Poverty and childhood undernutrition in developing countries:

A multi-national cohort study

Short running head: Poverty and childhood undernutrition in developing countries

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Abstract

The importance of reducing childhood undernutrition has been enshrined in the United Nations' Millennium Development Goals. This study explores the relationship between alternative indicators of poverty and childhood undernutrition in developing countries within the context of a multi-national cohort study (Young Lives). Approximately 2000 children in each of four countries - Ethiopia, India (Andhra Pradesh), Peru and Vietnam – had their heights measured and were weighed when they were aged between 6 and 17 months (survey one) and again between 4.5 and 5.5 years (survey two). The anthropometric outcomes of stunted, underweight and wasted were calculated using World Health Organization 2006 reference standards. Maximum-likelihood probit estimation was employed to model the relationship within each country and survey between alternative measures of living standards (principally a wealth index developed using principal components analysis) and each anthropometric outcome. An extensive set of covariates was incorporated into the models to remove as much individual heterogeneity as possible. The fully adjusted models revealed a negative and statistically significant coefficient on wealth for all outcomes in all countries, with the exception of the outcome of wasted in India (Andhra Pradesh) and Vietnam (survey one) and the outcome of underweight in Vietnam (surveys one and two). In survey one, the partial effects of wealth on the probabilities of stunting, being underweight and wasting was to reduce them by between 1.4 and 5.1 percentage points, 1.0 and 6.4 percentage points, and 0.3 and 4.5 percentage points, respectively, with each unit (10%) increase in wealth. The partial effects of wealth on the probabilities of anthropometric outcomes were larger in the survey two models. In both surveys, children residing in the lowest wealth quintile households had significantly increased probabilities of being stunted in all four study countries and of being underweight in Ethiopia, India (Andhra Pradesh) and Peru in comparison to children residing in the highest wealth quintile households. Random effects probit models confirmed the statistical significance of increased wealth in reducing the probability of being stunted and underweight across all four study countries. We conclude that, although multi-faceted, childhood undernutrition in developing countries is strongly rooted in poverty. Effective interventions aimed at preventing inappropriate feeding practices and behaviours and increasing micronutrient intake should be supplemented by targeted poverty-alleviating strategies that are known to be cost-effective.

Introduction

Childhood malnutrition has been defined as a pathological state resulting from inadequate nutrition, including undernutrition (protein-energy malnutrition) due to insufficient intake of energy and other nutrients, overnutrition (overweight and obesity) due to excessive consumption of energy and other nutrients, and deficiency diseases due to insufficient intake of one or more specific nutrients such as vitamins or minerals (Ge & Chang, 2001). Childhood undernutrition remains highly prevalent in developing countries with 178 million children less than 5 years of age estimated to be stunted (i.e., have a height-for-age Z score of less than -2), 112 million estimated to be underweight (i.e., have a weight-for-age Z score of less than -2) and 55 million estimated to be wasted (i.e., have a weight-for-height Z score of less than -2) in 2005 (Black, Allen, Bhutta, Caulfield, de Onis, & Ezzati, et al., 2008). Undernutrition is considered to be the underlying cause of more than one third of childhood deaths globally (Black, Morris, & Bryce, 2003). It is also considered to compromise physical and intellectual development during childhood, educational attainment, and health and labour market outcomes during adulthood (Alderman, Hoddinott, & Kinsey, 2003; Manary & Sandige, 2008; United Nations System Standing Committee on Nutrition, 2004; Victora, Adair, Fall, Hallal, Martorell, & Richter, et al., 2008). The importance of reducing childhood undernutrition has been enshrined in the United Nations' Millennium Development Goals (MDGs), a set of global time-bound and quantified targets for improving the social and economic conditions of the world's poorest (UN Millennium Project, 2005). MDG1, for example, set a target to reduce by half the prevalence of underweight children under-five years of age by 2015. MDG4 set a target to reduce by two-thirds the mortality rate among children under-five years of age by the same date, implicitly recognising the role of undernutrition as an underlying cause of many of these deaths. Progress towards achieving these goals has been variable. Notable progress towards reducing underweight prevalence, among children under-five years of age, has been made in Eastern Asia, whilst the majority of countries making the least progress in this area are in sub-Saharan Africa (UN Millennium Project, 2008; UN Millennium Project, 2009). Similarly, many countries, particularly in sub-Saharan Africa and Southern Asia, have made little or no progress towards reducing childhood deaths, among children under-five years of age (Countdown Coverage Writing Group, 2008; UN Millennium Project, 2009). Moreover, the recent worldwide economic and food crises have endangered, and even threatened the reversal of, the limited progress that has been made in these areas (UN Millennium Project, 2009).

A number of proximal determinants of childhood undernutrition amenable to effective intervention, such as inappropriate feeding practices and behaviours and inadequate micronutrient intake, have been identified in the scientific literature (Bhutta, Ahmed, Black, Cousens, Dewey, & Giugliani, et al., 2008). Other determinants of childhood undernutrition in developing countries include low maternal schooling (Ruel, Levin, Armar-Klemesu, Maxwell, & Morriss, 1999), living in a singe-parent household (Bronte-Tinkewa & DeJong, 2004), economic shocks to the household (Hoddinott & Kinsey, 2001), inadequate use of antenatal care (Gribble, Murray, & Menotti, 2009), low birthweight (Gribble, Murray, & Menotti, 2009), short periods of birth spacing (Gribble, Murray, & Menotti, 2009), rural areas of residence (Smith, Ruel, & Ndiaye, 2005), and poor access to services (Christiaensen & Alderman, 2004). Many of these factors are rooted in poverty, suggesting that a holistic and integrated approach to tackling childhood undernutrition over a life-course perspective is required. A previous study by Haddad et al., which modelled the relationship between both household and gross domestic product estimates of per capita income and childhood undernutrition in developing countries up to the 1990s, suggested that sustained income growth could lead to a sizeable reduction in undernutrition rates (Haddad, Alderman, Appleton, Song, & Yohannes, 2003). In this study, we use individual and household data from a more recent international study of childhood poverty to explore the relationship between alternative indicators of poverty and childhood undernutrition in developing countries. In so doing, we identify the potential contribution of poverty-alleviating strategies that lie at the heart of the MDG initiative to tackling childhood undernutrition.

