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Working Paper

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An International Study of Childhood Poverty

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Summary

This paper engages in the debate on the effects of children's health on their education in later life stages in low- and middle-income countries. Using three rounds from the rich panel data of the Young Lives study in Ethiopia, India, Peru and Vietnam, it endorses a multidimensional approach to health (and poverty in general). In detail, the paper has a fourfold objective: (1) to explore whether the positive relationship between children's height and cognitive skills at pre-school and primary-school age found in previous studies holds in our sample of countries, too; (2) to assess whether additional health and nutrition indicators, rarely available or used in the existing literature, are significantly associated with later cognitive achievements; (3) to examine whether the whole contribution of children's multidimensional health to mid-term cognitive attainments can be adequately summarised by a composite deprivation index; (4) to investigate a few possible channels through which early childhood health may affect cognitive skills.

In line with the main literature, the estimates show a positive, highly significant effect of the height-for-age of children between 6 and 18 months on almost all the dependent variables at both pre-school and primary-school age. The expansion of the informational basis to a multidimensional perspective proved to be informative, too. In particular, weight-for-height, proxy for acute malnutrition, is an important predictor of children's learning outcomes, especially in India, Peru and Vietnam. However, the final health variable, indicating whether the child had experienced a serious illness, helps to explain only Maths scores in Vietnam. We then constructed an aggregate health-deprivation index, based on a revised version of the Alkire-Foster method. While it is associated with a variety of outcomes in the various countries, the index proved to be substantially less informative than the 'suite of indicators'.

Finally, the paper sheds some light on the factors mediating the relationship between early childhood health conditions and mid-run cognitive abilities. In particular, it suggests that the level of formal education attended/completed is an important channel. However, in most of the cases, the inclusion of variables related to schooling in the estimates does not overrule the association between early health and middle-run cognition, which points to the persistent effects of health and nutrition in infancy on life-course skills formation.

Keywords

Health, cognition, nutrition, multidimensional poverty, cross-country, longitudinal

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About Young Lives

Young Lives is an international study of childhood poverty, following the lives of 12,000 children in 4 countries (Ethiopia, India, Peru and Vietnam) over 15 years. **www.younglives.org.uk**

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1. Introduction

There are both intrinsic and instrumental reasons for putting children at the centre of the development agenda. On the one hand, the reduction of childhood multidimensional poverty is a matter of basic human rights and global justice (Woodhead et al. 2012; Bhalotra and Pogge 2012). On the other, a child-focused approach to poverty reduction is also a means to sustainable and equitable development outcomes. First, because of the young demographic structure of most developing countries, poor children constitute a disproportionate proportion of the total numbers of poor people. Also, because children face a higher risk of poverty than other age groups, a third of all people living in poverty in the developing world are children aged 0–12 years – a percentage which rises to half of children in low-income countries (Olinto et al. 2013). Accordingly, reducing childhood poverty directly translates into poverty reduction at the population level (Gordon et al. 2003; Bhalotra and Pogge 2012). Second, impoverished children can, in turn, be future transmitters of poverty to their own children, leading to persistent poverty (Harper et al. 2003; Black et al. 2013).

In the last two decades, the growing economic literature on Early Child Development (ECD) has contributed to analyses of the long-run repercussions of poor health experienced *in utero* and during the first two or three years of life on a wide range of life-course attainments, such as productivity, wages, health, education, and, recently, non-cognitive abilities (Alderman et al. 2006, 2009; Maluccio et al. 2009; Grantham-McGregor et al. 2007; Dercon and Sanchez 2013). This paper engages in the specific debate on the effects of children's health and nutrition on their education in later life stages in low- and middle-income countries. While the dominant empirical literature provides some evidence of a positive relationship in a few countries, it usually suffers from one or more of these weaknesses: (a) it is based on cross-section data; (b) the height-for-age indicator is typically used as a proxy for child health; (c) education is measured in terms of school enrolment or completion. We overcome these drawbacks in the following way: first, we employ panel data from the younger cohort of the Young Lives study, collected in four low- and middle-income countries. Second, given its complex and multifaceted nature, and taking account of the fact that the greatest element of the burden of disease affecting children in developing countries is unlikely to affect height-for-age (Glewwe and Miguel 2008), we endorse a multidimensional approach to health. Finally, we examine the life-course effects of early childhood health on four different indicators of cognitive achievements, measured at both the pre-school and primary-school ages.

Specifically, the empirical analysis presented in this paper has four main objectives. The first is to examine the effect of child's height, the most commonly used indicator of health, on cognitive abilities at pre-school and primary-school ages in the Young Lives study. While numerous studies, including many that employ the Young Lives survey data, provide empirical evidence of this relationship, to the best of our knowledge none of these works has looked simultaneously at all the cognitive outcomes, child-development stages and countries that we analyse. In doing so, this paper also contributes to the mounting body of evidence generated through the analysis of Young Lives data concerning the medium-term effects of chronic malnutrition on cognitive outcomes (Crookston et al. 2010a, 2010b, 2013; Fink and Rockers 2014).

The second objective is to investigate whether cognitive abilities are better explained by a 'suite of health indicators', instead of the single metrics of height-for-age. Related to objective 2, we then analyse whether a composite index of health deprivation in early childhood, obtained by employing a revised version of the Alkire-Foster method (Alkire and Foster 2011), is able to synthesise adequately the overall effect of early childhood health deprivation on children's later cognitive outcomes.

The fourth objective consists of investigating a few possible channels through which child health may affect cognitive skills. We address this point by conducting a robustness analysis.

The paper is structured as follows: Section 2 reviews the existing literature; Section 3 illustrates our conceptual framework and explains the methodology employed in the quantitative analysis; Section 4 presents the data and the key indicators; Section 5 presents first the estimates of the main models and then the robustness analysis; finally, Section 6 summarises our conclusions.

2. Child health and lifecourse educational achievements

Since the late 1980s, within the so-called literature on Early Child Development (ECD), studies investigating the multiple life-course effects of early nutrition/health have proliferated. Given scarce data availability, in the context of child health in developing countries the height-for-age indicator[1] is typically employed as a proxy for child health, especially in the economic literature. In this section, we first examine the studies focusing directly on education as a dependent variable, and then review the relevant literature on non-cognitive abilities and health, because these could be important channels through which child health can affect mid- and long-run educational outcomes.

A number of studies have investigated whether health conditions during childhood are relevant determinants of life-course educational achievements. We differentiate between those that focus on educational outputs (for example, school enrolment, attendance and completion) and those that focus on outcomes (cognitive abilities).

One of the first contributions to this literature was the seminal paper by Glewwe and Jacoby (1995), which employed cross-sectional data concerning Ghanaian children aged 6–15 years. The authors find a negative effect of child health, measured by height-for-age, on delayed school enrolment, while the effect on the highest grade completed is insignificant. Other cross-section studies provided evidence of a negative influence of stunting (low height-for-age) on school completion in a number of countries (for example, Moock and Leslie 1986 in Nepal; Clark et al. 1990 in Jamaica; Shariff et al. 2000 in Malaysia).

However, the above studies do not make it possible to estimate a causal nexus (Behrman 1996; Glewwe and Miguel 2008). Alderman et al. (2001) use panel data collected from 1986 to 1991 for approximately 800 households in rural Pakistan. Their main finding is that height-for-age at 5 years is a key explanatory factor of school enrolment at age 7, especially for girls. Employing better data and estimation strategies (quasi-experimental approach), Alderman et al. (2006) analyse the impact of height in pre-school children on years of

1 The increasing amount of data available on morbidity is gradually leading to an expansion of this literature through new research which considers the effect of early infectious diseases on long-term outcomes in developing countries (Bhalotra and Venkataramani 2013; for a review see Jukes 2005). As of yet, this strand of research, nonetheless, has mostly been limited to advanced economies, and the USA in particular (Costa 2000; Holding and Snow 2001; Bleakley 2007; Case and Paxton 2009).

completed schooling among Zimbabwean adults. They find evidence of a strong, positive impact. More recent studies on the long-run panel dataset (over 35 years) from Guatemala provide evidence of a positive effect of nutritional supplementation on schooling in the female sample, helping to reduce the gender gap in education (Hoddinott et al. 2008; Maluccio et al. 2009).

Good health and nutritional conditions during childhood may affect school enrolment and completion later on, but this does not automatically translate into higher cognitive abilities. Fewer papers analyse the relationship between child health and cognitive skills in later life stages by means of longitudinal data, because such an exercise is highly data-demanding. Among the exceptions is the study by Glewwe et al. (2001) which uses panel data from more than 2000 households in the Philippines. The authors conclude that height at age 8 has a substantial impact on later academic skills, as measured by test scores. Evidence from the Guatemalan longitudinal data suggests that better nutrition in the first two years of life has a positive effect on performance in reading-comprehension tests and in non-verbal cognitive ability tests for both women and men (Hoddinott et al. 2008; Maluccio et al. 2009). Using the same data, Behrman et al. (2008) shed further light on the mechanisms by which child health is supposed to affect different types of cognitive abilities. In particular, controlling for both school and post-school experiences, not being stunted at the age of 6 has an impact on reading-comprehension cognition skills that is 'equivalent to the impact of four grades of schooling' (Behrman et al. 2008, pp. vi). A direct conclusion from this research is that schooling is only one input into the production of cognitive skills: excluding pre- and post-schooling experiences from the analysis tends to overestimate the effect of schooling, especially on non-verbal cognitive skills (here measured by the answers to a Raven's test).

