Linking Early Childhood Nutrition and Health Problems to School Achievement: A Cross-section Analysis of Grade 4 Students in Sri Lanka

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Abstract: This paper examines the separate impacts of early childhood nutrition and current health problems on academic achievement. Previous research has considered either only the impact of early childhood nutrition or the impact of specific health problems on academic achievement. This is the first paper to consider both measures of health in a comprehensive way. A unique cross-section dataset of grade 4 students in Sri Lanka allows one to address more convincingly endogeneity issues stemming from missing variable bias. Specifically, controlling for school heterogeneity and parental taste for education the results show that children affected by hearing problems, intestinal worms and early childhood malnutrition have significantly lower cognitive skills. These results are robust to conditioning on the rate of student absence from school. Implications of this research suggest that returns to investments made to improving school quality will be limited by any lack in investment in improving early childhood nutrition and health problems faced by children in school years.

Keywords: Early childhood; Nutrition; Health; Academic achievement; Economic development

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Introduction

Sri Lanka made great strides in improving public education across the country, but its education sector still suffers from several deficiencies. In the late 1990's the Government of Sri Lanka launched major public education policy reforms. Among the stated objectives were (1) to provide universal access to primary and secondary education, combined with full enrollment and completion of the compulsory basic education cycle (grades 1-9) and (2) to attain high levels of education quality, measured in terms of cognitive achievement and subject content mastery (World Bank, 2004).[1] So far Sri Lanka has been successful with respect to the first goal. Net enrollment rate in grade 1 is about 97% for both boys and girls and most students complete grade 5 (World Bank, 2004). Further, these enrollment rates are consistent across geographic regions and economic groups. However, challenges still exist. About 18% of children fail to complete grade 9 and school completion rates are worse for upper secondary education. From a learning achievement standpoint, by the end of Grade 4 only 37%, 38% and 10% of students achieve mastery of their first language (Sinhalese or Tamil), mathematics, or the English language, respectively. Further, the country's average pass rate from the GCE O/L examination (grade 11) is 37%, and of those who pass this exam, only 56% pass the GCE A/L examination (grade 13).

It is possible that these problems have been in part due to low quality of schools and teaching. It is also quite possible that something outside of the school system has a negative impact on primary and secondary education, namely early childhood nutrition

[1] The public sector dominates primary and secondary education, accounting for 93% of schools and 95% of enrollment. These students follow a national school curriculum and sit national examinations.

and health. In Sri Lanka, malnutrition is problem among adults and children: 29% of children under age five are underweight for their age and 23% of the total population is undernourished (UNDP 2003). Further, scientists agree that malnutrition in the first few years of life can hinder mental development by permanent, structural damage to the brain, limiting long term intellectual development (Brown and Pollitt 1996).[2] It is one thing to establish that malnutrition in the first two years of life has a physical or mental impact on the body; it is quite another thing to measure how this impact is felt in academic achievement.

Research on the causal effect of child health on schooling is not without its econometric challenges due to the endogeneity of health related choices and omitted variable bias. Nevertheless, a few papers have been somewhat convincing in their claims about the effect of early childhood health and nutrition on schooling. Most studies use standardized child height for age Z-score to represent overall child health. Height for age (*HAZ*), or stunting, is a cumulative, long-run indicator of slow physical growth caused by poor nutrition and/or episodes of diarrhea and other childhood illnesses. *HAZ* has been used to show that there is a strong impact of child health and nutrition on school enrollment rates (Glewwe and Jacoby 1995, Alderman et al. 2001). However, these studies are less useful in the context of Sri Lanka because the country has already been successful in getting children enrolled in school on time. Other studies assessed the impact of *HAZ* on school achievement with mixed results. Behrman and Lavy (1994) use cross section data in Ghana and find no evidence of an impact of child health on child

[2] Scientists now believe that some of the adverse effects of malnutrition in the first two years of life may be reversible, yet further injury to the brain can occur with continued malnutrition after these first years.

cognitive achievement; however their paper ignores problems with measurement error. Glewwe Jacoby and King (2001) use longitudinal data from the Philippines to show that better nourished children perform significantly better in school because they enroll earlier and have greater productivity per year of schooling. Few studies have looked at specific child health problems. One example is a recent study by Miguel and Kremer (2004) which uses experimental design to determine the effect of deworming drugs on primary education in Kenya. The findings show a positive impact on school attendance, but no impact on achievement on academic tests.

Studies that use *HAZ* to summarize overall child health or early childhood nutrition may put too much weight on this variable, ignoring the impact that ailments like poor vision or hearing problems and other childhood illnesses may have on education. This paper attempts to correct these problem by estimating separately the impacts of early childhood nutrition (as measured by *HAZ*) and of current child health problems. Further, it investigates whether there is both a direct impact of early childhood nutrition and current health status on cognitive achievement and an indirect impact through student absences.

Until recently, extensive data on school achievement, child nutritional status and other health problems have been difficult to find for any developing country. In 2003 the Sri Lankan National Education Research and Evaluation Center (NEREC) conducted a learning achievement survey of 16,383 students who completed grade 4 in 2002 across all nine provinces and 25 districts in Sri Lanka. The fact that this is a nation wide survey is remarkable given the civil strife that has persisted since the mid-1980s until 2001. The data include achievement tests scores for math, English and first language (Sinhalese or Tamil) taken at the start of the school year in 2003 when the students were in grade 5.[3] Later in the 2003 school year, the National Education Commission (NEC) in Sri Lanka conducted the Intersectoral Study on Education and Health, by taking a stratified random sample of 2,774 students in 144 schools surveyed from the NEREC study. The data include variables that describe the household's socioeconomic status, the parent's taste for education, the child's early childhood nutritional status and current health status. The advantage of this cross sectional dataset is twofold. First, it contains many health variables never used before in this type of research. Second, it contains many household and child specific variables that are often the cause of missing variable bias, such as parental preferences towards the child's education.

The rest of this paper is organized as follows. The next section describes the theoretical framework. It is followed by a presentation of the data and estimation methods. The next section provides the econometric results. The last section offers some conclusions.

