The Sooner The Better but It's Never Too Late: The Impact of Nutrition at Different Periods of Childhood on Cognitive Development[a]

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Abstract

Although, it has been argued that undernutrition and its consequences for child development are irreversible after the age of 2 years, the evidence in support of these hypotheses is inconclusive. This paper investigates the impact of nutrition at different periods from conception to age 8 years on cognitive achievement at age 8 years using data from Ethiopia, India, Peru, and Vietnam. In order to address estimation problems I develop a conceptual framework and use exogenous variation in nutritional status arising from weather shocks. Results suggest that undernutrition in utero and infancy and its impact on cognitive development can be reversed through nutrition and cognitive skills investments in later periods of childhood and that the direction of parental investment responses to changes in the child's nutritional status depends on the timing of undernutrition.

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1. Introduction

The literature on human development in economics, psychology, and other disciplines (Cunha and Heckman, 2007; Heckman, 2007; Grantham-McGregor et al., 2007) highlights the existence of critical and sensitive periods, when investments and environments are particularly effective in fostering the acquisition of capabilities. The identification of these periods for the development of different types of capabilities is therefore crucial for the design of effective interventions that mitigate harm and promote human development. Nevertheless, relatively little is still known on how resilient individuals are to adversity and the extent to which compensation at a later stage of life can remedy for earlier deficits (Rutter, 2004; Cunha et al., 2006; Almond and Currie, 2011).

In low- and middle-income countries, where child undernutrition is endemic and has deleterious implications for child survival, health, and development (Black et al., 2008, 2013), interventions focus on the first 1000 days of life, that is the period from conception to the age of 24 months, because this period is highlighted as a critical period during which physical growth and cognitive development are particularly susceptible to nutritional insults (Pollitt et al., 1996; Glewwe et al., 2001; Black et al., 2008, 2013). In particular, it has been suggested that growth retardation and cognitive deficits resulting from undernutrition during this period can hardly be reversed in later periods (Martorell et al., 1994; Glewwe et al., 2001; Victora et al., 2010). The evidence, however, does not seem to provide unequivocal support to these hypotheses, as several studies find evidence consistent with reversal of undernutrition and associated developmental setbacks through changes in the environment and interventions occuring after the age of 2 years (Golden, 1994; Alderman et al., 2006; Grantham-McGregor and Baker-Henningham, 2010; Prentice at al., 2013). Although, this evidence may refute the “irreversibility” claim, it has been suggested that a primary focus of nutrition- and growth-promoting interventions on the first 1000 days is still justified on the basis that the effect of undernutrition during this period on child health and development is larger compared to that of undernutrition in later periods (Black et al., 2013). Nevertheless, this is viewed by many as an assertion, as the evidence on the relative impact of nutrition at different periods of early life on cognitive development remains scarce (Glewwe and King, 2001; Maluccio et al., 2009). The few existing studies investigating how the timing of undernutrition affects subsequent cognitive achievement mainly include experimental studies based on interventions in children of different ages (McKay et al., 1978; Maluccio et al., 2009; Barham et al., 2013) and studies from the biomedical literature investigating the association between nutrition trajectories, as measured by growth at different periods, with cognitive achievement using observational data (Gandhi et al., 2011; Crookston et al., 2013; Georgiadis et al., 2016). These studies have advantages but are also hindered by several limitations. Experimental studies provide estimates of the impact of interventions on cognitive achievement that may not only manifest through nutrition improvements and produce mixed evidence that may partly reflect that results are context- and period-specific, and thus have limited external validity. Furthermore, the few studies from the biomedical literature examining the relationship between growth trajectories and cognition produce evidence of correlations that is difficult to interpret.

The only study, to our knowledge, to date, that directly investigates the impact of the timing of undernutrition on cognitive achievement is that by Glewwe and King (2001). In particular, Glewwe and King (2001) examine the effect of growth at different periods from conception to age 8 years on cognitive development at age 8 years using data from the Cebu longitudinal health and nutrition survey and instrumental variables (IV) estimation that enables them to address the endogeneity of child growth. Their key finding is that only growth during the second year of life has a positive and significant effect on cognitive achievement at age 8 years. Nevertheless, one reason why the authors do not find a significant effect of growth after the age of 2 years on cognitive achievement may be that they consider growth over a long period, i.e. between age 2 and 8 years, and this may dilute the significant effect of growth in any sub-period during these years. Furthermore, one limitation of this study, that also plagues other studies examining the relationship between nutrition trajectories and human capital outcomes (Martorell et al., 2010), stems from the inclusion in the same specification of nutrition measures at different periods that are strongly correlated. Despite the use of IV estimation, this is expected to lead to biased and inefficient estimates of the total effect of nutrition in all periods except of the latest period considered on cognition, because it does not account for the effect of nutrition at a given period on cognitive achievement in a later period manifesting through nutrition in interim periods.

Another limitation of existing studies purporting to identify critical periods for the impact of nutrition on cognitive development is that their results may reflect, at least partly, behavioural responses by parents, who may increase or decrease investments in the face of changes in child nutritional status (Glewwe and Jacoby, 1995; Alderman et al., 2001). Therefore, because these studies do not produce evidence of the direction of these responses, it is very difficult to infer from their results the magnitude of direct biological effects running from nutrition in each period to cognitive development that is needed for the identification of critical periods (Almond and Currie, 2011). The question of how parents respond to changes in child health, however, is little investigated and the existing evidence is rather mixed (Pitt et al., 1990; Behrman et al., 1994).

Moreover, we know very little on whether and how parental investment responses depend on the timing of changes in child health.

In this paper, I investigate the impact of child nutrition, as measured by growth, at different periods from conception through middle childhood on cognitive achievement at age 8 years using data from the Young Lives cohort study in Ethiopia, India, Peru, and Vietnam. Several features of my analysis allow me to address some of the key estimation problems hindering previous studies. As discussed above, one estimation problem arises from serial correlation of growth that makes it difficult to isolate the total effect of growth in each period on cognition. In order to address this problem, I develop a conceptual framework of the determination of child health and cognitive skills over different periods of childhood that delineates the channels through which health in each period impacts cognitive skills and allows health at a given period to impact cognitive skills at a later period also through health in interim periods. The framework is used to distinguish between two demand relationships for cognitive skills conditional on child health, one that accounts for all channels through which child health impacts cognitive skills and one that does not account for the effect of child health manifesting through health in subsequent periods. Estimation of both relationships allows one to identify the total effect of health in each period on cognitive skills and to assess the importance of the causal pathway linking early health with later cognition manifesting through health in interim periods. One key implication of the framework is that early health insults lead to cognitive deficits that are expected to accumulate over the life course and this process could be counteracted through compensatory investments in child health and cognitive skills in later periods.

Another problem in estimation emanates from endogeneity of child nutrition in different periods due to the simultaneous determination of child health and cognitive skills through parental investments and to various sources of measurement error in nutrition measures. I overcome this problem employing IV estimation using as instruments for nutrition in each period community weather shocks during the same period that are expected to impact child nutritional status through contributing to the prevalence of infectious diseases (Skoufias and Vinha, 2012). Finally, by using data from a unique international cohort study in low- and middle-income countries, I produce international evidence of higher external validity than those of studies focusing on a single context.

My key finding is that undernutrition in utero and through infancy and its impact on cognitive achievement in childhood can be reversed through investments in nutrition and cognitive skills in later periods of childhood. This is supported by evidence that child growth is responsive to weather shocks occuring after the age of 2 years and has a large effect on cognitive achievement at age 8 years across countries but also that a significant share of the impact of nutritional status from conception through infancy on later cognitive achievement at age 8 years manifests through nutrition in childhood. I also find evidence suggestive of a direct effect of nutrition both before and after infancy on cognitive achievement at age 8 years and that the effect of nutrition in each period on cognitive achievement can be partly explained by changes in parental nutrition and cognitive skills investments around the age of 8 years.

Moreover, another novel finding is that parental investment responses to a change in child health are heterogeneous across multiple dimensions. In particular, I find that a) different cognitive skills inputs may respond to opposite directions as a result of a change in child health at a given period, b) parents may compensate in health investments and reinforce in cognitive skills investments or vice versa after a change in child health at a given period, c) parents may compensate for a change in health in one period and reinforce for a change in health in another period, and d) there are unobserved parental investment responses to a change in child health at a given period. These results may explain the mixed evidence and the current lack of consensus in the literature on whether parents compensate or reinforce the impact of child health insults in early life and highlight that, under heterogeneous and partially observed parental investment responses to child health, it is very difficult to infer whether reduced form estimates provide lower or upper bounds of biological effects of health on cognitive skills.

Overall, my findings have important policy implications. On the one hand, results indicate that nutrition early in life is important for growth and cognitive development in subsequent stages of childhood, but on the other hand they suggest that nutrition-promoting investments after infancy and early childhood can act as a remedy for early nutrition and cognitive deficits and protect from nutritional insults in later stages that may also lead to developmental setbacks. The evidence here also highlights the importance of parental behavioural responses for the causal link between child nutrition and cognitive development and thus that these responses, which may counteract the impact of interventions, should be taken into account in the design of policies aiming to promote child growth and development. Thus, the evidence suggests that nutrition-promoting interventions that start early in life and continue to subsequent stages of childhood combined with support in other areas such as cognitive stimulation and parental involvement may hold the most promise for the promotion of child development.

The remainder of the paper is organized as follows. Section 1 presents a conceptual framework of the relationship between child health and cognitive skills over different periods of childhood and section 2 sets out the specification of the econometric model and the identification strategy adopted. Section 3, then discusses the data and presents descriptive statistics of all variables used in our analysis, whereas section 4 presents the estimation results, and section 5 concludes.

2. Conceptual Framework

2.1 *The Model*

In this section, I present a framework that considers an adaptation of Pollak's seminal work on conditional demand function in consumer theory (Pollak, 1969) in the case of the determination of child health and cognitive skills over multiple periods. The framework is used to derive the key relationship of interest that is the demand for cognitive skills conditional on child health that allows one to assess the total effect of child health in each period on child cognitive skills in the same or future periods.

The framework here deviates from other frameworks, as that by Glewwe and Miguel (2008) in one important respect. Glewwe and Miguel (2008) consider a conditional demand for child academic skills that can be used to assess the effect of an exogenous change in child health in one period on academic achievement in a later period that assumes that child health in interim periods does not respond to the change in child health. As a result of this assumption, the conditional demand relationship they derive can be used to evaluate only transitory changes in child health in one period on academic skills in a later period that do not have a direct effect on health in subsequent periods and does not take into account that, as also suggested by Pollak (1969), although parental health investments may be fixed in the short-run, in the long-run these investments may respond to the change in child health.

This paper addresses this limitation by considering a framework of the determination of child health and cognitive skills, where child health at a given period responds to a change in health at an earlier period either directly, through the health production function or through responses of child health inputs in that period. This allows me to derive a conditional demand for child cognitive skills that can be used to assess the total effect of a change in health in one period on cognitive skills in a later period, including the effect of a change in child health on cognitive skills manifesting through changes in health in interim periods. In this way, the framework here yields a key novel insight that highlights the potential of health investments later in life to mitigate cognitive deficits arising from early health insults.

I assume two periods of early life: period 1 starts at conception and ends at age 2 years and period 2 spanning from age 2 to 5 years, just before the child enters in primary school. Parents are assumed to maximise the following lifetime utility function:

$$U[\{C_t, l_t, H_t, CS_t\}_{t=1}^{2}; \delta, \xi, \{\xi_t\}_{t=1}^{2}] \quad (1)$$

where C_t is household consumption in period t, l_t is parental time spent in leisure, H_t is child health, and CS_t stands for child cognitive skills, ξ and ξ_t denote fixed and time-variant taste shifters respectively, δ captures parental time preferences, and $\{K_t\}_{t=1}^{2}$ for $K = C, l, H, CS, \xi$ denotes a sequence including the values of K from period 1 to period 2. I do not make any specific assumptions about the nature of preferences, other than that the utility function is increasing in its arguments and continuously differentiable that is needed for the optimization problem to have a unique solution.

Utility is maximized subject to technological, budget, and time constraints over the two periods. The technological constraints include the child health and cognitive skills production functions in each period that determine how health and cognitive skills inputs are converted into their respective outputs.

The production function for child health in each period is expressed by the following equation:

$$H_t = H_P[H_{t-1}, N_t, T_{H,t}; D_t, \lambda_t, u_t] = H_{t,P}[H_{t-1}, N_t, T_{H,t}] \quad (2)$$

where H_{t-1} is child health in the period just before period t, $T_{H,t}$ is parental time spent in the production of child health, N_t denotes other health inputs in period t, λ_t denotes time-variant health productivity shifters in period t, D_t is the disease environment, and u_t denotes health productivity shocks.[1] I also assume that child health prior to period 1, H_0, is child health endowment at conception and also captures the influence of fixed health productivity shifters, λ, on child health. As in Glewwe and Miguel (2008), equation (2) assumes that child health at a given point in time is a sufficient statistic for the history of investments in child health up to that point. Moreover, equation (2) assumes that the productivity of investments at any given period is

[1] The key distinction between shifters and shocks that is implied throughout this section is that the former are systematic factors determining the functional form whereas the latter are idiosyncratic. Another assumption that is imposed throughout is that shifters are determined either exogenously or prior to the first period.

determined by the level of D, λ, and u in that period. I also assume that (2) is a continuously differentiable function that is increasing in the direct inputs H_{t-1}, N_t, and T_{Ht}.

Similarly, the production function for child cognitive skills in each period is as follows:

$$CS_t = CS_P\left[\left\{H_\tau, T_{CS,\tau}, I_\tau\right\}_{\tau=1}^{t}; \alpha, \mu, \{S_\tau\}_{\tau=2}^{t}, \{\mu_\tau, v_\tau\}_{\tau=1}^{t}\right] = CS_{t,P}\left[\left\{H_\tau, T_{CS,\tau}, I_\tau\right\}_{\tau=1}^{t}\right] \quad (3)$$

where $T_{CS,t}$ is parental time allocated in the production of child cognitive skills in period t, I_t are other cognitive skills production inputs, α is the child's innate ability that is assumed to be fixed over time, μ_t and μ are time-variant and fixed cognitive skills productivity shifters respectively, S_t is the pre- school environment in period t[2] (that is assumed to be outside parents' control), and v_t denotes cognitive skills productivity shocks. Equation (3) also allows for direct effects of child health on cognitive skills at a given period by including child health in the same and all prior periods among the determinants of cognitive skills.[3] I also assume that the productivity of cognitive skills inputs at any given period is determined by the fixed level of α and μ, the level of S (for period 2 skills only), and the levels of time-variant shifters and shocks μ and v respectively in the same and all prior periods. Another assumption is that (3) is a continuously differentiable function that is increasing in the direct inputs $H_t, T_{CS,t}$, and I_t.

The lifetime budget constraint is expressed by the following equation:

$$V_T = \sum_{t=1}^{2}(1+r)^{2-t}\left(w_t L_t - p_{C,t}C_t - p_{N,t}N_t - p_{I,t}I_t\right) + (1+r)^2 A_0 \quad (4)$$

where V_T stands for assets at the end of period 2 which could be positive, negative, or zero, w_t is the wage in period t, $p_{C,t}, p_{N,t}$, and $p_{I,t}$ are prices of consumption goods, health inputs, and cognitive skills inputs in period t respectively, r is the interest rate, that is assumed to be fixed, L_t is parental labour supply, and A_0 are assets at the beginning of period 1.

Finally, the time constraint in period t can be written as follows:

$$L_t + l_t + T_{H,t} + T_{CS,t} = 1 \quad (5)$$

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[2] Note that $\{K_t\}_{t=t_0}^{t_1} = \emptyset$ if $t_0 > t_1$ for all K and $\{K_t\}_{t=t_0}^{t_1} = K_{t_0}$ if $t_0 = t_1$ for all K. This simply implies that, for example, in the case of equation (3), the pre-school environment is not expected to be among the determinants of cognitive skills in period 1.

[3] Equation (3) assumes that it is the stock of health at the end of period 1, as summarized by H_1, that matters for cognitive skills in each period and this is why it does not include H_0 among the determinants of child cognitive skills in each period.

where (5) suggests that total parental time endowment, that is normalized to 1, is allocated to four activities, namely, labour supply, leisure, production of child health, and production of child cognitive skills.

I assume a sequential optimizing decision-making procedure that involves the following sequence of events:

a) the values of exogenous variables other than shocks in period 1 are realised,

b) parents choose optimally child health inputs in period 1,

c) all shocks in period 1 are realised,

d) optimal child health in period 1 is determined through (2),[4]

e) parents choose optimally the rest of the variables in period 1 and 2 subject to the utility maximizing level of child health in period 1, resources (income and time) remaining after investments on child health in period 1 have been implemented, and

f) in period 2, parents update optimal choices in this period sequentially as in period 1, taking into account the realisations of the values of exogenous variables in that period that were unobserved prior to that point.

2.2 *Derivation of Conditional Demands for Child Cognitive Skills*

Under the above assumptions, the utility maximizing level of child health inputs, N^*, and parental time spent in child health production, T_H^* in period 1 are given by the following equations:

$$F_1^* = F_D\big(\omega_1, p_{N,1}, D_1, \lambda_1, \kappa, A_0, H_0\big) \quad F = N, T_H \quad (6)$$

where $\omega_1 = \{p_{C,1}, p_{I,1}, w_1, \xi_1, \mu_1\}$ and $\kappa = \{\delta, \alpha, r, \xi, \mu\}$. Equation (6) is the reduced form demand function for N and T_H that expresses optimal levels of these variables in period 1 in terms of all exogenous variables realised up to that point. The derivation of the reduced form demand function in (6) is based on the assumption that the shadow value of the budget constraint and predictions of the values of exogenous variables in period 2, as evaluated in period 1, that also determine optimal choices in period 1, are functions of all exogenous variables realised up to period 1.

[4] This assumption implies that optimal levels of child health investments in a given period cannot be altered in the face of realisations of shocks in the same period occurring after investments are determined.

Substituting the reduced form demand functions for N and T_H in period 1 into (2) yields the reduced form demand for child health in period 1 as follows:

$$H_1^* = H_D(\omega_1, p_{N,1}, D_1, \lambda_1, \kappa, A_0, H_0, u_1) \quad (7)$$

where equation (7), in contrast to (6), also includes the realized value of child health shocks in period 1, u_1, among the determinants of optimal child health in that period, because of the assumption that all shocks in period 1 are realized after the choice of child health inputs in that period.

Following the determination of H_1^*, parents choose the rest of the variables in period 1 subject to constraints given by (2), (3), (4), and (5) that are modified as follows: equation (2) for period 1 becomes $H_1 = H_1^*$; the time constraint for period 1 from (5) becomes $1 - T_{H1}^* = L_1 + l_1 + T_{CS,1}$, where $1 - T_{H1}^*$ is time remaining in period 1 after time spent in the production of child health; fixed income in (4), after using the time constraint to substitute for L_1, becomes $A_1^* =$ $A0-pN,1N1*-w1TH1*$, that is fixed income remaining after expenditure on health investments in period 1 has been incurred. Under these constraints, parental demands for C, I, l, L, and T_{CS} in period 1, that are conditional on H_1^*, are given by the following equations:

$$G_1^* = G_{1,CD}(H_1^*, \omega_1, v_1, A_1^*, \kappa) \quad G = C, I, l, L, T_{CS} \quad (8)$$

where (8) is derived after all realised values of exogenous variables and optimal child health in period 1 have been substituted for predictions of the values of exogenous variables in period 2. Using (8) to substitute for I and T_{CS} in (3), I derive the demand for cognitive skills in period 1, conditional on H_1^*, as follows:

$$CS_1^* = CS_{1,P}[H_1^*, T_{CS,1,CD}(H_1^*), I_{1,CD}(H_1^*)] = CS_{1,CD}(H_1^*, \omega_1, v_1, A_1^*, \kappa) \quad (9)$$

where the first equality in equation (9) suppresses arguments other than H_1^* in $T_{CS,1,CD}$ and $I_{1,CD}$ to make explicit the different channels through which H_1^* impacts CS_1^*. Equations (8) and (9) do not include realized values of D_1, λ_1, u_1, $p_{N,1}$, and child health endowment H_0 that are subsumed in H_1^*. Moreover, parental demands at the end of period 1 of the level of variables in period 2, conditional on H_1^*, can be expressed as follows:

$$J_2^* = J_{2,CD|1}(H_1^*, \omega_1, v_1, A_1^*, \kappa, M_1) \quad J = N, T_H, C, I, l, L, T_{CS}, H, CS \quad (10)$$

where M_1 is a vector of moments of the distributions of exogenous variables in period 2, i.e. $, p_{C,2}, p_{N,2}, p_{I,2}, w_2, D_2, \xi_2, \lambda_2, \mu_2, u_2, v_2, S_2,$ evaluated in period 1.[5]

In period 2, after exogenous variables other than shocks are realised, parents update child health inputs demands that are expressed as follows:

$$F_2^* = F_{2,CD}\left(H_1^*, \{\omega_t\}_{t=1}^2, S_2, p_{N,2}, D_2, \lambda_2, v_1, A_1^*, \kappa\right) \quad F = N, T_H \quad (11)$$

where $\{\omega_t\}_{t=1}^2 = \left\{p_{C,t}, p_{I,t}, w_t, \xi_t, \mu_t\right\}_{t=1}^2$. Equation (11) is derived by (10) by taking into account that M_1 is updated to include the realised values of $p_{C,2}, p_{N,2}, p_{I,2}, w_2, D_2, \xi_2, \lambda_2, \mu_2, S_2,$ and moments of the distributions of shocks in period 2, that are assumed to be independent of the realised values of exogenous variables realised up to that point. Substituting H_1 with H_1^* and demands for N and T_H in period 2 from (11) into (2) yields the demand for child health in period 2, conditional on the utility maximising level of child health in period 1 as follows:

$$H_2^* = H_{2,P}[H_1^*, N_{2,CD}(H_1^*), T_{H,2,CD}(H_1^*)] = H_{2,CD}\left(H_1^*, \{\omega_t\}_{t=1}^2, S_2, p_{N,2}, D_2, \lambda_2, v_1, A_1^*, \kappa, u_2\right) \quad (12)$$

where, again, as in (9), the first equality in (12) aims to highlight the different channels via which H_1^* impacts H_2^*.