Increasingly, the relationship between early childhood health and later schooling and cognition outcomes is being analysed by drawing on the Young Lives dataset. For instance, Sanchez (2009) and Outes-Leon et al (2011), by using different methodologies, examined the link between early stunting on cognitive outcomes of Peruvian pre-school children and showed significant and positive associations between early childhood nutrition and children's vocabulary development. Also, Crookston et al. (2013) scrutinised the relationship between age-adjusted height-for-age scores and cognitive outcomes across the four Young Lives countries and found that early nutrition is positively associated to Maths, reading and vocabulary development at age 8, and inversely related to overage-for-grade.[2]

The literature cited above concentrates on the *direct* effect of child health on education. However, in order to increase understanding of the nature of this relationship, it is also important to consider the relevant literature which focuses on dependent variables that could then affect educational indicators. Child health could have an *indirect* effect on learning abilities, for example, by increasing educational aspirations. In a recent paper, Dercon and Sanchez (2013) examine the specific effect of height-for-age at 7–8 years on educational aspirations for children aged 11 or 12. They find a positive and large effect: 'An increase of one standard deviation in height-for-age tends to increase school aspirations [...] by 16.4% ... of the standard deviation of school aspirations' (Dercon and Sanchez 2013, p. 429). More generally, ailments or under-nutrition can affect psychosocial competencies, such as agency or self-esteem (Jukes 2005; Cunha and Heckman 2008; Dercon and Sanchez 2013),

2 This last contribution is linked to a much wider strand of research which examines the associations between children's post-infancy growth trajectories in terms of height-for-age scores and children's cognitive development by using the Young Lives data (Crookston et al. 2010a, 2010b, 2013; Fink and Rockers 2014).

influencing, in turn, the way in which children interact with their environment and the way in which they learn at school. Accordingly, if children do not receive appropriate stimulation by caregivers in their early years, or at school later, it is likely that impaired cognitive development in the early years will be amplified over time (Jukes 2005).

Moreover, health and nutrition may affect long-run cognitive functioning by affecting short- and middle-run health outcomes. Early disease or under-nutrition can have direct effects on the brain, because infectious agents release neurotoxins or affect the immune response that affects the brain, or because the supply of nutrients is reduced. Both occurrences can damage, either permanently or temporarily, the structure of the brain, with related medium- or long-term consequences for cognitive functioning (Jukes 2005). Accordingly, a number of scholars have provided evidence of the inter-temporal relationship between health and nutritional indicators. For instance, using panel data from rural Zimbabwe, Alderman et al. (2006) find that better pre-school nutritional status is associated with significantly greater height in adolescence; Victora et al. (2008), while conducting new and comparable estimates, based on previously exploited longitudinal studies on the cohorts in Brazil, Guatemala, India, the Philippines, and South Africa, have obtained similar results.

3. Conceptual framework and econometric strategy

This section provides a conceptual framework for modelling the relationship between child health and educational outcomes and presents the econometric strategy used to estimate this association.

In line with previous literature (Glewwe 2005, Glewwe and Miguel 2008), we model cognitive outcomes in a 'production function' set-up, where cognitive skills are a function of children’s health, parental investments, children’s ability, and other educational inputs such as school quality. The contribution of the present paper to this literature consists of the way in which one of the inputs of the production function – health – is measured in early childhood. In particular, while the above-discussed empirical literature usually concentrates on height as a single metric of health, we endorse a multidimensional approach to its measurement (Strauss and Thomas 1998, 2008). This choice is motivated by a number of reasons.

First, like poverty, health is a complex and multifaceted phenomenon, only imperfectly proxied by the single metric of height-for-age. As noted by Glewwe and Miguel, about 15 per cent of 'healthy years of life' among children aged 0–4 in less developed countries is lost due to mortality and morbidity, and half of the burden of disease is due to communicable diseases such as, in descending order of importance, respiratory infections, diarrhoea, malaria and measles. In turn, most of the infectious diseases affecting children in developing countries are unlikely to affect height-for-age (Glewwe and Miguel 2008).

Additionally, malnutrition is itself a complex and many-faceted phenomenon which affects children’s life chances in a number of different ways: in this respect, the 2013 Lancet series on child and maternal under-nutrition observed that – beyond stunting (low height-for-age) – wasting (low weight-for-height) and deficits of vitamin A and zinc play a major role in the global burden of morbidity in children younger than 5 years, by together causing 45 per cent of child deaths, resulting in 3.1 million deaths annually (Black et al. 2013).

Also, as the relationship between height-for-age and other health outcomes is highly heterogeneous on the basis of sex, age and other individual characteristics, adopting multiple indicators to capture the complexity of health is likely to be highly informative (Strauss and Thomas 1998).

This variation is, in turn, reflected in the relationship between early health and subsequent education. Since malnutrition and disease can affect cognitive development through different pathways (Jukes 2005), and since different types of malnutrition may operate through distinct channels (for example, a child's height and weight may play different roles in improving his or her long-run learning abilities), we need to take account of this complexity when analysing the middle-term relationship between early childhood health and later educational outcomes.

We argue that these considerations have major implications for the measurement of early childhood health and its long-term consequences, and we underscore the need for the enlargement of the informational basis from height-for-age to other indicators in order to capture the complexity of the phenomenon and of these relationships. As anticipated, the latter are modelled by using a production-function set-up.

Following Glewwe (2005), we consider a three-period model, where Period 1 refers to early childhood (from conception to 24 months), Period 2 to the pre-school period (from 24 months to 5–6 years), and Period 3 to the years in which the child should be enrolled in primary school (6–11 years old). A convenient starting point to analyse the relationship between cognitive test scores (denoted by T_t in periods t=2,3) is the following:

$$T_{t=}T_P\left(\{H_\tau\}_{\tau=1}^{t},\{E_\tau\}_{\tau=1}^{t},\theta,SC,YS_t\right) \qquad (1)$$

where the subscript *p* stands for production function; H_τ represents the child's health in the *t* time periods, E_τ indicates the educational inputs provided by the parents (e.g. time spent with the child, school supplies), θ represents the child's innate ability, *SC* is school and teachers' characteristics, and *YS* the years of schooling at time *t.* For simplicity, it is assumed that school-quality variables *SC* do not vary over time. While this latter assumption can be relaxed in more refined versions of the model, it does not substantially change the substance of the production-function model.

By holding constant parental inputs, child's innate ability, school quality and years of education, (1) highlights the role of health in all the periods in determining cognitive abilities. This relation is structural, as all the variables included directly affect cognitive skills, although indirect effects are also possible (Glewwe 2005).

With regard to the econometric strategy, we estimate equation (1) using the following specification for child *i* born in cluster *j*:[3]

$$T_{ij,1}^{k}=\beta' H_{ij,1}^{m}+\Gamma' X_{ij,t}+\alpha_j+\mu_{ij,t} \qquad (2)$$

where $T_{ij,t}^{k}$ is the cognitive outcome *k* observed in period *t* for child *i*, with t=2, 3; $H_{ij,1}^{m}$ s the vector of the variables *m* related to child's health in time period 1, and β' is the associated vector of parameters; $X_{ij,t}$ is the vector of household and child characteristics, and Γ' is the associated vector of parameters; α_j represents community *j* pre-determined characteristics; and, finally, $\mu_{ij,t}$ is the error term.

3 In the ECD literature, similar specifications are usually interpreted as demand functions for skill, in which all the inputs except the variable of interest (in this case, the child-health measure) are replaced by their determinants.

In line with other works (Alderman et al. 2006; Sanchez 2009; Dercon and Sanchez 2013), we estimate equation (2) through Ordinary Least Squares (OLS). As the OLS estimator risks generating an omitted-variable bias due to the presence of many unobserved, time-invariant child-, household-, and school-level characteristics that influence children's cognitive attainments, this estimation strategy does not allow the determination of the strict causal effects of early childhood health on cognitive attainment, but only associations (Behrman 1996).[4]

In order to alleviate the potential bias induced by the OLS estimator, we exploit the rich Young Lives dataset (see Section 4.3) and, in contrast with many existing studies which used small datasets with a limited number of variables, we include a substantial number of relevant control variables, used in some of the previous works, at the child, caregiver and household levels. Also, we use cluster fixed effects to control for the factors that are common to all the children living in the same cluster which may affect achievements (for example, availability and quality of infrastructures, norms and culture). Leaving out contextual factors, the present estimation strategy only exploits the variance between children and households.