Theoretical Framework

The following framework is grounded in the basic household production model of Becker (1965) and the subsequent extensions of that model to health production and consumption by Grossman (1972). These ideas are extended in two ways. First, the model describes a household that produces early childhood nutrition, current child health, and child cognitive skills. Second, the model allows for intertemporal decision making. Assume parents make decisions for a single child and that their objective is to maximize a utility function that has five arguments: consumption of household goods and services, child

[3] A school year runs from January 1st to December 31st.

cognitive skills, early childhood nutrition, current child health and the future income of the child. Assume there are three time periods and only one child per household. In period 0, a child is born and provided inputs to produce a level of early childhood nutrition. In period 1, the child is of school age and attends school and inputs produce a level of child health and cognitive skill for the child. In period 2 the child becomes an adult and works. When a child works, a portion of the child's earnings are given to the parents. The parents maximize the following additively separable, intertemporal utility function[4]:

$$(1)\quad U_i = \sum_{t=0}^{2} \beta^t u(C_{it}) + \sum_{t=0}^{2} \beta^t u(L_{it}) + u(N_{i0}) + \beta u(A_{i1}) + \beta u(H_{i1}) + \beta^2 u(Y_{i2}^c)$$

The household enjoys consumption of purchased goods for the household (C_{it}) and leisure time (L_{it}) in all three time periods. They also enjoy a child that is well nourished (N_0) in period 0, has high cognitive skills (A_{i1}) and high health status (H_{i1}) in period 1 and a good income (Y^c_{i2}) in period 2. The reason for the time separation of the household's value of nutrition and health is that many child health problems are not observable until they reach school age. Moderate problems with hearing and vision are two examples. As a result many parents do not make decisions that affect health output until period 1. On the other hand, parents do make decisions on nutritional inputs that affect child nutrition in the first stages of their life. It is during this crucial time period of zero to age two, when a child's body and brain are rapidly growing, that any degree of malnutrition is likely to have the greatest effect. The separation of time allows one to weigh the

[4] Numeric subscripts denote time period t=0,1,2 and letter subscripts correspond to both the household and child since there is only one child per household.

importance of current health problems versus early childhood nutrition in the production of child cognitive skills.

Consider the following household production function for the child's cognitive skills:

(2) $A_{i1} = a\left(N_{i0}, H_{i1}, S_{i1}, X_i, Z_i, \phi_{i1}, \eta_{i1}, e_{i1}\right)$

Here A_{i1} describes the cognitive level achieved by the child in period 1 measured by academic achievement. It is produced by a vector describing the child's early childhood nutrition attained in period 0 (N_{i0}), current health status (H_{i1}), a vector of school inputs provided by the school (S_{i1}), socio-demographic characteristics of the household (X_i), community and environmental factors (Z_i), the inherent cognitive ability and motivation of the child ($\phi_{i,1}$), parental taste for education (η_{i1})and measurement error (e_{i1}). Any unobservable component of S_{i1}, Z_i, X_i, ϕ_{i1}, and η_{i1} is effectively added to the error term (e_{i1}). Further, note that Z_i and X_i are assumed to be constant over time. The household's problem is to maximize (1) subject to (2) plus time and budget constraints.

Data and Estimation Methods

Description of Data

The NEREC survey includes a random sample of 20 students in each of the 939 schools surveyed. The students may come from different grade 4 classes in each school. The data include achievement tests scores for math, English and first language for those who have completed grade 4 in 2002. The tests were conducted in March of 2003 when the students were in grade 5.[5] Besides English, there are two primary languages spoken in Sir Lanka based on ethnic group, Sinhala and Tamil. Tamil students took the Tamil test

[5] Kids who repeated grade 4 were included in the sample, while kids who repeat grade 5 were not. Further, the national average for the percentage of repeaters of primary school is 1% (UNESCO, 2004).

for first language and Sinhala students and other ethnic students took the Sinhala language achievement test. The score for each test was standardized to produce a variable with a mean of zero and a standard deviation of one. Table 1 provides a summary of the test scores of the students sampled in the NEC survey by gender and geographical province.

The NEC survey is a stratified random sample of 2,774 students in 144 schools surveyed from the NEREC study. The survey was conducted from June through August of 2003. Table 2 shows a detailed description of the independent variables. Starting with observable household and child characteristics (X_i), the data provide a number of control variables the child including gender, age, birth order, and ethnic group. Household variables include: household's monthly expenditure per capita, the type of toilet and the availability of electricity.

Data on child health and nutrition were collected in two different ways. First, trained field officers conducted health tests during a school medical inspection. Each child was tested for the extent of intestinal worms and vision problems. The children's vision in each eye was tested using a Snellen's eye chart.[6] For each eye, this analysis uses the score for the better eye (a lower number indicates better vision) in cases where the scores differ. Testing was done with any eye glasses on.[7] These data constitute part of the child

[6] In the Snellen fraction 6/6, the first number represents the test distance, 6 meters. The second number represents the distance that the average eye can see the letters on a certain line of the eye chart. So, 6/6 means that the eye being tested can read a certain size letter when it is 6 meters away. If a person sees 6/12, at 6 meters from the chart that person can read letters that a person with 6/6 vision could read from 12 meters away. If 6/6 is considered 100% visual efficiency, 6/12 visual acuity is 85% efficient.

[7] There is no data on which students or how many students wear eye glasses.

health vector (H_{i1}). Field officers also collected data on child height and weight. This data along with data on child age were used to compute stunting (low height for age), wasting (low weight for height) and underweight (low weight for age) measures. All three measures are expressed in the form of Z-scores that compare the child's weight and height with the weight and height of a similar child in a reference healthy population.[8] The reference population Z-score has a mean zero and standard deviation of one. Height for age is a cumulative, long-run indicator of slow physical growth caused by poor nutrition and/or episodes of diarrhea and other childhood illnesses since the birth of the child. Weight for age is a short-run indicator of recent malnutrition and/or episodes of diarrhea and other childhood illnesses and weight for height can reflect stunting, wasting or both. In this paper we use the child's height for age Z-score (*HAZ*) to represent early childhood nutrition (N_{i0}).

The second way data on child health were collected is described by parental responses to questions about their child's health. The parent's report of the child's health is measured by answering yes or no to the following questions: Has your child ever had malaria? Has your child ever passed worms? Does your child have problems with vision? Does your child have problems with hearing? These data constitute the other part of the child health vector (H_{i1}).

Finally, this data set includes many variables that can be used to represent inherent cognitive ability and motivation of the child and parental taste for education (ϕ_I).