After the determination of H_2^*, parents update optimal levels for $C, I, l, L,$ and T_{CS} in period 2 conditional on $H_2 = H_2^*$ and fixed income remaining in period 2 after child health expenditure in that period, $p_{N,2}N_2^* + w_2 T_{H2}^*$, that is given by the following equation:

$$A_2^* = A_1^* - p_{N,2}N_2^* - w_2 T_{H,2}^* = A_{2,CD}\left(H_1^*, \{\omega_t\}_{t=1}^2, S_2, p_{N,2}, D_2, \lambda_2, v_1, A_1^*, \kappa\right) \quad (13)$$

where A_2^* combines A_1^* and $[-(p_{N,2}N_2^* + w_2 T_{H2}^*)]$, and (13) is derived by substituting (11) for N_2^* and $T_{H,2}^*$. The optimal levels of $C, I, l, L,$ and T_{CS} in period 2, conditional on $H_2 = H_2^*$ and

[5] Similarly to Strauss and Thomas (2008, pp 3388) and Currie (2009), I assume that choices in each period are not only dependent on the expected values of exogenous variables in the future but on the entire distributions of these variables that in turn can be characterized by a set of distribution moments.

available income after expenditure on child health inputs in period 2 have been incurred, A_2^*, are given by the following equations:

$$G_2^* = G_{2,CD}\left[H_1^*, H_2^*, \{\omega_t, v_t\}_{t=1}^2, S_2, A_2^*, \kappa\right] \qquad G = C, I, l, L, T_{CS} \quad (14)$$

The demand for cognitive skills in period 2, conditional on H_1^* and H_2^*, can be derived by substituting H_1^* and H_2^* for H_1 and H_2 in (3) respectively and using (8) to substitute for I_1 and $T_{CS,1}$ and (14) to substitute for I_2 and $T_{CS,2}$ in (3), as follows:

$$CS_2^* = CS_{2,P}\left[\{H_t^*, T_{CS,t}^*, I_t^*\}_{t=1}^2\right] = C_{2,CD}\left[H_1^*, H_2^*, \{\omega_t, v_t\}_{t=1}^2, S_2, A_2^*, \kappa\right] \quad (15)$$

2.3 *The Impact of Contemporaneous and Prior Child Health and Nutrition on Child Cognitive Skills*

Using (15) and the fact that cognitive skills inputs demands, T_{CS}^* and I^*, in each period, are expected to respond to an exogenous change in child health in the same or previous periods, by (8) and (14), and that child health in the second period responds to a change in child health in period 1, by (12), one can express the total effect of an exogenous change in the utility maximizing level of child health in period 1 and 2 on the demand for cognitive skills in period 2 as follows:

$$\frac{dCS_2^*}{dH_1^*} = \frac{\partial CS_{2,P}}{\partial H_1^*} + \frac{\partial CS_{2,P}}{\partial H_2^*}\left(\frac{\partial H_{2,P}}{\partial H_1^*} + \frac{\partial H_{2,P}}{\partial N_2^*}\frac{\partial N_{2,CD}}{\partial H_1^*} + \frac{\partial H_{2,P}}{\partial T_{H,2}^*}\frac{\partial T_{H,2,CD}}{\partial H_1^*}\right) + \frac{\partial CS_{2,P}}{\partial T_{CS,1}^*}\frac{\partial T_{CS,1,CD}}{\partial H_1^*} + \frac{\partial CS_{2,P}}{\partial T_{CS,2}^*}\left[\frac{\partial T_{CS,2,CD}}{\partial H_1^*} + \right.$$

∂TCS,2,CD∂H2∗∂H2,P∂H1∗+∂H2,P∂N2∗∂N2,CD∂H1∗+∂H2,P∂TH,2∗∂TH,2,CD∂H1∗+∂TCS,

2,CD∂A2∗∂A2,CD∂H1∗ +∂CS2,P∂I1∗ ∂I1,CD∂H1∗+∂CS2,P∂I2∗

$$\left[\frac{\partial I_{2,CD}}{\partial H_1^*} + \frac{\partial I_{2,CD}}{\partial H_2^*}\left(\frac{\partial H_{2,P}}{\partial H_1^*} + \frac{\partial H_{2,P}}{\partial N_2^*}\frac{\partial N_{2,CD}}{\partial H_1^*} + \frac{\partial H_{2,P}}{\partial T_{H,2}^*}\frac{\partial T_{H,2,CD}}{\partial H_1^*}\right) + \frac{\partial I_{2,CD}}{\partial A_2^*}\frac{\partial A_{2,CD}}{\partial H_1^*}\right] \quad (16a)$$

$$\frac{dCS_2^*}{dH_2^*} = \frac{\partial CS_{2,P}}{\partial H_2^*} + \frac{\partial CS_{2,P}}{\partial T_{CS,2}^*}\frac{\partial T_{CS,2,CD}}{\partial H_2^*} + \frac{\partial CS_{2,P}}{\partial I_2^*}\frac{\partial I_{2,CD}}{\partial H_2^*} \quad (16b)$$

Equations (16a) and (16b) delineate all the channels through which an exogenous change in child health in period 1 and 2 respectively impacts child cognitive skills in period 2. In particular, equation (16b) suggests that the total effect of a contemporaneous change in child health on cognitive skills includes a direct effect, $\frac{\partial CS_{2,P}}{\partial H_2^*}$, operating through the cognitive skills production function in (3), and a set of indirect effects expressed by the second and third terms in (16b) that operate through responses of cognitive skills inputs demands in period 2 to a change in child health in the same period. The direction of this total effect is ambiguous, as, although, the direct effect is positive, by assumption, the indirect effects may be positive or negative, depending on whether parents reinforce or compensate for the impact of the change in child health by increasing or decreasing respectively cognitive skills investments. The situation is more complicated in the case of the total effect a change in child health in period 1 on cognitive skills in period 2, as this includes a larger set of indirect effects, as suggested by equation (16a). In particular, the total effect of H_1^* on CS_2^* includes the following effects:

i) the direct effect of H_1on CS_2, $\frac{\partial CS_{2,P}}{\partial H_1^*}$, operating through the production function in (3),

ii) an indirect and purely biological effect, $\frac{\partial CS_{2,P}}{\partial H_2^*}\frac{\partial H_{2,P}}{\partial H_1^*}$, operating through H_2 that is directly affected by a change in H_1, through the health production function in (2), and in turns has a direct effect on CS_2 through the cognitive skills production function in (3),

iii) a set of indirect effects, given by the terms $\frac{\partial CS_{2,P}}{\partial H_2^*}\left(\frac{\partial H_{2,P}}{\partial N_2^*}\frac{\partial N_{2,CD}}{\partial H_1^*}+\frac{\partial H_{2,P}}{\partial T_{H,2}^*}\frac{\partial T_{H,2,CD}}{\partial H_1^*}\right)$, manifesting through responses of child health inputs demands in period 2, N_2^* and $T_{H,2}^*$, holding A_2^* constant, that affect the level of H_2^*, that in turns impacts CS_2 directly through (3),

iv) a set of indirect effects, as expressed by $\frac{\partial CS_{2,P}}{\partial Y_1^*}\ \frac{\partial Y_{1,CD}}{\partial H_1^*}$ with $Y = T_{CS}$,I, that operate through cognitive skills inputs demands in period 1 responses to a change in H_1^*,

v) a set of indirect effects, as expressed by $\frac{\partial CS_{2,P}}{\partial Y_2^*}\ \frac{\partial Y_{2,CD}}{\partial H_1^*}$ with $Y = T_{CS}$,I, that operate through responses of cognitive skills inputs demands in period 2 to a change in H_1^*, holding H_2^* and A_2^* constant,

vi) a set of indirect effects, as expressed by the terms $\frac{\partial CS_{2,P}}{\partial Y_2^*}\ \frac{\partial Y_{2,CD}}{\partial H_2^*}\frac{\partial H_{2,P}}{\partial H_1^*}$ with $Y = T_{CS}$,I, that operate through responses of cognitive skills inputs demands in period 2 to a change in H_2^* resulting directly from the change in H_1^* by (2),

vii) a set of indirect effects, as expressed by the terms $\frac{\partial CS_{2,P}}{\partial Y_2^*}\ \frac{\partial Y_{2,CD}}{\partial H_2^*}\left(\frac{\partial H_{2,P}}{\partial N_2^*}\frac{\partial N_{2,CD}}{\partial H_1^*}+\frac{\partial H_{2,P}}{\partial T_{H,2}^*}\frac{\partial T_{H,2,CD}}{\partial H_1^*}\right)$ with $Y = T_{CS}$,I, that operate through cognitive skills inputs demands responses to a change in H_2^* resulting from a change in child health inputs in period 2, N_2^* and $T_{H,2}^*$, that in turns respond to the change in H_1^*, holding A_2^* constant, and

viii) a set of indirect effects, as expressed by the terms $\frac{\partial CS_{2,P}}{\partial Y_2^*} \frac{\partial Y_{2,CD}}{\partial A_2^*} \frac{\partial A_{2,CD}}{\partial H_1^*}$ with $Y = T_{CS}, I$, that operate through cognitive skills inputs demands responses to a change in A_2^* resulting from change in H_1^*, holding H_2^* constant.[6]

The direction of effects i) and ii) is positive, by assumption, and the same holds for viii) under certain assumptions,[7] and provided that at least one of the child health inputs in period 2 responds to a change in child health in period 1, one of the effects in iii) is expected to be positive and the other negative.[8] The rest of the indirect effects of H_1^* on CS_2^* are expected to have an ambiguous sign, that depends on the direction of health and cognitive skills inputs demands responses to a change in child health in period 1 that, as discussed above is ambiguous that further implies that the total effect of a change in H_1^* on CS_2^* is also ambiguous.

The key implication of equation (16a) is that, under certain conditions, cognitive deficits resulting from health insults in early life will tend to accumulate over the life course[9] and this process can be attenuated by compensatory (remedial) investments in child health and cognitive skills in later periods.

The rate of accumulation of cognitive deficits over the life course and the extent to which remedial investments can counteract this process depend partly on the nature of health and

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[6] Effects in viii) can be viewed as an income effect of a change in child health in period 1 on cognitive skills in period 2 (Pollak, 1969), holding child health in period 2 constant. Intuitively, a change in H_1^* will impact H_2^* directly through the health production function in (2) and thus for H_2^* to decrease to the same level as before the increase in H_1^*, at least some of health inputs should decrease. The change in the demand for health inputs will lead to a change in child health expenditure in period 2 and thus in resources available for all other goods, A_2^*, that in turns is going to lead to a change in the demand for cognitive skills inputs in period 2 and through that to child cognitive skills.

[7] The assumptions required for this effect to be positive are that the health production function is homothetic and cognitive skills inputs are normal goods. The homotheticity assumption implies that after an increase in H_1^* that increases H_2^* directly, for H_2^* to decrease at the initial level, all child health inputs in period 2 will decrease (i.e. it is not possible to achieve a reduction in H_2^* by increasing some inputs and decrease others), and this will lead to an unambiguous decrease in child health expenditure and thus an increase in income available to be spent on goods other than child health inputs. The assumption that child cognitive skills inputs are normal goods implies that the increase in income available for other goods will lead to an increase in the demand for cognitive skills inputs and thus in child cognitive skills.

[8] Effects in iii) and vii) that manifest through adjustments of child health inputs in period 2, N_2^* and $T_{H,2}^*$, to a change in H_1^*, holding A_2^* constant, involve a change in child health inputs resulting from a reallocation of the same child health expenditure across health inputs (Pollak, 1969). This implies that not all inputs are expected to respond in the same direction, as for the demand of a given input to increase as a result of an increase in child health in period 1 and for expenditure in child health to remain unchanged, the demand for another child health input should necessarily decrease.

[9] This means that, assuming away responses of parental child health and cognitive skills inputs demands in period 2 to child health in period 1, the effect of H_1^* on cognitive skills in period 2 is expected to be larger than that in period 1. Based on (9) and (16a), this implies that $\frac{dCS_1^*}{dH_1^*} = \frac{\partial CS_{1,P}}{\partial H_1^*} + \frac{\partial CS_{1,P}}{\partial T_{CS,1}^*} \frac{\partial T_{CS,1,CD}}{\partial H_1^*} + \frac{\partial CS_{1,P}}{\partial I_1^*} \frac{\partial I_{1,CD}}{\partial H_1^*} < \frac{\partial CS_{2,P}}{\partial H_1^*} + \frac{\partial CS_{2,P}}{\partial T_{CS,1}^*} \frac{\partial T_{CS,1,CD}}{\partial H_1^*} + \frac{\partial CS_{2,P}}{\partial I_1^*} \frac{\partial I_{1,CD}}{\partial H_1^*} + \frac{\partial CS_{2,P}}{\partial H_2^*} \frac{\partial H_{2,P}}{\partial H_1^*} + \frac{\partial CS_{2,P}}{\partial T_{CS,2}^*} \frac{\partial T_{CS,2,CD}}{\partial A_2^*} \frac{\partial A_{2,CD}}{\partial H_1^*} + \frac{\partial CS_{2,P}}{\partial I_2^*} \frac{\partial I_{2,CD}}{\partial A_2^*} \frac{\partial A_{2,CD}}{\partial H_1^*}$.

cognitive skills production technology.[10] One key aspect of these production technologies is related to the existence of critical and sensitive periods for investments (Cunha and Heckman, 2007). For example, in the case of child nutrition, it has been suggested that the period from conception to 2 years is a critical period for investments in nutrition (Hoddinott and Kinsey, 2001) and for the impact of nutrition on cognitive development (Glewwe et al., 2001). Based on Cunha and Heckman (2007), assuming that H stands for child nutrition, under the framework here, the hypothesis that period 1 is a critical period for investments in child nutrition implies that $\frac{\partial H_{2,P}}{\partial H_1^*} = 1$, $\frac{\partial H_{2,P}}{\partial X_2^*} = 0$ with $X = T_H, N$, and $\frac{\partial A_{2,CD}}{\partial H_1^*} = 0$, whereas the hypothesis that period 1 is a critical period for the impact of nutrition on cognitive development implies that $\frac{\partial CS_{2,P}}{\partial H_2^*} = 0$.[11] If both these hypotheses hold, then equations (16a) and (16b) become as follows:

$$\frac{dCS_2^*}{dH_1^*} = \frac{\partial CS_{2,P}}{\partial H_1^*} + \frac{\partial CS_{2,P}}{\partial T_{CS,1}^*}\frac{\partial T_{CS,1,CD}}{\partial H_1^*} + \frac{\partial CS_{2,P}}{\partial T_{CS,2}^*}\left(\frac{\partial T_{CS,2,CD}}{\partial H_1^*} + \frac{\partial T_{CS,2,CD}}{\partial H_2^*}\right) + \frac{\partial CS_{2,P}}{\partial I_1^*}\frac{\partial I_{1,CD}}{\partial H_1^*} + \frac{\partial CS_{2,P}}{\partial I_2^*}\left(\frac{\partial I_{2,CD}}{\partial H_1^*} + \frac{\partial I_{2,CD}}{\partial H_2^*}\right)$$
(17a)

$$\frac{dCS_2^*}{dH_2^*} = 0 \quad (17b)$$[12]

Therefore, the key implication of these two hypotheses is that there is scope for remediation in later periods of cognitive deficits arising from early undernutrition through cognitive skills investments but not through nutrition investments. The implications are the same, if period 1 is a critical period for nutritional investments but not for the impact of nutrition on cognitive

[10] They are also expected to depend on the nature of parental preferences.

[11] Condition $\frac{\partial H_{2,P}}{\partial X_2^*} = 0$ with $X = T_H, N$, expresses that nutrition investments outside the critical period have no impact on nutrition, condition $\frac{\partial H_{2,P}}{\partial H_1^*} = 1$ suggests that the nutrition stock in periods following the critical period will be equal to that at the end of the critical period, whereas condition $\frac{\partial CS_{2,P}}{\partial H_2^*} = 0$ suggests that nutrition outside the critical period has no impact on cognitive skills. Condition $\frac{\partial A_{2,CD}}{\partial H_1^*} = 0$ expresses that, given that nutrition inputs in period 2 have no impact on nutrition, there will be no expenditure on child nutrition in period 2, i.e. $p_{N,2}N_2^* + w_2 T_{H,2}^* = 0$ and thus from (13) we have that $A_2^* = A_1^*$, and A_1^*, by assumption, is set prior to the change in H_1^* and does not respond to a change in H_1^*.

[12] This is because, $\frac{dCS_2^*}{dH_2^*}$, expresses the effect of an exogenous change in nutrition in period 2, arising from a change in factors outside the control of parents, such as the disease environment, D_2 or a health productivity shock, u_2, in that period that are assumed to have no effect on H_2^*.

skills, but the negative effect of early undernutrition on later cognitive skills will be larger.[13] This further implies that, in this case, there is a larger tendency for cognitive deficits arising from early undernutrition to accumulate over the life-course and more scope for nutritional investments during the critical period, compared to the first scenario. If period 1 is only a critical period for the impact of nutrition on cognitive skills, then the total effect of a change in H_1^* and H_2^* on CS_2^* will be as given by (16a) and (16b) respectively, with the difference that the second term in (16a) and the first term in (16b) will be equal to zero. Under this scenario, there is scope for remediation of developmental setbacks resulting from early undernutrition through nutrition investments in later periods, but the impact of these investments on cognitive skills is expected to manifest only through behavioural channels related to parental responses to a change in child health in later periods.[14] Finally, when period 1 is neither a critical period for investments in nutrition nor for the impact of nutrition on cognitive achievement, there is more scope compared to the other cases for remediation of cognitive deficits arising from early undernutrition through nutrition investments in later periods, as in this case, nutrition investments are expected to also have a positive direct impact on cognitive skills.

2.4 *Additional Conditional Demands for Child Cognitive Skills and Model Extension*

Equations (16a) and (16b) can be alternatively expressed in terms of the effect of child health in each period on the conditional demand for cognitive skills in period 2, in (15), as follows:

$$\frac{dCS_2^*}{dH_1^*} = \frac{\partial CS_{2,CD}}{\partial H_1^*} + \frac{\partial CS_{2,P}}{\partial H_2^*}\frac{\partial H_{2,CD}}{\partial H_1^*} + \frac{\partial CS_{2,P}}{\partial T_{CS,2}^*}\left(\frac{\partial T_{CS,2,CD}}{\partial H_2^*}\frac{\partial H_{2,CD}}{\partial H_1^*} + \frac{\partial T_{CS,2,CD}}{\partial A_2^*}\frac{\partial A_{2,CD}}{\partial H_1^*}\right) + \frac{\partial CS_{2,P}}{\partial I_2^*}\left(\frac{\partial I_{2,CD}}{\partial H_2^*}\frac{\partial H_{2,CD}}{\partial H_1^*} + \frac{\partial I_{2,CD}}{\partial A_2^*}\frac{\partial A_{2,CD}}{\partial H_1^*}\right)$$

(18a)

$$\frac{dCS_2^*}{dH_2^*} = \frac{\partial CS_{2,CD}}{\partial H_2^*} \quad (18b)$$

where $\frac{\partial CS_{2,CD}}{\partial H_k^*}$ for k=1,2, is the effect of a change in child health in period k on cognitive skills in period 2, holding other arguments of the conditional demand for cognitive skills expressed by

[13] Under these assumptions, $\frac{dCS_2^*}{dH_1^*}$ will include, in addition to all effects in (17a), the effect $\frac{\partial CS_{2,P}}{\partial H_2^*}$, that is positive by assumption.

[14] As discussed above, an improvement in child nutrition arising from a nutrition-promoting intervention in period 2, may lead to an improvement in child cognitive skills in this period, through a behavioural channel operating through the reallocation of resources spent on child health towards cognitive skills investments.

equation (15) constant and $\frac{\partial H_{2,CD}}{\partial H_1^*}$ is the effect of a change in child health in period 1 on the demand of child health in period 2 using the second equality in (12).

This derivation shows, that, although, equation (15), can be used to assess the total effect of a contemporaneous change in child health on cognitive skills, the same does not hold for the case of a change in the level of health in a prior period, as the effect identified by equation (15) does not capture the impact of early health on later cognitive skills manifesting through child health and expenditure excluding expenditure on child health in subsequent periods. The total effect of a change in child health in period 1 on cognitive skills in period 2, can be identified by the relationship derived by substituting (12) and (13) for H_2^* and A_2^* respectively in (15) as follows:

$$CS^*_{2,CD|H_1^*} = CS^A_{2,CD}\left(H_1^*, A_1^*, S_2, D_2, \lambda_2, u_2, \{\omega_t, v_t\}_{t=1}^2, \kappa\right) \quad (19)$$

where $CS^A_{2,CD}$ denotes a different function than $C_{2,CD}$ in (15) and equation (19) is the conditional demand for child cognitive skills in period 2, where conditioning is only in terms of child health in period 1, whereas equation (15) is the demand for cognitive skills in period 2 conditional on child health in the same and the previous period.