Methods

Study context

This study uses data from the Young Lives international research project of childhood poverty. Young Lives is tracing the lives of approximately 12,000 children in Ethiopia, India (Andhra Pradesh), Peru and Vietnam over the timeframe set by the United Nations to assess progress towards the MDGs. The study countries were selected to reflect a wide range of cultural, political, geographical and social contexts. Detailed descriptive information on the study countries can be found on the Young Lives website (www.younglives.org.uk). In brief, the United Nations Development Programme's (UNDP's) Human Poverty Index 2007 places Ethiopia 169th out of 177 countries, with a life expectancy at birth of only 51.8 years. Ethiopia is currently half-way through its second five year donor-supported poverty reduction programme, which has resulted in a reduction in rural poverty. Despite these efforts, approximately 47% of Ethiopian children are either stunted in growth or chronically undernourished, whilst more than 12% of Ethiopian children die before they reach the age of 5. The Indian state of Andhra Pradesh is benefiting from the process of liberalisation that is referred to nationally as LPG ('liberalisation, privatisation and globalisation'). Despite this, child mortality below the age of 5 remains stubbornly high at 85.5 per 1000 children, and is higher for girls than boys, whilst childhood immunisation levels remain around 40%. Peru is regarded as a ‘medium human development’ country according to United Nations criteria and boasts the fastest growing economy in Latin America today. Undernutrition affects almost one third of Peruvian children, although this figure masks an urban-rural divide. Twice as many children in the countryside are undernourished as those living in cities and towns. Stunting rates across Peru have remained almost unchanged for children in over a decade. Finally, Vietnam has experienced significant economic growth since the policy of 'Doi Moi' (renovation) was introduced in 1986 following years of economic failure after reunification. It has made significant progress towards achieving the MDGs generally, but rather slower progress towards achieving MDG4.

Study population

In each of the four study countries, approximately 2000 children aged between 6 and 17 months and approximately 1000 children aged between 7.5 and 8.5 years were recruited in 2002. In each country, a sentinel site sampling approach was employed whereby 20 sentinel sites were selected semi-purposively by local experts to represent a range of regions, policy contexts and living conditions, with oversampling of sites covering poor areas (Wilson & Huttly, 2004). Within each site, 150 children (100 for the younger cohort and 50 for the older cohort) were selected by an equivalent of random sampling; the exact sampling procedure varied between sites because of topographical and administrative differences within and between countries, but was carefully documented to ensure a sample indistinguishable from one drawn at random from qualifying households, with reasonable control of bias (Wilson & Huttly, 2004). Children in both cohorts were followed up in 2006 with an attrition rate of less than 5% in all four countries (Outes-Leon & Dercon, 2008). The lives of children in both the younger and older cohorts are being examined in a multi-disciplinary way, including questionnaire-based surveys of all children and their carers in local languages combined with more in-depth research using participatory methods for selected children. Ethical clearance for data collection was obtained from the participating research institutions in the United Kingdom and each study country. Prior to data collection, informed consent was obtained from all study participants. Further details about the Young Lives study, its sampling and recruitment procedures, methodology and response rates are reported elsewhere (Outes-Leon & Dercon, 2008; Wilson & Huttly, 2004). For the purposes of the investigation reported in this paper, all analyses are restricted to children in the younger cohort in order to focus on the period of early childhood when interventions for tackling childhood undernutrition are likely to be most effective (Bhutta et al., 2008).

Anthropometric outcomes

As part of the Young Lives study, children in the younger cohort had their heights measured and were weighed when they were aged between 6 and 17 months (survey one) and again when they were aged between 4.5 and 5.5 years (survey two). Child height (H) was measured to the nearest 0.1 cm using height boards made for the purpose. Child weight (W) was measured using calibrated child scales and recorded to the nearest 0.1 kg. These measures coupled with the age of the child, measured in days based on the birth and interview dates, enabled us to estimate height-for-age (H/A), weight-for-age (W/A) and weight-for-height (W/H). The anthropometric outcomes of stunted, underweight and wasted were subsequently calculated using the Epi-Info statistical package (Dibley, Goldsby, Staehling, & Trowbridge, 1987), and based on the World Health Organization 2006 reference standards for assessing the growth and development of children (de Onis, Onyango, Borghi, Siyam, Nishidaa, &

Siekmanna, 2007; World Health Organization, 2006). Children were classified as stunted if they had a height-for-age Z score < -2, underweight if they a weight-for-age Z score < -2 and wasted if they had a weight-for-height Z score < -2. All three of these anthropometric outcomes were calculated for survey one, whilst only the outcomes of stunted and underweight were calculated for survey two due to the absence of current World Health Organization reference standards for weight-for–height beyond 60 months of age (de Onis et al., 2007; World Health Organization, 2006).

Measures of living standards

Alternative measures of living standards were incorporated into the Young Lives study. These were developed on the basis of evidence from a literature review of measures of childhood poverty in developing countries and descriptive analyses of relevant data sets, including the Demographic and Health Survey, the Living Standards Measurement Survey and the UNICEF Multiple Indicator Cluster Survey (Attawell, 2004; White, Leavy, & Masters, 2002). Information gathered from these preliminary reviews and analyses was used to inform the development of a broader conceptual framework for analysing the causes and consequences of childhood poverty (Attawell, 2004), building on previous work in this area by other social scientists (Brookes-Gunn & Duncan, 1997; García Coll & Magnuson, 1999; Mosley & Chen, 1984). A comprehensive pilot study conducted in two South African sites (one urban, one rural) during 2001 and 2002 among the households of 277 children subsequently refined the final approach to measuring living standards (Seager & de Wet, 2003). The data requirements for alternative measures of living standards were incorporated into household questionnaires completed by caregivers in both surveys.