[8] Z-scores were calculated using Anthro software developed by Kevin M. Sullivan and Jonathan Gorstein for the U.S. Center for Disease Control and Prevention and the World Health Organization.

Variables that reflect inherent cognitive ability are years of education for both parents. Variables that reflect parental taste for education include the amount of time the child devotes to leisure, studying, and household or non-household economic activity, the availability of non-school books at home, parental involvement in school, whether or not the child attends tuition classes, and a variable that describes the highest level of educational expectation they have for the student and the child's attendance record.

Estimation Strategy

There are several estimation challenges present in the theoretical framework. The first is omitted variable bias. There are many unobservable factors in the school (S_{i1}) and community (Z_{i1}) that could be correlated with nutrition, health and schooling. While this dataset described above does contain additional variables that describe S_{i1} and Z_{i1} in detail, there may still be some factors that are correlated with the key household and child variables. For this reason and because the focus of this paper is early childhood nutrition and health, the analysis controls for community and school heterogeneity with a fixed effects model at the school level.

The second problem is that nutrition and health variables may be endogenous. In order to establish that child health and early childhood nutrition have a causal impact on school achievement neither N_{i0} nor H_{i1} can be correlated with something in the error term. The type of endogeneity that is most troublesome is spurious correlation between child health (or nutritional status) and school achievement. Spurious correlation is a situation in which measures of health and school achievement (for example) are statistically related but are not in fact causally linked, usually because the statistical relation is caused by a third (omitted) variable. In most papers the omitted variables are often the parental taste for education and the child's innate ability. Parents may possess attitudes towards their child's education or observe a child's innate ability (which is unobservable to the researcher) and adjust their inputs to their child's nutrition or health accordingly. There are two reasons why this endogeneity is less of a problem in this paper. First, in the theoretical model early childhood nutrition is established in the first two years of life when the parents are neither likely to impose educational beliefs on their child's nutritional intake nor to know the child's innate ability. Second, endogeneity of the child's current health and early childhood nutrition is less severe because in this dataset the parent's taste for education is observable. Bias associated with this endogeneity is significantly reduced by including variables that control for parental taste for education.

A third problem that plagues estimation is measurement error of the nutrition and health variables. A common procedure is to instrument these variables using two stage least squares. The child's weight for age Z-score (*WAZ*) is used as an instrument for *HAZ*. However, using *WAZ* may not eliminate all bias due to measurement error in *HAZ*. In general data on child height and age reflect three possibilities. First, child height and weight reflect nutritional history. Second, child height and weight contain some general measurement error, or random noise, because children may wiggle when measured for height or drink a quart of water just before being measured for weight. Three, child height and weight might reflect normal variation that has nothing to do with early childhood nutrition. So by using *WAZ* as an instrument for *HAZ* the error due to normal variation in child weight may be positively correlated to the error due to normal variation in child height. The result is that we may still underestimate the impact of child height for age on cognitive skills. But at least there is a lower bound on the parameter. See the derivation of this result in Appendix C.

As described above there are two different types of measures for the state of current child health (H_{i1}). One type describes parental response to questions about the child's problems with hearing, vision, intestinal worms and malaria. Two of the questions refer to whether or not the child has *ever* had malaria or passed worms. Thus the extent to which these two variables predict cognitive achievement is suspect because there is no way of knowing whether the problem existed before or during the child's time spent at school. Two questions simply ask whether or not the child has a problem with vision or hearing. These two variables could be measured with error since it is possible that the parents may not be aware that a problem exists. The second type of child health measure is actual data collected in the field from health tests. Children were tested for vision problems and a stool sample was taken to test for intestinal worms. Since these data are collected by trained field officers, it subject to less measurement error. However, the data collected on intestinal worms represents a current health problem, and not one that might have existed when the child was in grade 4 or when they took the exam a few months prior to the collection of health data. To avoid as much measurement error as possible, the health data collected in the field for intestinal worms are included in H_{i1} and the corresponding data collected from the parents are used as instruments. Further, we include the parental report of whether or not the child has ever had malaria or if they have hearing problems in H_{i1}. Even though we do not have corresponding instruments to correct for any measurement error, to leave them out would further contaminate the model with missing variable bias.

A fourth problem is caused by three types of selectivity bias related to school choice. First, students may select into the sample by the parent's choice of whether or not to send their child to school. However, as of 2001, the net primary enrollment ratio for Sri Lanka is 97% (UNDP 2003), which implies very little scope for sample selection bias. Second, parents may choose which school their children attend resulting in biased OLS estimates for school quality variables. It is likely that parents who send their kids to live elsewhere to go to school have the freedom and financial ability to choose the school their child will attend. One way to determine the extent of the problem is to see how many children live away from home during the school year. In this survey sample, only 3.7% of children live away from home, thus it is believed that this bias will not pose a serious threat to the school quality estimates. Also, other studies have shown that selectivity bias due to school choice does not have much effect on coefficient estimates and may not be an important issue (Glewwe and Jacoby 1994). Finally, recall that this analysis had data that can control for parental tastes for education, which helps correct for parental school choice.

A third type of selectivity bias can also when some children are not tested because they are absent on the days the test is administered. The survey was a random sample of 20 children in each school. While it is possible that a child originally chosen for the sample was absent on the day of the test, the likelihood is small for schools with a larger pool of children from which to draw a sample. A related issue is the hypothesis that part of the way early childhood nutrition and current health affect school achievement is through student absences. Above, school attendance reflects child or parent motivation to send the child to school. For example, a child may not attend school on a particular day because they have to help the family at home with economic activity. They also may not attend school on a particular day because they are sick. On the other hand, a parent or child who highly values education may send a child to school even if they are sick (or have problems with vision or hearing) because they believe that school when you are sick is better than no school at all. It is an interesting exercise to determine the impact of early childhood nutrition and early health status on school achievement, conditional on child attendance in school. Consider again equation (2) where in the fixed effects model S_i and X_i are dropped, and time subscripts are dropped for notational convenience:

$$(2) \quad A_i = a(N_i, H_i, X_i, \phi_i, \eta_i, e_i) = \beta_0 + \beta_1 N_i + \beta_2 H_i + \beta_3 X_i + \beta_4 \phi_i + \beta_5 \eta_i + e_i$$