Although, this framework considers the determination of cognitive skills and child health over two periods in order to simplify the exposition of the key results, the key relationships and insights, can generalize, mutatis mutandis, to more than two periods. Under an extension of the framework that considers a third period, that includes the early primary school years, during which the child is between 5 and 8 years old, there are three different conditional demand relationships for cognitive skills in period 3 that can be used to assess the total effect of an exogenous change in child health in each period, as follows:

$$CS^*_{3,CD|H_1^*} = CS^A_{3,CD}\left(H_1^*, A_1^*, \left\{S_t, p_{N,t}, D_t, \lambda_t\right\}_{t=2}^3, \{\omega_t, v_t\}_{t=1}^3, \kappa\right) \quad (20)$$

$$CS^*_{3,CD|H_1^*,H_2^*} = CS^B_{3,CD}(H_2^*, H_1^*, A_2^*, S_3, D_3, \lambda_3, u_3, , \{\omega_t, v_t\}_{t=1}^3, \kappa) \quad (21)$$

$$CS_3^* = C_{3,CD}(\{H_t^*, \omega_t, v_t\}_{t=1}^3, A_3^*, \{S_t\}_{t=2}^3, \kappa) \quad (22)$$

where equations (20) and (22) are the analogues of (19) and (15) respectively in the case of three periods and can be used to assess the total effect on cognitive skills in period 3 from a change in child health in period 1 and 3 respectively, and equation (21) is the demand for cognitive skills in period 3, conditional on child health in period 1 and 2, that can be used to assess the total effect of a change in child health in period 2 on cognitive skills in period 3.

3. Econometric Model Specification and Identification Strategy

The aim of the empirical analysis is to identify the independent impact of child nutrition in each of three different periods of childhood on cognitive skills in middle childhood. Thus, I consider the following linear empirical analogues of the conditional demand functions for child cognitive skills in period 3[15] expressed by equations (22), (21), and (20) respectively:

$$CS_{i3}^{*} = a_0 + \alpha_1 H_{i1}^{*} + \alpha_2 H_{i2}^{*} + \alpha_3 H_{i3}^{*} + \alpha_4 A_0 + \boldsymbol{\alpha_5' CH_{it}} + \boldsymbol{\alpha_6' HH_{it}} + \sum_{t=1}^{3} \boldsymbol{\alpha_{t+6}' LE_{it}} + \varepsilon_{i3} \quad (E.1)$$

$$CS_{i3}^{*} = \beta_0 + \beta_1 H_{i1}^{*} + \beta_2 H_{i2}^{*} + \beta_3 A_0 + \boldsymbol{\beta_4' CH_{it}} + \boldsymbol{\beta_5' HH_{it}} + \sum_{t=1}^{3} \boldsymbol{\beta_{t+5}' LE_{it}^{A}} + \psi_{i3} \quad (E.2)$$

$$CS_{i3}^{*} = \gamma_0 + \gamma_1 H_{i1}^{*} + \gamma_2 A_0 + \boldsymbol{\gamma_3' CH_{it}} + \boldsymbol{\gamma_4' HH_{it}} + \sum_{t=1}^{3} \boldsymbol{\gamma_{t+4}' LE_{it}^{B}} + \varphi_{i3} \quad (E.3)$$

where CS_{i3}^{*} stands for a cognitive achievement test score of child i in period 3 and H_{i1}^{*}, H_{i2}^{*}, and H_{i3}^{*} denotes child i's height-for-age z score (HAZ)[16] in period 1, 2, and 3 respectively, that is a common indicator of a child's nutritional status and summarises nutritional history from conception up to the point of measurement (Glewwe et al., 2001). Moreover, A_0 is a measure of assets/wealth at the beginning of period 1, whereas $\boldsymbol{CH_{it}}$ and $\boldsymbol{HH_{it}}$ are vectors of child and parental/household fixed and time-variant characteristics respectively in period t[17] that aim to control for heterogeneity in parental preferences, child cognitive skills technology, and child

[15] Linear empirical analogues of conditional demands can be viewed as linear approximations of the corresponding theoretical relationships or can be derived as a solution of the optimization program presented in the previous section under the assumption that the utility function is quadratic and child health and cognitive skills production function are linear functions of their arguments.

[16] HAZ is the difference between a child's height from the median height of a reference distribution of healthy growing children of the same monthly age and gender provided by the WHO (WHO, 2006; de Onis et al., 2007) divided by the standard deviation of the reference distribution.

[17] For simplicity, I assume that contemporaneous values of the time-variant child and household/parental characteristics are sufficient statistics for the history of these characteristics up to the time of measurement.

health technology reflected in $\{\xi_t, \mu_t\}_{t=1}^3, \mu, \xi, \ \delta, \{\lambda_t\}_{t=2}^3$.[18] Equation (E.1) includes a vector of local environment characteristics in all three periods, $\{\boldsymbol{LE_{it}}\}_{t=1}^3$, that aim to control for local economic conditions reflected in $\{p_{C,t}, p_{I,t}, w_t,\}_{t=1}^3$ and r, and the quality of the preschool and school environment, $\{S_t\}_{t=2}^3$, included in (22), and the same holds for equations (E.2) and (E.3), with the difference that (E.2) also includes controls for the local disease environment in period 3, D_3, that is included in (21), whereas (E.3) also includes controls for the disease environment in periods 2 and 3, $\{D_t,\}_{t=2}^3$, included in (22).[19] Furthermore, the error term, ε_{i3}, in (E.1) includes unobserved child cognitive ability, α, cognitive skills productivity shocks in all three periods, $\{v_t\}_{t=1}^3$, and expenditure in child health in all three periods, $\sum_{\tau=1}^3 p_{N,\tau} N_\tau^* + w_\tau T_{H,\tau}^*$, because equation (E.1) controls for assets at the beginning of period 1, A_0, and not for child non-health expenditure across the three periods, A_3^*, included in (22), that is equal to $A_0 - \sum_{\tau=1}^3 p_{N,\tau} N_\tau^* + w_\tau T_{H,\tau}^*$, by (13).[20] Similarly, by (21), the error term in (E.2), ψ_{i3}, includes $\alpha, \{v_t\}_{t=1}^3$, but also child health productivity shocks in period 3, u_3, and expenditure in child health in the first two periods, $\sum_{\tau=1}^2 p_{N,\tau} N_\tau^* + w_\tau T_{H,\tau}^*$ and by (20), the error term in (E.3), φ_{i3}, includes unobservables $\alpha, \{v_t\}_{t=1}^3$, u_3, but also child health productivity shocks in period 2, u_2, and expenditure in child health in the first period, $p_{N,1} N_1^* + w_1 T_{H,1}^*$. Finally, $\{\alpha_j\}_{j=0}^4$, $\{\beta_j\}_{j=0}^3$, and $\{\gamma_j\}_{j=0}^2$ are parameters and $\{\boldsymbol{\alpha_j'}\}_{t=5}^9$, $\{\boldsymbol{\beta_j'}\}_{t=4}^8$, and $\{\boldsymbol{\gamma_j'}\}_{t=3}^7$ are vectors of coefficients.

The coefficient γ_1 of H_{i1}^* in (E.3) is expected to capture the total effect of child nutrition in period 1 on child cognitive skills in period 3, whereas β_1 in (E.2) expresses the effect of H_{i1}^* on CS_{i3}^*, that does not include the impact of H_{i1}^* on CS_{i3}^* manifesting through H_{i2}^*, and α_1 in (E.1) expresses the effect of H_{i1}^* on CS_{i3}^*, that does not include the impact of H_{i1}^* on CS_{i3}^* manifesting through H_{i2}^* and H_{i3}^*.[21] Similarly, β_2 expresses the total effect of child nutrition in period 2 on child cognitive skills in period 3 and α_2 the effect of H_{i1}^* on CS_{i3}^*, excluding the effect of H_{i2}^* on

[18] Note that, provided that $\boldsymbol{CH_{it}}$ and $\boldsymbol{HH_{it}}$, that are included in all three empirical specifications, include measures of $\{\xi_t, \mu_t\}_{t=1}^3, \mu, \xi, \ \delta, \{\lambda_t\}_{t=2}^3$, equation (E.1) also controls for characteristics that are excluded from (22), such as $\{\lambda_t\}_{t=2}^3$, and the same holds for equation (E.2) that controls for λ_3 that is excluded from (21). The main reason for this is that it was difficult, given the data at hand (see next section for details), to identify measures of child and parental characteristics that may affect the productivity of health inputs but not that of cognitive skills inputs. Nevertheless, this is only expected to affect the available exclusion restrictions that can be used for identification and not the interpretation of the coefficients of child nutrition in each period identified by equations (E.1) and (E.2).

[19] This suggests that $\{\boldsymbol{LE_{it}^B}\}_{t=1}^3$=$\{D_2, \{\boldsymbol{LE_{it}^A}\}_{t=1}^3\}$=$\{\{D_t,\}_{t=2}^3, \{\boldsymbol{LE_{it}}\}_{t=1}^3\}$ implying that $\{\boldsymbol{LE_{it}^A}\}_{t=1}^3$=$\{D_3, \{\boldsymbol{LE_{it}}\}_{t=1}^3\}$

[20] This is because the data I use do not include information on expenditure on child health inputs in period 1 and the value of parental time spent in the production of child health in all periods (see next section for details).

[21] In contrast to the effect of H_{i1}^* on CS_{i3}^* identified by (21) and (22), β_1 and α_1 will also pick up the effect of H_{i1}^* on CS_{i3}^* manifesting through adjustments in child non-health expenditure in subsequent periods, captured by A_2^* and A_3^* because (E.1) does not control for A_3^*, included in (22) and (E.2) does not control for A_2^*, included in (21).

CS_{i3}^{*} manifesting through H_{i3}^{*}.[22] Moreover, α_3 captures the total effect child health in period 3 on cognitive skills in the same period. Therefore, consistent estimation of equations (E.1), (E.2), and (E.3), not only enables one to identify the total effect of child nutrition in each period on cognitive skills in period 3, but also to investigate some of the causal pathways through which the total effect of nutrition on cognitive skills manifests, and in particular those that operate through child nutrition in subsequent periods. Moreover, this discussion and the related analysis in the conceptual framework illustrate why studies that estimate specifications similar to (E.3), such as Glewwe and King (2001), fare expected to produce biased estimates of the total effects of child growth and nutrition at a given period on cognitive achievement in a later period.

Ordinary least squares (OLS) estimation of equations (E.1), (E.2), and (E.3) is not expected to produce consistent estimates of the coefficients of child nutrition across periods, as nutrition in all periods is endogenous. Nevertheless, all three equations can be estimated consistently by Instrumental Variables (IV) using as instruments for child nutrition in each period, child health productivity shocks, u, in the same period. This is because these shocks have a direct impact on nutrition through the child health production function in (2) and are expected to be uncorrelated with unobservables included in the error term of the conditional demands for cognitive skills such as child ability and cognitive skills productivity shocks, but also with child non-health expenditure incurred before these shock are realized, as shocks are unanticipated at the time health and thus non-health expenditure in these periods were determined. In the case where shocks are realized prior to the assessment of child health, according to the conceptual framework, conditional demand for cognitive skills should condition for child non-health expenditure before shocks are realized, as child non-health expenditure after the shock is expected to adjust to the change in child health resulting from the shock. Nevertheless, if health productivity shocks do not affect non-child health expenditure through their impact on child health they are not expected to be valid instruments for child health.

Under these assumptions, health productivity shocks are the only valid instruments in this case, as all other exogenous or predetermined determinants of child nutrition at a given period, such as prices of health inputs, p_N, the disease environment, D, child health productivity shifters, λ, in the same period, are correlated with child health expenditure in the same period, $p_N N^{*} + wT_H^{*}$, that is included in the error term in each equation, because they are correlated with child health inputs demands, N^{*} and T_H^{*} in each period, as indicated by equations (6) and (11). IV

[22] Again, α_2, in contrast to (22), picks up the effect of H_{i2}^{*} on CS_{i3}^{*} manifesting through A_3^{*}, because (E.1) does not control for A_3^{*} that is included in (22).

estimation is expected also to address endogeneity of child nutrition in equations (E.1), (E.2), and (E.3) arising from random measurement error in child's HAZ that may be either due to imprecise measurement of child's height, age, and gender, or due to genetic and environmental factors that affect height but are independent of child's nutrition (Glewwe et al., 2001).[23]

4. Data and Descriptive Statistics

4.1 *Dependent and Independent Variables*

The data used in my analysis are collected as part of the Young Lives study, an international cohort study in Ethiopia, India (the states of Andhra Pradesh and Telangana), Peru, and Vietnam. In particular, Young Lives follows around 12,000 children of two cohorts: around 2000 children in each country born in 2001/02 (younger cohort) and around 1000 children in each country born in 1994/1995 (older cohort). Young Lives has conducted to date four rounds of data collection, the first in 2002, the second in 2006, the third in 2009, and the fourth in 2013. The analysis here uses data on the younger cohort children for the first three data collection rounds including information on children at age 1,5, and 8 years. Because the data does not include information on children at age 2 years the periods considered in the empirical analysis deviate somewhat from those in the conceptual framework. Nevertheless, although the age 2 years is considered as the threshold of the critical period, in the following sections we show that this does not affect the inferences drawn from the data analysis.

The Young Lives data include rich information on household, parental, and community characteristics as well as detailed information on child characteristics and outcomes, including child anthropometry and cognitive achievement that are assessed using the same instruments across the four countries (see Barnett et al. (2012) and Petrou and Kupek (2010) for details of Young Lives sampling and data collection).

Cognitive development of children at age 8 years was assessed using the Peabody Picture Vocabulary Test (PPVT), a test of receptive vocabulary that has been widely used as a test of verbal cognitive ability in many settings (Rosenzweig and Wolpin, 1994; Paxson and Schady,

[23] Another source of bias arises if parental investments in child health and cognitive skills respond to variation in height due to factors unrelated to nutrition (see Dercon and Sanchez, 2013 and Scholder et al., 2013 for a discussion). Although, in this case, height is not valid indicator of nutritional status (Wooldridge, 2002), us\ing shocks directly related to nutrition as instruments for HAZ, addresses this bias. Moreover, as highlighted by Glewwe and King (2001), there is also the case of non-random measurement error in child's height stemming from the fact that differences in height may not reflect differences in some micronutrients, suggesting that the measurement error is correlated with the unobserved true measure that is child nutritional status. Although IV cannot address the latter bias, this non-random measurement error will lead to the same bias in coefficient estimates of child growth across periods and thus it is not expected to affect estimates of the relative impact of nutrition across periods on cognitive skills.

2007), and a mathematics achievement test (MATH henceforth) used as a test of quantitative cognitive ability (Cueto and Leon, 2012). Both tests were administered in different languages within each country to allow for differences in the native language across children and to allow the children to respond in the language they felt most comfortable. As suggested by Cueto and Leon (2012), PPVT scores are not meant to be comparable across countries and within country across languages, whereas MATH scores are comparable only across children within country.

Table 1 presents descriptive statistics of cognitive achievement measures, including the language at which tests were administered, and of measures of cognitive skills and nutrition inputs at age 8 years for each country. The sample is restricted to children with non-missing information on PPVT and MATH in round 3, and with no missing or extreme values of HAZ (all values less than -6 or greater than 6 according to WHO standards) in all rounds. In order to maximise the sample used in estimation, I imputed the values of all variables except of key outcomes, causing variables, and instrumental variables with the sample mean of non-missing values. The number of missing values across all variables for which imputation was performed does not exceed 5% of the sample. Cognitive skills inputs measures include hours spent in school and studying on a typical day, the age the child was enrolled in school that can provide an indication of how long the child has been attending school, and expenditure on child's education, that includes expenditure on child's school uniform, school fees, tuition, school books and stationery, and transport to school in the 12 months prior to the third round of the survey. Nutrition inputs measures include the number of meals consumed by the child in the last 24 hours, the dietary diversity score of the child that is the number of different food groups consumed by the child in the last 24 hours, out of 17 food groups in total in Ethiopia and 14 groups in the other countries (see Humphries et al., 2015 for details), that is a well-validated measure of the macro- and micro-nutrient adequacy of the diet (Ruel, 2002; FAO, 2007), and expenditure on child's health that includes expenditure on medical consultation, treatment, and medication in the 12 months prior to the third round of the survey.

According to table 1, the majority of children took the tests in their native language, and, at age 8 years, children in India spent, on average, 10 hours in a typical day in school and studying, whereas in Peru and Vietnam they spent around 8 hours, and in Ethiopia 6 hours. Moreover, average primary school enrolment age is around 6 years in Vietnam and Peru, whereas children in India start school at 5.5, and in Ethiopia at much older age compared to the other countries, i.e. at 8.5 years.[24] As far as the quantity and quality of nutrition is concerned, table 1

[24] In the case of Ethiopia, because around 20% of the children were not enrolled in school by round 3, I use also information on primary school starting age from round 4.

suggests that children in Ethiopia consume, on average, less meals and have a less diverse diet compared to children in the other countries, whereas the number of meals consumed in the last 24 hours is very similar in the other three countries, and children in Peru have the most diverse diets among the four countries, consuming on average 9 out of 14 food groups in the last 24 hours.

Table 2 presents descriptive statistics of the independent variables used in our analysis, including HAZ scores at each age, that are used as indicators of child nutritional status, and other child, household, and community characteristics. HAZ scores indicate that average child HAZ in all countries and rounds is at least one standard deviation below the WHO reference, suggesting that undernutrition is highly prevalent across countries and over time but also that the prevalence of undernutrition is changing with children's age. In particular, the average growth deficit increases between age 1 and 5 years, except of Ethiopia, and falls between age 5 and 8 years in all countries. Moreover, the gender composition of the sample was balanced in all countries and children in Ethiopia were, on average, more likely to have older siblings than children in the other countries. Furthermore, caregivers were younger in India compared to the other countries, where the average caregiver's age in round 3 was around 35 years and parental education was the highest in Peru, followed by Vietnam and India and was the lowest for the Ethiopian sample.

Table 2 also includes summary statistics of the household's wealth index, a composite variable combining information on housing quality, access to services, and consumer durables (Filmer and Pritchett, 2001; see also Woldehanna et al. 2011 for details of the components and methodology used to compute the wealth index in the Young Lives data), that is used as a measure of assets at the beginning of period 1, A_0, of the number of pre-schools in the locality in 2006 when the child was age 5 years, and of schools when the child was 8 years that are used as proxies of the local school environment, S, of the number of credit providing institutions in the locality in round 1 that is a proxy of the local interest rate. Information on local prices of a range of items was used to calculate price indices for nutrition inputs (combining prices of medication and food items), p_N, education inputs, p_I, and other consumption items, p_C for all three periods (see table A.1 in the appendix for descriptive statistics of all prices and how price indices were calculated). Finally, information on local wages was used to calculate a wage index for all three periods and a set of variables measuring aspects of the local disease environment were combined to compute an index of the quality of the local health environment in all three periods (see table A.2 in the appendix for descriptive statistics of these variables and details of how the wage and disease environment indices were calculated).

4.2 *Instruments for Child Nutrition Across Periods*

Table 2 also presents information on rainfall and temperature shocks in the community occurred between the child's conception and round 3 that are used as measures of shocks to child nutrition, u, and thus as instruments for child HAZ in each period. Weather shocks were calculated as deviations of rainfall and temperature from the community's historical average rainfall and temperature respectively during the period 1900 to 2010 using data from the Global Climate Database of the University of Delaware (Willmott and Matsuura, 2012) and information on the geographical coordinates of the different communities in the Young Lives data.[25]

Temperature and rainfall shocks are expected to be relevant instruments for child nutrition, as they affect child nutrition directly through affecting the prevalence of infectious diseases that are among the major causes of undernutrition and stunting for children in poor contexts (Skoufias and Vinha, 2012). Although, this is particularly true for rural areas it is also expected to hold for poor urban areas constituting the majority of the Young Lives urban sub-sample across countries, because of the poor quality of infrastructure in these areas. According to Skoufias and Vinha (2012), ruling out extreme conditions, higher precipitation and temperature will in general increase the prevalence of diarrheal diseases that lead to stunting. Nevertheless, this is not expected to hold for children younger than 2 years, if the hypothesis that the first 1000 days is a critical period for nutritional investments is true. Therefore, investigating whether child nutrition after the age of 2 years is responsive to weather shocks provides a direct test of the hypothesis that the first 1000 days is a critical period for investments in nutrition. Moreover, weather shocks are also expected to be valid instruments for child nutrition, as they are exogenous to the household's decision-making problem and plausibly unanticipated by the household, and as long as long as they impact child cognitive achievement only through child nutrition. There are several potential cases, however, under which the latter condition may not hold that would render IV estimation invalid. First, in rural areas, weather shocks may impact cognitive skills investments and thus child cognitive achievement through an income channel, as they are expected to affect agricultural production and income (Skoufias and Vinha, 2012). Although, this is expected to be a valid problem for the majority of the sample in Ethiopia, India, and Vietnam and for a significant share

[25] The Global Climate Database of the University of Delaware is a gridded data set created by interpolating weather station averages to a 0.5 degree or latitude/longitude grid, where the grid nodes are centered on 0.25 degree. Rainfall and temperature shocks are calculated as deviations of distance-weighted averages for each community during a given period over the four nearest grid nodes from the distance-weighted average for the same community for the period between 1900 and 2010. In cases where weather shocks in the community were calculated for periods different from 12 months, the historical average was calculated as the average between 1900 and 2010 for the reference period only to take into account seasonal variation.

of the sample in Peru (35%) (see table A.2 in the appendix for details), it can be addressed through the inclusion of controls such as household wealth in round 1 and local economic conditions such as local prices and wages in all periods in the estimated specifications. Moreover, using marginal deviations from normal weather rather than indicators of drought or flood and heat waves as instruments for child nutrition may further ameliorate concerns related to this problem and provide further confidence in the validity of the identification strategy adopted here, as small deviations from a normal climate can make large areas susceptible to infectious diseases but are not expected to have major economic implications (Skoufias and Vinha, 2012). This will also address any concerns related to an impact of weather shocks on cognitive skills through extreme weather conditions that may disrupt school attendance. Another potential threat to the validity of IV could be that infectious diseases impact cognition directly and over and above their effect manifesting through child nutrition. Existing evidence does not seem to provide support to this hypothesis. To the contrary, Fischer Walker et al. (2012) find that diarrhea influence cognition only through the diarrhea-stunting pathway.

