04)
Months old	1.09*** (0.182)	1.06*** (0.163)	1.14*** (0.174)
Mother's height	-0.047 (0.105)		
Mother's weight	0.007 (0.072)	0.001 (0.071)	0.044 (0.078)
Mother's age at birth of child	-0.213 (0.789)	-0.191 (0.788)	-0.476 (0.937)
Squared mother's age	0.003 (0.014)	0.003 (0.014)	0.008 (0.017)
Number of older half/siblings	-0.816 (0.716)	-0.839 (0.712)	-1.02 (0.792)
Mother's schooling (years)	0.658*** (0.199)	0.672*** (0.197)	0.489** (0.215)
Father's schooling (years)	0.664*** (0.179)	0.673*** (0.179)	0.679*** (0.198)
If-adverse-events	-1.14 (1.74)	-1205 (1.73)	-0.307 (1.98)
Mekong	1.42 (2.07)	1.46 (2.07)	0.071 (2.19)
Urban	15.33*** (2.07)	15.49** (2.08)	15.05*** (2.33)
Number of observations	950	950	806
First stage's F-statistics and R^2	17.4; 0.32	17.4; 0.32	14.8; 0.31
Centered R^2	0.39	0.39	0.38
Under-identification χ^2 (2) p-value	0.000	0.0000	0.0000
Cragg-Donald F-statistic	79.3	70.1	62.2
p-value for Hansen J-statistic test of over-identification	0.0 (exactly identified)	0.65	0.14

Notes: 1. *** denotes statistical significance at 1%, ** at 5%, and * at 10%.
2. Standard errors in parentheses.
3. For the estimates of aM2-2SLS and a2SLS-full-term, two instrument variables (birth weight and mother's height) are used.
4. Community fixed effects for nine clusters are not displayed.