Here, the impact of early childhood nutrition and current health status is simply:

$$(3) \quad \frac{\partial A_i}{\partial N_i} = \frac{\partial a}{\partial N_i} = \beta_1 \quad \text{and} \qquad (4) \quad \frac{\partial A_i}{\partial H_i} = \frac{\partial a}{\partial H_i} = \beta_2$$

Now consider the impact of nutrition and health, conditional on the student's attendance record, which may also be a function of nutrition and health. Equation (2) becomes:

$$(2') \quad A_i' = a(N_i, H_i, X_i, R_i, \phi_i, \eta_i, e_i) = \gamma_0 + \gamma_1 N_i + \gamma_2 H_i + \gamma_3 X_i + \gamma_4 R_i + \gamma_5 \phi_i + \gamma_6 \eta_i + e_i$$

Here R_i is the rate of child absences from school. It is not an additional variable, rather it is simply separated out from the vector (η_i) where,

$$(5) \quad R_i = \delta_0 + \delta_1 N_i + \delta_2 H_i + \delta_3 D_i + u_i$$

Here D_i is a vector of all other variables that predict child attendance. Conditional on the rate of student absence from school, the impact of early childhood nutrition and current health status is

(3') $$\frac{\partial A_i'}{\partial N_i} = \frac{\partial a}{\partial N_i} + \frac{\partial a}{\partial R_i} \cdot \frac{\partial R_i}{N_i} = \gamma_1 + \gamma_4 \delta_1$$ (4') $$\frac{\partial A_i'}{\partial H_i} = \frac{\partial a}{\partial H_i} + \frac{\partial a}{\partial R_i} \cdot \frac{\partial R_i}{H_i} = \gamma_2 + \gamma_4 \delta_2$$

In equations (3') and (4'), this analysis predicts that γ_1, and γ_1 have the same sign as the unconditional effects β_1 and β_2, and it predicts that the effect of the rate of student absences on test scores (γ_4) is negative. However, it is possible that δ_1 and δ_2 may be positive or negative. Consider (4') where H_i is an indicator problems with intestinal worms. Here, δ_2 is positive if the child or parent values child health over education and the child stays home when they are sick with intestinal worms. It is negative if the child or parent values education more (or has more motivation to send their child to school) and they sent their child to school under the assumption that school when the child is sick is better than no school at all.

Note that the rate of student absences (R_i) may also suffer from the same type of endogeneity as the current health variables. For example, a parent might observe some innate ability of the student and make a corresponding decision about whether or not to send their child to school on any particular day. However, as with the health variables this endogeneity is corrected by controlling for parental taste for education.

Estimation Results

Table 3 shows the first set of school fixed effects regressions of equation (2) for each of the three subjects when the nutrition and health variables are not instrumented. While these estimates are likely to be biased due to measurement error, they are a useful starting point. First note that observable household and child characteristics (X_i) are largely significant and have the expected sign. Compared to girls, boys fair poorly on all three scholastic achievement tests. While child age is not significant, first born children achieve higher scores than children who were born second or otherwise. Compared to the Sinhalese ethnic group, Tamil and Moor/Malay children do much more poorly on the first language exam.[9] The log of monthly per capital expenditures is positive, but not significant. This is likely to be due to the fact that there are other household variables included that also reflect the household economic status. For example, compared to a water sealed type of latrine, households that have a pit type latrine (*latrine3*) have lower test scores in English. Also, children in households with electricity all perform better on the exams. One reason is that the added electricity allows students to study better at night. Another variable that reflects household expenditures is whether or not the parents send their child to extra tuition classes. While this variable also parental taste for education, it is an added expense that some household's might not be able to afford.

Second, the variables that reflect child motivation (ϕ_i) or parental taste for education (η_i) are also largely significant with the expected signs. In particular, note that the variable *hope*, an indicator for the highest level of education the parent has for the child, is positive and significant for math and first language. The years of education for each parent are positive and significant.[10] Children who are sent to extra tuition classes also

[9] Recall Tamil students took the Tamil first language test and the Moor/Malay stunts took the Sinhala first language test.
[10] To reduce sample attrition, missing observations were replaced with the sample mean and a dummy variable was included to indicate the replaced observation.

have significantly higher test scores. The more time children spend studying has a positive impact on first language test scores, and those who spend more time in leisure activities have higher English test scores. Perhaps this is because some of these leisure activities involve English skills. The coefficient on the amount of time children spend in household or economic activities is negative, although it is not significant. The last two variables that reflect parental taste for education are the number of books the child has to read at home and how often the parent discusses the progress of the child with the teacher. Both of these variables are positive and significant.

Third, *HAZ* has a positive and significant effect in all three achievement tests. Further, this effect is quite distinctive from the effect of the child's current health status. Parental report of whether or not the child has a hearing problem and the log of the child's worm count is negative and significant for all three achievement tests. Poor vision according to medical field tests have no effect on achievement tests, although it has the expected sign for math and first language. The coefficient estimate for the parental report of whether or not the child has ever had malaria is inconsistent in sign and not significant. This is not surprising since the parent could be reporting an affliction that occurred before the child entered school years.

As discussed above, it is possible that the nutrition and health variables are measured with error. Table 4 shows the results for two stage least squares regressions with school fixed effects. Set B instruments *HAZ* with *WAZ* and the log of the intestinal worm count collected in the field (*lntworms*) with the parents report of whether or not the child has ever passed worms (*worms*). Surprisingly, none of the regressor are significant. The problem can be found in the first stage regression reported in the Appendix B. While *WAZ* is a good instrument for *HAZ*, *worms* is a poor instrument for *lntworms*. It is difficult to say why the parents report is such a poor instrument for a field test given by trained officers. Perhaps the parents were never aware that the child had a problem or perhaps the field test reflect a current problem with worms, and not a problem that existed prior to when the child took the exams.[11] However, the main problem is that employing weak instruments results in inaccurate estimated standard errors (Hausman 2001).