Rainfall shocks averages across countries and periods, reported in table 2, indicate a negative rainfall shock in the Young Lives sites in Ethiopia and India in the period between the child’s conception and round 1 and for Vietnam between rounds 1 and 2, whereas there was a positive rainfall shock in Vietnam between rounds 2 and 3. Temperature shocks information is consistent with changes in daily average temperature deviations from the historical mean over time within each country but does not seem to suggest a large positive or negative temperature shock during a particular period or for a given country.

5. Results

5.1 *The Impact of Child Nutrition At Different Stages of Childhood on Cognitive Achievement in Middle Childhood*

Tables 3 and 4 present coefficient estimates of nutrition measures at age 1, 5, and 8 years produced after estimation of equations (E.1), (E.2), and (E.3) respectively by OLS and 2SLS (see tables A.3-A.10 in the appendix for the full set of results). First-stage results are not reported (they are available by the author on request), as according to Shea (1997) and Stock et al. (2002) in the case of more than one endogenous variable the independent first-stage F-statistics from a regression of each endogenous variables on the instruments can provide misleading information about the instruments relevance. The dependent variables in tables 3 and 4 are the monthly age-standardized PPVT and MATH scores respectively.

In the case of 2SLS, there is a different set of potential instruments for each child HAZ measure depending on how the periods before the first measurement and between consecutive measurements are partitioned. We considered as instruments the rainfall and temperature shocks over the following periods: i) the full periods between conception and the first HAZ measurement and between HAZ measurements, ii) the three trimesters of gestation and all 6-monthly periods after birth through the first measurement and between measurements, iii) same as ii) for the period before the first measurement and between the second and third measurement but partitioning the period between the first and second measurement into the period before the first 1000 days and all 6-monthly periods between the first 1000 days and the second measurement, iv) gestation and all 12-monthly periods after birth through the first measurement and between measurements, v) same as iv) for the period before the first measurement and between the second and third measurement but partitioning the period between the first and second measurement into the period before the first 1000 days and all 12-monthly periods between the first 1000 days and the second measurement, vi) the three trimesters of gestation and the first and second half of each year after birth up to age 8 years, and vii) gestation and each year after birth up to age 8 years.[26]

2SLS results reported in tables 3 and 4 are those estimated using the strongest single instrument for each HAZ measure, as identified by an LM test of instruments' redundancy (Breusch et al., 1999) performed separately using each of the seven different sets of instruments, because in this way we maximize the precision of the estimates and minimize concerns related to weak instruments (Angrist and Pischke, 2009). 2SLS estimates are not expected to depend on the choice of instruments, unless there are heterogeneous effects of child nutrition on cognitive achievement in which case an additional assumption of instruments' monotonicity is needed for IV to be valid (Imbens and Angrist, 1994). According to Vinha and Skoufias (2012) the monotonicity assumption is expected to hold in the case of weather shocks and child nutrition, ruling out extreme weather events. In the cases of HAZ at age 5 and 8 years the strongest instruments included weather shocks after the age of 2 and 5 years respectively for all countries (see notes of tables 3 and 4 for details).

In most of the cases, OLS estimates in tables 3 and 4 suggest a positive and significant total association between nutrition in each period and cognitive achievement at age 8 years. In contrast

[26] In the case the periods considered could not be partitioned into an integer number of 6-monthly periods the set of instruments also include weather shocks during a period of less than 6 months just before each measurement that is the period remaining after the full period considered is partitioned into 6-monthly periods starting from the beginning of the period. The same procedure was followed in the case of partitioning the periods into 12-monthly periods. Due to this procedure, these remaining periods vary in length across children.

to OLS, 2SLS estimates of the total effect of nutrition across periods on achievement test scores at age 8 years is most of the times either insignificant or negative and significant, and it is positive and significant only for the period from conception to age 1 year in Ethiopia, and the period between age 5 and 8 years but only for PPVT in Vietnam. In general, the magnitude of 2SLS estimated coefficients is much larger in absolute value than OLS and much larger for the periods after age 1 year than before age 1 year. In fact, the effects of nutrition between age 1 and 5 and 5 and 8 years in some cases appear particularly large. For example, according to the 2SLS estimated coefficient of HAZ at age 8 years in the sixth column of table 3, in Vietnam, a change in height between 5 and 8 years leading to 1 standard deviation higher height relative to the WHO reference at age 8 years led, on average, to around 2 standard deviations increase in PPVT scores relative to children of the same monthly age. The differences in the magnitudes of the 2SLS effects before and after age 1 are expected to reflect, at least partly, differences in the magnitude of growth (change in height) as measured in cm, associated with a one standard deviation change in HAZ at each age. This is firstly because the standard deviation of the WHO reference height distribution is larger in cm at older ages (Leroy et al., 2013) and secondly because, although the standard deviation of the height and growth distributions are the same between conception and age 1 year (accounting for the fact that during this period initial height is 0), the standard deviation of height is expected to be larger than that of growth between age 1 and 5 and between 5 and 8 years. Therefore, one standard deviation higher HAZ is associated with much larger growth in cm between age 1 and 5 years and between age 5 and 8 years compared to age 1 year.

Results presented in tables 3 and 4 suggest that the 2SLS estimates are unlikely to be due to weak instruments. This is because, at least in the cases of specifications including HAZ at age 1 year only and HAZ at age 1 and 5 years across all countries, the Kleibergen-Paap F statistic values are sufficiently large and larger in all cases than the Stock and Yogo critical value for a 10% maximal IV test size distortion. Nevertheless, this evidence may not be sufficient to rule out any concerns related to weak instruments, as there is no Stock and Yogo critical value in the just-identified case with more than two endogenous variables (Stock and Yogo, 2005), but also because these critical values may be misleading in general, as the estimation here relaxes the assumption that errors in the structural equation are i.i.d., that is required for Stock and Yogo critical values to be valid (Stock et al., 2002). This is why I compared 2SLS estimates with those obtained using the GMM Continuously Updated Estimator (CUE) that is both robust to weak instruments and to non i.i.d errors (Hansen et al., 1996) (see tables A.11 and A.12 in the appendix for details). I found no systematic differences between the 2SLS and GMM CUE estimates that limits concerns related to weak instruments. Although, there are no issues with weak instruments, 2SLS estimates are less precise than the OLS and imprecision is expected to be higher as the number of variables instrumented increases, as suggested by the fall in the Kleibergen-Paap F statistic in tables 3 and 4, that results from correlation of the fitted values. The larger imprecision reduces the power of significance tests particularly for the coefficients of HAZ at age 8 years.

The comparison between 2SLS and GMM CUE uses an over-identifying restriction, as in the just-identified case the two estimators are identical (Stock et al., 2002), that enables me to perform an over-identification test that cannot reject the null that instruments are valid and do not violate the exclusion restrictions (see tables A.11 and A.12 in the appendix for details). I have also conducted additional tests of potential violation of the exclusion restrictions by checking whether shocks may impact child cognitive skills through either child health expenditure, that is not controlled for due to lack or limited information in all rounds, or household income by controlling for measures of these available in rounds 2 and 3 and found no differences in the results (results are available from the author on request). I also investigated whether results may reflect sample selection bias due to attrition or missing values in PPVT or MATH at age 8 years or HAZ at any age by comparing OLS estimates in tables 3 and 4 with those produced using the Heckman two-step sample selection correction method using as instruments the age of the child and of the caregiver in round 1 and dummies for the month of interview in round 1 (see tables A.13 and A.14 in the appendix). The age of the child and the caregiver in round 1 are assumed to be excluded from the structural equation that conditions for the values of these variables in round 3, and month of interview dummies are expected to capture seasonal variation in the responsiveness of households to the survey that is assumed to be uncorrelated with the outcome variable. Results of the two estimators are very similar supporting limited concerns related to sample selection.

Overall, results do not seem to be consistent with the hypothesis that the period from conception to age 2 years is a critical period for investments in nutrition. This is firstly because, as suggested by the values of the Kleibergen-Paap F statistic across specifications and countries, and considering that the instruments for HAZ at age 5 and 8 years include weather shocks after the first 1000 days, child nutritional status is responsive to shocks after this period. Moreover, in many cases, the total effect of nutrition between age 1 and 5 years, that reflects the effect of growth after the first 1000 days resulting from shocks after this period, and the effect of nutrition between age 5 and 8 years is different than zero that would be the case, as shown in the conceptual framework section, if the first 1000 days was a critical period for investments in nutrition. To the extent that the latter effects reflect a direct (biological) causal link between nutrition after the age of 2 years and cognition, these results would also cast doubt to the hypothesis that the first 1000 days is a critical period for the impact of child nutrition on cognitive development. Another result that could be suggestive of this is that a significant share of the total effect of early nutrition on later cognitive achievement across countries manifests through nutrition in subsequent periods. This could be verified by the marked change in the magnitude of the 2SLS estimated coefficient of HAZ at age 1 year and at age 5 year resulting after conditioning for HAZ in subsequent periods across countries, as presented in tables 3 and 4. This supports that the causal link between early nutrition and later cognitive development is partly mediated through biological or behavioural mechanisms linking nutrition in later periods with cognition.

Another pattern, as identified by results included in tables 3 and 4 is that, in many cases, the effects of nutrition at a given period on PPVT and MATH may differ in magnitude, significance, and even sign. For example, this is the case for nutrition between age 5 and 8 years in India and Peru, and for nutrition in all three periods considered in Vietnam. This finding could be explained in terms of different production technologies for verbal and quantitative cognitive skills that is supported by evidence from psychology (see special issue of *Intelligence*, vol.37, no. 1, January/February 2009 and McGrew (2009) for details) but also by evidence of differential marginal productivities of inputs, as estimated by value-added production functions for PPVT and MATH using Young Lives data across the four countries.[27]

5.2 *The Impact of Child Nutrition At Different Stages of Childhood on Parental Nutrition and Cognitive Skills Investments in Middle Childhood*

Estimates of the impact of nutrition at different periods on cognitive achievement are expected to reflect, at least partly, behavioural responses by parents who may increase or decrease investments on nutrition and cognitive skills as a response to changes in child nutrition. For example, according to the conceptual framework, the negative effects of nutrition in some cases on cognitive achievement, as suggested by 2SLS estimates presented in tables 3 and 4, could only reconcile with compensatory nutrition and cognitive skills investment responses that more than

[27] These results are available from the author on request. Even if OLS estimation of value-added production functions does not produce consistent estimates of the marginal productivities of inputs (Todd and Wolpin, 2003), different magnitudes of statistical associations between cognitive skills inputs and verbal and quantitative achievement measures are still expected to be suggestive of differential production technologies for PPVT and MATH. This is because differential associations are expected to reflect partly differential magnitudes of bias that in turns is consistent with differential magnitudes of correlations between excluded and included inputs and/or between excluded inputs and PPVT and MATH.

offset any positive direct or indirect effects of nutrition on cognitive achievement. Identifying the direction of parental investment responses to changes in child nutrition may also allow to infer whether there is a direct (biological) effect of nutrition after the first 1000 days on cognitive development that may offer a direct test of the hypothesis that the first 1000 days is a critical period for the impact of nutrition on cognitive development.

Table 5 presents 2SLS estimates of the total effect of nutrition in each period on the different cognitive skills and nutrition inputs implemented in the third round survey when children were around 8 years old across the four countries. These estimates are produced by estimating variants of equations (E.1), (E.2), and (E.3) using as outcomes the different cognitive skills and nutrition inputs. In particular, the first row of each panel in table 5 reports 2SLS estimates of the coefficient of HAZ at age 1 year from (E.3) for all inputs across the four countries. Similarly, the second row of each panel in table 5 includes estimates of the coefficient of HAZ at age 5 from (E.2) for all inputs and the third row of each panel in the table includes estimates of the coefficient of HAZ at age 8 from (E.1) across inputs.

Results in table 5 suggest that in almost all cases, the direction of parental investment responses can be consistent with the estimated total effects of nutrition in each period on cognitive achievement. This is based on the hypotheses that reallocation of time from any activity (leisure, work, or sleep) towards school and studying and enrollment in school at a younger age are expected to have a positive direct effect on cognitive achievement that are supported by existing evidence (Glewwe et al., 2001; Fiorini and Keane, 2014). For example, the negative effects of HAZ at age 1 year and at age 5 years on PPVT in Vietnam, of HAZ at age 8 years on MATH in Vietnam, and on PPVT in India, in tables 3 and 4, can be explained by a decrease in some of nutrition and cognitive skills inputs resulting from an increase in HAZ at these ages and that this effect more than offsets any positive direct and indirect effect of HAZ on cognitive achievement. Nevertheless, observed parental investment responses cannot reconcile with the negative total effect of nutrition improvements between age 1 and 5 years and 5 and 8 years on the two tests and on PPVT respectively in Peru, as there is no significant effect of nutrition in these periods across inputs in table 5. This may be suggestive of unobserved investment responses that are not in the same direction to those observed. I have investigated this possibility, as in the case of Peru only, the third round of Young Lives survey, includes information on a range of additional cognitive skills inputs related to the home environment, parental assessment of teachers' effort, and parental involvement in school activities when the child was around 8 years old and found evidence consistent with compensatory cognitive skills investment responses that could reconcile with the negative effect of nutrition in these periods on child cognitive achievement responses (results are available from the author on request).

Moreover, there are also some results suggestive of a direct effect of early and later nutrition on cognitive skills. For example, provided that there are no unobserved parental investment responses or that unobserved responses are in the same direction to those observed, the negative effect of improvement in child nutrition between age 5 and 8 years on MATH in Vietnam could only be explained in terms of compensatory nutrition investment responses that more than offset any positive effect arising from reinforcing cognitive skills investments. This evidence supports a direct link between nutrition in middle childhood and cognitive achievement and thus it is not consistent with the hypothesis that the first 1000 days is a critical period for the impact of nutrition on cognitive development. Similarly, in the case of India and Peru the insignificant effect of nutrition from conception through age 1 year on PPVT and MATH at age 8 years, considering also that at least one cognitive skills input fell as a result of an increase in HAZ, could only be explained by a direct positive effect running from nutrition during this period on cognitive achievement at age 8 years. This evidence is consistent with previous studies supporting a direct effect of nutrition up to age of two years of on cognitive development (Glewwe et al., 2001).

Results in table 5 reveal a number of patterns related to the direction of parental investment responses to a change in child nutrition. First, results suggest that, in many cases, nutrition investments may respond to the opposite direction than cognitive skills investments, as for example in the case of nutrition between 5 and 8 years in India.[28] This could be explained by the conceptual framework indicating that the direction of cognitive skills and health investment responses to a change in child health is ambiguous and that the latter impacts the former two through different channels and it is consistent with recent evidence by Yi et al. (2015) who find that parents compensate for an early child health insult in terms of health investments and reinforce in terms of education investments. Second, within the same human capital dimension, different inputs may respond to the opposite direction, as for example in the case of cognitive skills inputs in Vietnam in the periods between conception and age 1 and age 1 and 5 years. Again this result could be explained by the conceptual framework through the different counteracting effects of child health on cognitive skills inputs that may differ in magnitude across inputs. Third,

[28] In the case of India, the result that a deterioration of nutritional status between age 5 and 8 years leads to early enrolment may be interpreted as both a compensatory investment in cognitive skills and in nutrition due to the provision of free school meals in all public primary schools. In fact, the latter could explain the positive relationship between nutrition between age 5 and 8 years and school enrolment in India that does not seem to be consistent with evidence from other countries (Glewwe and Jacoby, 1995; Alderman et al., 2001).

the direction of parental investment responses may depend on when in the child's life course the change in nutritional status occurs. For example, in the case of Vietnam, results in table 5 indicate that improvements in nutrition before age 5 years have the opposite effect on time spent in school and studying, dietary diversity, and the number of meals the child consumed at around age 8 years than improvements in child nutrition between age 5 and 8 years.

Overall, these results may explain the mixed evidence and the current lack of consensus in the literature on whether parents compensate or reinforce the impact of child health insults in early life (Pitt et al., 1990; Behrman et al., 1994) and highlight that, under heterogeneous and partially observed parental investment responses to child health, it is very difficult to infer whether reduced form estimates provide lower or upper bounds of biological effects of health on cognitive skills.

5 Conclusion

Child undernutrition is highly prevalent in low- and middle-income countries and has deleterious implications for child development. Nutrition-promoting interventions in poor contexts focus mainly on the first 1000 days since conception, as it has been suggested that nutritional insults during this period may lead to physical growth deficits and cognitive developmental setbacks that are irreversible beyond this period. The evidence, however, in support of these hypotheses is rather thin because there are few studies purporting to identify critical periods for the impact of nutrition on cognitive development that suffer from various methodological limitations. Moreover, these studies produce results reflecting both biological and behavioural effects of nutrition at different stages of the child's life course on cognitive development and do not produce evidence on the direction of behavioural effects that depends on whether parents increase or decrease investments in the face of changes of child nutrition. Therefore, it is very difficult to infer from the results of these studies the magnitude of biological effects of nutrition in each period on cognitive development that is needed for the identification of critical periods. The question of how parents respond to changes in child health is little investigated, the existing evidence is rather mixed (Pitt et al., 1990; Behrman et al., 1994), and we know very little on whether and how parental investment responses depend on the timing of changes in child health.

In this paper, I investigate the impact of child nutrition at different stages from conception to middle childhood on cognitive achievement at age 8 years using data from Ethiopia, India, Peru, and Vietnam. In order to identify the independent effect of nutrition in each period on cognitive achievement, I develop a conceptual framework of the determination of child health and cognitive skills over different periods of childhood that I use to guide the specification of the econometric model and the choice of the identification strategy and use exogenous variation in nutrition across periods arising from weather shocks.

My key finding is that, although early undernutrition has negative implications for child health and cognitive development in later stages, these implications are not irreversible and there is scope for remediation of physical growth and cognitive deficits arising from early undernutrition through nutrition and cognitive skills investments in later stages of childhood. Another novel result is that parental investment responses to a change in child health are heterogeneous across multiple dimensions. In particular, I find that the direction of investment responses may differ a) across human capital dimensions, b) across inputs within a given human capital dimension, and c) with the timing of the change in child health. The heterogeneity of parental investment responses and the fact that these responses are imperfectly observed may explain the mixed evidence and the current lack of consensus in the literature on whether parents compensate or reinforce the impact of child health insults in early life and highlight that it is very difficult to infer whether reduced form estimates provide lower or upper bounds of biological effects of health on cognitive skills.

Overall, my findings have important policy implications. On the one hand, results indicate that nutrition early in life is important for physical growth and cognitive development in subsequent stages of childhood, but on the other hand they suggest that nutrition-promoting investments after infancy and early childhood can act as a remedy for early nutrition and cognitive deficits and protect from nutritional insults in later stages that may also lead to developmental setbacks. The evidence here also highlights the importance of parental behavioural responses for the causal link between child nutrition and cognitive development and thus that these responses, which may counteract the impact of interventions, should be taken into account in the design of policies aiming to promote child growth and development. Thus, the evidence suggests that nutrition-promoting interventions that start early in life and continue to subsequent stages of childhood combined with support in other areas such as cognitive stimulation and parental involvement may hold the most promise for the promotion of child development.

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Table 1: Descriptive Statistics of Cognitive Skills Measures and Cognitive Skills and Nutrition Inputs at Age 8 Years across Countries

Variable	Ethiopia	India	Peru	Vietnam
PPVT score	79.60	58.76	59.30	94.91
	(44.34)	(30.53)	(17.39)	(28.07)
MATH score	6.58	12.05	14.29	18.41
	(5.41)	(6.42)	(5.76)	(5.77)
Language of administration of tests				
Amharic	0.41			
	(0.49)			
Oromifa	0.20			
	(0.40)			
Tigrigna	0.19			
	(0.39)			
Telugu		0.84		
		(0.37)		
English		0.14		
		(0.34)		
Spanish			0.93	
			(0.26)	
Quechua			0.03	
			(0.17)	
Vietnamese				0.99
				(0.11)
Other	0.20	0.03	0.04	0.01
	(0.40)	(0.16)	(0.20)	(0.11)
Test administered in native language	0.99	0.81	0.91	0.81
	(0.07)	(0.39)	(0.29)	(0.39)
Cognitive skills inputs				
Expenditure on child's education in the last 12 months	14.19	209.68	33.22	79.16
	(36.88)	(290.69)	(52.52)	(178.20)
Hours spent on a typical day in school and studying	6.07	9.60	7.88	7.87
	(2.96)	(1.36)	(1.29)	(1.62)
Primary school entry age (months)	90.83	68.16	73.99	73.03
	(18.22)	(11.89)	(5.19)	(6.61)
Nutrition inputs				
Expenditure on child's health in the last 12 months	2.38	90.79	3.80	39.51
	(11.28)	(232.97)	(14.00)	(171.03)
Dietary diversity score in the last 24 hours	5.11	6.44	9.01	7.79
	(1.81)	(1.63)	(1.84)	(2.28)
Number of meals consumed in the last 24 hours	3.92	4.86	4.87	4.36
	(0.70)	(1.10)	(0.88)	(1.08)
Number of observations	1709	1837	1787	1775

Notes: The table reports averages with standard deviations in parentheses. The sample is restricted to children with no missing observations in PPVT and MATH in round 3 and no missing or extreme values (less than -6 or greater than 6) of HAZ in all rounds. Expenditure on child's education and health is in national currency units. Expenditure on child's education in the last 12 months includes expenditure on child's school uniform, school fees, tuition, school books and stationery, and transport to school, whereas expenditure on child's health in the last 12 months includes expenditure on medical consultation, treatment, and medication.