We estimate several different models for every dependent variable, country and round of survey. The baseline model includes only the height-for-age indicator as explanatory variable related to health; we then add the other two variables to verify whether they are significantly correlated with children's achievements and whether they contribute to a better explanation of the model. The results obtained with this 'suite of indicators' are then compared with those obtained by including only a composite health-deprivation index. Details about these variables are provided in Section 4. As Young Lives data are highly clustered, we employ clustered standard errors in all the models.

Finally, given the data available, for Round 3 outcomes only we extend our model in order to include four variables related to the child's concurrent nutrition and schooling status, as well as his or her cognitive test scores in Round 2.[5] In this way we test the robustness of our results and explore possible pathways by which the relationship between early childhood health and learning skills is likely to operate.

4. Data

Data come from Young Lives, an innovative and multidisciplinary study which investigates the causes and consequences of childhood poverty. Begun in 2002, the study is tracking two cohorts of 12,000 children over a 15-year time span in Peru, Ethiopia, Vietnam and India (Andhra Pradesh). These countries were chosen to represent the richness and diversity of national experiences and development paths. This paper focuses only on the younger-cohort children, which comprises a total sample of 8,000 children born between 2001 and 2002 across the four countries. Specifically, the empirical analysis uses the three rounds of data collection available so far (2002, 2006 and 2009), when children were approximately 1, 5 and 8 years old. This way, we analyse three distinct stages of child development: early childhood, pre-school and mid-primary school (Glewwe 2005).

4 In this paper we do not discuss the possible measurement error. For a specific analysis of this problem connected with the use of cognitive test scores, see Cunha and Heckman (2008) and Jerrim and Vignoles (2011).

5 This model is akin to a 'value-added' model of cognitive achievements (Todd and Wolpin 2003).

The Young Lives study adopted a 'pro-poor' and multi-stage sampling procedure[6] in order to select the sample: first, 20 'sentinel sites' from each country were non-randomly selected with the purpose of excluding rich areas and oversampling poorer ones. Then, children in the appropriate age group in the sentinel sites were randomly sampled. Given this structure, the sample (with the exception of Peru) is not nationally representative (Barnett et al. 2012). Nonetheless, comparisons with DHS and other surveys suggest that the Young Lives data are representative of the type of variation that can be found in nationally representative surveys (Dercon and Singh 2013). Attrition in the Young Lives sample is extraordinarily low, due to a particular effort in tracking children when they move (Outes-Leon and Dercon 2008).

4.1 Dependent variables

In addition to the indicators that are commonly employed in similar analyses for developing countries (enrolment, grade attainment, etc.), the Young Lives study offers a wealth of data on children's cognitive abilities in various domains at different developmental stages. These tests were designed by experts in various disciplines such as child psychology, education, economics and sociology, and were adapted to relate closely to the formal school curricula in the four countries.[7] For this reason, test scores are not directly comparable across countries, but only within countries and controlling for the language in which the test was administered. However, given that tests were designed to capture the same underlying construct in each country, comparisons of associations between the underlying abilities measured by the tests and other variables, as in the present analysis, can still be established (Cueto et al. 2009).

In order to assess children's verbal and quantitative ability at pre-school age (Round 2), we employ raw scores in the Peabody Picture Vocabulary Test (PPVT) and the Cognitive Developmental Assessment (CDA) test. The former is a widely used test of age-specific vocabulary acquisition. For each of the 204 questions, the child has to indicate which picture matches a word presented orally by the interviewer. In turn, the CDA measures children's grasp of quantity-related concepts by asking the child to choose from a series of images the ones that best represent the concepts expressed by the examiner (*few, most*, etc.). The test consists of 10 questions.

Children's cognitive abilities in Round 3 are measured through PPVT, which includes 204 questions as in the previous round, and a Mathematics Achievement Test. The latter is an indicator of children's basic numeracy skills. It consists of 29 simple arithmetical problems (i.e. 2 + 3 = __ , or 7 x 8 =__). Descriptive statistics of the four indicators are presented in Table 1.

6 For each country, the sample is described in detail in the Young Lives sampling reports (Escobal and Flores 2008; Kumra 2008; Nguyen 2008; Outes-Leon and Sanchez 2008).

7 For an extensive discussion of the validity and reliability of these tests, see Cueto et al. (2009).

Table 1. *Descriptive statistics of the outcome indicators, by country and by round*

		Round 2		Round 3	
		PPVT	CDA	PPVT	Maths
Ethiopia	Mean	21.26	8.22	79.09	6.58
	SD	12.07	3.00	44.17	5.38
India	Mean	27.46	9.40	49.22	12.01
	SD	21.16	2.60	26.70	6.42
Peru	Mean	29.10	8.38	58.98	14.20
	SD	17.86	2.15	17.63	5.82
Vietnam	Mean	36.98	9.79	76.91	18.42
	SD	18.19	2.51	23.71	5.84

4.2 Indicators of early childhood multidimensional health

As explained in Section 3, we adopt a multidimensional approach to capture children's health status in Round 1 and analyse its relationship with cognitive outcomes at pre-school and primary-school age. In particular, we focus on two core, interrelated, dimensions of health: nutrition and morbidity. This is because nutrition and morbidity are intrinsically and instrumentally relevant dimensions of children's well-being in the early years, and because, as discussed earlier, deprivation in these dimensions leads to enormous loss of human potential in low- and middle-income countries.

We selected the indicators of early childhood health on the basis of the criteria outlined in the literature on the measurement of children's well-being and children's deprivations (Dercon 2012). Specifically, our indicators display the following features: (i) they focus on children; (ii) they measure distinct facets of deprivations experienced by the children themselves; (iii) they are age-specific; (iv) they are relevant to the different country contexts. By following these principles, we identified three indicators: two indicators of nutrition and one of morbidity.

The first indicator is the height-for-age z-score (HAZ), which measures – in terms of standard deviations – the difference between the child's height and the median height of the NCHS/WHO age- and sex-specific reference population (WHO 2006). The second indicator is weight-for-height z-score (WHZ), which indicates the number of standard deviations of the actual weight of the child from the median weight of the reference population (WHO 2006). Both anthropometric indicators were selected because they capture different phenomena: the first measures chronic malnutrition, while the second measures acute malnutrition (Frongillo 1999; Burchi 2012).

Morbidity is measured by a binary variable indicating whether the child has experienced a life-threatening illness or injury since birth, as reported by the main caregiver. Given that self-reported indicators of health are often criticised because they may capture perception of illness rather than the occurrence of an actual morbidity (Murray and Chen 1992; Strauss and Thomas 1998), a more extensive discussion of this indicator is required. Specifically, in the survey the child's caregiver is asked if the child has experienced a list of symptoms which led the caregiver to think that the child might have died. The list encompasses the symptoms associated with the major drivers of child morbidity and mortality in the sample countries (for example, high fever/malaria, pneumonia/severe cough, epilepsy/convulsions, diarrhoea). This increases the objectivity of the assessment, as 'symptoms have the characteristic of observability, even if they are not actually observed' (Idler 1992, p. 42, quoted in Ruggeri Laderchi 2008, p. 214). In conclusion, this indicator provides valuable information on overall children's morbidity which complements the two indicators of nutritional status.

Far from being perfect, these indicators represent a reasonable compromise between (on the one hand) the need for theoretical soundness and adherence to the concept being measured and (on the other hand) data availability and comparability. Although the Young Lives dataset has been designed to ensure comparability across countries, difficulties have been encountered in the choice of the indicators (particularly the ones relating to morbidity), and also in the light of data-comparability issues.

In the models, we used these indicators separately (as a 'suite of indicators'), but we also aggregated them into one single composite index, labelled 'Multidimensional Health Poverty Index' (MHPI). This is possible because our health indicators have similar characteristics, being all outcome indicators (Burchi and De Muro, forthcoming). A large literature on aggregated child-poverty indices exists. For example, UNICEF classified children as poor if they experienced at least one deprivation, and as living in absolute poverty if they experienced two or more deprivations (Gordon et al. 2003). However, this method addresses only the issue of poverty incidence, while it is insensitive to the breadth and distribution of deprivations. In order to overcome such an important shortfall, we adopted the Alkire-Foster method (Alkire and Foster 2011), which extends the Foster-Greer-Thorbecke class of poverty measures to the multidimensional space. Depending on the type of data used and on the degree of inequality aversion adopted, this method can accommodate the issues of both depth and distribution of experienced poverty.

In order to construct the index, we first define deprivations in each indicator. In contrast to the morbidity indicator, which assumes the value of 1 when the child has experienced any life-threatening disease, we had to transform HAZ and WHZ into dichotomous variables that measure deprivations in nutrition. In particular, we identified children as 'stunted' and 'wasted' respectively if their HAZ and WHZ were below -2SD, the nutritional deprivation cut-off identified by WHO (WHO 2006). As the chosen indicators measure three intrinsically important dimensions of early childhood health deprivation, we opted for an equal weighting system.