The second set of two stage least square estimates with school fixed effects (set C) assumes that the field test for intestinal worms is not measured with error and removes it from the first stage regression. Also the literature suggests that no instruments are better than weak instruments (Bound, Jaeger and Baker 1995 and Hausman 2001). Here there results improve in comparison to set B. Compared to the uninstrumented version in set A, the size of the coefficient for *HAZ* is bigger. The coefficient estimate *vis* is still insignificant, with the expected negative sign on math and first language. There are a few explanations for this result. First, regarding the insignificant result, students were allowed to wear glasses for the eye exam if they normally wear them. Thus this analysis can not capture the extent of vision problems persistent in school. Second, students who have vision problems wear glasses and lessening any negative impact of their disability does not affect their academic performance. Third, for those who have poor vision, but

[11] Recall the timing of the exams and survey were such that all grade 4 students who passed grade 4 (by December 2002) took the achievement tests towards the beginning of grade 5 (March 2003); the surveys were conducted a few months later in June-August (2003).

do not have glasses, perhaps the parents who know their child has trouble seeing provide them with extra help with school resulting in an underestimation of the effect of the vision problem on scholastic achievement. Forth, with regard to the negative sign on math and first language scores, it is possible that these two subjects are more challenging for near-sighted students if they are taught on the blackboard, when English is taught through desk work. Yet, the data provide no indication of which subjects are taught on the board. With regard to problems with hearing or malaria, the results are similar to the unistrumented version in set A. Also, note that the rest of the regressors are also consistent with set A. From regression set C we know that early childhood nutrition and current child health have a separate and direct impact on cognitive skill attainment.

Finally, consider any indirect effects transmitted through loss of time at school due to absences. Set D in Table 4 reports two stage least square with fixed effects estimates if equation (2') which separate the rate of student absences from ϕ_i. The rate of student absence has a large and significantly negative effect on achievement test scores. Further, the inclusion of this variable also has a slight effect on the size of the coefficients for each of the early childhood nutrition and current health variables. However, when regressing nutrition and health on the rate of student absence from school, the only variable the have a significant impact is the parental report of whether or not the child has ever had malaria. Equation (4') can be used to calculate the effect of malaria on school achievement, conditional on student absences (consider English test scores):

$\gamma_2 + \gamma_4 \delta_2 = -.070 + (-1.604)(.021) = -1.11$.

While it may be true that a child stays home because he or she is sick, it is not necessarily true that they are more likely to stay home due to malnourishment in early childhood or most of the current health ailments included in this study. Yet it does seem that these nutrition and health variables affect schooling indirectly through rate of student absences. Interestingly, the variables that do seem to have a significant impact on student absences are many of the same variables that describe student and parent motivation or parental taste for education.

Conclusions

Using a new cross-section data set from Sri Lanka this paper controls for missing variable bias and endogeneity enough to show that both early childhood nutrition and current health status both have significant causal effects on child academic achievement, conditional on student absence. Specifically an increase of one standard deviation in height raises school achievement by 0.07-0.09 standard deviation. Further children with hearing problems and problems with worm infestation are shown to have lower school achievement scores of 0.35-0.59 and 0.04 standard deviations respectively.

These conclusions suggest that after controlling for school quality and absences, early childhood nutrition and current health problems are still significant inhibitors to cognitive achievement. Policy makers who are interested in raising the ultimate human capital should not limit their investments to improving school enrollment and school quality. Rather, returns to investments made directly in the education sector will be limited by lack of investment in improving early childhood nutrition and addressing health problems faced by children in school years.

Appendix A

Table 1: Test Scores by Geographic Location and Gender for Students in NEC Sample

	Standardized English			Standardized Math			Standardized First Language		
	n	Mean	Std. Dev	n	Mean	Std. Dev	n	Mean	Std. Dev
Boys	1464	.00	1.02	1427	-.04	1.03	1450	-.08	1.02
Girls	1214	.31	1.03	1195	.18	.93	1208	.25	.93
Western	403	.42	.99	397	.10	.94	401	.18	.95
Central	313	.28	1.05	308	-.02	1.04	314	.01	1.04
Southern	301	.01	1.10	289	.17	1.01	295	.13	1.04
Eastern	280	.14	1.04	274	-.02	.99	279	-.04	1.00
Northern	291	-.24	.93	274	-.22	1.00	281	-.16	.96
North-Central	287	.14	1.04	278	.22	.93	282	.11	.97
North-Western	288	.14	1.07	287	.12	1.01	287	.16	1.00
Sabaragamuwa	278	.13	1.00	276	.11	1.00	279	.08	1.00
Uva	280	.14	1.00	276	.07	.94	277	.11	.97

Table 2: Description of Independent Variables for Students in NEC Sample

Variable	Description	n	Mean	Std. Dev
$X_{i,1}$				
sex	Indicator 1=boy, 0=girl	2693	.55	.50
age	Child age	2691	10.04	.43
rank	Indicator 1=child is first born, 0=otherwise	2536	.40	.49
Sinhala	Indicator 1=child is Sinhalese, 0=otherwise	2689	.65	.48
Tamil	Indicator 1=child is Tamil, 0=otherwise	2689	.23	.42
Moor	Indicator 1=child is Moor/Malay, 0=otherwise	2689	.11	.32
Ethnic4	Indicator 1=child is Burgher/other, 0=otherwise	2689	.00	.07
lnexpcap	Log of household monthly expenditure per capita	2680	7.22	.64
latrine1	Indicator 1=water sealed, 0=otherwise	2594	.65	.48
latrine2	Indicator 1=flush type, 0=otherwise	2594	.15	.36
latrine3	Indicator 1=pit type, 0=otherwise	2594	.18	.38
latrine4	Indicator 1=other, 0=otherwise	2594	.02	.15
electric	Indicator 1=Household uses electricity, 0=otherwise	2681	.70	.46
$\phi_{i,1}$				
nyrsedu	Mother's years of education	2666	9.46	3.15
mdum	Indicator 1=mean(myrsedu) used in place of missing value, 0=otherwise	2666	.20	.40
dyrsedu	father's years of education	2578	9.16	3.38
ddum	Indicator 1=mean(dyrsedu) used in place of missing value, 0=otherwise	2578	.21	.40
$\eta_{i,1}$				
hope	Indicator for highest level of expectation parent has for child, 1=other or no special expectation,	2691	6.15	2.28