The main measure of living standards used in our study was a wealth index. It measures economic well-being in such a way that it is neither production nor location specific. The wealth index was initially constructed by the Young Lives research team using an arbitrary weighting system (Seager et al., 2003), but was subsequently developed for the purposes of this empirical investigation using principal components analysis (Bartholomew, Steele, Moustkaki, & Galbraith, 2002). The following variables were used in the principal components analysis: (a) the number of people per room as a continuous variable; (b) a set of 10 consumer durable dummy variables, each equal to one if a household member owned a radio, fridge, TV, bicycle, motor vehicle, mobile phone, landline phone, microwave, sewing machine, or satellite TV; (c) a set of three dummy variables equal to one if the house had electricity, brick or plastered wall, or a sturdy roof (such as corrugated iron, tiles or concrete); (d) a dummy variable equal to one if the dwelling floor was made of a finished material (such as cement, tile or a laminated material); (e) a dummy variable equal to one if the household's source of drinking water was piped into the dwelling or yard; (f) a dummy variable equal to one if the household had a flush toilet or pit latrine; and (g) a dummy variable equal to one if the household used electricity, gas or kerosene. Our revised wealth index was defined as the principal component score for the first principal component for each country and for each survey, i.e. it accounted for as much of the variability in the original data as possible while being uncorrelated with other linear combinations (Bartholomew et al., 2002). The revised wealth index was scaled from 0 to 10 in order to simplify the interpretation of results.

Statistical methods

Descriptive statistics were estimated for the study population in each country. Evidence of attrition bias across the surveys was assessed using the attrition probit test proposed by

Fitzgerald, Gottschalk, & Moffitt (1998) and the BGLW test proposed by Becketti, Gould, Lillard, & Welch (1988).

Maximum-likelihood probit estimation was employed to model the relationship within each country between the wealth index developed using principal components analysis and each of the anthropometric outcomes (dependent variables: stunted, underweight and wasted). Although other estimators have been proposed, maximum likelihood estimation produces theoretically the smallest variance of the parameter estimates and is generally the first choice in statistical analyses applying probit models (Greene, 2003). As noted above, separate models were constructed for all three anthropometric outcomes for survey one and for the stunted and underweight outcomes for survey two.

The relationship between wealth and anthropometric outcomes might be biased because of unobserved heterogeneity. We addressed this by controlling for an extensive set of covariates to remove as much individual heterogeneity as possible. Blocks of covariates were selected on the basis of UNICEF's model for the determinants of childhood undernutrition (UNICEF, 1998) and entered into the probit models sequentially in order to evaluate the change in the marginal effect of wealth on each anthropometric outcome. UNICEF's conceptual framework has been used at local, district and national levels to help plan effective actions to reduce childhood undernutrition. For survey one, the following blocks of covariates were entered sequentially into the models: (a) sociodemographic characteristics of child: sex (male, female), age of child (continuous variable), youngest child (yes, no), sibling composition (only child, index child was only girl with male siblings, index child was only boy with female siblings, female index child from all female children, male index child from all male children, index child with male and female siblings), type of sentinel site (urban, rural) and child lived with both parents (yes, no); (b) direct health effects: birthweight (<2500 g, ≥2500 g) and the duration of breastfeeding (<3, 3-6, >6 months); (c) indirect health effects via disease prevention: child vaccinated against tuberculosis (yes, no), child vaccinated against measles (yes, no) and level of antenatal care (none, low, medium, high) (Attawell, 2004; Seager et al., 2003); (d) caregiver social capital, i.e., measures of the caregiver's quantity and quality of social interactions in the community (Coleman, 1990): cognitive social capital (low, medium, high), social support received in the last year (low, medium, high), group membership (low, medium, high) and level of citizenship (none, some) (Attawell, 2004; Seager et al., 2003); (e) caregiver profile (the biological mother was the primary caregiver for at least 96% of children in each country): caregiver spoke main local language (yes, no), education level of caregiver (completed primary education, did not complete primary education), age of caregiver (<20, 20-39, ≥40 years) and caregiver had depression (yes, no; based on the WHO recommended screening tool, the self reporting questionnaire 20 items (SRQ20) (Harpham, Huttly, De Silva, & Abramsky, 2005)); (f) economic livelihood: household had debts (yes, no) and caregiver received financial transfers from external sources (yes, no); (g) external shocks: total number of shocks to the household since pregnancy, including natural disasters, theft of livestock, destruction of crops, death of household members, events of food insecurity and shocks from other sources (0, 1, ≥2).

For the survey two models, a measure of permanent wealth was created by averaging values across the follow-up period. This generated a less noisy measure of living standards and reduced problems of attenuation bias (Berger, Paxson, & Waldfogel, 2005). The following blocks of covariates were entered sequentially into the survey two models (categorised as above unless otherwise stated): (a) sociodemographic characteristics of child: sex, age of child, youngest child, sibling composition, type of sentinel site, child spoke most commonly used language in locality (yes, no), child followed dominant religion (yes, no) and number of people in household (continuous variable); (b) direct health effects: birthweight and the duration of breastfeeding; (c) caregiver social capital: cognitive social capital, social support received in the last year, group membership and level of citizenship; (d) caregiver profile: caregiver spoke main local language, education level of caregiver, education level of head of household, age of caregiver, caregiver had depression, maternal height (continuous variable entered only into the stunted model) and maternal weight (continuous variable entered only into the underweight model); (e) economic livelihood: household had debts at survey one (yes, no) and at survey two (yes, no), and caregiver received financial transfers from external sources at survey one (yes, no) and at survey two (yes, no); (f) external shocks: total number of shocks to the household since survey one (0, 1, 2, ≥3); (g) childhood services: access to health services (yes, no), child attended crèche (yes, no) and child attended pre-school (yes, no). Missing values were treated as a separate category for each covariate in all models if they exceeded 5%.

All sequential maximum likelihood probit models were re-estimated following re-scaling of the revised wealth index into quintiles and defining the highest wealth quintile as the baseline predictor of anthropometric outcomes. This approach is robust for the scale variations of the wealth index, preserves the ordered nature of the principal component scores and facilitates the interpretation of its effects in terms of comprehensible population segments such as quintiles of wealth.

