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Young Lives

Maternal Undernutrition and Childbearing in Adolescence and Offspring Growth and Development in Low- and Middle-Income Countries:

Is Adolescence a Critical Window for Interventions Against Stunting?

Liza Benny, Paul Dornan, and Andreas Georgiadis

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About Young Lives

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

Summary

Maternal undernutrition and adolescent childbearing are prevalent in low- and middle-income countries and have harmful consequences for children. However, less is known on whether these implications persist throughout the offspring's life course. Moreover, although adult nutritional status has been suggested to largely reflect conditions during the period from conception to 2 years old ("the first 1,000 days"), others have argued that adolescence is an equally important period for nutrition. This is not well established, however, and there is less evidence on the relative importance of conditions during the first 1,000 days of a girl's life, versus during adolescence, for her nutritional status during pregnancy.

This working paper addresses these gaps through two interrelated investigations. First, we document associations of mothers' stunting and adolescent childbearing with their children's developmental outcomes from infancy through early adolescence, using data on a cohort of children and their mothers from Ethiopia, India, Peru, and Vietnam. Second, in order to infer whether maternal adult undernutrition may reflect undernutrition during adolescence, we use data from another cohort of girls in each of these countries who were surveyed throughout adolescence to estimate the extent of catch-up growth during adolescence.

The results suggest that maternal stunting and adolescent childbearing are both associated with offspring stunting at infancy, that the association between the mother's and offspring's stunting persists through the offspring's early adolescence, and that the two maternal outcomes are not systematically associated with offspring cognitive achievement. For example, taking account of many variables which could affect children's stunting, we find that being born to a stunted adolescent mother was associated with a 15 percentage point increased chance of child being stunted, compared with being born to a non-stunted older mother. We also find that among adolescent girls with height below the WHO standard at 12 years old, on average, 40 per cent of the height deficit was recovered by age 19. As most of this change is likely to have occurred during early adolescence (in this data 12-15 years old), this may be a particularly promising time for interventions to take place.

Overall, the findings reinforce concerns over the long-term implications of mother's nutritional circumstances for their children's healthy growth. An important implication of these findings is that interventions that aim to delay childbearing and promote catch-up growth among adolescent girls, particularly in early adolescence, may be effective in breaking the intergenerational cycle of stunting in low- and middle-income countries.

1. Introduction

Maternal undernutrition during pregnancy and adolescent childbearing are very prevalent in low- and middle-income countries and are among the primary risks to mothers' and their offspring's survival, health, and development (Black et al. 2013; Fall et al. 2015).

A number of studies from low- and middle-income countries document associations between maternal height, an indicator of mother's chronic undernutrition, and age at childbearing on the one hand, and offspring nutritional status and schooling at particular ages on the other (Özaltin et al. 2010; Victora et al. 2008; Fall et al. 2015; Shaw, Lawlor, and Najman 2006). Nevertheless, there are only a few studies examining how these associations evolve over the offspring's life course (Addo et al. 2013). This is an important gap. Evidence on the evolution of associations between maternal outcomes and offspring health and development over the life course can be suggestive of the extent to which the responsiveness of child outcomes to interventions is constrained by earlier maternal circumstances (Martorell and Zongrone 2012).

Maternal undernutrition and adolescent childbearing are very likely to coexist in conditions of poverty (Pradhan, Wynter, and Fisher 2015; Rah et al. 2008). The implications of maternal stunting for offspring health and development are expected to be exacerbated by adolescent pregnancy, as pregnancy when mothers are not fully developed presents important health risks (Dewey and Begum 2011). However, to our knowledge, no study has investigated this hypothesis in low- and middle-income countries.

Many have argued that, because the period from conception to 2 years old (the "first 1,000 days") is when growth is most responsive to interventions, with limited opportunities for catch-up growth thereafter (Prendergast and Humphrey, 2014), mother's stunting during pregnancy largely reflects growth failure during her first 1,000 days of life (Martorell and Zongrone 2012). Others have suggested that adolescence, a period when growth velocity is high, may be another critical window during which girls' growth is particularly susceptible to nutritional insults (Prentice et al. 2013), such as pregnancy, that may stunt adolescent girls' growth (Gigante, Rasmussen, and Victora 2005; Rah et al. 2008). Nevertheless, the potential for catch-up growth and the extent of growth plasticity during adolescence is not well established. Therefore, we know little about the relative importance of circumstances early in life, compared with those during adolescence, for a mother's nutritional status during pregnancy and breastfeeding.