Table 2: Descriptive Statistics of Independent and Instrumental Variables across Countries

Variable	Ethiopia	India	Peru	Vietnam
Height-for-age z score (HAZ) in round 1	-1.50 (1.83)	-1.29 (1.46)	-1.26 (1.28)	-1.11 (1.23)
HAZ in round 2	-1.44 (1.10)	-1.63 (0.98)	-1.52 (1.09)	-1.33 (1.00)
HAZ in round 3	-1.19 (1.11)	-1.42 (1.02)	-1.14 (1.03)	-1.09 (1.04)
Male	0.52 (0.50)	0.53 (0.50)	0.50 (0.50)	0.51 (0.50)
First-born	0.23 (0.42)	0.39 (0.49)	0.37 (0.48)	0.47 (0.50)
Second-born	0.20 (0.40)	0.39 (0.49)	0.26 (0.44)	0.36 (0.48)
Third or later-born	0.56 (0.50)	0.22 (0.41)	0.38 (0.48)	0.17 (0.38)
Caregiver's age in round 3 (years)	36.36 (9.35)	31.51 (6.76)	35.19 (8.49)	36.28 (9.22)
Caregiver's education (years)	2.93 (3.76)	3.71 (4.44)	7.68 (4.47)	6.96 (3.94)
Father's education (years)	4.95 (4.27)	5.64 (5.03)	9.08 (3.82)	7.72 (3.89)
Wealth index in round 1	0.22 (0.18)	0.41 (0.20)	0.43 (0.24)	0.44 (0.21)
Caregiver's ethnicity				
Amhara	0.30 (0.46)			
Gurage	0.08 (0.28)			
Hadia	0.05 (0.21)			
Oromo	0.21 (0.41)			
Sidama	0.05 (0.21)			
Tigrian	0.21 (0.41)			
Wolayta	0.06 (0.24)			
Scheduled castes		0.18 (0.38)		
Scheduled tribes		0.13 (0.34)		
Backward castes		0.48 (0.50)		

White			0.03 (0.18)	
Quechua			0.20 (0.40)	
Mixed			0.72 (0.45)	
Kinh	0.30 (0.46)	0.13 (0.34)	0.20 (0.40)	0.88 (0.33)
H'mong	0.08 (0.28)	0.48 (0.50)	0.03 (0.18)	0.04 (0.19)
Other	0.04 (0.20)	0.21 (0.41)	0.05 (0.22)	0.08 (0.27)
Number of preschools in the community in round 2	0.94 (0.97)	2.61 (1.76)	2.17 (0.78)	1.37 (0.69)
Number of schools in the community in round 3	5.60 (1.57)	7.31 (3.31)	1.16 (0.69)	6.14 (3.37)
Number of credit-providing institutions in the community in round 1	2.03 (1.08)	2.52 (0.92)	1.53 (1.20)	2.71 (1.11)
Community rainfall shock between child's conception and round 1 (mm)	-210.60 (186.51)	-115.40 (124.31)	-54.96 (126.70)	10.05 (404.93)
Community rainfall shock between round 1 and 2	-28.78 (239.41)	203.91 (170.75)	0.74 (337.97)	-334.09 (419.97)
Community rainfall shock between round 2 and 3	-85.23 (161.51)	120.65 (285.89)	7.85 (132.14)	767.51 (884.02)
Community temperature shock between child's conception and round 1 (degrees Celcius)	0.44 (0.17)	0.48 (0.28)	0.15 (0.33)	0.23 (0.23)
Community temperature shock between round 1 and 2	0.62 (0.24)	0.23 (0.15)	0.06 (1.51)	0.29 (0.23)
Community temperature shock between round 2 and 3	0.51 (0.21)	0.16 (0.21)	-0.03 (0.57)	0.14 (0.23)
Number of observations	1709	1837	1787	1775

Notes: Figures are averages with standard deviations in parentheses. The sample is restricted to children with no missing observations in PPVT and MATH test in round 3 and no missing or extreme values (less than -6 or greater than 6) of HAZ in all rounds. Community rainfall and temperature shocks are calculated using the Global Climate Database of the University of Delaware (Willmott and Matsuura, 2012) as distance weighted deviations of community's total rainfall or average temperature at a given period from their associated average over a period of the same length and including the same calendar months between 1900 and 2010.

Table 3: The Impact of Nutrition at Different Stages of Childhood on PPVT Score at Age 8 Years across Countries

			Ethiopia			
	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.053***	0.089**	0.043***	0.134***	0.040***	0.131
	(0.010)	(0.040)	(0.012)	(0.043)	(0.012)	(0.080)
HAZ at age 5 y			0.036*	-0.218	0.017	-0.370
			(0.019)	(0.148)	(0.024)	(0.358)
HAZ at age 8 y					0.032	0.185
					(0.023)	(0.250)
R-squared	0.473		0.470		0.470	
Kleibergen-Paap F statistic		135.7		13.60		4.577
Stock and Yogo critical value		16.38		7.03		
Observations	1709	1709	1709	1709	1709	1709
			India			
	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.066***	0.108	0.053***	0.117	0.044**	0.127
	(0.016)	(0.115)	(0.018)	(0.121)	(0.018)	(0.147)
HAZ at age 5 y			0.049*	-0.126	-0.029	0.809**
			(0.026)	(0.243)	(0.035)	(0.366)
HAZ at age 8 y					0.112***	-0.905**
					(0.035)	(0.415)
R-squared	0.233		0.229		0.233	
Kleibergen-Paap F statistic		32.14		8.412		4.412
Stock and Yogo critical value		16.38		7.03		
Observations	1837	1837	1837	1837	1837	1837
			Peru			
	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.052***	0.033	0.028	-0.074	0.025	-0.062
	(0.016)	(0.105)	(0.019)	(0.117)	(0.019)	(0.150)
HAZ at age 5 y			0.059***	-0.507**	0.043	0.363
			(0.021)	(0.239)	(0.028)	(0.377)
HAZ at age 8 y					0.024	-1.197**
					(0.033)	(0.519)
R-squared	0.452		0.453		0.449	
Kleibergen-Paap F statistic		32.95		11.83		4.827
Stock and Yogo critical value		16.38		7.03		
Observations	1787	1787	1787	1787	1787	1787
			Vietnam			
	OLS	2SLS	OLS	2SLS	OLS	2SLS

HAZ at age 1 y	0.046***	-0.359*	0.049**	-0.017	0.046**	-0.139
	(0.017)	(0.184)	(0.022)	(0.155)	(0.022)	(0.195)
HAZ at age 5 y			-0.006	-0.549**	-0.107***	-1.681***
			(0.028)	(0.272)	(0.038)	(0.532)
HAZ at age 8 y					0.125***	1.970***
					(0.034)	(0.501)
R-squared	0.309		0.309		0.311	
Kleibergen-Paap F statistic		22.82		9.152		8.556
Stock and Yogo critical value		16.38		7.03		
Observations	1775	1775	1775	1775	1775	1775

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the age-standardized PPVT score. The Stock and Yogo critical value is the weak identification test critical value for a 10% maximal IV test size distortion. Excluded instruments for HAZ at age 1, HAZ at age 5, and HAZ at age 8 y include: a) in Ethiopia, temperature shocks in the second year of life and between the completion of the first 1000 days since conception and round 2, and the rainfall shock during the period that is less than 6 months before the round 3 interview respectively, b) in India, temperature shocks in the first trimester of pregnancy, during the second half of the fifth year after birth, and the first half during the eighth year after birth respectively, c) in Peru, rainfall shocks during the second trimester of pregnancy, the second half of the third year after round 1, and the temperature shock during the period that is less than one year before the round 3 interview respectively, and d) in Vietnam, rainfall shocks in the first trimester of pregnancy, during the first year after completion of the first 1000 days since conception, and the first half of the second year after round 2. The full set of controls included in each specification are presented in tables A.3-A.6 of the appendix.

Table 4: The Impact of Nutrition at Different Stages of Childhood on MATH Score at Age 8 Years across Countries

	OLS	2SLS	OLS	2SLS	OLS	2SLS
			Ethiopia			
	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.057***	0.068*	0.042***	0.099**	0.036***	0.014
	(0.010)	(0.038)	(0.011)	(0.041)	(0.012)	(0.064)
HAZ at age 5 y			0.058***	-0.191	0.030	0.178
			(0.020)	(0.160)	(0.025)	(0.280)
HAZ at age 8 y					0.046**	0.184
					(0.023)	(0.243)
R-squared	0.468		0.465		0.463	
Kleibergen-Paap F statistic		136.1		12.04		4.505
Stock and Yogo critical value		16.38		7.03		
Observations	1709	1709	1709	1709	1709	1709
			India			
	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.109***	0.014	0.086***	0.018	0.078***	0.006
	(0.015)	(0.116)	(0.018)	(0.122)	(0.018)	(0.116)
HAZ at age 5 y			0.071***	-0.069	0.025	-0.147
			(0.026)	(0.235)	(0.037)	(0.308)
HAZ at age 8 y					0.072*	0.231
					(0.039)	(0.326)
R-squared	0.295		0.298		0.299	
Kleibergen-Paap F statistic		31.88		8.256		4.637
Stock and Yogo critical value		16.38		7.03		
Observations	1837	1837	1837	1837	1837	1837
			Peru			
	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.051***	-0.062	0.021	-0.228	0.015	-0.224
	(0.017)	(0.130)	(0.020)	(0.161)	(0.020)	(0.178)
HAZ at age 5 y			0.072***	-0.846**	0.042	-0.582
			(0.024)	(0.355)	(0.031)	(0.451)
HAZ at age 8 y					0.048	-0.491
					(0.035)	(0.619)
R-squared	0.314		0.316		0.313	
Kleibergen-Paap F statistic		32.93		11.39		4.876
Stock and Yogo critical value		16.38		7.03		
Observations	1787	1787	1787	1787	1787	1787
			Vietnam			
	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.104***	0.187	0.099***	0.184	0.099***	0.211
	(0.018)	(0.151)	(0.024)	(0.136)	(0.025)	(0.158)
HAZ at age 5 y			0.006	-0.008	-0.056	0.467

			(0.030)	(0.229)	(0.042)	(0.399)
HAZ at age 8 y					0.065*	-0.804**
					(0.035)	(0.383)
R-squared	0.316		0.313		0.305	
Kleibergen-Paap F statistic		22.82		9.152		8.556
Stock and Yogo critical value		16.38		7.03		
Observations	1775	1775	1775	1775	1775	1775

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the age-standardized MATH score. The Stock and Yogo critical value is the weak identification test critical value for a 10% maximal IV test size distortion. Excluded instruments for HAZ at age 1, HAZ at age 5, and HAZ at age 8 y include: a) in Ethiopia, temperature shocks in the second year of life and between the completion of the first 1000 days since conception and round 2, and the rainfall shock during the period that is less than 6 months before the round 3 interview respectively, b) in India, temperature shocks in the first trimester of pregnancy, during the second half of the fifth year after birth, and the first half during the eighth year after birth respectively, c) in Peru, rainfall shocks during the second trimester of pregnancy, the second half of the third year after round 1, and the temperature shock during the period that is less than one year before the round 3 interview respectively, and d) in Vietnam, rainfall shocks in the first trimester of pregnancy, during the first year after completion of the first 1000 days since conception, and the first half of the second year after round 2. The full set of controls included in each specification are presented in tables A.7-A.10 of the appendix.

Table 5: 2SLS Estimates of the Total Effect of Nutrition at Different Stages of Childhood on Cognitive Skills and Nutrition Inputs Demands at Age 8 Years across Countries

	Education Expenditure	Time in School and Studying	School Entry Age	Health Expenditure	Dietary Diversity	Number of Meals
	Cognitive Skills Inputs			Nutrition Inputs		
Ethiopia						
HAZ at age 1 y	0.020	-0.201*	0.800	0.055	0.144*	0.076**
	(0.054)	(0.113)	(0.747)	(0.046)	(0.078)	(0.037)
HAZ at age 5 y	0.759**	-1.573**	12.384***	0.521	0.769*	0.031
	(0.373)	(0.636)	(4.725)	(0.350)	(0.405)	(0.171)
HAZ at age 8 y	-0.447	0.587	7.416	-0.074	-1.234*	0.114
	(0.466)	(1.031)	(5.942)	(0.318)	(0.720)	(0.281)
India						
HAZ at age 1 y	0.070	-0.429**	0.174	-0.008	0.033	0.087
	(0.104)	(0.187)	(1.547)	(0.137)	(0.206)	(0.135)
HAZ at age 5 y	0.280	-0.373	-0.900	0.400	0.378	0.294
	(0.250)	(0.421)	(3.092)	(0.327)	(0.449)	(0.304)
HAZ at age 8 y	0.099	0.790	14.256**	1.341**	-0.813	-0.674
	(0.396)	(0.659)	(6.120)	(0.559)	(0.675)	(0.477)
Peru						
HAZ at age 1 y	0.069	-0.123	3.574***	0.152	0.143	-0.046
	(0.116)	(0.182)	(1.082)	(0.110)	(0.268)	(0.137)
HAZ at age 5 y	-0.290	0.285	-1.155	-0.296	-0.280	-0.016
	(0.195)	(0.350)	(1.739)	(0.224)	(0.457)	(0.232)
HAZ at age 8 y	-1.006*	-0.320	-2.641	-0.756	1.428	0.334
	(0.537)	(0.603)	(2.976)	(0.526)	(0.874)	(0.412)
Vietnam						
HAZ at age 1 y	0.169	-0.543**	-8.221***	0.075	0.767**	0.763***
	(0.227)	(0.271)	(1.904)	(0.228)	(0.374)	(0.229)
HAZ at age 5 y	0.100	-1.825***	-12.735***	0.081	1.111*	0.803**
	(0.215)	(0.473)	(3.331)	(0.160)	(0.605)	(0.373)
HAZ at age 8 y	1.189***	3.484***	-2.922	-0.640	-2.210**	-1.959***
	(0.361)	(0.849)	(5.157)	(0.443)	(0.924)	(0.578)

Notes: ***significant at 1%, **significant at 5%, *significant at 10%. The first, second, and third row of each country panel present coefficient estimates, with associated robust standard errors in parentheses, of HAZ at age 1 y from equation (E.3), 5 y from equation (E.2), and 8 y from equation (E.3) respectively using as outcomes the inputs listed in the third row of the table. Diagnostics test results and the sample size are the same as those from the estimation of the associated equations for PPVT and MATH presented in tables 3 and 4 respectively. Excluded instruments for HAZ at age 1, HAZ at age 5, and HAZ at age 8 y include: a) in Ethiopia, temperature shocks in the second year of life and between the completion of the first 1000 days since conception and round 2, and the rainfall shock during the period that is less than 6 months before the round 3 interview respectively, b) in India, temperature shocks in the first trimester of pregnancy, during the second half of the fifth year after birth, and the first half during the eighth year after birth respectively, c) in Peru, rainfall shocks during the second trimester of pregnancy, the second half of the third year after round 1, and the temperature shock during the period that is less than one year before the round 3 interview respectively, and d) in Vietnam, rainfall shocks in the first trimester of pregnancy, during the first year after completion of the first 1000 days since conception, and the first half of the second year after round 2. The full set of controls included in each specification are the same as those presented in tables A.3-A.10 of the appendix.

APPENDIX

Table A.1: Descriptive Statistics of Community Prices of Food, Medication, Education, and Other Consumption Items

Variable	2002				2006				2009			
	Ethiopia	India	Peru	Vietnam	Ethiopia	India	Peru	Vietnam	Ethiopia	India	Peru	Vietnam
Food items												
Cereals	1.67				2.45				6.69			
	(0.38)				(0.86)				(0.96)			
Rice		9.81	1.49	3.08		11.78	1.71	5.10		20.39	1.96	8.39
		(2.55)	(0.31)	(0.35)		(2.29)	(0.27)	(0.55)		(5.29)	(0.45)	(1.79)
Potato			0.63				0.86				1.02	
			(0.27)				(0.15)				(0.20)	
Pasta			2.61				2.67				3.18	
			(0.46)				(0.38)				(0.34)	
Coffee	6.87	86.72	6.79	40.06	14.12	117.19	9.39	16.07	38.03	206.29	11.76	58.93
	(1.18)	(44.95)	(4.42)	(6.73)	(8.12)	(44.02)	(3.25)	(18.15)	(9.15)	(73.52)	(3.68)	(22.34)
Sugar	4.93	15.24	1.74	6.07	8.27	19.77	2.05	9.43	14.36	34.04	2.04	15.32
	(0.38)	(0.71)	(0.31)	(0.57)	(0.80)	(1.59)	(0.19)	(1.27)	(0.63)	(2.66)	(0.24)	(1.03)
Oil	10.76	45.89	3.76	13.93	8.82	53.79	3.99	17.61	20.06	56.55	5.88	26.25
	(1.61)	(3.80)	(0.51)	(1.12)	(5.82)	(4.39)	(0.46)	(1.70)	(2.86)	(9.51)	(0.68)	(3.89)
Medication												
Oral rehydration salts	1.24	11.09	1.01	0.91	1.65	8.40	1.01	1.08	1.78	12.95	0.83	1.35
	(0.25)	(5.59)	(0.41)	(0.17)	(0.78)	(4.06)	(0.32)	(0.24)	(0.41)	(7.66)	(0.22)	(0.32)
Paracetamol	0.10	0.53	0.01	0.10	0.73	0.99	0.15	0.92	0.21	1.18	0.13	2.16
	(0.02)	(0.17)	(0.01)	(0.06)	(0.60)	(0.95)	(0.07)	(0.58)	(0.17)	(1.25)	(0.05)	(1.36)
Amoxicillin	0.83	3.69	0.01	0.26	1.16	3.48	0.27	2.43	0.52	3.67	0.29	1.67
	(0.25)	(1.04)	(0.01)	(0.20)	(0.88)	(0.90)	(0.13)	(1.50)	(0.23)	(0.82)	(0.13)	(1.50)
Mebendazole	2.43	4.29	0.30	0.58	1.50	7.24	0.36	1.97	0.19	13.06	0.16	3.35
	(0.11)	(3.92)	(0.27)	(0.46)	(1.59)	(4.79)	(0.21)	(1.81)	(0.07)	(3.53)	(0.10)	(1.80)
Education items												
Notebook	2.01	4.47	1.04	0.94	2.56	5.36	1.31	2.46	3.39	6.14	1.43	4.18
	(0.85)	(1.06)	(0.21)	(0.17)	(0.41)	(1.40)	(0.20)	(0.80)	(0.90)	(2.59)	(0.18)	(1.97)
School shoes	25.13	110.62	28.76	15.00	30.00	110.33	30.79	32.71	57.40	128.68	37.21	25.39
	(18.02)	(78.49)	(4.26)	(5.92)	(20.73)	(36.95)	(3.70)	(19.29)	(28.29)	(33.63)	(6.83)	(15.24)
Boy’s shirt	19.42	94.60	12.74	14.75	20.98	68.12	10.87	26.43	30.63	112.63	13.80	30.74
	(10.44)	(32.59)	(3.37)	(3.76)	(9.06)	(32.18)	(2.45)	(6.97)	(15.37)	(48.19)	(2.72)	(8.10)
Girl’s shirt	17.16	105.23	12.59	15.31	25.44	73.98	10.55	25.58	38.11	109.82	13.71	32.09
	(8.75)	(54.33)	(3.00)	(4.11)	(10.11)	(45.64)	(2.62)	(6.55)	(17.46)	(56.15)	(2.65)	(8.43)
Boy’s shorts	19.53	102.12	20.39	9.15	26.20	100.97	24.16	9.92	52.74	183.19	27.22	15.73
	(12.52)	(69.68)	(5.35)	(1.41)	(18.81)	(42.23)	(4.36)	(4.30)	(47.07)	(69.85)	(3.89)	(6.89)
Girl’s skirt	19.75	110.47	18.06	17.07	29.69	91.67	20.78	28.53	54.24	162.91	23.95	30.21
	(9.48)	(59.59)	(4.84)	(6.62)	(14.75)	(30.22)	(3.04)	(11.20)	(48.61)	(75.58)	(3.53)	(7.73)
Other consumption												

items												
Cigarettes	3.91	29.38	3.19	1.99	1.75	18.29	3.77	6.39	5.77	24.06	3.79	10.23
	(0.63)	(14.81)	(0.87)	(0.03)	(1.76)	(2.70)	(0.87)	(3.08)	(0.76)	(7.18)	(1.05)	(3.85)
Detergent	4.66	14.32	2.06	13.07	1.63	6.18	1.62	17.53	23.79	8.17	1.18	25.77
	(4.94)	(7.40)	(1.02)	(1.46)	(1.02)	(2.91)	(0.42)	(2.94)	(8.05)	(4.25)	(0.19)	(2.89)
Kerosene	2.51	14.61	1.86	4.35	4.05	16.46	12.62	10.22	8.95	12.63	14.34	15.77
	(0.73)	(2.02)	(0.35)	(0.40)	(1.33)	(4.81)	(2.02)	(3.28)	(0.93)	(4.19)	(1.81)	(1.42)
Observations	1709	1837	1787	1775	1709	1837	1787	1775	1709	1837	1787	1775

Notes: Figures are averages with standard deviations in parentheses. Prices are in national currency units. Prices of food items are per kg except for oil for which price is per lt. Price of cereals in Ethiopia is the average of the prices of white teff, sorghum, and barley. Prices of medication are per tablet except for oral rehydration salts for which price is per sachet. Price for cigarettes is for one pack of 20 and price for kerosene is per lt. Prices were combined to calculate Paasche price indices for food, medication, education, and other consumption items using equal weights except for the food price index for which weights used were items shares in the total consumption expenditure on all these food items in the community computed using information on household consumption expenditure Base prices in the price index were the median prices of the items used. The food and medication price index were combined by averaging to produce a price index of health inputs.