In order to test the robustness of our results to an alternative measure of living standards, we re-estimated our models using an asset index that measured ownership of livestock, land, a house, consumer durables and productive assets. Multi-level analysis was used to account for the hierarchical structure of the data. Intra-class correlations within sentinel sites were addressed using the ‘cluster’ option for the ‘dprobit’ and ‘probit’ commands in STATA software (StataCorp. 2007. *Stata Statistical Software:* Release 10 College Station, TX: StataCorp LP). Robust standard errors (Huber’s “sandwich” estimator) were used in all maximum likelihood probit models, which are less sensitive to variance inflation due to multicollinearity than model-based standard errors. In addition, multicollinearity was verified in all models using variance inflation factors (VIF) based on model residuals. We checked the hypothesis of homoskedasticity of model residuals using the Breusch-Pagan test and the hypothesis of no omitted variables in the models using Ramsey's RESET test using powers of the fitted values of model residuals (Greene, 2003). Finally, we exploited the panel dimension of our data by constructing random effects probit models for the stunted and underweight outcomes common to both surveys; these models had been identified as superior to fixed effects models on the basis of likelihood ratio tests. In all models, *P*-values less than 0.05 were considered to be statistically significant.

Results

A total of 1999, 2011, 2052 and 2000 children were recruited into the study in Ethiopia, India (Andhra Pradesh), Peru and Vietnam, respectively. The proportion of these children who were boys was estimated at 52.5%, 53.8%, 50.0% and 51.5% in Ethiopia, India (Andhra Pradesh), Peru and Vietnam, respectively. The mean (SD) age at recruitment was 11.7 (3.6), 11.8 (3.5), 11.5 (3.5) and 11.6 (3.2) months, whilst the proportion of children recruited from urban sentinel sites was estimated at 35.0%, 25.1%, 66.1% and 20.0%, in Ethiopia, India (Andhra Pradesh), Peru and Vietnam, respectively. Attrition rates at survey two were estimated at 4.3%, 3.0%, 4.3% and 1.5%, including child deaths, and at 1.3%, 1.4%, 4.1% and 1.0%, excluding child deaths, in Ethiopia, India (Andhra Pradesh), Peru and Vietnam, respectively. These attrition rates are relatively low compared to attrition rates reported in other longitudinal studies conducted in developing countries (Outes-Leon et al., 2008). Although there was some evidence to suggest that attriting households tended to be poorer and less educated than non-attriting households, there was very limited evidence of attrition bias when tested on anthropometric outcomes (Outes-Leon et al., 2008). A summary of anthropometric outcomes in each survey and in each country is presented in table 1. At survey one, the prevalence of stunting and underweight was highest in Ethiopia, whilst the prevalence of wasting was highest in India (Andhra Pradesh). At survey two, the prevalence of stunting and underweight was highest in India (Andhra Pradesh). In India (Andhra Pradesh), Peru and Vietnam, prevalence rates for stunting were higher at survey two than at survey one. Preliminary analyses by Young Lives researchers have suggested that this is partly explained by local factors, although evidence of an effect of poor access to sanitation and safe water supply was a common theme (www.younglives.org.uk/publications/country-reports/index_html). Mean (standard deviations) scores for the revised wealth index were estimated at 2.06 (1.83), 3.15 (1.91), 4.01 (2.49) and 3.71 (2.02) in Ethiopia, India (Andhra Pradesh), Peru and Vietnam over the follow-up period. A full breakdown of the other demographic, socioeconomic and health characteristics of the study population is available from the authors upon request.

Table 2 reports the estimates of the impact of wealth on anthropometric outcomes at survey one in each country. Separate results are presented for each of the model specifications delineated in the methods section. All the estimates are computed as partial effects and can, therefore, be given a quantitative interpretation in terms of units of probability. Focusing on model specification one, which did not control for covariates, our analyses revealed that the coefficient on wealth was negative and statistically significant for all anthropometric outcomes in all countries, with the exception of the outcome of wasted in Vietnam. Notably, the coefficient on wealth was significant at the 0.1-percent level for the outcome of stunted in all countries. The results remained largely unchanged with each sequential block of covariates entered into the model specifications. Model specification eight, which controlled for all covariates, revealed a negative and statistically significant coefficient on wealth for all outcomes in all countries, with the exception of the outcome of wasted in India (Andhra Pradesh) and Vietnam and the outcome of underweight in Vietnam. The partial effect of wealth on the probability that the child is stunted was to reduce it by between 1.4 percentage points in Vietnam and 5.1 percentage points in Ethiopia with each unit (10%) increase in wealth. Similarly, the partial effect of wealth on the probability that the child is underweight was to reduce it by between 1.0 percentage point in Peru and 6.4 percentage points in Ethiopia, whilst the partial effect on the outcome of wasted was to reduce it by between 0.3 percentage points in Peru and 4.5 percentage points in Ethiopia, with each unit (10%) increase in wealth. The results of the fully adjusted models (model specification eight) are reported in full in online appendix 1 for each anthropometric outcome and for each country. Of particular note in the fully adjusted models was the association between male gender, increasing age of the child, low birthweight and elevated maternal age and the anthropometric outcomes of stunting, being underweight and being wasted between 6 and 17 months.

Table 3 reports the estimates of the impact of permanent wealth on anthropometric outcomes at survey two in each country. As with survey one, separate results are presented for each of the model specifications delineated in the methods section. Model specification one revealed that the coefficient on permanent wealth was negative and statistically significant at the 0.1-percent level for all anthropometric outcomes in all countries. The magnitude of the permanent wealth coefficients were generally larger than the wealth coefficients calculated by the survey one models. Notably, the partial effect of permanent wealth on the probability that the child is stunted at approximately 5 years was to reduce it by over 6 percentage points in all countries, with each unit (10%) increase in permanent wealth. The results remained largely unchanged with each sequential block of covariates entered into the model specifications. However, the inclusion of caregiver characteristics in the models (model specification five) did reduce the magnitude of the permanent wealth coefficients for all outcomes in all countries. Model specification eight, which controlled for all covariates, revealed that the partial effect of permanent wealth on the probability that the child is stunted at approximately 5 years was to reduce it by between 3.2 percentage points in Vietnam and 5.6 percentage points in India (Andhra Pradesh), with each unit (10%) increase in permanent wealth. The analogous effects on the probability that the child is underweight at approximately 5 years varied between a reduction of 0.7 percentage points in Peru and 5.8 percentage points in Ethiopia. The results of the fully adjusted models (model specification eight) are reported in full in online appendix 2 for each anthropometric outcome and for each country. Other than increased permanent wealth, the only covariates associated with consistent negative effects on stunting and being underweight at approximately 5 years were increased maternal height in the stunted models and increased maternal weight in the underweight models.