After defining the relevant deprivation thresholds for each indicator and the weights, we constructed the MHPI as the weighted sum of the deprivations experienced by the child in the nutrition and morbidity indicators. In doing so, we do not define the second identification cut-off – a typical feature of the Alkire-Foster (2011) methodology – because our purpose is not to provide a measure of the share of the 'multidimensional health-poor', but rather to define a multidimensional score of children's joint deprivations in the health dimension. Accordingly, the indicator has four possible values, ranging from 0, when the child is not deprived in any of the three indicators, to 1, when the child is deprived in all three indicators. If the child is deprived in only one indicator, he or she will receive a weighted score of 0.33, and 0.67 if he or she is deprived in two out of three indicators. This implies that we adopted a 'union approach' to identification, i.e. it is sufficient to be deprived in at least one indicator to be considered health-poor.[8] This approach is theoretically justifiable, because each attribute is considered to be an essential attribute of health (Tsui 2002; Bourguignon and Chakravarty 2003), and it avoids the typical substitutability across attributes that equal weighting systems entail.

In conclusion, we use four indicators of early childhood health in our analysis. The first two should be interpreted as indicators of well-being in the health dimension; therefore we expect

8 A similar index has been used, among others, by Burchi and Passacantilli (2013) to measure household well-being in Peru.

them to be positively associated with learning abilities. By contrast, given that morbidity and the MHPI are indicators of deprivations in health, we hypothesise a negative relationship with learning achievements. Means and standard deviations of these indicators are summarised in Table 2.

Table 2. *Descriptive statistics of indicators of children's health in Round 1*

		Height-for-age z-scores	Weight-for-height z-scores	Life-threatening illness	MHPI
Ethiopia	Mean	-1.48	-0.73	0.30	0.29
	SD	-1.83	1.39	0.46	0.27
India	Mean	-1.3	-1.21	0.22	0.24
	SD	1.47	1.06	0.42	0.26
Peru	Mean	-1.28	0.61	0.32	0.2
	SD	1.27	1.16	0.47	0.23
Vietnam	Mean	-1.12	-0.62	0.13	0.13
	SD	1.25	0.95	0.34	0.21

4.3 Control variables

In all the models we included the following controls: (a) child's sex; age (in months); ethnicity (or caste in India); child's mother tongue; disability status; whether or not the child is first-born; whether or not born in a health facility; vaccinations; pre-school attendance; (b) caregiver's sex, age, level of education; (c) household's size; sex, age and education of the head of the household; mother's and father's presence in the household. Three composite indicators which measure households' access to services, housing quality and ownership of various consumer durables were used as proxies for household economic conditions.[9] Finally, in the case of PPVT test scores, the model includes a variable which controls for the language in which the test was taken. All these control variables refer to the same round in which the outcome indicator is measured.

For the robustness check, we use four additional control variables. The first is the child's contemporaneous nutritional status (Round 3), as measured by Body Mass Index for age (BMI-for-age), which is the ratio of weight to squared height. Akin to HAZ and WHZ, this status is measured in z-scores, computed by using the WHO growth reference standards for school-aged children and adolescents (de Onis et al. 2007).

The second set of variables refers to whether the child is enrolled in school, and, if so, at what current grade. The variable is again measured in Round 3, because, with the exception of India, where the official age of starting school is 5, in Round 2 all the children in the other countries are not yet enrolled in primary education. Also, the analysis of the data in Table 3 shows a great deal of heterogeneity in terms of enrolment and grade completion across countries.[10]

9 The housing-quality index averages the number of rooms per person and reflects the floor type, and roof and wall type, while the access-to-services index measures a household's access to safe drinking water, electricity, toilet facilities and cooking fuel, all of which are dummy variables. Finally, the consumer-durable index aggregates a series of variables related to the household's assets, such as radio, fridge, bicycle, TV, motorbike/scooter, motorcar/truck, electric fan, mobile phone, landline phone, modern bed, table or chair and sofa.

10 While 99 per cent of children in Andhra Pradesh, Vietnam and Peru are enrolled at the age of 8, in Ethiopia almost a quarter are still out of school at Round 3. Moreover, there is great variation in terms of grades attained by the children enrolled in school, ranging from 40 per cent of those who did not complete any grade to 2 per cent of those who completed Grade 3.

Finally, we include the scores of children's cognitive attainments referred to in Round 2. By including previous PPVT and CDA scores, we can explore the role of previous cognition in mediating the relationship between child health and learning skills. Descriptive statistics for all control variables are reported in Table 3.

Table 3. *Descriptive statistics of control variables, by country and round*

	Ethiopia				India				Peru				Vietnam			
Variables	Round 2		Round 3		Round 2		Round 3		Round 2		Round 3		Round 2		Round 3	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Male	0.53	0.50	0.53	0.50	0.54	0.50	0.54	0.50	0.50	0.50	0.50	0.50	0.51	0.50	0.51	0.50
Age (months)	61.83	3.85	92.16	5.65	64.27	3.88	94.01	4.60	63.98	4.69	95.43	3.61	63.05	3.75	93.30	5.07
First-born child	0.23	0.42	0.23	0.42	0.39	0.49	0.39	0.49	0.36	0.48	0.37	0.48	0.46	0.50	0.46	0.50
Long-term illness or disability	0.04	0.20	0.09	0.29	0.06	0.24	0.03	0.18	0.10	0.30	0.21	0.41	0.09	0.29	0.14	0.34
Born in a health facility	0.17	0.38	0.18	0.38	0.49	0.50	0.49	0.50	0.69	0.46	0.68	0.46	0.78	0.41	0.79	0.41
Attended pre-school	0.25	0.43	0.25	0.43	0.87	0.33	0.87	0.33	0.84	0.37	0.84	0.37	0.91	0.29	0.91	0.29
Mother in the household	0.92	0.27	0.89	0.31	0.98	0.14	0.97	0.18	0.96	0.20	0.94	0.24	0.96	0.19	0.94	0.24
Father in the household	0.79	0.41	0.76	0.43	0.95	0.21	0.92	0.27	0.81	0.39	0.77	0.42	0.93	0.25	0.89	0.31
Child not vaccinated as of Round 2	1.00	0.07	1.00	0.07	0.99	0.08	0.99	0.08	0.02	0.13	0.02	0.13	0.98	0.16	0.98	0.15
Caregiver's education: none	0.58	0.49	0.54	0.50	0.60	0.49	0.58	0.49	0.02	0.15	0.07	0.25	0.11	0.31	0.11	0.31
Caregiver's education: primary	0.32	0.47	0.29	0.45	0.08	0.27	0.08	0.27	0.32	0.47	0.38	0.49	0.27	0.44	0.27	0.44
Caregiver's education: secondary	0.04	0.20	0.04	0.18	0.29	0.45	0.28	0.45	0.39	0.49	0.36	0.48	0.44	0.50	0.45	0.50
Caregiver's age	32.95	8.55	36.30	9.03	28.12	5.77	31.52	6.51	34.87	8.23	35.03	8.26	32.78	8.52	35.71	8.40
Caregiver is male	0.02	0.12	0.04	0.20	0.00	0.07	0.01	0.09	0.02	0.33	0.01	0.12	0.04	0.19	0.04	0.19
Housing-quality index	0.29	0.21	0.32	0.20	0.54	0.28	0.58	0.26	0.40	0.25	0.43	0.25	0.62	0.29	0.66	0.27
Services index	0.35	0.26	0.40	0.24	0.59	0.26	0.64	0.23	0.67	0.32	0.77	0.26	0.44	0.22	0.54	0.28
Consumer-durables index	0.21	0.18	0.27	0.20	0.29	0.19	0.31	0.19	0.35	0.24	0.42	0.23	0.44	0.21	0.55	0.19
Household size	6.05	2.06	6.20	1.98	5.51	2.22	5.51	2.30	5.50	2.07	5.43	1.90	4.67	1.51	4.66	1.52
Household head's education: none	0.40	0.49	0.37	0.48	0.49	0.50	0.40	0.49	0.04	0.19	0.04	0.19	0.08	0.28	0.08	0.27
Household head's education: primary	0.46	0.50	0.43	0.49	0.11	0.32	0.09	0.29	0.14	0.35	0.14	0.35	0.27	0.44	0.27	0.44
Household head's education: secondary	0.04	0.21	0.05	0.21	0.31	0.46	0.28	0.45	0.26	0.44	0.26	0.44	0.42	0.49	0.42	0.49
Household head is male	0.81	0.39	0.81	0.39	0.95	0.22	0.94	0.23	0.89	0.31	0.87	0.34	0.88	0.33	0.87	0.33
BMI-for-age z-score	-0.63	1.08	-1.28	0.95	-1.18	0.94	-1.38	1.06	0.66	0.96	0.51	1.05	-0.29	1.11	-0.67	1.28
Currently in school	0.28	0.45	0.77	0.42	0.96	0.21	0.99	0.10	0.84	0.37	0.99	0.08	0.9	0.3	0.99	0.12
No grade completed	n/a	n/a	0.38	0.49	0.85	0.36	0.13	0.34	n/a	n/a	0	0	0.99	0.06	0.02	0.14
Completed Grade 1	n/a	n/a	0.43	0.49	0.15	0.36	0.26	0.44	n/a	n/a	0.05	0.2	0.003	0.05	0.25	0.43
Completed Grade 2	n/a	n/a	0.18	0.38	0	0	0.42	0.49	n/a	n/a	0.6	0.49	0	0	0.72	0.45
Completed Grade 3	n/a	n/a	0.02	0.13	0	0	0.18	0.38	n/a	n/a	0.34	0.47	0	0	0.01	0.11
Completed Grade 4	n/a	n/a	0	0	0	0	0.01	0.11	n/a	n/a	0	0	0	0	0	0

continued overleaf

Accordingly, we created a variable for Ethiopia only which assumes the baseline value of 0 when the child is out of school or has not completed any grade, and the values of 1, 2 and 3 for children who have completed grade 1 and 2 or 3 respectively. With regard to the other countries, the specific grades attained by the children that are included in the models vary, depending on the way in which grades are distributed across children in the sample.