	2= complete primary 3=below GCE O/L, 4=Pass GCE O/L, 5=Pass GCE A/L, 6= Technical/vocational education, 7=First degree, 8=Other professional (e.g. law, accounting, medicine, engineering), 9=Postgraduate degree			
tuition	Indicator 1=parents send child to tuition classes, 0=otherwise	2731	.74	.44
hacademic	Hours per week child spends studying at home or in tuition classes	27	5.91	1.63
hleisure	Hours per week child spends playing, supervised sports, aesthetic activities, reading, listening to radio, or watching TV	2700	12.57	2.49
hwork	Hours per week child spends in non-economic household tasks, family economic activity or paid economic activity.	2700	4.07	1.10
kbook	How many books child has to read at home other than school text books	2656	1.98	1.01
discteach	Indicator for how often parent discuses the progress of the child with the class teacher 1=not at al, 2=only on PTA days, 3=sometimes on other days, 4=regularly, on other days	2692	2.77	.85
pabsent	Ratio of the number of days absent from school per number of days school was held	2687	.14	.11
$\boldsymbol{N_{i.0}}$				
haz	Height for age Z-score	2526	-.98	.95
waz	Weight for age Z-score	2526	-1.39	.89
$\boldsymbol{H_{i,1}}$				
malaria	Indicator for parents' report of whether the child ever had malaria 1=yes, 0=no	2688	.06	.24
worms	Indicator for parents' report of whether or not the child has ever passed worms 1=yes, 0=no	2688	.09	.28
hearing	Indicator for parents' report of whether or not the child has any problem with hearing 1=yes, 0=no	2684	.01	.11
vision	Indicator for parents' report of whether or not the child has any problem with vision 1=yes, 0=no	2690	.04	.19
lntworms	Log of total egg count for intestinal worms collected by field workers	2088	.41	1.58
vis	A continuous variable equal to the Snellen's eye score that is better between the two eyes.	2526	6.37	2.31

Table 3: School fixed effects

	A		
	stdmath	stdeng	stdsin
sex	-0.182***	-0.305***	-0.308***
	(0.044)	(0.042)	(0.042)
age	-0.006	-0.021	-0.026
	(0.068)	(0.064)	(0.065)
myrsedu	0.007	0.018**	0.015**
	(0.008)	(0.007)	(0.007)
mdum	-0.143*	-0.150**	-0.137*
	(0.078)	(0.074)	(0.074)
dyrsedu	0.028***	0.050***	0.035***
	(0.008)	(0.008)	(0.007)
ddum	-0.171**	-0.230***	-0.123
	(0.078)	(0.075)	(0.075)
lnexpcap	0.039	0.005	0.004
	(0.045)	(0.043)	(0.042)
hope	0.029***	0.014	0.021**
	(0.011)	(0.010)	(0.010)
latrine2	0.003	0.072	-0.021
	(0.082)	(0.079)	(0.078)
latrine3	-0.080	-0.201***	-0.048
	(0.069)	(0.066)	(0.065)
latrine4	0.245	0.013	0.250
	(0.245)	(0.237)	(0.234)
electric	0.182***	0.109**	0.187***
	(0.057)	(0.055)	(0.054)
tuition	0.277***	0.271***	0.267***
	(0.065)	(0.062)	(0.062)
rank	0.083**	0.188***	0.105***
	(0.041)	(0.039)	(0.039)
tamil	-0.309	-0.068	-0.494**
	(0.214)	(0.207)	(0.204)
moor	-0.279	0.241	-0.482**
	(0.206)	(0.198)	(0.195)
ethnic4	-0.050	0.068	-0.332
	(0.370)	(0.357)	(0.353)
hacademic	0.030*	0.011	0.047***
	(0.017)	(0.017)	(0.017)
hleisure	0.015	0.023**	0.013
	(0.010)	(0.010)	(0.010)
hwork	-0.027	-0.027	-0.021
	(0.021)	(0.020)	(0.020)
kbook	0.083***	0.152***	0.095***
	(0.027)	(0.026)	(0.026)
discteach	0.089***	0.115***	0.121***

	(0.029)	(0.028)	(0.027)
hearing	-0.584***	-0.368**	-0.326**
	(0.172)	(0.162)	(0.160)
malaria	0.030	-0.105	0.029
	(0.103)	(0.098)	(0.098)
vis	-0.012	0.003	-0.001
	(0.010)	(0.010)	(0.010)
lntworms	-0.044***	-0.046***	-0.031**
	(0.017)	(0.016)	(0.016)
haz	0.059**	0.073***	0.096***
	(0.023)	(0.022)	(0.022)
Constant	-1.222	-1.256*	-1.005
	(0.779)	(0.737)	(0.740)
Observations	1693	1717	1708
Number of sc_code	135	135	135
R-squared	0.14	0.23	0.19