The probabilities of anthropometric outcomes in survey one are presented in table 4 for quintiles of the revised wealth index. These analyses controlled for the full set of covariates described in the methods section. In comparison to children residing in the highest (5^{th}) wealth quintile households, children residing in the lowest (1^{st}) wealth quintile households had significantly increased probabilities of being stunted in all four study countries. These increased probabilities were estimated at 22.7%, 22.3%, 16.0% and 14.8% in Ethiopia, India (Andhra Pradesh), Peru and Vietnam, respectively. Furthermore, in comparison to children residing in the highest (5^{th}) wealth quintile households, children residing in the lowest (1^{st}) wealth quintile households had significantly increased probabilities of being underweight in Ethiopia, India (Andhra Pradesh) and Peru and of being wasted in Ethiopia. Results of similar analyses for the survey two data when the children were approximately 5 years of age are presented in table 5. As with the survey one data, in comparison to children residing in the highest (5th) wealth quintile households, children residing in the lowest (1st) wealth quintile households had significantly increased probabilities of being stunted in all four study countries and of being underweight in Ethiopia, India (Andhra Pradesh) and Peru.

In order to test the robustness of the results of our probit models, a number of sensitivity analyses modelled the relationship between an alternative measure of living standards, i.e. an asset index, and anthropometric outcomes. These analyses revealed a consistent negative and statistically significant relationship between the alternative measure of living standards and the anthropometric outcomes of stunted, underweight and wasted, regardless of survey and country. These results are available from the authors upon request. Model convergence in our study was not affected by multicollinearity. The application of Breusch-Pagan test and Ramsey's RESET test led us to reject the hypothesis of homoskedasticity of model residuals and the hypothesis of no omitted variables for a small number of models. However, the use of robust standard errors diminished the impact of omitted variables on the variance of the fitted predictors. Moreover, the final random effects probit models confirmed the statistical significance of increased wealth in reducing the probability of being stunted and underweight across all four study countries (table 6).

Discussion

This study has demonstrated a negative and statistically significant association between alternative measures of living standards and childhood undernutrition in developing countries. This association held regardless of the wide range of socioeconomic, cultural, political, geographical and policy contexts reflected in the study countries. It also held regardless of the anthropometric outcome, although was least pronounced for the outcome of wasted, which tends to be sensitive to temporary food shortages and episodes of illness (Van de Poel, Hosseinpoor, Speybroeck, Van Ourti, & Vega, 2008). Moreover, for the outcome of stunted, which is considered a reliable indicator of long-standing undernutrition in childhood (Van de Poel et al., 2008), there was evidence of a steepening gradient with age, which suggests that the adverse effects of poverty on undernutrition accumulate during the early years of childhood.

The results of this study should be set in context of the broader literature. A number of what have been described as largely descriptive analyses (O'Donnell, van Doorslaer, Wagstaff, & Lindelow, 2008) have identified socioeconomic-status related inequalities in childhood undernutrition in developing countries (Fotso & Kuate-Defo, 2005; Hong, 2007; Larrea & Freire, 2002; Thang & Popkin, 2003; Van de Poel et al., 2008; Wagstaff, van Doorslaer, & Watanabe, 2003; Wagstaff & Watanabe, 2000; Zere & McIntyre, 2003). These studies revealed a consistently strong inverse socioeconomic gradient in childhood undernutrition across the developing world, although a number of ethnic and regional factors were also identified as important (Hong, 2007; Larrea & Freire, 2002; Thang & Popkin, 2003). Notably, however, these studies are limited in their potential to place causal interpretations on their estimates (O'Donnell, van Doorslaer, Wagstaff, & Lindelow, 2008). A broader body of work, conducted in developed countries and focused largely on non-nutritional outcomes, has used multivariate models to draw stronger causal inferences. This body of work itself can broadly be divided into two categories. On the one hand, there are a number of observational studies conducted in North America, which provide consistent empirical support for the view that socioeconomic status is a relevant determinant of children's health and its influence appears to increase as children age (Case, Lubotsky, & Paxon, 2002; Currie & Stabile, 2003). On the other hand, there is a growing stream of recent empirical studies, mainly from the United Kingdom, which shows that the association between socioeconomic status and child health is weak and, in some cases, seems not to hold at all (Currie, Shields, & Wheatley Price, 2007; Propper, Rigg, & Burgess, 2007; Violato, Petrou, & Gray, 2009). In the developing country context, Desai and Alva analysed Demographic and Health Survey data for 22 countries and show that the strong association between maternal education and three measures of child health weakens considerably when controls for husband's education and area of residence are included (Desai and Alva, 1998). More recently, Chou and colleagues found that initiatives to improve parental education in Taiwan, such as increases in compulsory education from six to nine years, combined with an aggressive school building programme, were associated with an 11 percent decline in the infant mortality rate (Chou, Liu, Grossman, & Joyce, 2007). Our empirical approach was broadly in line with these latter sets of multivariate analyses, which controlled for an extensive set of covariates to remove as much individual heterogeneity as possible. In the process, we were able to demonstrate that the association between alternative measures of living standards and early childhood undernutrition largely holds even when large sets of confounders identified elsewhere were entered into our sequential models (Currie, 2009).