Table 3. *Descriptive statistics of control variables, by country and round* continued

	Ethiopia				India				Peru				Vietnam			
Variables	Round 2		Round 3		Round 2		Round 3		Round 2		Round 3		Round 2		Round 3	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Child's ethnic group: Amhara	0.28	0.45	0.28	0.45												
Child's ethnic group: Oromo	0.21	0.41	0.21	0.41												
Child's ethnic group: Tigrayan	0.22	0.42	0.22	0.42												
Child's ethnic group: Gurage	0.08	0.27	0.08	0.27												
Child's ethnic group: Wolayta	0.06	0.24	0.06	0.24												
Child's ethnic group: Other	0.05	0.23	0.05	0.23									0.09	0.28	0.09	0.28
Child's ethnic group: Kinh													0.86	0.35	0.86	0.35
Child's ethnic group: H'mong													0.05	0.22	0.05	0.22
Child from scheduled caste					0.18	0.39	0.18	0.39								
Child from scheduled tribe					0.15	0.35	0.15	0.35								
Child from backward caste					0.47	0.50	0.47	0.50								
Child from non-Hindu background					0.06	0.24	0.06	0.24								
Child ethnic group: White									0.06	0.23	0.06	0.23				
Child ethnic group: Mestizo									0.92	0.28	0.92	0.28				
Child ethnic group: Native of the Amazon									0.02	0.15	0.02	0.15				
Child's first language is Amhara	0.43	0.50	0.43	0.50												
Child's first language is Oromifa	0.16	0.37	0.16	0.37												
Child's first language is Tigrigna	0.20	0.40	0.20	0.40												
Child's first language is Telugu					0.81	0.39	0.81	0.39								
Child's first language is Spanish									0.85	0.35	0.85	0.35				
Child's first language is Vietnamese													0.88	0.34	0.88	0.34
PPVT test taken in Amarigna	0.47	0.50	0.46	0.50												
PPVT test taken in Guraghigna	0.05	0.21	n/a	n/a												
PPVT test taken in Hadiyigna	0.05	0.22	0.05	0.22												
PPVT test taken in Oromifa	0.16	0.36	0.19	0.39												
PPVT test taken in Sidamigna	0.03	0.17	0.05	0.21												
PPVT test taken in Tigrigna	0.20	0.40	0.20	0.40												
PPVT test taken in Welayitegna	0.04	0.20	0.05	0.21												
PPVT test taken in Telugu					0.95	0.22	0.84	0.37								
PPVT test taken in Spanish									0.89	0.32	0.94	0.25				
PPVT test taken in Vietnamese													0.96	0.19	0.99	0.11

5. Results

First we tested whether height-for-age, the indicator of children's chronic nutritional status widely adopted in the ECD literature, is significantly associated with later cognitive abilities in the Young Lives sample. Reflecting a large body of previous literature (Glewwe and Miguel 2008; Crookston et al. 2013), the estimates show that the effect of the HAZ indicator is, in most cases, large and statistically significant in both rounds (see Columns 1, 4, 7 and 10 of Tables A–D in the Appendix).

With the exception of PPVT scores in Round 3 in Vietnam, the coefficient is statistically associated with all the outcomes and periods considered in all four countries. The magnitude of the coefficient varies across countries, outcomes and child-development stages, and, given the heterogeneity of the outcome indicators and samples, it is not possible to directly compare the associations between HAZ and cognitive outcomes. For instance, an increase in the HAZ of one standard deviation of the international reference population – keeping everything else constant – is associated with an increment of between 3 and 8 per cent of a standard deviation in PPVT in both rounds, and with an increase of between 5 and 10 per cent and between 4 and 8 per cent of a standard deviation in CDA and Maths scores respectively. Such heterogeneity, however, was expected, given that the relation between nutrition and cognitive achievement is likely to be moderated by the broader socio-economic context of the country (Wachs 1996).

It is nonetheless possible to provide some benchmarking on the magnitude of the increments in test scores following an increase of a standard deviation in HAZ, by comparing them with mean cognitive outcomes by gender or by rural/urban location. In India, for instance, a 40 per cent increase of a standard deviation in HAZ would bridge the gap between rural and urban children in CDA scores, while in Vietnam it would be sufficient to equalise the performances of boys and girls in terms of PPVT at Round 2. Similarly, an increase of a standard deviation in HAZ would close half of the gender gap in Maths scores in Peru in Round 3.

The second empirical question that we tested relates to whether the enlargement of the informational basis from HAZ to other two indicators of nutrition and disease contributes to a better comprehension of the health-cognition nexus. Table 4 presents the results from the model in which the 'suite of indicators approach' is adopted for our three key health indicators (corresponding to columns 2, 5, 8 and 11 in Appendices A, B, C and D).

We find that WHZ is significantly associated with all the cognitive outcomes in Andhra Pradesh, which is perhaps unsurprising, given the extent of malnutrition in India (Deaton and Drèze 2009), and with Maths scores in Peru. When significant, the magnitudes of the WHZ coefficients are similar to, or slightly smaller than, the ones of the HAZ indicator. While HAZ remains the most influential nutritional factor, the inclusion of the WHZ indicator proves to be useful in capturing the complexity of early nutrition and its potential effects on cognitive development. In the case of Maths scores in India, the interaction between whether the child is wasted and stunted is also statistically significant, suggesting that in a context like Andhra Pradesh both forms of malnutrition, rooted in distinct causes (Frongillo 1999; Burchi 2012), work in concert to hinder children's cognitive development.[11]

11 Results are available upon request from the authors.

By contrast, the indicator related to life-threatening disease in early childhood is not significantly associated with any outcomes in any countries, with the exception of Vietnam in Maths. The lack of association may be due to measurement issues, as well as to its dichotomous nature, which may hamper the ability of the indicator to carry as much variation as the two nutrition ones.

We also assessed the suite of indicators specification by comparing its predictive power (as measured by the adjusted R-square) with the baseline model, in which HAZ is included as unique variable of interest. In terms of proportion of variation explained, the inclusion of additional indicators related to child early health and nutrition, when significant, is able to slightly increase the predictive power of the model consistently across all countries and outcomes.

The last row in Table 4 for each country presents the results of a distinct model specification in which the composite index MHPI is adopted as single indicator of early childhood health. The same results can be found in Columns 3, 6, 9 and 12 in the tables in Appendices A, B, C and D. In order to increase the interpretability, MHPI scores have also been standardised with mean 0 and standard deviation equal to 1. When significant, MHPI is strongly and negatively associated with cognitive outcomes. As in the case of WHZ, MHPI is significant in all the outcomes and rounds considered in Andhra Pradesh and Peru, as well as in Vietnam (with the only exception of PPVT scores at round 3), while in Ethiopia it is significant only in the case of Maths scores.

Given the loss of information following the dichotomisation of the indicators in order to construct the index, as expected, the 'composite index' specification does not increase the model fit with respect to the 'suite of indicators' approach. Beyond model fit, however, the full 'suite of indicators' specification appears to be more informative, because it shows which type of initial deprivation matters for cognitive achievement, in which country, and in which stage of children's development, although great heterogeneity exists in relation to all these factors.

Table 4. *Synthetic table of results (only significant coefficients displayed)*

		Age 5 (Round 2)		Age 8 (Round 3)	
		PPVT	CDA	PPVT	Maths
Ethiopia	Height-for-age	0.038**	0.045***	0.03**	0.037***
	Weight-for-height				
	Illness				
	MHPI				-0.035**
India	Height-for-age	0.079***	0.10***	0.043***	0.08***
	Weight-for-height	0.054***	0.062***	0.053***	0.065***
	Illness				
	MHPI	-0.068***	-0.102***	-0.074***	-0.108***
Peru	Height-for-age	0.05**	0.038***	0.037***	0.057***
	Weight-for-height				0.044***
	Illness				
	MHPI	- 0.04**	-0.03**	-0.03*	-0.06***
Vietnam	Height-for-age	0.072***	0.045**		0.047***
	Weight-for-height				
	Illness				0.043**
	MHPI	-0.062**	-0.043**		-0.039*

Levels of statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: the results for the three health indicators are derived from the 'suite of indicators' specification (Columns 2, 5, 8 and 11 in Appendices A, B, C and D), while the results from MHPI stem from the model in which the MHPI is used as only relevant variable of health deprivation (Columns 3, 6, 9 and 12 in the same appendices).