Standard errors in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%

Table 4: Two stage least squares with school fixed effects

	B			C			D			
	stdmath	stdeng	stdsin	stdmath	stdeng	stdsin	stdmath	stdeng	stdsin	pabsent
sex	-0.319	-0.381	0.093	-0.182***	-0.305***	-0.308***	-0.167***	-0.283***	-0.285***	0.013***
	(0.745)	(0.399)	(3.178)	(0.044)	(0.042)	(0.042)	(0.044)	(0.042)	(0.041)	(0.005)
age	0.391	0.308	-1.036	-0.004	-0.020	-0.025	0.040	0.017	0.031	0.023***
	(1.860)	(1.442)	(7.820)	(0.068)	(0.064)	(0.065)	(0.069)	(0.065)	(0.065)	(0.008)
myrsedu	0.046	0.033	-0.052	0.007	0.018**	0.015**	-0.000	0.013*	0.007	-0.004***
	(0.188)	(0.074)	(0.535)	(0.008)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.001)
mdum	0.907	0.372	-2.973	-0.139*	-0.149**	-0.136*	-0.126	-0.143*	-0.121*	0.008
	(4.664)	(2.276)	(21.611)	(0.078)	(0.074)	(0.074)	(0.077)	(0.074)	(0.073)	(0.009)
dyrsedu	0.072	0.079	-0.088	0.028***	0.050***	0.035***	0.029***	0.051***	0.036***	0.001
	(0.208)	(0.132)	(0.949)	(0.008)	(0.008)	(0.007)	(0.008)	(0.007)	(0.007)	(0.001)
ddum	0.122	-0.100	-0.450	-0.174**	-0.230***	-0.123	-0.173**	-0.225***	-0.123*	0.015*
	(1.510)	(0.682)	(2.985)	(0.078)	(0.075)	(0.075)	(0.078)	(0.076)	(0.074)	(0.009)
lnexpcap	-0.690	-0.363	1.681	0.036	0.005	0.003	0.032	0.007	-0.002	-0.002
	(3.207)	(1.572)	(12.816)	(0.045)	(0.043)	(0.042)	(0.044)	(0.043)	(0.042)	(0.005)
hope	-0.031	-0.027	0.210	0.028***	0.014	0.020**	0.024**	0.013	0.016	-0.002
	(0.282)	(0.187)	(1.453)	(0.011)	(0.010)	(0.010)	(0.011)	(0.010)	(0.010)	(0.001)
latrine2	1.336	0.749	-2.747	0.000	0.072	-0.021	-0.012	0.070	-0.030	-0.001
	(5.907)	(2.900)	(20.829)	(0.083)	(0.079)	(0.078)	(0.082)	(0.078)	(0.077)	(0.009)
latrine3	0.878	0.314	-2.254	-0.083	-0.201***	-0.049	-0.087	-0.197***	-0.050	0.002
	(4.276)	(2.235)	(16.823)	(0.069)	(0.066)	(0.065)	(0.068)	(0.065)	(0.064)	(0.008)
latrine4	4.298	2.078	-8.339	0.250	0.014	0.251	0.210	-0.008	0.215	-0.018
	(17.959)	(8.944)	(65.470)	(0.246)	(0.237)	(0.234)	(0.241)	(0.233)	(0.228)	(0.028)
electric	0.574	0.356	-0.798	0.177***	0.108**	0.186***	0.123**	0.062	0.133**	-0.028***
	(1.831)	(1.103)	(7.575)	(0.057)	(0.055)	(0.054)	(0.057)	(0.054)	(0.053)	(0.007)
tuition	0.934	0.523	-1.192	0.276***	0.271***	0.267***	0.235***	0.227***	0.218***	-0.028***
	(2.963)	(1.137)	(11.175)	(0.065)	(0.062)	(0.062)	(0.064)	(0.062)	(0.061)	(0.007)
rank	0.314	0.309	-0.282	0.078*	0.187***	0.104***	0.049	0.160***	0.076**	-0.012**
	(1.103)	(0.544)	(3.087)	(0.041)	(0.039)	(0.039)	(0.041)	(0.039)	(0.038)	(0.005)
tamil	0.887	0.499	-2.912	-0.322	-0.070	-0.497**	-0.361*	-0.074	-0.511**	-0.001
	(5.731)	(2.682)	(18.876)	(0.215)	(0.207)	(0.205)	(0.217)	(0.210)	(0.205)	(0.025)
moor	2.353	1.577	-5.870	-0.282	0.240	-0.483**	-0.256	0.249	-0.472**	0.002
	(11.765)	(5.834)	(41.148)	(0.206)	(0.198)	(0.195)	(0.208)	(0.200)	(0.195)	(0.024)

ethnic4	7.039	3.632	-15.165	-0.044	0.069	-0.330	0.228	0.326	-0.010	0.161***
	(31.356)	(15.427)	(112.959)	(0.371)	(0.357)	(0.353)	(0.366)	(0.354)	(0.346)	(0.043)
hacademic	-0.064	-0.043	0.313	0.030*	0.011	0.047***	0.018	0.001	0.034**	-0.007***
	(0.447)	(0.247)	(2.052)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.016)	(0.002)
hleisure	0.008	0.018	0.016	0.014	0.023**	0.013	0.020*	0.027***	0.018*	0.002
	(0.106)	(0.056)	(0.215)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.001)
hwork	0.066	0.030	-0.182	-0.026	-0.026	-0.020	-0.037*	-0.031	-0.030	0.001
	(0.455)	(0.264)	(1.302)	(0.021)	(0.020)	(0.020)	(0.021)	(0.020)	(0.020)	(0.002)
kbook	-0.070	0.065	0.422	0.083***	0.152***	0.094***	0.083***	0.146***	0.094***	-0.002
	(0.731)	(0.411)	(2.529)	(0.027)	(0.026)	(0.026)	(0.027)	(0.026)	(0.025)	(0.003)
discteach	0.049	0.172	-0.019	0.086***	0.114***	0.120***	0.069**	0.101***	0.104***	-0.009***
	(0.329)	(0.285)	(1.224)	(0.029)	(0.028)	(0.027)	(0.029)	(0.027)	(0.027)	(0.003)
hearing	4.240	1.757	-9.407	-0.574***	-0.366**	-0.324**	-0.584***	-0.375**	-0.340**	-0.001
	(21.234)	(9.166)	(69.089)	(0.172)	(0.162)	(0.160)	(0.169)	(0.160)	(0.156)	(0.019)
malaria	-0.744	-0.445	0.700	0.033	-0.104	0.030	0.067	-0.070	0.073	0.021*
	(3.566)	(1.553)	(5.531)	(0.103)	(0.098)	(0.098)	(0.101)	(0.097)	(0.096)	(0.012)
vis	-0.177	-0.084	0.357	-0.012	0.003	-0.001	-0.012	0.002	-0.001	0.001
	(0.733)	(0.378)	(2.721)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.001)
lntworms	-6.490	-3.301	13.598	-0.044***	-0.046***	-0.031*	-0.037**	-0.043***	-0.024	0.002
	(28.339)	(13.986)	(103.530)	(0.017)	(0.016)	(0.016)	(0.017)	(0.016)	(0.016)	(0.002)
haz	0.033	0.034	0.250	0.096***	0.078**	0.106***	0.086***	0.070**	0.095***	-0.005
	(0.421)	(0.246)	(1.287)	(0.032)	(0.031)	(0.031)	(0.032)	(0.031)	(0.030)	(0.004)
pabsent							-1.822***	-1.604***	-2.045***	
							(0.225)	(0.215)	(0.213)	
Constant	1.663	-1.176	-6.286	-1.170	-1.249*	-0.994	-1.102	-1.243*	-1.017	0.021
	(14.644)	(3.895)	(43.407)	(0.781)	(0.738)	(0.740)	(0.785)	(0.743)	(0.739)	(0.090)
n	1689	1713	1704	1693	1717	1708	1670	1695	1685	1704
Number of schools	135	135	135	135	135	135	135	135	135	135

Standard errors in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%. See Appendix B for first stage regressions of set B, C and D.