The wealth coefficients estimated by our models suggest that initiatives by finance ministries and development agencies aimed at increasing the living standards of the poorest in developing countries may lead to significant reductions in childhood undernutrition. For example, a 10% increase in wealth is associated with average reductions in the probabilities of stunting, being underweight and wasting in early childhood of between 1.4 and 5.1 percentage points, 1.0 and 6.4 percentage points, and 0.3 and 4.5 percentage points, respectively. Similarly, a 10% increase in permanent wealth is associated with average reductions in the probabilities of stunting and being underweight at approximately 5 years of age of between 3.2 and 5.6 percentage points, and 0.7 and 5.8 percentage points, respectively. The larger coefficients for the survey two models might be explained, at least in part, by a cumulative rather than transitory effect of wealth on outcomes (Blau, 1999). Additional analyses that explored the relationship between an alternative measure of living standards, namely an asset index that included ownership of livestock, land, a house, consumer durables and productive assets, and anthropometric outcomes, revealed the same pattern of results. Moreover, random effects probit models that exploited the panel dimension of the Young Lives data confirmed the statistical significance of increased wealth in reducing the probabilities of being stunted and underweight across the follow-up period in all four study countries. The gains revealed by our analyses compare very favourably with those achieved by proximal interventions aimed at improving feeding practices and behaviours and inadequate micronutrient intake (Bhutta et al., 2008). Achieving such gains would require strong political commitment, efficient delivery strategies, and an assessment of the cost-effectiveness of these strategies in comparison to competing demands on finite resources. Over and above the effects of wealth, our findings of an association between male gender, increasing age of the child, low birthweight, elevated maternal age, reduced maternal height and reduced maternal weight and the anthropometric outcomes of stunting, being underweight and being wasted are broadly in keeping with reports elsewhere in the literature (Gribble, Murray, & Menotti, 2009; Ozaltin, Hill, & Subramanian, 1990; Svedberg, 1990; UNICEF, 1998).

There are a number of caveats to our results, which should be borne in mind by readers. First, although Young Lives followed a rigorous sampling strategy, the oversampling of sentinel sites in poor areas suggests that the final samples of children recruited within each country were not nationally representative with respect to socioeconomic characteristics. In addition, the measurement of some of the covariates included in our analyses, for example, the level of antenatal care, the duration of breastfeeding and childhood vaccination history, may have been subject to recall bias.

Second, the main measure of living standards we used in our analyses was a scaled wealth index derived from principal components analysis. It was developed out of a holistic and multi-dimensional approach to understanding childhood poverty, and is consistent with other measures of welfare or living standards used in population surveys (O'Donnell et al., 2008). Nevertheless, we recognise that the wealth index and the alternative measures of living standards used in our analyses are generally poor proxies for income and consumption expenditure, which tend to be preferred by economists as welfare indicators on theoretical grounds (Howe, Hargreaves, Gabrysch, & Huttly, 2009). Income and consumption expenditure data are notoriously expensive and difficult to collect and quantify in population surveys. Moreover, there are a number of conceptual and practical limitations with measuring income in developing countries, for example, formal employment is often uncommon, many households have multiple and continually changing sources of income, and home production is widespread (O'Donnell et al., 2008), whilst consumption expenditure was not measured in survey one of the Young Lives study. In addition, the relationship between the measures of living standards used in our analyses and both income and consumption expenditure is likely to be mediated by complex institutional factors, such as the nature of local credit markets and property rights, which are themselves poorly described in the Young Lives study.

A third caveat relates to our attempts to directly account for as many potential confounding factors as possible in our cross-sectional analyses of each survey. Our rationale was to 'mop-up' residual heterogeneity in such a way that the error term in the model specifications was orthogonal to the measure of living standards and, therefore, estimation biases may be ruled out. We acknowledge that, although we included a comprehensive set of variables in our models, this is unlikely to have removed all possible sources of residual data heterogeneity. Analogously, the results obtained from our panel data analyses might be affected by the limited variability of key variables across only two waves of Young Lives data. The availability of future waves of Young Lives data will allow us to take advantage of the extended longitudinal data collection and increase our understanding of the mechanisms by which poverty influences childhood undernutrition.

In conclusion, although the problem of childhood undernutrition in developing countries is multi-faceted, we have demonstrated that it is strongly rooted in poverty. Effective interventions aimed at preventing inappropriate feeding practices and behaviours and increasing micronutrient intake should be supplemented by targeted poverty-alleviating strategies that are known to be cost-effective. It is incumbent upon national governments and development agencies to prudently consider the resource implications of these strategies in the near future if the MDGs are to be met.

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Table 1: Anthropometric outcomes in Young Lives study; n (%)

Variable	Ethiopia	India (Andhra Pradesh)	Peru	Vietnam
Round 1 survey				
Study population	1999 (100.0)	2011 (100.0)	2052 (100.0)	2000 (100.0)
Stunted				
No	1317 (65.9)	1584 (78.8)	1674 (81.6)	1794 (89.7)
Yes	609 (30.5)	394 (19.6)	361 (17.6)	199 (10.0)
Missing	73 (3.7)	33 (1.6)	17 (0.8)	7 (0.4)
Underweight				
No	1277 (63.9)	1403 (69.8)	1909 (93.0)	1771 (88.6)
Yes	570 (28.5)	590 (29.3)	129 (6.3)	223 (11.2)
Missing	152 (7.6)	18 (0.9)	14 (0.7)	6 (0.3)
Wasted*				
No	1447 (72.4)	1458 (72.5)	1975 (96.3)	1840 (92.0)
Yes	383 (28.5)	526 (26.2)	52 (2.5)	152 (7.6)
Missing	169 (8.5)	27 (1.3)	25 (1.2)	8 (0.4)
Round 2 survey				
Study population	1913 (100.0)	1950 (100.0)	1963 (100.0)	1970 (100.0)
Stunted				
No	1332 (69.6)	1275 (65.4)	1329 (67.7)	1497 (76.0)
Yes	577 (30.2)	668 (34.3)	625 (31.8)	464 (23.6)
Missing	4 (0.2)	7 (0.4)	9 (0.5)	9 (0.5)
Underweight				
No	1446 (76.6)	1097 (56.3)	1851 (94.3)	1633 (82.9)
Yes	443 (23.2)	846 (43.4)	104 (5.3)	330 (16.8)
Missing	4 (0.2)	7 (0.4)	8 (0.4)	7 (0.4)

* Measures of wasting not estimated at survey two due to the absence of current World Health Organization reference standards for weight-for–height beyond 60 months of age.