5.1 Robustness checks

In this sub-section we conduct a robustness check: by adding other relevant (and potentially endogenous) determinants of cognitive skills – contemporaneous nutrition, schooling attainment and past cognitive outcomes – we analyse whether and to what extent the magnitude and statistical significance (when applicable) of the coefficients of the initial health variables change.[12] This also allows us to provide some insights on possible channels through which child health may influence our outcome variables. Due to data constraints, these estimates refer to Round 3 dependent variables only.

In Tables 5–8 we provide the results. In particular, in columns (1) and (5) we report the baseline estimates, which are those with all the three health variables and the basic controls, for PPVT and Maths, respectively. In columns (2) and (6), instead, we add the BMI z-scores in Round 3 – a proxy for the concurrent nutritional status of the child – as this could be an important predictor of cognitive skills, and early childhood health could improve mid-run learning abilities by further improving health conditions. Our estimates show that the BMI is not an important input in the cognition-production function, as it has a statistically significant (and negative) effect only on PPVT in Ethiopia. Even in this case, the coefficient of the only significant health variable, HAZ, does not change compared with the baseline model: we therefore conclude that BMI is not an important channel. We ran the same regressions with BMI for Round 2 and obtained approximately the same results.[13]

The schooling-related variables added in columns (3) and (7) are always highly significant and in many cases produce a substantial increase in the adjusted R-square. This is an expected finding, as schooling is likely to be one of the most important predictors of cognitive abilities all around the world. The inclusion of these covariates produces a significant change in the coefficients of the health variables in most of the models, although the size of this change varies, depending on the country and the dependent variable. The early-health coefficients, however, remain statistically significant, with the exception of Ethiopia for Maths skills, where HAZ moves from highly significant (at the 0.01 level) to non-significant. Peru represents a clear outlier in this overall picture, as the coefficients and standard errors of all the health variables are highly robust to the inclusion of schooling for both PPVT and Maths. Finally, in Vietnam there are no significant changes for PPVT, because none of the health variables is significant in the baseline model.

In conclusion, this analysis seems to provide evidence of the importance of schooling as intermediate outcome between early childhood health and cognitive abilities. However, in most of the cases health-related variables remain significant at least at the 10 per cent level, suggesting that there might be channels other than enrolment and grade attained through which this relationship operates. Exposure to a better-quality school environment and,

12 Clearly, child health could influence cognitive skills through other pathways, for example the increase in educational aspirations. As briefly summarised in Section 2, the recent work of Dercon and Sanchez (2013) provided empirical evidence of the health–aspirations relationship in the same countries here examined. An increase in school aspirations is then likely to influence school achievements and, finally, cognitive skills. However, we could not test this channel, since Young Lives collects data on school aspirations only for the older cohort of children, while for this study we use data from the younger cohort. In the dataset our information is limited to whether the parents want the child to go to university, but this suffers from two problems: (1) the question is posed to the parents and not to the child; (2) it refers to levels of education beyond primary or secondary. We run regressions with this covariate: they show that this measure of educational aspirations is often a significant predictor of learning abilities, but its addition does not modify the significance and magnitude of the coefficients of early-childhood health variables. The results are not presented here, for due to limitations on space.

13 Results are omitted for space considerations. Tables can be provided by the authors on request.

generally speaking, exposure to a better and more stimulating (formal and informal) learning environment are likely to be some of these channels (Wachs 1996; Cunha and Heckman 2008). Finally, as results are very heterogeneous across the models, any finding should be analysed with reference to the local educational context.

Columns (4) and (8) show the results of the model in which lagged cognitive scores were included in order to control for heterogeneity in pre-school ability that may explain variation in school learning outcomes across children. The inclusion of the lagged PPVT and CDA scores increases the overall fit of the model, but in general does not modify the magnitude and statistical significance of the coefficients for our key measurement variables. This suggests that the overall association between early childhood health conditions and later cognitive attainments is only marginally mediated by a shorter-run improvement of cognitive skills[14] (Glewwe and Miguel 2008).

To summarise, the fact that in most of the extended specifications the coefficients that were significant in the baseline model do not lose statistical significance after the inclusion of these potential channels indicates the relevance of early health outcomes for later cognitive achievements (Cunha and Heckman 2008).

Table 5. *Results from the extended models, Ethiopia Round 3*

Variables	(1) PPVT	(2) PPVT	(3) PPVT	(4) PPVT	(5) Maths	(6) Maths	(7) Maths	(8) Maths
Height-for-age z-scores	0.030 (2.470)**	0.030 (2.461)**	0.018 (1.753)*	0.025 (2.110)**	0.037 (3.553)***	0.037 (3.540)***	0.014 (1.540)	0.036 (3.477)***
Weight-for-height z-scores	0.009 (0.587)	0.016 (1.048)	0.005 (0.344)	0.007 (0.455)	0.027 (1.688)	0.030 (1.790)*	0.019 (1.327)	0.027 (1.624)
Illness (z-scores)	-0.009 (-0.888)	-0.008 (-0.791)	-0.016 (-1.579)	-0.010 (-0.833)	0.014 (0.842)	0.014 (0.832)	-0.002 (-0.141)	0.012 (0.671)
Enrolled but not completed Grade 1			0.063 (1.038)				0.118 (2.583)**	
Enrolled and completed Grade1			0.283 (3.972)***				0.678 (10.085)***	
Enrolled and completed Grades 2 or 3			0.537 (5.742)***				0.970 (7.913)***	
BMI-for-age z-scores		-0.038 (-2.155)**				-0.016 (-0.860)		
CDA raw score R2 z-scores				0.118 (5.663)***				0.078 (2.759)**
PPVT raw score R2 z-scores				0.105 (2.918)***				0.079 (2.478)**
Constant	-3.613 (-7.579)***	-3.645 (-7.834)***	-3.077 (-7.231)***	-2.989 (-6.758)***	-2.569 (-5.102)***	-2.591 (-5.110)***	-1.723 (-4.700)***	-2.111 (-4.550)***
Observations	1,639	1,638	1,628	1,599	1,596	1,595	1,584	1,560
Number of clusters	20	20	20	20	20	20	20	20
Adj. R-squared	0.140	0.141	0.174	0.179	0.126	0.126	0.263	0.144
R3 core controls	YES	YES	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

14 We also estimated a model with both the variables related to schooling and those related to previous cognitive achievements. Since the results are not substantially different from the ones reported in Tables 5–8, we do not report them here.

Table 6. *Results from the extended models, India Round 3*

Variables	(1) PPVT	(2) PPVT	(3) PPVT	(4) PPVT	(5) Maths	(6) Maths	(7) Maths	(8) Maths
Height-for-age z-scores	0.043	0.043	0.033	0.024	0.080	0.080	0.062	0.057
	(2.898)***	(2.856)**	(1.874)*	(1.695)	(5.126)***	(5.072)***	(4.748)***	(3.431)***
Weight-for-height z-scores	0.053	0.046	0.047	0.042	0.065	0.060	0.050	0.044
	(3.943)***	(2.542)**	(3.489)***	(3.076)***	(3.476)***	(3.732)***	(3.220)***	(2.237)**
Illness (z-scores)	-0.014	-0.014	-0.013	-0.008	-0.016	-0.016	-0.020	-0.008
	(-0.670)	(-0.702)	(-0.660)	(-0.393)	(-0.756)	(-0.783)	(-1.141)	(-0.357)
Completed Grade 1			0.062				0.267	
			(0.796)				(4.973)***	
Completed Grade 2			0.240				0.733	
			(4.662)***				(15.257)***	
Completed Grade 3, 4, 5 or 6			0.407				1.066	
			(6.321)***				(19.297)***	
BMI-for-age z-scores		0.016				0.011		
		(0.627)				(0.599)		
CDA raw score R2 z-scores				0.120				0.204
				(6.718)***				(8.442)***
PPVT raw score R2 z-scores				0.138				0.129
				(4.205)***				(3.750)***
Constant	-0.887	-0.904	-0.671	-0.466	-1.662	-1.673	-1.231	-0.999
	(-1.568)	(-1.658)	(-1.163)	(-0.712)	(-2.620)**	(-2.666)**	(-2.482)**	(-1.616)
Observations	1,828	1,828	1,766	1,744	1,832	1,832	1,776	1,748
Number of clusters	20	20	20	20	20	20	20	20
R3 core controls	YES	YES	YES	YES	YES	YES	YES	YES
Adj. R-squared	0.106	0.106	0.124	0.143	0.168	0.167	0.305	0.232

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 7. *Results from the extended models, Peru Round 3*