Table A.2: Descriptive Statistics of Community Wages and Disease Environment Items

Variable	2002				2006				2009			
	Ethiopia	India	Peru	Vietnam	Ethiopia	India	Peru	Vietnam	Ethiopia	India	Peru	Vietnam
Urban	0.36 (0.48)	0.25 (0.43)	0.68 (0.47)	0.18 (0.38)	0.41 (0.49)	0.26 (0.44)	0.69 (0.46)	0.19 (0.39)	0.41 (0.49)	0.26 (0.44)	0.72 (0.45)	0.20 (0.40)
Average wage of adult male agricultural worker	5.40 (1.82)	45.70 (10.20)	11.40 (3.31)	20.41 (4.93)	9.99 (2.18)	61.01 (11.23)	12.58 (4.02)	35.28 (5.84)	19.20 (4.82)	119.81 (29.26)	17.28 (4.44)	73.30 (15.52)
Average wage of adult male unskilled factory worker	8.18 (2.11)	50.02 (3.01)	21.58 (1.24)	22.66 (4.88)	8.59 (1.54)	70.56 (14.18)	15.74 (3.80)	27.75 (7.76)	508.49 (131.55)	135.77 (23.37)	23.00 (3.14)	57.92 (10.51)
Air pollution is a severe problem in the locality	0.68 (0.41)	0.79 (0.30)	0.90 (0.50)	0.48 (0.50)	0.62 (0.49)	0.59 (0.49)	0.35 (0.48)	0.15 (0.36)	0.44 (0.50)	0.57 (0.50)	0.41 (0.49)	0.15 (0.36)
Water pollution is a severe problem in the locality	0.52 (0.50)	0.49 (0.40)	0.80 (0.49)	0.40 (0.48)	0.61 (0.49)	0.82 (0.38)	0.50 (0.50)	0.44 (0.50)	0.48 (0.50)	0.72 (0.45)	0.62 (0.49)	0.21 (0.41)
Access to improved drinking water in the locality	0.69 (0.46)	0.93 (0.25)	0.99 (0.09)	0.71 (0.46)	0.95 (0.21)	0.98 (0.13)	0.94 (0.23)	0.83 (0.38)	0.80 (0.40)	0.78 (0.41)	0.93 (0.25)	0.98 (0.14)
Access to improved sanitation in the locality	0.65 (0.48)	0.63 (0.48)	0.94 (0.24)	0.79 (0.41)	1.00 (0.00)	0.92 (0.26)	0.96 (0.19)	1.00 (0.00)	0.84 (0.37)	0.98 (0.14)	0.96 (0.20)	0.97 (0.17)
Garbage collection by truck in the locality	0.13 (0.34)	0.19 (0.39)	0.51 (0.50)	0.25 (0.43)	0.20 (0.40)	0.28 (0.45)	0.67 (0.47)	0.36 (0.48)	0.10 (0.30)	0.27 (0.45)	0.69 (0.46)	0.54 (0.50)
Observations	1709	1837	1787	1775	1709	1837	1787	1775	1709	1837	1787	1775

Notes: Figures are averages with standard deviations in parentheses. Wages are in national currency units. A wage index was constructed by dividing the average wage of adult male agricultural worker in rural communities and the average wage for adult male unskilled factory worker in urban communities with their median analogue. An index of the quality of the hygienic environment in the locality was constructed by taking the average of all disease environment items. Access to improved drinking water here means that, during data collection, the household had access to improved drinking water and toilets as defined by WHO/UNICEF (see http://www.wssinfo.org/definitions-methods/watsan-categories/), not that access to drinking water and sanitation improved between rounds of data collection.

Table A.3: The Impact of Nutrition at Different Stages of Childhood on PPVT Score at Age 8 Years in Ethiopia

	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.053***	0.089**	0.043***	0.134***	0.040***	0.131
	(0.010)	(0.040)	(0.012)	(0.043)	(0.012)	(0.080)
HAZ at age 5 y			0.036*	-0.218	0.017	-0.370
			(0.019)	(0.148)	(0.024)	(0.358)
HAZ at age 8 y					0.032	0.185
					(0.023)	(0.250)
Male	-0.002	0.012	-0.000	0.001	-0.001	0.008
	(0.036)	(0.038)	(0.036)	(0.042)	(0.036)	(0.054)
Second-born	-0.043	-0.043	-0.041	-0.107	-0.041	-0.130
	(0.057)	(0.056)	(0.057)	(0.070)	(0.057)	(0.111)
Third- or later-born	0.058	0.059	0.057	0.027	0.058	0.024
	(0.048)	(0.048)	(0.049)	(0.054)	(0.048)	(0.073)
Caregiver's age in round 3 (years)	-0.002	-0.002	-0.001	-0.001	-0.001	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Caregiver's education	0.016**	0.015**	0.016**	0.015*	0.016**	0.015*
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Father's education	0.018***	0.017***	0.017***	0.022***	0.018***	0.023**
	(0.006)	(0.006)	(0.006)	(0.007)	(0.006)	(0.010)
Wealth index in round 1	0.963***	0.882***	0.867***	0.824***	0.867***	0.798***
	(0.207)	(0.224)	(0.205)	(0.244)	(0.205)	(0.283)
Community consumption price index in round 1	-0.227**	-0.208**	-0.227**	-0.164*	-0.192**	-0.123
	(0.093)	(0.094)	(0.092)	(0.099)	(0.090)	(0.115)
Community consumption price index in round 1	0.173	0.162	0.180*	0.264**	0.187*	0.310
	(0.108)	(0.106)	(0.105)	(0.119)	(0.102)	(0.193)
Community consumption price index in round 1	0.585***	0.592***	0.715***	0.705***	0.617***	0.643***
	(0.199)	(0.199)	(0.181)	(0.194)	(0.118)	(0.127)
Community cognitive skills inputs price index in round 1	0.046	0.052	0.086	0.098	0.103	0.130
	(0.103)	(0.102)	(0.102)	(0.105)	(0.101)	(0.106)
Community cognitive skills inputs price index in round 2	-0.309*	-0.295*	-0.393**	-0.550***	-0.489***	-0.756**
	(0.163)	(0.163)	(0.156)	(0.194)	(0.137)	(0.335)
Community cognitive skills inputs price index in round 3	-0.218	-0.215	-0.158	-0.154	-0.237***	-0.181*
	(0.141)	(0.140)	(0.126)	(0.131)	(0.085)	(0.097)
Community wage index in round 1	0.008	0.029	-0.115	-0.113	-0.156*	-0.152*
	(0.102)	(0.103)	(0.088)	(0.095)	(0.081)	(0.090)
Community wage index in round 2	-0.109	-0.081	0.036	0.167	0.068	0.235
	(0.195)	(0.195)	(0.186)	(0.201)	(0.178)	(0.254)
Community wage index in round 3	0.569***	0.578***	0.564***	0.596***	0.553***	0.632***
	(0.152)	(0.150)	(0.145)	(0.153)	(0.142)	(0.162)
Number of credit-	-0.082**	-0.083**	-0.130***	-0.149***	-0.141***	-0.159***

providing institutions in the community in round 1	(0.034)	(0.035)	(0.030)	(0.032)	(0.029)	(0.045)
Number of schools in the community round 2	0.310*** (0.059)	0.317*** (0.058)	0.326*** (0.058)	0.318*** (0.060)	0.311*** (0.058)	0.292*** (0.069)
Number of schools in the community in round 3	0.094*** (0.036)	0.091** (0.036)	0.127*** (0.032)	0.144*** (0.035)	0.126*** (0.026)	0.161*** (0.048)
Community disease environment index in round 2	0.851*** (0.288)	0.884*** (0.291)				
Community disease environment index in round 3	0.688** (0.323)	0.677** (0.326)	0.368 (0.295)	0.474 (0.324)		
Community health inputs price index in round 2	-0.039 (0.144)	-0.046 (0.144)				
Community health inputs price index in round 3	-0.611* (0.352)	-0.591* (0.351)	-0.462 (0.333)	-0.411 (0.357)		
R-squared	0.473		0.470		0.470	
Kleibergen-Paap F statistic		135.7		13.60		4.577
Stock and Yogo critical value		16.38		7.03		
Observations	1709	1709	1709	1709	1709	1709

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the age-standardized PPVT score. All specifications include dummies for caregiver's ethnicity, the language at which the test was administered, whether the test was administered in the native language, and a constant but estimated coefficients for these variables are not reported. The Stock and Yogo critical value is the weak identification test critical value for a 10% maximal IV test size distortion. Excluded instruments for HAZ at age 1, HAZ at age 5, and HAZ at age 8 y include temperature shocks in the second year of life, between the completion of the first 1000 days since conception and round 2, and the rainfall shock during the period that is less than 6 months before the round 3 interview respectively.

Table A.4: The Impact of Nutrition at Different Stages of Childhood on PPVT Score at Age 8 Years in India

	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.066***	0.108	0.053***	0.117	0.044**	0.127
	(0.016)	(0.115)	(0.018)	(0.121)	(0.018)	(0.147)
HAZ at age 5 y			0.049*	-0.126	-0.029	0.809**
			(0.026)	(0.243)	(0.035)	(0.366)
HAZ at age 8 y					0.112***	-0.905**
					(0.035)	(0.415)
Male	0.265***	0.271***	0.264***	0.254***	0.261***	0.308***
	(0.041)	(0.045)	(0.041)	(0.050)	(0.041)	(0.068)
Second-born	-0.045	-0.051	-0.048	-0.052	-0.035	-0.129*
	(0.049)	(0.051)	(0.049)	(0.051)	(0.049)	(0.074)
Third- or higher-born	-0.142**	-0.142**	-0.133**	-0.160**	-0.114**	-0.199**
	(0.058)	(0.058)	(0.058)	(0.071)	(0.058)	(0.096)
Caregiver’s age in round 3 (years)	0.003	0.003	0.003	0.004	0.002	0.007
	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.005)
Caregiver’s education	0.026***	0.025***	0.026***	0.027***	0.026***	0.037***
	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)	(0.011)
Father’s education	0.020***	0.020***	0.020***	0.021***	0.020***	0.012
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.009)
Wealth index in round 1	0.502***	0.479***	0.510***	0.563***	0.499***	0.766***
	(0.151)	(0.166)	(0.150)	(0.189)	(0.149)	(0.272)
Community consumption price index in round 1	0.113	0.102	0.044	0.069	0.014	0.236
	(0.092)	(0.095)	(0.090)	(0.101)	(0.082)	(0.170)
Community consumption price index in round 1	0.011	-0.020	-0.192	-0.157	-0.160	-0.256
	(0.173)	(0.188)	(0.165)	(0.183)	(0.159)	(0.246)
Community consumption price index in round 1	-0.213	-0.193	-0.190	-0.215	-0.193	-0.425*
	(0.171)	(0.181)	(0.171)	(0.180)	(0.172)	(0.239)
Community cognitive skills inputs price index in round 1	-0.211**	-0.203**	-0.295***	-0.277***	-0.301***	-0.213**
	(0.084)	(0.086)	(0.081)	(0.089)	(0.077)	(0.109)
Community cognitive skills inputs price index in round 2	-0.585***	-0.570***	-0.433***	-0.445***	-0.500***	-0.394**
	(0.142)	(0.147)	(0.132)	(0.135)	(0.128)	(0.171)
Community cognitive skills inputs price index in round 3	0.081	0.080	0.076	0.053	0.108	-0.030
	(0.109)	(0.108)	(0.109)	(0.113)	(0.102)	(0.149)
Community wage index in round 1	-0.045	-0.013	-0.058	0.024	-0.034	0.176
	(0.162)	(0.187)	(0.161)	(0.199)	(0.158)	(0.254)
Community wage index in round 2	-0.227	-0.220	-0.284*	-0.239	-0.304**	-0.439**
	(0.157)	(0.156)	(0.154)	(0.163)	(0.152)	(0.204)
Community wage index in round 3	0.508***	0.498***	0.516***	0.528***	0.526***	0.257
	(0.147)	(0.148)	(0.145)	(0.151)	(0.143)	(0.222)
Number of credit-	0.077***	0.076***	0.048*	0.053*	0.036	0.053

providing institutions in the community in round 1	(0.029)	(0.029)	(0.028)	(0.029)	(0.027)	(0.037)
Number of schools in the community round 2	-0.056** (0.027)	-0.050* (0.030)	-0.077*** (0.026)	-0.065** (0.033)	-0.087*** (0.026)	-0.005 (0.050)
Number of schools in the community in round 3	0.032*** (0.009)	0.031*** (0.010)	0.030*** (0.009)	0.030*** (0.010)	0.038*** (0.009)	0.0001 (0.019)
Community disease environment index in round 2	-0.064 (0.160)	-0.055 (0.161)				
Community disease environment index in round 3	0.177 (0.129)	0.194 (0.136)	0.177 (0.131)	0.150 (0.147)		
Community health inputs price index in round 2	-0.903*** (0.255)	-0.844*** (0.300)				
Community health inputs price index in round 3	0.401* (0.238)	0.349 (0.280)	0.162 (0.220)	0.084 (0.250)		
R-squared	0.233		0.229		0.233	
Kleibergen-Paap F statistic		32.14		8.412		4.412
Stock and Yogo critical value		16.38		7.03		
Observations	1837	1837	1837	1837	1837	1837

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the age-standardized PPVT score. All specifications include dummies for caregiver's ethnicity, the language at which the test was administered, whether the test was administered in the native language, and a constant but estimated coefficients for these variables are not reported. The Stock and Yogo critical value is the weak identification test critical value for a 10% maximal IV test size distortion. Excluded instruments for HAZ at age 1, HAZ at age 5, and HAZ at age 8 y include temperature shocks in the first trimester of pregnancy, during the second half of the fifth year after birth, and the first half during the eighth year after birth respectively.

Table A.5: The Impact of Nutrition at Different Stages of Childhood on PPVT Score at Age 8 Years in Peru

	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.052***	0.033	0.028	-0.074	0.025	-0.062
	(0.016)	(0.105)	(0.019)	(0.117)	(0.019)	(0.150)
HAZ at age 5 y			0.059***	-0.507**	0.043	0.363
			(0.021)	(0.239)	(0.028)	(0.377)
HAZ at age 8 y					0.024	-1.197**
					(0.033)	(0.519)
Male	0.078**	0.074*	0.071**	0.062	0.071**	0.004
	(0.035)	(0.042)	(0.035)	(0.054)	(0.035)	(0.068)
Second-born	-0.003	-0.002	-0.001	-0.037	0.005	-0.080
	(0.043)	(0.042)	(0.043)	(0.060)	(0.043)	(0.081)
Third- or higher-born	-0.022	-0.024	-0.014	-0.113	-0.010	-0.137
	(0.049)	(0.050)	(0.049)	(0.073)	(0.050)	(0.094)
Caregiver's age in round 3 (years)	0.001	0.001	0.000	0.004	0.000	0.006
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.005)
Caregiver's education	0.038***	0.039***	0.036***	0.066***	0.036***	0.077***
	(0.006)	(0.007)	(0.006)	(0.013)	(0.006)	(0.018)
Father's education	0.038***	0.038***	0.037***	0.048***	0.038***	0.061***
	(0.007)	(0.007)	(0.007)	(0.009)	(0.007)	(0.013)
Wealth index in round 1	0.765***	0.774***	0.742***	1.328***	0.835***	1.515***
	(0.110)	(0.118)	(0.110)	(0.252)	(0.108)	(0.326)
Community consumption price index in round 1	-0.094	-0.088	-0.060	0.021	-0.003	-0.010
	(0.118)	(0.122)	(0.116)	(0.152)	(0.115)	(0.192)
Community consumption price index in round 1	0.138	0.148	0.153	0.309*	0.125	0.720**
	(0.141)	(0.151)	(0.140)	(0.176)	(0.138)	(0.291)
Community consumption price index in round 1	0.320*	0.326*	0.286*	0.542**	0.419***	0.669***
	(0.165)	(0.167)	(0.166)	(0.222)	(0.158)	(0.260)
Community cognitive skills inputs price index in round 1	0.291***	0.294***	0.260**	0.431***	0.186*	0.418**
	(0.108)	(0.110)	(0.108)	(0.147)	(0.105)	(0.187)
Community cognitive skills inputs price index in round 2	-0.281**	-0.272*	-0.223	-0.260	-0.211	0.039
	(0.142)	(0.147)	(0.143)	(0.190)	(0.143)	(0.254)
Community cognitive skills inputs price index in round 3	-0.189	-0.193	-0.137	-0.277	-0.099	-0.332
	(0.163)	(0.162)	(0.160)	(0.208)	(0.155)	(0.268)
Community wage index in round 1	0.398**	0.386**	0.452***	0.157	0.496***	0.278
	(0.167)	(0.181)	(0.166)	(0.237)	(0.165)	(0.268)
Community wage index in round 2	0.012	0.018	0.013	0.312**	0.058	0.184
	(0.090)	(0.095)	(0.089)	(0.157)	(0.090)	(0.195)
Community wage index in round 3	0.460***	0.462***	0.450***	0.435***	0.490***	0.595***
	(0.125)	(0.124)	(0.124)	(0.151)	(0.123)	(0.191)
Number of credit-						

providing institutions in the community in round 1	0.035** (0.018)	0.036** (0.018)	0.027 (0.017)	0.065*** (0.025)	0.030* (0.017)	0.112*** (0.039)
Number of schools in the community round 2	0.072** (0.031)	0.073** (0.031)	0.091*** (0.030)	0.117*** (0.038)	0.091*** (0.030)	0.171*** (0.054)
Number of schools in the community in round 3	-0.069** (0.027)	-0.067** (0.028)	-0.066** (0.028)	-0.071* (0.037)	-0.057** (0.027)	-0.045 (0.050)
Community disease environment index in round 2	0.156 (0.124)	0.158 (0.123)				
Community disease environment index in round 3	0.251** (0.117)	0.253** (0.116)	0.283** (0.116)	0.367** (0.150)		
Community health inputs price index in round 2	0.261** (0.121)	0.263** (0.121)				
Community health inputs price index in round 3	0.197* (0.111)	0.200* (0.111)	0.268*** (0.101)	0.242* (0.136)		
R-squared	0.452		0.453		0.449	
Kleibergen-Paap F statistic		32.95		11.83		4.827
Stock and Yogo critical value		16.38		7.03		
Observations	1787	1787	1787	1787	1787	1787

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the age-standardized PPVT score. All specifications include dummies for caregiver's ethnicity, the language at which the test was administered, whether the test was administered in the native language, and a constant but estimated coefficients for these variables are not reported. The Stock and Yogo critical value is the weak identification test critical value for a 10% maximal IV test size distortion. Excluded instruments for HAZ at age 1, HAZ at age 5, and HAZ at age 8 y include the rainfall shock during the second trimester of pregnancy, the second half of the third year after round 1, and the temperature shock during the period that is less than one year before the round 3 interview respectively.