Appendix B
First stage regressions for sets B, C and D

	B		C	D
	haz	lntworms	haz	haz
sex	-.014	-.019	-.014	-.012
	(.034)	(.068)	(.034)	.034
age	.015	.059	.017	.031
	(.053)	(.105)	(.053)	.054
myrsedu	.002	.006	.002	.002
	(.006)	(.012)	(.006)	.006
mdum	-.048	.162	-.049	-.047
	(.060)	(.119)	(.060)	.060
dyrsedu	-.013**	.007	-.014**	-.014**
	(.006)	(.012)	(.006)	.006
ddum	.060	.050	.060	.059
	(.060)	(.119)	(.060)	.061
lnexpcap	.006	-.113*	-.001	.002
	(.035)	(.069)	(.035)	.035
hope	.014*	-.009	.014*	.014*
	(.008)	(.016)	(.008)	.008
latrine2	.105*	.206	.109*	.100
	(.063)	(.126)	(.064)	.064
latrine3	.089*	.147	.089*	.089*
	(.053)	(.105)	(.053)	.054
latrine4	.012	.630*	.013	.014
	(.189)	(.375)	(.190)	.190
electric	.102**	.062	.103**	.101**
	(.044)	(.087)	(.044)	.044
tuition	.017	.103	.024	.027
	(.050)	(.100)	(.050)	.051
rank	.057*	.036	.063**	.060*
	(.031)	(.062)	(.032)	.032
tamil	.208	.186	.206	.241
	(.165)	(.327)	(.165)	.171
moor	.095	.408	.095	.066
	(.158)	(.315)	(.159)	.164
ethnic4	-.249	1.103*	-.246	-.217
	(.285)	(.565)	(.286)	.289
hacademic	-.003	-.014	-.004	-.006
	(.013)	(.027)	(.013)	.014
hleisure	-.003	-.001	-.002	-.000
	(.008)	(.016)	(.008)	.008
hwork	-.020	.014	-.020	-.020
	(.016)	(.032)	(.016)	.016
kbook	-.015	-.024	-.012	-.015
	(.021)	(.041)	(.021)	.021

discteach	.044**	-.006	.047**	.050**
	(.022)	(.044)	(.022)	.022
hearing	-.079	.749***	-.079	-.074
	(.132)	(.262)	(.133)	.133
malaria	-.021	-.120	-.022	-.023
	(.079)	(.157)	(.079)	.080
vis	.005	.026	.005	-.005
	(.008)	(.016)	(.008)	.008
waz	.724***	-.007	.722***	.720***
	(.018)	(.036)	(.018)	.018
worms	.000	.031		
	(.069)	(.136)		
lntworms			-.001	-.006
			(.013)	.013
pabsent				-.056
				.177
Constant	-.252	.463	-.229	-.401
	(.602)	(1.195)	(.602)	.618
n	1689	1689	1693	1670
Number of schools	135	135	135	135

Standard errors in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%.

Appendix C

Consider the simple case of a regression model with a single regressor and no constant term where *y*=child test scores and *x*=HAZ, $y = \beta x^* + \varepsilon$. Further assume the model conforms to all the assumptions of a classical normal regression model. If our observed data are imperfectly measured versions of x^* then our observed *x* contain errors of measurement such that $x = x^* + u$ with $u \sim N[0, \sigma_u^2]$. Then our actual regression becomes:

(1) $y = \beta[x-u] + \varepsilon = \beta x + [\varepsilon - \beta u] = \beta x + v$

The result is our regressor *x* is correlated with the disturbance *v*, violating a central assumption of the classical model. It follows that our least squares estimator *b* will be inconsistent and bias the estimate towards zero. To see this, we can find the probability limits and use the Slutksy theorem:

(2)

$$p\lim b = \frac{p\lim\left(1/n\right)\sum_{i=1}^{n}\left(x_i^* + u_i\right)\left(\beta x_i^* + \varepsilon_i\right)}{p\lim\left(1/n\right)\sum_{i=1}^{n}\left(x_i^* + u_i\right)^2} = \frac{\beta p\lim\left(1/n\right)\sum_{i=1}^{n}\left(x_i^{*2}\right)}{p\lim\left(1/n\right)\sum_{i=1}^{n}\left(x_i^{*2}\right) + \sigma_u^2} = \frac{\beta}{1 + \dfrac{\sigma_u^2}{p\lim\left(1/n\right)\sum_{i=1}^{n}\left(x_i^{*2}\right)}}$$

As long as σ_u^2 is positive *b* will be inconsistent with a bias towards zero. The value of *b* will underestimate the true effect of HAZ on child test scores. A common procedure is to use an instrument variable *z* that is correlated with x^* but not with *u*. Then, if $Cov[x^*,z] \neq 0$ then the estimate is consistent.

(3) $$p\lim b_{IV} = \frac{p\lim\left(1/n\right)\sum_{i=1}^{n}\left(\beta x_i^* + \varepsilon_i\right)\left(z_i\right)}{p\lim\left(1/n\right)\sum_{i=1}^{n}\left(x_i^* + u_i\right)\left(z_i\right)} = \frac{\beta Cov\left[x^*, z\right]}{Cov\left[x^*, z\right]} = \beta$$

However, in this case z=WAZ is also measured with the same type error as HAZ, $z = z^* + w$ with $w \sim N[0, \sigma_w^2]$. Further, this type of measurement error in WAZ will be correlated with the measurement error in HAZ. Then our estimate of b_{IV} becomes

(4) $$p\lim b_{IV} = \frac{p\lim\left(1/n\right)\sum_{i=1}^{n}\left(\beta x_i^* + \varepsilon_i\right)\left(z_i^* + w_i\right)}{p\lim\left(1/n\right)\sum_{i=1}^{n}\left(x_i^* + u_i\right)\left(z_i^* + w_i\right)} = \frac{\beta Cov\left[x^*, z\right]}{Cov\left[x^*, z\right] + \sigma_{uw}} = \frac{\beta}{1 + \dfrac{\sigma_{uw}}{Cov\left[x^*, z^*\right]}}$$

Since we expect σ_{uw} and $Cov[x^*,z^*]$ to be positive, b_{IV} will still be inconsistent and biased toward zero.

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