Variables	(1) PPVT	(2) PPVT	(3) PPVT	(4) PPVT	(5) Maths	(6) Maths	(7) Maths	(8) Maths
Height-for-age z-scores	0.037	0.036	0.033	0.026	0.057	0.055	0.043	0.052
	(3.789)***	(3.583)***	(3.449)***	(3.490)***	(5.919)***	(5.832)***	(4.232)***	(5.349)***
Weight-for-height z-scores	0.008	0.005	0.005	0.005	0.044	0.037	0.034	0.039
	(0.818)	(0.605)	(0.537)	(0.591)	(3.423)***	(3.030)***	(2.678)**	(2.757)**
Illness (z-scores)	-0.004	-0.005	-0.004	-0.001	-0.010	-0.010	-0.009	-0.009
	(-0.434)	(-0.450)	(-0.390)	(-0.148)	(-0.896)	(-0.886)	(-0.785)	(-0.713)
Completed Grade 2			0.293				0.631	
			(7.146)***				(7.492)***	
Completed Grade 3 or 4			0.368				1.061	
			(7.318)***				(11.411)***	
Bmi-for-age z-scores		0.009				0.022		
		(0.836)				(1.435)		
CDA raw score R2 z-scores				0.041				0.106
				(4.576)***				(4.474)***
PPVT raw score R2 z-scores				0.198				0.170
				(10.046)***				(7.813)***
Constant	-3.223	-3.217	-2.761	-2.131	-5.919	-5.901	-2.849	-4.849
	(-10.882)***	(-10.709)***	(-6.097)***	(-6.626)***	(-11.809)***	(-11.847)***	(-5.516)***	(-9.466)***
Observations	1,762	1,760	1,752	1,720	1,800	1,798	1,790	1,756
Number of clusters	20	20	20	20	20	20	20	20
R3 core controls	YES	YES	YES	YES	YES	YES	YES	YES
Adj. R-squared	0.265	0.265	0.286	0.374	0.251	0.251	0.322	0.287

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 8. *Results from the extended models, Vietnam Round 3*

Variables	(1) PPVT	(2) PPVT	(3) PPVT	(4) PPVT	(5) Maths	(6) Maths	(7) Maths	(8) Maths
Height-for-age z-scores	-0.002	-0.006	-0.004	-0.009	0.050	0.050	0.049	0.051
	(-0.111)	(-0.302)	(-0.189)	(-0.476)	(3.413)***	(3.318)***	(4.194)***	(3.127)***
Weight-for-height z-scores	-0.000	-0.026	-0.004	-0.002	0.025	0.031	0.022	0.024
	(-0.007)	(-0.848)	(-0.201)	(-0.082)	(1.715)	(1.911)*	(1.344)	(1.352)
Illness (z-scores)	0.014	0.010	0.015	0.017	0.042	0.043	0.036	0.038
	(0.562)	(0.406)	(0.607)	(0.742)	(2.145)**	(2.068)*	(1.925)*	(1.954)*
Completed Grade 1			-0.554				-1.084	
			(-4.242)***				(-5.109)***	
Completed Grade 2			-0.292				-0.071	
			(-2.615)**				(-0.312)	
Completed Grade 3 or 4 or more			-0.182				0.074	
			(-0.770)				(0.225)	
BMI-for-age z-scores		0.039				-0.008		
		(1.415)				(-0.493)		
CDA raw score R2 z-scores				0.110				0.155
				(4.857)***				(5.153)***
PPVT raw score R2 z-scores				0.233				0.101
				(6.305)***				(4.023)***
Constant	-2.558	-2.501	-0.969	-1.651	-5.204	-5.115	0.198	-4.652
	(-4.622)***	(-4.465)***	(-1.710)	(-2.907)***	(-8.484)***	(-8.090)***	(0.421)	(-7.112)***
Observations	1,762	1,738	1,741	1,556	1,840	1,816	1,831	1,628
Number of clusters	20	20	20	20	20	20	20	20
R3 core controls	YES	YES	YES	YES	YES	YES	YES	YES
Adj. R-squared	0.116	0.117	0.119	0.180	0.195	0.191	0.337	0.230

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

6. Conclusions

By recognising the multifaceted nature of health, this paper engages in the lively debate on the effects of health in early childhood on educational outcomes in later life stages, bringing new evidence from four low- and middle-income countries. Unlike the existing ECD literature, it follows a multidimensional perspective to capture the complexity of child health and to assess its effects on medium-term cognitive abilities.

Using the rich panel data from the Young Lives surveys in Ethiopia, India, Peru and Vietnam, the paper has four main objectives: (1) to examine the relationship between children's height and different cognitive skills in the pre-school and primary-school period in these diverse social, economic and geographical contexts; (2) to assess whether additional health/nutrition indicators, rarely available or used in this literature, are significantly associated with these skills; (3) to scrutinise whether the whole contribution of children's multidimensional health can be well summarised by a composite health-deprivation index, and to investigate the dynamic associations between multidimensional health deprivations and later cognitive outcomes; (4) to investigate possible channels through which early child health affects cognitive abilities at primary-school age.

With respect to the first goal, the paper extended the existing literature by focusing on different stages of children's development, variety of countries and different outcomes. With the exception of PPVT scores in Round 3 in Vietnam, in line with the dominant literature the estimates show a positive, highly significant influence of the HAZ indicator on the dependent variables in Round 1. This is because this nutritional indicator summarises the child's nutritional history up to the time of measurement (Glewwe et al. 2001), as well as multiple dimensions of children's well-being (access to food, health status, health care and environment) (Burchi 2012). Given the heterogeneity of the samples, it is not possible to compare directly the magnitude of the HAZ coefficients across countries. However, it is still possible to provide some comparisons with other key indicators related to gaps in cognitive development, such as rural/urban or gender. In India, for instance, keeping everything else constant, a 40 per cent increase of a standard deviation in HAZ would translate into equalising the performances of rural and urban children in CDA scores, while an increase of a standard deviation in HAZ would be equivalent to closing half of the gender gap in Maths scores in Peru in Round 3.

With regard to the second research question, we provide evidence of the relevance of weight-for-height, proxy for acute malnutrition, particularly in India, where its coefficient is always significant, and in the case of Maths scores in Peru. More investigation is required in order to understand the differences between the countries in the patterns of associations, although it is particularly relevant for policy that in India, a country where malnutrition rates remain high despite rapid economic growth, the effect of acute malnutrition compounds the effect of linear growth retardation.

The final health variable, indicating whether the child has experienced a serious illness, helps to explain only Maths scores in Vietnam.

Our conclusion is that while height-for-age remains the key indicator for the measurement of early childhood deprivation, enlargement of the ECD model to the other indicators of health and nutrition is able to provide additional policy-relevant information on the complexity of the mechanisms through which early health and nutrition operate.

This expansion of the informational basis does not necessarily imply supplementary costs of data collection: data for weight and height, for example, are usually collected jointly.

The comparison between a 'suite of indicators' approach and a 'composite index' approach reveals that the former provides substantially more information. It also helps to identify which specific health factor makes the greatest contribution to the development of children's cognitive abilities, therefore offering important insights to policy makers. As a target tool, the index could nonetheless be employed as a 'quick and dirty' tool which provides a general picture of early childhood multidimensional health deprivation in the context of low- and middle-income countries.

The robustness analysis shed some important lights on the channels through which the relationship between early health and later cognition may operate. A large part of the early-childhood health-cognition nexus is mediated by variation in grade attainment, especially in Ethiopia and India, and in Vietnam only for Maths skills. In these countries, however, other channels may play an additional role, including exposure to a good-quality educational environment. The situation in Peru is different from all the other countries: the effect of the health indicators does not seem to be mediated by the years of schooling. Future, *ad hoc* research should explore in depth the causes of this country's performance.

Finally, while it has been increasingly shown that there is scope for nutritional interventions beyond infancy (Crookston et al. 2010a, 2010b, 2013), in accordance with previous literature, the empirical evidence provided in this paper shows that both chronic and acute malnutrition experienced in early childhood have a long-lasting, negative effect on children. This suggests that, beyond good-quality education, good school performance requires an integrated approach to nutrition and health which starts early and is sustained over children's life course.