Table 2: Association between wealth index and anthropometric outcomes at survey one: multivariate probit models (marginal effects)[a]

Model specification	Ethiopia			India (Andhra Pradesh)			Peru			Vietnam		
	Stunted	Under-weight	Wasted	Stunted	Under-weight	Wasted	Stunted	Under-weight	Wasted	Stunted	Under-weight	Wasted
Model 1[b]	-0.050***	-0.082***	-0.060***	-0.043***	-0.046***	-0.017**	-0.046***	-0.018***	-0.004*	-0.032***	-0.022***	-0.008
	(0.016)	(0.017)	(0.018)	(0.007)	(0.006)	(0.007)	(0.008)	(0.003)	(0.002)	(0.008)	(0.006)	(0.004)
Model 2[c]	-0.056***	-0.079***	-0.053**	-0.043***	-0.048***	-0.011*	-0.028***	-0.012***	-0.004*	-0.030***	-0.019**	-0.004
	(0.015)	(0.016)	(0.018)	(0.007)	(0.006)	(0.005)	(0.006)	(0.003)	(0.002)	(0.008)	(0.007)	(0.005)
Model 3[d]	-0.056***	-0.080***	-0.054**	-0.040***	-0.045***	-0.009	-0.028***	-0.012***	-0.003*	-0.020***	-0.016*	-0.006
	(0.015)	(0.017)	(0.018)	(0.006)	(0.007)	(0.005)	(0.006)	(0.003)	(0.002)	(0.005)	(0.007)	(0.005)
Model 4[e]	-0.055***	-0.077***	-0.053**	-0.038***	-0.046***	-0.012*	-0.027***	-0.011***	-0.002	-0.018***	-0.016**	-0.010*
	(0.014)	(0.018)	(0.019)	(0.007)	(0.007)	(0.005)	(0.006)	(0.003)	(0.001)	(0.005)	(0.006)	(0.005)
Model 5[f]	-0.058***	-0.070***	-0.043**	-0.041***	-0.046***	-0.009	-0.026***	-0.011***	-0.002*	-0.017***	-0.015*	-0.009
	(0.014)	(0.016)	(0.016)	(0.007)	(0.007)	(0.005)	(0.005)	(0.003)	(0.001)	(0.005)	(0.007)	(0.005)
Model 6[g]	-0.053***	-0.065***	-0.044**	-0.037***	-0.041***	-0.005	-0.025***	-0.010***	-0.003*	-0.014**	-0.012	-0.008
	(0.015)	(0.017)	(0.016)	(0.008)	(0.008)	(0.005)	(0.005)	(0.003)	(0.001)	(0.005)	(0.007)	(0.005)
Model 7[h]	-0.052***	-0.064***	-0.044**	-0.038***	-0.042***	-0.005	-0.024***	-0.010***	-0.003*	-0.014**	-0.012	-0.007
	(0.015)	(0.017)	(0.016)	(0.008)	(0.008)	(0.005)	(0.005)	(0.003)	(0.001)	(0.005)	(0.007)	(0.005)
Model 8[i]	-0.051***	-0.064***	-0.045**	-0.038***	-0.042***	-0.006	-0.025***	-0.010***	-0.003*	-0.014**	-0.012	-0.007
	(0.014)	(0.018)	(0.016)	(0.008)	(0.009)	(0.005)	(0.005)	(0.003)	(0.001)	(0.005)	(0.007)	(0.005)

Notes: * Significant at the 5-percent level; ** Significant at the 1-percent level; *** Significant at the 0.1-percent level.

[a] Robust standard errors in parentheses.

[b] Raw correlation between wealth index and anthropometric outcome.

[c] Controls include sociodemographic characteristics of child.

[d] Controls include sociodemographic characteristics of child and direct health effects.

[e] Controls include sociodemographic characteristics of child, direct and indirect health effects.

[f] Controls include sociodemographic characteristics of child, direct and indirect health effects, and caregiver social capital.

[g] Controls include sociodemographic characteristics of child, direct and indirect health effects, caregiver social capital and caregiver profile.

[h] Controls include sociodemographic characteristics of child, direct and indirect health effects, caregiver social capital, caregiver profile and economic livelihood characteristics.

[i] Controls include sociodemographic characteristics of child, direct and indirect health effects, caregiver social capital, caregiver profile, economic livelihood characteristics and external shocks.

Table 3: Association between wealth index and anthropometric outcomes at survey two: multivariate probit models (marginal effects)[a]

Model specification	Ethiopia		India (Andhra Pradesh)		Peru		Vietnam	
	Stunted	Underweight	Stunted	Underweight	Stunted	Underweight	Stunted	Underweight
Model 1[b]	-0.061***	-0.061***	-0.072***	-0.061***	-0.087***	-0.014***	-0.074***	-0.039***
	(0.009)	(0.011)	(0.009)	(0.009)	(0.009)	(0.003)	(0.019)	(0.007)
Model 2[c]	-0.072***	-0.073***	-0.072***	-0.067***	-0.069***	-0.011***	-0.050***	-0.030***
	(0.009)	(0.015)	(0.009)	(0.010)	(0.007)	(0.002)	(0.013)	(0.009)
Model 3[d]	-0.069***	-0.073***	-0.067***	-0.060***	-0.065***	-0.010***	-0.044***	-0.028***
	(0.010)	(0.016)	(0.009)	(0.009)	(0.007)	(0.003)	(0.013)	(0.008)
Model 4[e]	-0.067***	-0.074***	-0.066***	-0.059***	-0.063***	-0.009**	-0.043***	-0.026***
	(0.009)	(0.016)	(0.008)	(0.009)	(0.008)	(0.003)	(0.013)	(0.007)
Model 5[f]	-0.056***	-0.060***	-0.058***	-0.026*	-0.055***	-0.006**	-0.032***	-0.018**
	(0.013)	(0.016)	(0.009)	(0.010)	(0.007)	(0.003)	(0.010)	(0.006)
Model 6[g]	-0.058***	-0.061***	-0.059***	-0.027*	-0.055***	-0.007**	-0.030**	-0.015*
	(0.013)	(0.016)	(0.009)	(0.011)	(0.008)	(0.003)	(0.010)	(0.006)
Model 7[h]	-0.057***	-0.062***	-0.057***	-0.025*	-0.055***	-0.007**	-0.031**	-0.015*
	(0.012)	(0.016)	(0.009)	(0.011)	(0.008)	(0.003)	(0.012)	(0.007)
Model 8[i]	-0.052***	-0.058***	-0.056***	-0.024*	-0.055***	-0.007**	-0.032**	-0.012
	(0.014)	(0.017)	(0.009)	(0.011)	(0.009)	(0.003)	(0.012)	(0.008)

Notes: * Significant at the 5-percent level; ** Significant at the 1-percent level; *** Significant at the 0.1-percent level.