Table A.6: The Impact of Nutrition at Different Stages of Childhood on PPVT Score at Age 8 Years in Vietnam

	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.046***	-0.359*	0.049**	-0.017	0.046**	-0.139
	(0.017)	(0.184)	(0.022)	(0.155)	(0.022)	(0.195)
HAZ at age 5 y			-0.006	-0.549**	-0.107***	-1.681***
			(0.028)	(0.272)	(0.038)	(0.532)
HAZ at age 8 y					0.125***	1.970***
					(0.034)	(0.501)
Male	0.031	-0.045	0.030	0.023	0.038	0.134
	(0.039)	(0.056)	(0.039)	(0.055)	(0.040)	(0.089)
Second-born	-0.060	-0.076	-0.059	-0.127**	-0.073	-0.061
	(0.044)	(0.050)	(0.044)	(0.061)	(0.045)	(0.108)
Third- or higher-born	-0.119**	-0.109	-0.119**	-0.220**	-0.146**	-0.257*
	(0.060)	(0.069)	(0.060)	(0.090)	(0.061)	(0.136)
Caregiver's age in round 3 (years)	0.005**	0.005*	0.005*	0.006**	0.005*	0.013**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.006)
Caregiver's education	0.050***	0.059***	0.049***	0.070***	0.049***	0.059***
	(0.008)	(0.010)	(0.008)	(0.013)	(0.008)	(0.021)
Father's education	0.024***	0.033***	0.024***	0.036***	0.023***	0.024
	(0.007)	(0.010)	(0.007)	(0.010)	(0.008)	(0.019)
Wealth index in round 1	0.360**	0.602***	0.381**	0.778***	0.339**	0.696
	(0.156)	(0.208)	(0.156)	(0.249)	(0.157)	(0.426)
Community consumption price index in round 1	2.837***	2.189***	2.738***	2.631***	1.980***	-0.024
	(0.453)	(0.603)	(0.443)	(0.575)	(0.412)	(1.027)
Community consumption price index in round 1	0.420**	0.375*	0.355**	0.317*	0.145	0.073
	(0.186)	(0.210)	(0.162)	(0.192)	(0.152)	(0.304)
Community consumption price index in round 1	0.491***	0.593***	0.571***	0.608***	0.458***	0.721**
	(0.176)	(0.213)	(0.158)	(0.198)	(0.140)	(0.321)
Community cognitive skills inputs price index in round 1	0.518*	0.851**	0.641**	1.111***	0.621**	1.252**
	(0.312)	(0.384)	(0.264)	(0.376)	(0.265)	(0.513)
Community cognitive skills inputs price index in round 2	-0.176*	-0.221*	-0.176*	-0.188	-0.115	-0.437**
	(0.100)	(0.115)	(0.099)	(0.118)	(0.086)	(0.186)
Community cognitive skills inputs price index in round 3	-0.659***	-0.846***	-0.633***	-0.938***	0.004	0.109
	(0.190)	(0.230)	(0.181)	(0.257)	(0.166)	(0.435)
Community wage index in round 1	-0.255*	0.094	-0.310**	0.319	-0.195*	0.979**
	(0.148)	(0.230)	(0.135)	(0.323)	(0.101)	(0.415)
Community wage index in round 2	-0.321	-0.327	-0.296	-0.327	-0.374*	-0.328
	(0.200)	(0.226)	(0.198)	(0.231)	(0.193)	(0.400)
Community wage index in round 3	-0.710***	-0.818***	-0.741***	-0.769***	-0.398**	-1.555***
	(0.188)	(0.224)	(0.182)	(0.230)	(0.169)	(0.495)
Number of credit-	-0.002	0.010	0.009	-0.015	-0.010	-0.117**

providing institutions in the community in round 1	(0.026)	(0.030)	(0.024)	(0.031)	(0.023)	(0.051)
Number of schools in the community round 2	-0.441*** (0.051)	-0.458*** (0.057)	-0.442*** (0.048)	-0.404*** (0.057)		
Number of schools in the community in round 3	0.035*** (0.012)	0.037*** (0.013)	0.030*** (0.011)	0.047*** (0.015)		
Community disease environment index in round 2	-0.006 (0.136)	0.076 (0.159)				
Community disease environment index in round 3	0.498** (0.204)	0.579** (0.230)	0.455** (0.205)	0.571** (0.238)		
Community health inputs price index in round 2	0.227 (0.197)	0.145 (0.222)				
Community health inputs price index in round 3	0.280 (0.205)	0.327 (0.231)	0.267 (0.196)	0.505** (0.250)		
R-squared	0.309		0.309		0.311	
Kleibergen-Paap F statistic		22.82		9.152		8.556
Stock and Yogo critical value		16.38		7.03		
Observations	1775	1775	1775	1775	1775	1775

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the age-standardized PPVT score. All specifications include dummies for caregiver's ethnicity, the language at which the test was administered, whether the test was administered in the native language, and a constant but estimated coefficients for these variables are not reported. The Stock and Yogo critical value is the weak identification test critical value for a 10% maximal IV test size distortion. Excluded instruments for HAZ at age 1, HAZ at age 5, and HAZ at age 8 y include the rainfall shock in the first trimester of pregnancy, during the first year after completion of the first 1000 days from conception, and the first half of the second year after round 2.

Table A.7: The Impact of Nutrition at Different Stages of Childhood on MATH Score at Age 8 Years in Ethiopia

	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.057***	0.068*	0.042***	0.099**	0.036***	0.014
	(0.010)	(0.038)	(0.011)	(0.041)	(0.012)	(0.064)
HAZ at age 5 y			0.058***	-0.191	0.030	0.178
			(0.020)	(0.160)	(0.025)	(0.280)
HAZ at age 8 y					0.046**	0.184
					(0.023)	(0.243)
Male	0.039	0.044	0.042	0.032	0.048	0.081*
	(0.036)	(0.037)	(0.036)	(0.043)	(0.036)	(0.047)
Second-born	0.034	0.035	0.047	-0.017	0.041	0.087
	(0.055)	(0.055)	(0.056)	(0.070)	(0.056)	(0.091)
Third- or higher-born	0.022	0.023	0.022	-0.008	0.020	0.051
	(0.047)	(0.047)	(0.048)	(0.053)	(0.048)	(0.061)
Caregiver's age in round 3 (years)	-0.002	-0.002	-0.002	-0.002	-0.001	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Caregiver's education	0.019**	0.018**	0.018**	0.018**	0.019**	0.017**
	(0.008)	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)
Father's education	0.027***	0.027***	0.026***	0.030***	0.025***	0.019**
	(0.006)	(0.006)	(0.006)	(0.007)	(0.006)	(0.009)
Wealth index in round 1	1.092***	1.066***	1.013***	1.048***	1.032***	0.866***
	(0.225)	(0.242)	(0.223)	(0.263)	(0.222)	(0.272)
Community consumption price index in round 1	-0.045	-0.039	-0.084	-0.039	-0.123	-0.154
	(0.090)	(0.091)	(0.092)	(0.098)	(0.088)	(0.099)
Community consumption price index in round 1	-0.364***	-0.367***	-0.271***	-0.180	-0.218**	-0.311**
	(0.104)	(0.104)	(0.097)	(0.117)	(0.092)	(0.148)
Community consumption price index in round 1	-0.550***	-0.547***	-0.257	-0.280	0.117	0.121
	(0.211)	(0.210)	(0.202)	(0.209)	(0.128)	(0.135)
Community cognitive skills inputs price index in round 1	0.129	0.131	0.158	0.161	0.188*	0.188*
	(0.102)	(0.101)	(0.101)	(0.105)	(0.096)	(0.101)
Community cognitive skills inputs price index in round 2	-0.247*	-0.243	-0.326**	-0.495**	-0.383***	-0.221
	(0.150)	(0.149)	(0.149)	(0.199)	(0.136)	(0.259)
Community cognitive skills inputs price index in round 3	-0.519***	-0.517***	-0.300**	-0.305**	-0.019	-0.001
	(0.147)	(0.146)	(0.137)	(0.144)	(0.087)	(0.097)
Community wage index in round 1	-0.178*	-0.171	-0.173*	-0.185*	-0.057	-0.043
	(0.105)	(0.107)	(0.095)	(0.102)	(0.082)	(0.089)
Community wage index in round 2	-0.059	-0.050	0.158	0.263	0.215	0.133
	(0.171)	(0.173)	(0.160)	(0.172)	(0.150)	(0.206)
Community wage index in round 3	0.177	0.180	0.003	0.033	0.089	0.093
	(0.161)	(0.159)	(0.143)	(0.149)	(0.139)	(0.154)
Number of credit-						

providing institutions in the community in round 1	-0.010 (0.032)	-0.010 (0.032)	-0.092*** (0.027)	-0.108*** (0.029)	-0.081*** (0.027)	-0.061* (0.036)
Number of schools in the community round 2	0.223*** (0.059)	0.226*** (0.059)	0.282*** (0.059)	0.267*** (0.064)	0.296*** (0.058)	0.312*** (0.061)
Number of schools in the community in round 3	-0.055 (0.034)	-0.056 (0.034)	0.008 (0.032)	0.027 (0.035)	0.051** (0.026)	0.033 (0.039)
Community disease environment index in round 2	0.428*** (0.148)	0.425*** (0.146)				
Community disease environment index in round 3	1.113*** (0.378)	1.118*** (0.374)	1.021*** (0.374)	1.062*** (0.388)		
Community health inputs price index in round 2	0.837*** (0.253)	0.847*** (0.253)				
Community health inputs price index in round 3	0.469* (0.284)	0.464 (0.283)	0.051 (0.280)	0.161 (0.317)		
R-squared	0.468		0.465		0.463	
Kleibergen-Paap F statistic		136.1		12.04		4.505
Stock and Yogo critical value		16.38		7.03		
Observations	1709	1709	1709	1709	1709	1709

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the age-standardized MATH score. All specifications include dummies for caregiver's ethnicity, the language at which the test was administered, whether the test was administered in the native language, and a constant but estimated coefficients for these variables are not reported. The Stock and Yogo critical value is the weak identification test critical value for a 10% maximal IV test size distortion. Excluded instruments for HAZ at age 1, HAZ at age 5, and HAZ at age 8 y include the temperature shock in the second year of life, between the completion of the first 1000 days after conception and round 2, and the rainfall shock during the period that is less than 6 months before the round 3 interview respectively.

Table A.8: The Impact of Nutrition at Different Stages of Childhood on MATH Score at Age 8 Years in India

	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.109***	0.014	0.086***	0.018	0.078***	0.006
	(0.015)	(0.116)	(0.018)	(0.122)	(0.018)	(0.116)
HAZ at age 5 y			0.071***	-0.069	0.025	-0.147
			(0.026)	(0.235)	(0.037)	(0.308)
HAZ at age 8 y					0.072*	0.231
					(0.039)	(0.326)
Male	0.094**	0.079*	0.097**	0.070	0.094**	0.072
	(0.040)	(0.044)	(0.040)	(0.049)	(0.040)	(0.053)
Second-born	-0.009	0.004	-0.008	0.005	-0.004	0.019
	(0.046)	(0.048)	(0.045)	(0.049)	(0.045)	(0.056)
Third- or higher-born	-0.110*	-0.109*	-0.098*	-0.119*	-0.096*	-0.089
	(0.056)	(0.056)	(0.056)	(0.068)	(0.056)	(0.076)
Caregiver's age in round 3 (years)	0.001	0.002	0.001	0.002	0.0001	0.0001
	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.004)
Caregiver's education	0.046***	0.048***	0.046***	0.049***	0.045***	0.044***
	(0.006)	(0.007)	(0.006)	(0.007)	(0.006)	(0.008)
Father's education	0.018***	0.019***	0.017***	0.020***	0.018***	0.020***
	(0.005)	(0.005)	(0.005)	(0.006)	(0.005)	(0.007)
Wealth index in round 1	0.475***	0.530***	0.463***	0.578***	0.415***	0.431**
	(0.151)	(0.161)	(0.150)	(0.189)	(0.149)	(0.217)
Community consumption price index in round 1	-0.063	-0.038	-0.089	-0.047	-0.109	-0.116
	(0.088)	(0.094)	(0.086)	(0.100)	(0.081)	(0.129)
Community consumption price index in round 1	-0.038	0.032	-0.093	-0.010	-0.109	-0.060
	(0.169)	(0.190)	(0.158)	(0.183)	(0.156)	(0.179)
Community consumption price index in round 1	-0.452***	-0.495***	-0.449***	-0.519***	-0.406***	-0.396**
	(0.145)	(0.157)	(0.145)	(0.164)	(0.140)	(0.176)
Community cognitive skills inputs price index in round 1	-0.045	-0.060	-0.074	-0.091	-0.087	-0.110
	(0.085)	(0.089)	(0.082)	(0.092)	(0.078)	(0.088)
Community cognitive skills inputs price index in round 2	-0.206	-0.233*	-0.176	-0.189	-0.136	-0.156
	(0.130)	(0.135)	(0.124)	(0.128)	(0.120)	(0.125)
Community cognitive skills inputs price index in round 3	-0.078	-0.075	-0.068	-0.084	-0.073	-0.046
	(0.106)	(0.105)	(0.105)	(0.110)	(0.101)	(0.117)
Community wage index in round 1	0.466***	0.390**	0.431***	0.402**	0.371**	0.296
	(0.158)	(0.184)	(0.157)	(0.200)	(0.152)	(0.201)
Community wage index in round 2	0.049	0.032	0.028	0.035	0.059	0.077
	(0.142)	(0.145)	(0.141)	(0.153)	(0.138)	(0.149)
Community wage index in round 3	0.191	0.215	0.200	0.242	0.230	0.301*
	(0.145)	(0.150)	(0.141)	(0.154)	(0.142)	(0.182)
Number of credit-						

providing institutions in the community in round 1	0.032 (0.026)	0.034 (0.027)	0.023 (0.026)	0.025 (0.027)	0.029 (0.025)	0.026 (0.027)
Number of schools in the community round 2	-0.155*** (0.024)	-0.168*** (0.029)	-0.161*** (0.023)	-0.173*** (0.032)	-0.167*** (0.023)	-0.189*** (0.040)
Number of schools in the community in round 3	0.012 (0.010)	0.015 (0.010)	0.011 (0.009)	0.014 (0.010)	0.010 (0.009)	0.017 (0.015)
Community disease environment index in round 2	-0.193 (0.259)	-0.322 (0.297)				
Community disease environment index in round 3	-0.151 (0.250)	-0.027 (0.295)	-0.159 (0.224)	-0.108 (0.258)		
Community health inputs price index in round 2	0.071 (0.153)	0.055 (0.155)				
Community health inputs price index in round 3	-0.155 (0.141)	-0.193 (0.152)	-0.143 (0.141)	-0.214 (0.164)		
R-squared	0.295		0.298		0.299	
Kleibergen-Paap F statistic		31.88		8.256		4.637
Stock and Yogo critical value		16.38		7.03		
Observations	1837	1837	1837	1837	1837	1837

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the age-standardized MATH score. All specifications include dummies for caregiver's ethnicity, the language at which the test was administered, whether the test was administered in the native language, and a constant but estimated coefficients for these variables are not reported. The Stock and Yogo critical value is the weak identification test critical value for a 10% maximal IV test size distortion. Excluded instruments for HAZ at age 1, HAZ at age 5, and HAZ at age 8 y include the temperature shock in the first trimester of pregnancy, during the second half of the fifth year after birth, and the first half during the eighth year after birth respectively.

Table A.9: The Impact of Nutrition at Different Stages of Childhood on MATH Score at Age 8 Years in Peru

	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.051***	-0.062	0.021	-0.228	0.015	-0.224
	(0.017)	(0.130)	(0.020)	(0.161)	(0.020)	(0.178)
HAZ at age 5 y			0.072***	-0.846**	0.042	-0.582
			(0.024)	(0.355)	(0.031)	(0.451)
HAZ at age 8 y					0.048	-0.491
					(0.035)	(0.619)
Male	0.125***	0.100**	0.116***	0.083	0.116***	0.062
	(0.039)	(0.049)	(0.039)	(0.074)	(0.039)	(0.080)
Second-born	-0.056	-0.050	-0.053	-0.107	-0.044	-0.128
	(0.051)	(0.052)	(0.051)	(0.086)	(0.052)	(0.099)
Third- or higher-born	-0.153***	-0.163***	-0.142**	-0.310***	-0.138**	-0.333***
	(0.056)	(0.057)	(0.056)	(0.100)	(0.056)	(0.112)
Caregiver's age in round 3 (years)	0.002	0.002	0.002	0.008*	0.002	0.009*
	(0.003)	(0.003)	(0.003)	(0.005)	(0.003)	(0.005)
Caregiver's education	0.044***	0.048***	0.042***	0.093***	0.042***	0.102***
	(0.007)	(0.009)	(0.007)	(0.018)	(0.007)	(0.021)
Father's education	0.035***	0.037***	0.034***	0.052***	0.034***	0.059***
	(0.007)	(0.008)	(0.007)	(0.012)	(0.007)	(0.015)
Wealth index in round 1	0.433***	0.487***	0.391***	1.380***	0.479***	1.612***
	(0.137)	(0.150)	(0.138)	(0.376)	(0.134)	(0.398)
Community consumption price index in round 1	0.337**	0.375***	0.333**	0.489**	0.395***	0.532**
	(0.132)	(0.140)	(0.131)	(0.211)	(0.129)	(0.233)
Community consumption price index in round 1	0.362**	0.424***	0.360**	0.654***	0.349**	0.830**
	(0.142)	(0.158)	(0.141)	(0.229)	(0.140)	(0.343)
Community consumption price index in round 1	0.234	0.276	0.210	0.633**	0.358**	0.826***
	(0.177)	(0.183)	(0.178)	(0.292)	(0.169)	(0.296)
Community cognitive skills inputs price index in round 1	0.022	0.042	-0.017	0.273	-0.070	0.240
	(0.131)	(0.135)	(0.130)	(0.223)	(0.128)	(0.236)
Community cognitive skills inputs price index in round 2	-0.184	-0.132	-0.131	-0.155	-0.129	-0.043
	(0.169)	(0.184)	(0.169)	(0.283)	(0.169)	(0.310)
Community cognitive skills inputs price index in round 3	-0.234	-0.263	-0.232	-0.475	-0.147	-0.495
	(0.199)	(0.206)	(0.194)	(0.306)	(0.186)	(0.330)
Community wage index in round 1	-0.007	-0.084	0.023	-0.513*	0.058	-0.471
	(0.170)	(0.197)	(0.171)	(0.300)	(0.171)	(0.310)
Community wage index in round 2	0.064	0.098	0.058	0.561**	0.103	0.583**
	(0.100)	(0.106)	(0.100)	(0.232)	(0.100)	(0.240)
Community wage index in round 3	0.430***	0.439***	0.423***	0.413**	0.465***	0.502**
	(0.128)	(0.129)	(0.128)	(0.199)	(0.129)	(0.222)
Number of credit-	-0.036*	-0.030	-0.042**	0.025	-0.036*	0.053

providing institutions in the community in round 1	(0.020)	(0.021)	(0.020)	(0.037)	(0.020)	(0.047)
Number of schools in the community round 2	-0.021 (0.037)	-0.015 (0.037)	-0.011 (0.035)	0.038 (0.054)	-0.012 (0.035)	0.064 (0.064)
Number of schools in the community in round 3	-0.021 (0.032)	-0.011 (0.034)	-0.019 (0.032)	-0.021 (0.052)	-0.012 (0.032)	-0.006 (0.057)
Community disease environment index in round 2	-0.096 (0.139)	-0.087 (0.142)				
Community disease environment index in round 3	0.202 (0.129)	0.208 (0.130)	0.185 (0.124)	0.328 (0.202)		
Community health inputs price index in round 2	0.212* (0.127)	0.222* (0.128)				
Community health inputs price index in round 3	0.225* (0.129)	0.242* (0.131)	0.331*** (0.118)	0.303 (0.192)		
R-squared	0.314		0.316		0.313	
Kleibergen-Paap F statistic		32.93		11.39		4.876
Stock and Yogo critical value		16.38		7.03		
Observations	1787	1787	1787	1787	1787	1787

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the age-standardized MATH score. All specifications include dummies for caregiver's ethnicity, the language at which the test was administered, whether the test was administered in the native language, and a constant term but estimated coefficients for these variables are not reported. The Stock and Yogo critical value is the weak identification test critical value for a 10% maximal IV test size distortion. Excluded instruments for HAZ at age 1, HAZ at age 5, and HAZ at age 8 y include the rainfall shock during the second trimester of pregnancy, the second half of the third year after round 1, and the temperature shock during the period that is less than one year before the round 3 interview respectively.

Table A.10: The Impact of Nutrition at Different Stages of Childhood on MATH Score at Age 8 Years in Vietnam

	OLS	2SLS	OLS	2SLS	OLS	2SLS
HAZ at age 1 y	0.104***	0.187	0.099***	0.184	0.099***	0.211
	(0.018)	(0.151)	(0.024)	(0.136)	(0.025)	(0.158)
HAZ at age 5 y			0.006	-0.008	-0.056	0.467
			(0.030)	(0.229)	(0.042)	(0.399)
HAZ at age 8 y					0.065*	-0.804**
					(0.035)	(0.383)
Male	-0.007	0.009	-0.010	0.006	-0.006	-0.030
	(0.040)	(0.050)	(0.040)	(0.048)	(0.040)	(0.058)
Second-born	-0.052	-0.048	-0.048	-0.047	-0.044	-0.090
	(0.044)	(0.045)	(0.045)	(0.053)	(0.045)	(0.062)
Third- or higher-born	-0.023	-0.026	-0.022	-0.026	-0.015	-0.044
	(0.062)	(0.061)	(0.062)	(0.078)	(0.063)	(0.090)
Caregiver's age in round 3 (years)	0.001	0.000	0.000	0.000	0.000	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Caregiver's education	0.026***	0.024***	0.025***	0.024**	0.023***	0.031**
	(0.007)	(0.008)	(0.007)	(0.010)	(0.007)	(0.012)
Father's education	0.040***	0.039***	0.040***	0.039***	0.041***	0.047***
	(0.007)	(0.008)	(0.007)	(0.008)	(0.007)	(0.010)
Wealth index in round 1	0.348**	0.298	0.373**	0.333	0.303*	0.410
	(0.160)	(0.186)	(0.161)	(0.218)	(0.159)	(0.251)
Community consumption price index in round 1	0.762	0.896	0.681	0.819	0.973**	1.744***
	(0.529)	(0.572)	(0.509)	(0.547)	(0.494)	(0.669)
Community consumption price index in round 1	0.038	0.048	-0.032	-0.024	-0.225	-0.132
	(0.173)	(0.173)	(0.159)	(0.159)	(0.153)	(0.177)
Community consumption price index in round 1	1.429***	1.408***	1.611***	1.602***	1.417***	1.320***
	(0.200)	(0.204)	(0.184)	(0.184)	(0.181)	(0.219)
Community cognitive skills inputs price index in round 1	0.626**	0.557*	0.723***	0.662**	0.755***	0.754**
	(0.293)	(0.321)	(0.239)	(0.299)	(0.228)	(0.318)
Community cognitive skills inputs price index in round 2	-0.098	-0.089	-0.084	-0.073	-0.121	-0.018
	(0.101)	(0.102)	(0.101)	(0.102)	(0.093)	(0.114)
Community cognitive skills inputs price index in round 3	-0.433**	-0.394**	-0.432**	-0.403*	-0.320*	-0.602**
	(0.186)	(0.197)	(0.177)	(0.206)	(0.177)	(0.256)
Community wage index in round 1	0.025	-0.047	-0.043	-0.101	0.181	0.042
	(0.145)	(0.195)	(0.129)	(0.257)	(0.111)	(0.284)
Community wage index in round 2	-0.227	-0.225	-0.218	-0.220	-0.381**	-0.379
	(0.212)	(0.212)	(0.208)	(0.207)	(0.194)	(0.231)
Community wage index in round 3	-0.091	-0.068	-0.106	-0.082	0.060	0.365
	(0.204)	(0.207)	(0.198)	(0.200)	(0.184)	(0.265)
Number of credit-						

providing institutions in the community in round 1	0.051** (0.026)	0.049* (0.026)	0.075*** (0.024)	0.074*** (0.025)	0.044* (0.024)	0.076** (0.033)
Number of schools in the community round 2	-0.169*** (0.048)	-0.165*** (0.048)	-0.187*** (0.045)	-0.185*** (0.047)	-0.167*** (0.045)	-0.178*** (0.056)
Number of schools in the community in round 3	0.057*** (0.012)	0.057*** (0.012)	0.050*** (0.011)	0.050*** (0.013)	0.063*** (0.011)	0.066*** (0.014)
Community disease environment index in round 2	-0.155 (0.144)	-0.172 (0.145)				
Community disease environment index in round 3	-0.376* (0.209)	-0.393* (0.211)	-0.484** (0.203)	-0.506** (0.208)		
Community health inputs price index in round 2	0.370** (0.184)	0.387** (0.185)				
Community health inputs price index in round 3	-0.701*** (0.181)	-0.711*** (0.179)	-0.772*** (0.174)	-0.783*** (0.192)		
R-squared	0.316		0.313		0.305	
Kleibergen-Paap F statistic		22.82		9.152		8.556
Stock and Yogo critical value		16.38		7.03		
Observations	1775	1775	1775	1775	1775	1775

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the age-standardized MATH score. All specifications include dummies for caregiver's ethnicity, the language at which the test was administered, whether the test was administered in the native language, and a constant term but estimated coefficients for these variables are not reported. The Stock and Yogo critical value is the weak identification test critical value for a 10% maximal IV test size distortion. Excluded instruments for HAZ at age 1, HAZ at age 5, and HAZ at age 8 y include the rainfall shock in the first trimester of pregnancy, during the first year after completion of the first 1000 days from conception, and the first half of the second year after round 2.