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Appendix A

OLS estimates with cluster fixed effects of the associations between early health indicators and MHPI with cognitive indicators at 5 and 8, Ethiopia

	Age 5 – Round 2						Age 8 – Round 3					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	PPVT	PPVT	PPVT	CDA	CDA	CDA	PPVT	PPVT	PPVT	Maths	Maths	Maths
Height-for-age z-scores	0.037	0.038		0.046	0.045		0.028	0.030		0.040	0.037	
	(2.895)***	(2.841)**		(3.704)***	(3.546)***		(2.346)**	(2.470)**		(3.994)***	(3.553)***	
Weight-for-height z-scores		0.017			0.005			0.009			0.027	
		(0.979)			(0.249)			(0.587)			(1.688)	
Illness (z-scores)		0.004			-0.019			-0.009			0.014	
		(0.167)			(-0.988)			(-0.888)			(0.842)	
MHPI (z-scores)			-0.018			-0.034			-0.029			-0.035
			(-0.822)			(-1.269)			(-2.084)*			(-2.915)***
Constant	-3.463	-3.658	-3.309	-3.240	-3.238	-3.107	-3.577	-3.613	-3.563	-2.610	-2.569	-2.542
	(-5.946)***	(-6.198)***	(-6.141)***	(-4.770)***	(-4.577)***	(-4.797)***	(-7.944)***	(-7.579)***	(-7.820)***	(-5.450)***	(-5.102)***	(-5.757)***
Observations	1,721	1,636	1,718	1,750	1,664	1,747	1,725	1,639	1,722	1,681	1,596	1,678
Number of clusters	20	20	20	20	20	20	20	20	20	20	20	20
Core controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Adj. R-squared	0.0990	0.101	0.0946	0.0594	0.0564	0.0536	0.142	0.140	0.139	0.124	0.126	0.118

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

Appendix B

OLS estimates with cluster fixed effects of the associations between early health indicators and MHPI with cognitive indicators at 5 and 8, Andhra Pradesh (India)

	Age 5 – Round 2						Age 8 – Round 3					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	PPVT	PPVT	PPVT	CDA	CDA	CDA	PPVT	PPVT	PPVT	Maths	Maths	Maths
Height-for-age z-scores	0.079	0.079		0.101	0.101		0.044	0.043		0.080	0.080	
	(4.617)***	(4.741)***		(5.799)***	(6.011)***		(2.870)***	(2.898)***		(5.051)***	(5.126)***	
Weight-for-height z-scores		0.054			0.062			0.053			0.065	
		(3.483)***			(2.966)***			(3.943)***			(3.476)***	
Illness (z-scores)		-0.013			-0.019			-0.014			-0.016	
		(-0.529)			(-0.781)			(-0.670)			(-0.756)	
MHPI (z-scores)			-0.068			-0.102			-0.074			-0.108
			(-3.055)***			(-4.206)***			(-3.263)***			(-4.247)***
Constant	-2.765	-2.667	-2.619	-3.803	-3.701	-3.649	-0.962	-0.887	-1.012	-1.747	-1.662	-1.825
	(-4.077)***	(-4.090)***	(-3.889)***	(-5.634)***	(-5.465)***	(-5.153)***	(-1.785)*	(-1.568)	(-1.762)*	(-2.898)***	(-2.620)**	(-2.754)**
Observations	1,693	1,693	1,693	1,852	1,852	1,852	1,828	1,828	1,828	1,832	1,832	1,832
Number of clusters	20	20	20	20	20	20	20	20	20	20	20	20
Core controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Adj. R-squared	0.169	0.173	0.160	0.121	0.125	0.111	0.103	0.106	0.105	0.163	0.168	0.161

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

Appendix C

OLS estimates with cluster fixed effects of the associations between early health indicators and MHPI with cognitive indicators at 5 and 8, Peru

	Age 5 – Round 2						Age 8 – Round 3					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	PPVT	PPVT	PPVT	CDA	CDA	CDA	PPVT	PPVT	PPVT	Maths	Maths	Maths
Height-for-age z-scores	0.052	0.050		0.039	0.038		0.037	0.037		0.058	0.057	
	(2.901)***	(2.820)**		(3.286)***	(3.203)***		(3.749)***	(3.789)***		(6.050)***	(5.919)***	
Weight-for-height z-scores		0.014			0.003			0.008			0.044	
		(1.126)			(0.150)			(0.818)			(3.423)***	
Illness (z-scores)		-0.019			-0.011			-0.004			-0.010	
		(-1.210)			(-0.907)			(-0.434)			(-0.896)	
MHPI (z-scores)			-0.044			-0.033			-0.027			-0.059
			(-2.484)**			(-2.275)**			(-1.898)*			(-3.365)***
Constant	-4.043	-4.128	-4.011	-3.339	-3.368	-3.246	-3.174	-3.223	-3.078	-5.691	-5.919	-5.633
	(-12.99)***	(-13.59)***	(-13.29)***	(-7.21)***	(-6.991)***	(-6.655)***	(-10.746)***	(-10.882)***	(-10.713)***	(-11.697)***	(-11.809)***	(-11.751)***
Observations	1,803	1,801	1,809	1,848	1,846	1,855	1,764	1,762	1,769	1,802	1,800	1,807
Number of clustid2	20	20	20	20	20	20	20	20	20	20	20	20
Core controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Adj. R-squared	0.253	0.253	0.251	0.115	0.114	0.112	0.266	0.265	0.266	0.246	0.251	0.247

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

Appendix D

OLS estimates with cluster fixed effects of the associations between early health indicators and MHPI with cognitive indicators at 5 and 8, Vietnam

	Age 5 – Round 2						Age 8 – Round 3					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	PPVT	PPVT	PPVT	CDA	CDA	CDA	PPVT	PPVT	PPVT	Maths	Maths	Maths
Height-for-age z-scores	0.071	0.072		0.046	0.045		-0.003	-0.002		0.053	0.050	
	(3.138)***	(3.110)***		(2.994)***	(2.711)**		(-0.128)	(-0.111)		(3.631)***	(3.413)***	
Weight-for-height z-scores		-0.004			0.008			-0.000			0.025	
		(-0.236)			(0.468)			(-0.007)			(1.715)	
Illness (z-scores)		-0.023			-0.021			0.014			0.042	
		(-1.426)			(-1.196)			(0.562)			(2.145)**	
MHPI (z-scores)			-0.062			-0.043			0.005			-0.039
			(-2.498)**			(-2.726)**			(0.182)			(-2.029)*
Constant	-3.979	-4.022	-3.860	-3.109	-3.132	-3.018	-2.575	-2.558	-2.571	-5.196	-5.204	-5.177
	(-10.017)***	(-10.058)***	(-10.387)***	(-6.074)***	(-6.013)***	(-6.374)***	(-4.484)***	(-4.622)***	(-4.533)***	(-8.570)***	(-8.484)***	(-8.314)***
Observations	1,690	1,690	1,690	1,842	1,842	1,842	1,762	1,762	1,762	1,840		1,840
Number of clusters	20	20	20	20	20	20	20	20	20	20	1,840	20
Core controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	20	YES
Adj. R-squared	0.147	0.147	0.143	0.129	0.129	0.128	0.116	0.116	0.116	0.193	YES	0.191

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

Children's Multidimensional Health and Medium-Run Cognitive Skills in Low- and Middle-Income Countries

This paper engages in the debate on the effects of children's health on their education in later life stages in low- and middle-income countries. Using three rounds from the rich panel data of the Young Lives study in Ethiopia, India, Peru and Vietnam, it endorses a multidimensional approach to health (and poverty in general). In detail, the paper has a fourfold objective: (1) to explore whether the positive relationship between children's height and cognitive skills at pre-school and primary-school age found in previous studies holds in our sample of countries, too; (2) to assess whether additional health and nutrition indicators, rarely available or used in the existing literature, are significantly associated with later cognitive achievements; (3) to examine whether the whole contribution of children's multidimensional health to mid-term cognitive attainments can be adequately summarised by a composite deprivation index; (4) to investigate a few possible channels through which early childhood health may affect cognitive skills.

In line with the main literature, the estimates show a positive, highly significant effect of the height-for-age of children between 6 and 18 months on almost all the dependent variables at both pre-school and primary-school age. The expansion of the informational basis to a multidimensional perspective proved to be informative, too. In particular, weight-for-height, proxy for acute malnutrition, is an important predictor of children's learning outcomes, especially in India, Peru and Vietnam. However, the final health variable, indicating whether the child had experienced a serious illness, helps to explain only Maths scores in Vietnam. We then constructed an aggregate health-deprivation index, based on a revised version of the Alkire-Foster method. While it is associated with a variety of outcomes in the various countries, the index proved to be substantially less informative than the 'suite of indicators'.

Finally, the paper sheds some light on the factors mediating the relationship between early childhood health conditions and mid-run cognitive abilities. In particular, it suggests that the level of formal education attended/completed is an important channel. However, in most of the cases, the inclusion of variables related to schooling in the estimates does not overrule the association between early health and middle-run cognition, which points to the persistent effects of health and nutrition in infancy on life-course skills formation.

Young Lives
An International Study of Childhood Poverty

Young Lives
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About Young Lives

Young Lives is an international study of childhood poverty, involving 12,000 children in 4 countries over 15 years. It is led by a team in the Department of International Development at the University of Oxford in association with research and policy partners in the 4 study countries: Ethiopia, India, Peru and Vietnam.

Through researching different aspects of children's lives, we seek to improve policies and programmes for children.

Young Lives Partners

Young Lives is coordinated by a small team based at the University of Oxford, led by Professor Jo Boyden.

- *Ethiopian Development Research Institute, Ethiopia*
- *Pankhurst Development Research and Consulting plc*
- *Save the Children (Ethiopia programme)*
- *Centre for Economic and Social Sciences, Andhra Pradesh, India*
- *Save the Children India*
- *Sri Padmavathi Mahila Visvavidyalayam (Women's University), Andhra Pradesh, India*
- *Grupo de Análisis para el Desarollo (GRADE), Peru*
- *Instituto de Investigación Nutricional, Peru*
- *Centre for Analysis and Forecasting, Vietnamese Academy of Social Sciences, Vietnam*
- *General Statistics Office, Vietnam*
- *University of Oxford, UK*

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