[a] Robust standard errors in parentheses.

[b] Raw correlation between wealth index and anthropometric outcome.

[c] Controls include sociodemographic characteristics of child.

[d] Controls include sociodemographic characteristics of child and direct health effects.

[e] Controls include sociodemographic characteristics of child, direct health effects and caregiver social capital.

[f] Controls include sociodemographic characteristics of child, direct health effects, caregiver social capital and caregiver profile.

[g] Controls include sociodemographic characteristics of child, direct health effects, caregiver social capital, caregiver profile and economic livelihood characteristics.

[h] Controls include sociodemographic characteristics of child, direct health effects, caregiver social capital, caregiver profile, economic livelihood characteristics and external shocks.

[i] Controls include sociodemographic characteristics of child, direct health effects, caregiver social capital, caregiver profile, economic livelihood characteristics, external shocks and access and utilisation variables.

Table 4: Probabilities of anthropometric outcomes at survey one for quintiles of the wealth index: multivariate probit models (marginal effects)[a]

Wealth quintile	Ethiopia			India (Andhra Pradesh)			Peru			Vietnam		
	Stunted	**Under-weight**	**Wasted**	**Stunted**	**Under-weight**	**Wasted**	**Stunted**	**Under-weight**	**Wasted**	**Stunted**	**Under-weight**	**Wasted**
1st	0.227*** (0.072)	0.244** (0.093)	0.190* (0.095)	0.223*** (0.063)	0.227*** (0.052)	0.027 (0.035)	0.160*** (0.050)	0.059* (0.031)	0.020 (0.015)	0.148** (0.064)	0.064 (0.049)	0.053 (0.043)
2nd	0.313*** (0.067)	0.163* (0.071)	0.075 (0.071)	0.193*** (0.050)	0.155** (0.057)	-0.017 (0.029)	0.214*** (0.045)	0.088*** (0.036)	0.031* (0.018)	0.133** (0.055)	0.058 (0.044)	0.045 (0.039)
3rd	0.237*** (0.064)	0.114** (0.042)	0.055 (0.056)	0.131** (0.047)	0.096* (0.046)	0.021 (0.036)	0.102*** (0.037)	0.036 (0.025)	0.015 (0.014)	0.080* (0.048)	0.018 (0.032)	0.023 (0.029)
4th	0.120*** (0.039)	0.084** (0.028)	0.046 (0.035)	0.064 (0.043)	0.040 (0.044)	-0.007 (0.027)	0.045 (0.032)	-0.002 (0.019)	0.007 (0.011)	0.088* (0.047)	0.048* (0.024)	0.044 (0.027)
5th	†	†	†	†	†	†	†	†	†	†	†	†

Notes: * Significant at the 5-percent level; ** Significant at the 1-percent level; *** Significant at the 0.1-percent level.
[a] Robust standard errors in parentheses. † Represents baseline quintile in analyses.
All analyses controlled for sociodemographic characteristics of child, direct and indirect health effects, caregiver social capital, caregiver profile, economic livelihood characteristics and external shocks.

Table 5: Probabilities of anthropometric outcomes at survey two for quintiles of the wealth index: multivariate probit models (marginal effects)[a]

Wealth quintile	Ethiopia		India (Andhra Pradesh)		Peru		Vietnam	
	Stunted	**Underweight**	**Stunted**	**Underweight**	**Stunted**	**Underweight**	**Stunted**	**Underweight**
1st	0.285***	0.305***	0.218***	0.131**	0.349***	0.056*	0.228***	0.070
	(0.078)	(0.084)	(0.041)	(0.043)	(0.064)	(0.039)	(0.069)	(0.047)
2nd	0.253***	0.265***	0.232***	0.047	0.334***	0.052*	0.247***	0.028
	(0.076)	(0.075)	(0.047)	(0.049)	(0.054)	(0.034)	(0.074)	(0.038)
3rd	0.177**	0.139*	0.176***	0.034	0.220***	0.062*	0.248***	0.039
	(0.067)	(0.071)	(0.046)	(0.046)	(0.050)	0.038	(0.069)	(0.037)
4th	0.193***	0.141**	0.093**	0.070	0.037	0.007	0.195***	0.076*
	(0.046)	(0.050)	(0.037)	(0.039)	(0.041)	(0.020)	(0.059)	(0.039)
5th	†	†	†	†	†	†	†	†

Notes: * Significant at the 5-percent level; ** Significant at the 1-percent level; *** Significant at the 0.1-percent level.
[a] Robust standard errors in parentheses. † Represents baseline quintile in analyses.
All analyses controlled for sociodemographic characteristics of child, direct health effects, caregiver social capital, caregiver profile, economic livelihood characteristics, external shocks and access and utilisation variables.

Table 6: Random effects probit models: the relationship between the wealth index and anthropometric outcomes

Country	Outcome	Wealth coefficient	SE	95% CI	P-value
Ethiopia	Stunted	-0.147	0.020	(-0.187, -0.107)	*P*<0.0001
	Underweight	-0.245	0.024	(-0.292, -0.197)	*P*<0.0001
India (AP)	Stunted	-0.185	0.023	(-0.230, -0.140)	*P*<0.0001
	Underweight	-0.137	0.021	(-0.179, -0.096)	*P*<0.0001
Peru	Stunted	-0.207	0.021	(-0.249, -0.166)	*P*<0.0001
	Underweight	-0.110	0.026	(-0.162, -0.058)	*P*<0.0001
Vietnam	Stunted	-0.161	0.029	(-0.217, -0.105)	*P*<0.0001
	Underweight	-0.114	0.029	(-0.172, -0.056)	*P*<0.0001

SE denotes standard error; CI denotes confidence interval: AP denotes Andhra Pradesh.
All analyses controlled for sex, youngest child, sibling composition, duration of breastfeeding, birthweight, level of antenatal care, cognitive social capital, social support received in the last year, group membership, level of citizenship, main language spoken by caregiver, age of caregiver, caregiver depression status, external shocks, household debt status and financial transfers from external sources.