Table A.11: 2SLS and GMM CUE Estimates of the Impact of Nutrition at Different Stages of Childhood on PPVT Score across Countries

	Ethiopia					
	2SLS	GMM CUE	2SLS	GMM CUE	2SLS	GMM CUE
HAZ at age 1 y	0.090**	0.088**	0.134***	0.134***	0.123**	0.122**
	(0.040)	(0.040)	(0.043)	(0.043)	(0.056)	(0.056)
HAZ at age 5 y			-0.232*	-0.231*	-0.340	-0.336
			(0.140)	(0.140)	(0.267)	(0.264)
HAZ at age 8 y					0.198	0.202
					(0.224)	(0.222)
Kleibergen-Paap F statistic	67.97	67.97	12.16	12.16	5.512	5.512
Stock and Yogo critical value	19.93	8.68	13.43	5.44		
Hansen J statistic	0.515	0.516	0.056	0.056	0.023	0.023
	(0.473)	(0.473)	(0.812)	(0.812)	(0.880)	(0.879)
Observations	1709	1709	1709	1709	1709	1709
	India					
	2SLS	GMM CUE	2SLS	GMM CUE	2SLS	GMM CUE
HAZ at age 1 y	0.117	0.118	0.134	0.138	0.126	0.129
	(0.094)	(0.093)	(0.118)	(0.118)	(0.141)	(0.143)
HAZ at age 5 y			-0.082	-0.096	0.774**	0.793**
			(0.239)	(0.239)	(0.351)	(0.355)
HAZ at age 8 y					-0.776**	-0.820**
					(0.370)	(0.374)
Kleibergen-Paap F statistic	25.41	25.41	6.001	6.001	3.695	3.695
Stock and Yogo critical value	19.93	8.68	13.43	5.44		
Hansen J statistic	0.026	0.026	0.682	0.680	0.467	0.459
	(0.871)	(0.871)	(0.409)	(0.410)	(0.495)	(0.498)
Observations	1837	1837	1837	1837	1837	1837
	Peru					
	2SLS	GMM CUE	2SLS	GMM CUE	2SLS	GMM CUE
HAZ at age 1 y	-0.013	-0.013	-0.098	-0.101	-0.075	-0.078
	(0.075)	(0.075)	(0.104)	(0.105)	(0.139)	(0.145)
HAZ at age 5 y			-0.447**	-0.465**	0.251	0.295
			(0.216)	(0.218)	(0.343)	(0.355)
HAZ at age 8 y					-0.990**	-1.084**
					(0.448)	(0.464)
Kleibergen-Paap F statistic	37.15	37.15	8.635	8.635	4.205	4.205
Stock and Yogo critical value	19.93	8.68	13.43	5.44		
Hansen J statistic	0.380	0.380	0.296	0.290	0.930	0.890
	(0.538)	(0.538)	(0.587)	(0.590)	(0.335)	(0.345)
Observations	1787	1787	1787	1787	1787	1787
	Vietnam					
	2SLS	GMM CUE	2SLS	GMM CUE	2SLS	GMM CUE
HAZ at age 1 y	-0.285**	-0.289**	-0.004	-0.004	-0.213	-0.210
	(0.145)	(0.145)	(0.149)	(0.149)	(0.171)	(0.172)
HAZ at age 5 y			-0.509**	-0.507**	-1.396***	-1.437***
			(0.248)	(0.247)	(0.379)	(0.383)
HAZ at age 8 y					1.762***	1.803***
					(0.405)	(0.410)

Kleibergen-Paap F statistic	15.63	15.63	7.573	7.573	7.788	7.788
Stock and Yogo critical value	19.93	8.68	13.43	5.44		
Hansen J statistic	0.544	0.543	0.232	0.233	0.642	0.635
	(0.461)	(0.461)	(0.630)	(0.629)	(0.423)	(0.426)
Observations	1775	1775	1775	1775	1775	1775

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. Hansen J test p-values in parentheses below Hansen J statistics. The dependent variable is the age-standardized PPVT score. The Stock and Yogo critical value is the weak identification test critical value for a 10% maximal IV or LIML test size distortion. Excluded instruments in specifications including HAZ at age 1 y only include: a) in Ethiopia, the temperature shock in the second year of life and the rainfall shock from birth to round 1, b) in India, the temperature shock in the first trimester of pregnancy and the rainfall shock from conception to round 1, c) in Peru, the rainfall shock during the second trimester of pregnancy and the temperature shock in the first half of the first year after birth, d) in Vietnam, the rainfall shock in the first trimester of pregnancy and the temperature shock from birth to round 1. Excluded instruments in specifications including HAZ at age 1 and 5 y only include: a) in Ethiopia, temperature shocks in the second year of life, between the completion of the first 1000 days since conception and round 2, and between round 1 and 2, b) in India, temperature shocks in the first trimester of pregnancy, the first six months after the completion of the first 1000 days since conception, and during the second half of the fifth year after birth, c) in Peru, rainfall shocks during the second trimester of pregnancy and the second half of the third year after round 1, and the temperature shock one year before conception, d) in Vietnam, rainfall shocks in the first trimester of pregnancy, during the first year after completion of the first 1000 days since conception, and the first half of the second year after round 1. Excluded instruments in specifications including HAZ at age 1, 5, and 8 y include: a) in Ethiopia, temperature shocks in the second year of life and between round 1 and 2, and rainfall shocks between the completion of the first 1000 days since conception and round 2 and during the period that is less than 6 months before the round 3 interview, b) in India, temperature shocks in the first trimester of pregnancy, the first 6 months after the completion of 1000 days since conception, the third year after round 1, and the first half during the eighth year after birth, c) in Peru, rainfall shocks during the second trimester of pregnancy, the second half of the third year after round 1, the first 6 months after birth, and the temperature shock during the period that is less than one year before the round 3 interview, and d) in Vietnam, rainfall shocks in the first trimester of pregnancy, during the first year after completion of 1000 days since conception, and the first half of the second year after round 2, and the temperature shock in the period that is less than 6 months before the round 2 interview. The full set of controls included in each specification are the same as those presented in tables A.3-A.6.

Table A.12: 2SLS and GMM CUE Estimates of the Impact of Nutrition at Different Stages of Childhood on MATH Score across Countries

	Ethiopia					
	2SLS	GMM CUE	2SLS	GMM CUE	2SLS	GMM CUE
HAZ at age 1 y	0.068*	0.068*	0.098**	0.094**	0.046	0.042
	(0.039)	(0.038)	(0.040)	(0.040)	(0.053)	(0.053)
HAZ at age 5 y			-0.094	-0.114	0.044	0.059
			(0.133)	(0.134)	(0.246)	(0.244)
HAZ at age 8 y					0.130	0.138
					(0.233)	(0.232)
Kleibergen-Paap F statistic	68.19	68.19	11.27	11.27	5.035	5.035
Stock and Yogo critical value	19.93	8.68	13.43	5.44		
Hansen J statistic	0.101	0.101	1.985	1.967	0.617	0.618
	(0.751)	(0.751)	(0.159)	(0.161)	(0.432)	(0.432)
Observations	1709	1709	1709	1709	1709	1709
	India					
	2SLS	GMM CUE	2SLS	GMM CUE	2SLS	GMM CUE
HAZ at age 1 y	-0.048	-0.055	0.035	0.036	0.005	0.0001
	(0.097)	(0.097)	(0.118)	(0.118)	(0.118)	(0.119)
HAZ at age 5 y			-0.024	-0.019	-0.184	-0.202
			(0.224)	(0.223)	(0.313)	(0.315)
HAZ at age 8 y					0.417	0.445
					(0.304)	(0.307)
Kleibergen-Paap F statistic	25.12	25.12	5.891	5.891	3.235	3.235
Stock and Yogo critical value	19.93	8.68	13.43	5.44		
Hansen J statistic	0.923	0.920	0.861	0.863	1.853	1.845
	(0.337)	(0.337)	(0.354)	(0.353)	(0.173)	(0.174)
Observations	1837	1837	1837	1837	1837	1837
	Peru					
	2SLS	GMM CUE	2SLS	GMM CUE	2SLS	GMM CUE
HAZ at age 1 y	-0.077	-0.078	-0.242*	-0.242*	-0.234	-0.239
	(0.088)	(0.088)	(0.145)	(0.145)	(0.172)	(0.175)
HAZ at age 5 y			-0.809***	-0.809***	-0.680	-0.688
			(0.306)	(0.306)	(0.415)	(0.423)
HAZ at age 8 y					-0.317	-0.341
					(0.546)	(0.555)
Kleibergen-Paap F statistic	37.27	37.27	8.480	8.480	4.212	4.212
Stock and Yogo critical value	19.93	8.68	13.43	5.44		
Hansen J statistic	0.027	0.027	0.048	0.048	0.463	0.455
	(0.869)	(0.869)	(0.826)	(0.826)	(0.496)	(0.500)
Observations	1787	1787	1787	1787	1787	1787
	Vietnam					
	2SLS	GMM CUE	2SLS	GMM CUE	2SLS	GMM CUE
HAZ at age 1 y	0.281**	0.281**	0.168	0.177	0.271**	0.279**
	(0.130)	(0.130)	(0.135)	(0.135)	(0.133)	(0.135)
HAZ at age 5 y			-0.056	-0.058	0.240	0.253
			(0.216)	(0.216)	(0.280)	(0.284)
HAZ at age 8 y					-0.639*	-0.680**
					(0.333)	(0.336)
Kleibergen-Paap F statistic	15.63	15.63	7.573	7.573	7.788	7.788

Stock and Yogo critical value	19.93	8.68	13.43	5.44		
Hansen J statistic	1.052	1.055	0.421	0.420	0.677	0.666
	(0.305)	(0.304)	(0.516)	(0.517)	(0.411)	(0.414)
Observations	1775	1775	1775	1775	1775	1775

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. Hansen J test p-values in parentheses below Hansen J statistics. The dependent variable is the age-standardized MATH score. The Stock and Yogo critical value is the weak identification test critical value for a 10% maximal IV or LIML test size distortion. Excluded instruments in specifications including HAZ at age 1 y only include: a) in Ethiopia, the temperature shock in the second year of life and the rainfall shock from birth to round 1, b) in India, the temperature shock in the first trimester of pregnancy and the rainfall shock from conception to round 1, c) in Peru, the rainfall shock during the second trimester of pregnancy and the temperature shock in the first half of the first year after birth, d) in Vietnam, the rainfall shock in the first trimester of pregnancy and the temperature shock from birth to round 1. Excluded instruments in specifications including HAZ at age 1 and 5 y only include: a) in Ethiopia, temperature shocks in the second year of life, between the completion of the first 1000 days since conception and round 2, and between round 1 and 2, b) in India, temperature shocks in the first trimester of pregnancy, the first six months after the completion of the first 1000 days since conception, and during the second half of the fifth year after birth, c) in Peru, rainfall shocks during the second trimester of pregnancy and the second half of the third year after round 1, and the temperature shock one year before conception, d) in Vietnam, rainfall shocks in the first trimester of pregnancy, during the first year after completion of the first 1000 days since conception, and the first half of the second year after round 1. Excluded instruments in specifications including HAZ at age 1, 5, and 8 y include: a) in Ethiopia, temperature shocks in the second year of life and between round 1 and 2, and rainfall shocks between the completion of the first 1000 days since conception and round 2 and during the period that is less than 6 months before the round 3 interview, b) in India, temperature shocks in the first trimester of pregnancy, the first 6 months after the completion of 1000 days since conception, the third year after round 1, and the first half during the eighth year after birth, c) in Peru, rainfall shocks during the second trimester of pregnancy, the second half of the third year after round 1, the first 6 months after birth, and the temperature shock during the period that is less than one year before the round 3 interview, and d) in Vietnam, rainfall shocks in the first trimester of pregnancy, during the first year after completion of 1000 days since conception, and the first half of the second year after round 2, and the temperature shock in the period that is less than 6 months before the round 2 interview. The full set of controls included in each specification are the same as those presented in tables A.7-A.10.

Table A.13: OLS and Heckit Estimates of the Impact of Nutrition at Different Stages of Childhood on PPVT Score at Age 8 Years across Countries

Ethiopia

	OLS	Heckit	OLS	Heckit	OLS	Heckit
HAZ at age 1 y	0.053***	0.053***	0.043***	0.043***	0.040***	0.040***
	(0.010)	(0.010)	(0.012)	(0.011)	(0.012)	(0.012)
HAZ at age 5 y			0.036*	0.036*	0.017	0.017
			(0.019)	(0.019)	(0.024)	(0.023)
HAZ at age 8 y					0.032	0.031
					(0.023)	(0.023)
R-squared	0.473		0.470		0.470	
Inverse Mills ratio		0.581		0.363		0.387
		(0.696)		(0.678)		(0.678)
Censored observations		290		290		290
Uncensored Observations		1709		1709		1709
Observations	1709	1709	1709	1709	1709	1709
India						
	OLS	Heckit	OLS	Heckit	OLS	Heckit
HAZ at age 1 y	0.066***	0.069***	0.053***	0.059***	0.044**	0.049**
	(0.016)	(0.017)	(0.018)	(0.021)	(0.018)	(0.021)
HAZ at age 5 y			0.049*	0.041	-0.029	-0.038
			(0.026)	(0.032)	(0.035)	(0.038)
HAZ at age 8 y					0.112***	0.114***
					(0.035)	(0.036)
R-squared	0.233		0.229		0.233	
Inverse Mills ratio		1.147**		1.224**		1.126**
		(0.548)		(0.584)		(0.528)
Censored observations		174		174		174
Uncensored Observations		1837		1837		1837
Observations	1837	2011	1837	2011	1837	2011
Peru						
	OLS	Heckit	OLS	Heckit	OLS	Heckit
HAZ at age 1 y	0.052***	0.052***	0.028	0.028	0.025	0.025
	(0.016)	(0.015)	(0.019)	(0.018)	(0.019)	(0.019)
HAZ at age 5 y			0.059***	0.058***	0.043	0.043
			(0.021)	(0.022)	(0.028)	(0.029)
HAZ at age 8 y					0.024	0.024
					(0.033)	(0.030)
R-squared	0.452		0.453		0.449	
Inverse Mills ratio		0.498		0.303		0.125
		(0.634)		(0.621)		(0.613)
Censored observations		265		265		265
Uncensored Observations		1787		1787		1787
Observations	1787	2052	1787	2052	1787	2052
Vietnam						
	OLS	Heckit	OLS	Heckit	OLS	Heckit
HAZ at age 1 y	0.046***	0.047**	0.049**	0.051*	0.046**	0.048**
	(0.017)	(0.024)	(0.022)	(0.031)	(0.022)	(0.027)
HAZ at age 5 y			-0.006	-0.009	-0.107***	-0.110***
			(0.028)	(0.040)	(0.038)	(0.049)
HAZ at age 8 y					0.125***	0.125***
					(0.034)	(0.040)
R-squared	0.309		0.309		0.311	
Inverse Mills		1.312		1.271		1.127

ratio		(1.056)		(1.000)		(0.865)
Censored observations		225		225		225
Uncensored Observations		1775		1775		1775
Observations	1775	2000	1775	2000	1775	2000

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the age-standardized PPVT score. The full set of controls included in each specification are presented in tables A.3-A.6 of the appendix. Controls in the selection equation include child gender, birth order, caregiver's ethnicity, education, height, and age in round 1 y, father's education, wealth index in round 1, community price indices for education and other consumption items in round 1 and number of credit-providing institutions in the community in round 1. Excluded instruments in the selection equation include the age of the child and caregiver's age in round 1 and dummies for the month of interview in round 1.

Table A.14: OLS and Heckit Estimates of the Impact of Nutrition at Different Stages of Childhood on MATH Score at Age 8 Years across Countries

	Ethiopia					
	OLS	Heckit	OLS	Heckit	OLS	Heckit
HAZ at age 1 y	0.057***	0.057***	0.042***	0.042***	0.036***	0.036***

	(0.010)	(0.010)	(0.011)	(0.011)	(0.012)	(0.012)
HAZ at age 5 y			0.058***	0.057***	0.030	0.031
			(0.020)	(0.019)	(0.025)	(0.024)
HAZ at age 8 y					0.046**	0.046**
					(0.023)	(0.023)
R-squared	0.468		0.465		0.463	
Inverse Mills ratio		0.743		0.234		0.168
		(0.716)		(0.676)		(0.673)
Censored observations		290		290		290
Uncensored Observations		1709		1709		1709
Observations	1709	1709	1709	1709	1709	1709
			India			
	OLS	Heckit	OLS	Heckit	OLS	Heckit
HAZ at age 1 y	0.109***	0.113***	0.086***	0.092***	0.078***	0.085***
	(0.015)	(0.021)	(0.018)	(0.023)	(0.018)	(0.024)
HAZ at age 5 y			0.071***	0.063*	0.025	0.015
			(0.026)	(0.035)	(0.037)	(0.047)
HAZ at age 8 y					0.072*	0.074*
					(0.039)	(0.045)
R-squared	0.295		0.298		0.299	
Inverse Mills ratio		1.447**		1.345**		1.385**
		(0.691)		(0.642)		(0.649)
Censored observations		174		174		174
Uncensored Observations		1837		1837		1837
Observations	1837	2011	1837	2011	1837	2011
			Peru			
	OLS	Heckit	OLS	Heckit	OLS	Heckit
HAZ at age 1 y	0.051***	0.051*	0.021	0.023	0.015	0.017
	(0.017)	(0.035)	(0.020)	(0.039)	(0.020)	(0.038)
HAZ at age 5 y			0.072***	0.067	0.042	0.036
			(0.024)	(0.048)	(0.031)	(0.057)
HAZ at age 8 y					0.048	0.049
					(0.035)	(0.061)
R-squared	0.314		0.316		0.313	
Inverse Mills ratio		2.023		1.907		1.771
		(1.553)		(1.463)		(1.354)
Censored observations		265		265		265
Uncensored Observations		1787		1787		1787
Observations	1787	2052	1787	2052	1787	2052
			Vietnam			
	OLS	Heckit	OLS	Heckit	OLS	Heckit
HAZ at age 1 y	0.104***	0.105**	0.099***	0.102***	0.099***	0.101***
	(0.018)	(0.042)	(0.024)	(0.036)	(0.025)	(0.027)
HAZ at age 5 y			0.006	0.002	-0.056	-0.059
			(0.030)	(0.046)	(0.042)	(0.048)
HAZ at age 8 y					0.065*	0.064
					(0.035)	(0.039)
R-squared	0.316		0.313		0.305	
Inverse Mills ratio		1.738		1.485		1.109
		(1.399)		(1.168)		(0.851)
Censored		225		225		225

observations						
Uncensored Observations		1775		1775		1775
Observations	1775	2000	1775	2000	1775	2000

Notes: Robust standard errors in parentheses, ***significant at 1%, **significant at 5%, *significant at 10%. The dependent variable is the age-standardized MATH score. The full set of controls included in each specification are presented in tables A.3-A.6 of the appendix. Controls in the selection equation include child gender, birth order, caregiver's ethnicity, education, height, and age in round 1 y, father's education, wealth index in round 1, community price indices for education and other consumption items in round 1 and number of credit-providing institutions in the community in round 1. Excluded instruments in the selection equation include the age of the child and caregiver's age in round 1 and dummies for the month of interview in round 1.