This paper addresses these gaps in the literature through two interrelated investigations. First, we document associations of maternal stunting and adolescent childbearing with offspring stunting and cognitive achievement from the offspring's infancy and early childhood to early adolescence, using data on a cohort of children and their mothers from Ethiopia, India, Peru, and Vietnam. Second, we use longitudinal data on another cohort of girls from these countries, who were followed throughout adolescence, to estimate the extent of catch-up growth and thus the extent to which maternal adult undernutrition reflects undernutrition during adolescence.

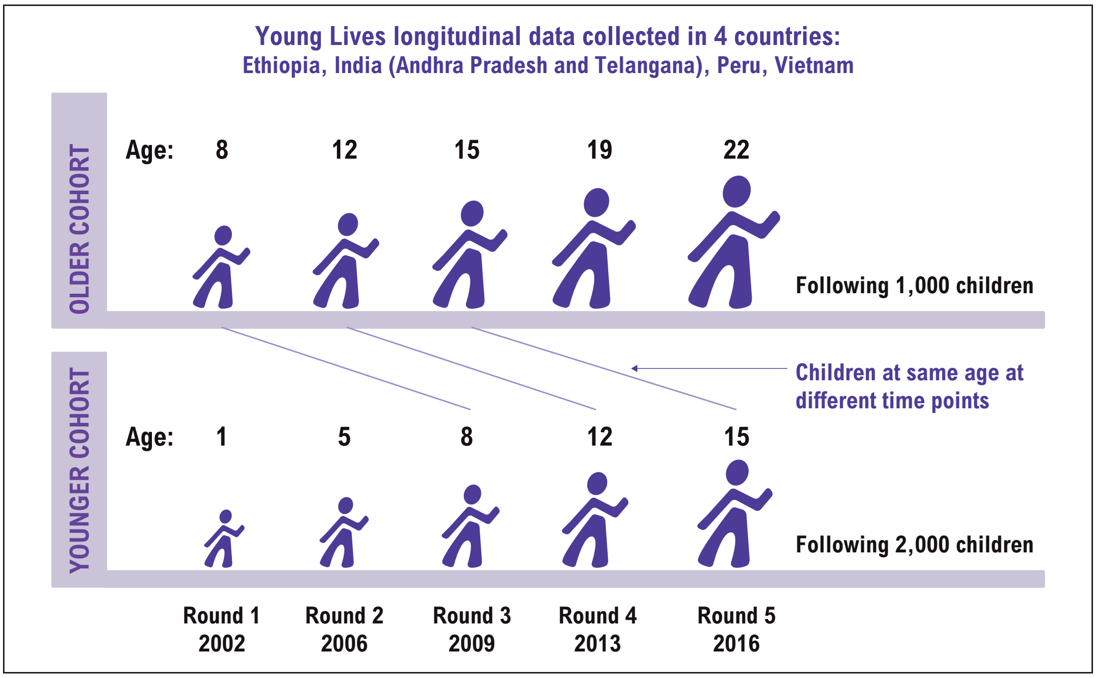
2. Methods

2.1 Study population

Study children were participants in Young Lives, an international cohort study of childhood poverty in Ethiopia, India (the states of Andhra Pradesh and Telangana), Peru, and Vietnam. Young Lives follows around 12,000 children in two cohorts: around 2,000 children in each country born in 2001/02 (the Younger Cohort) and around 1,000 children in each country born in 1994/95 (Older Cohort). Information is also collected on the child's primary caregiver, who in the majority of cases is the child's biological mother. The study has conducted, to date, four rounds of data collection (see Figure 1). Details of the study methods, sampling, and information collected have been published elsewhere (Barnett et al. 2013; Crookston et al. 2013; Lundeen et al. 2014; Petrou and Kupek 2010). The Young Lives protocol was approved by the Central University Ethics Committee of the University of Oxford and the Instituto de Investigación Nutricional Peru. Collective consent was obtained within communities and informed consent was obtained from caregivers and from children.

For our analysis on the associations of maternal undernutrition and adolescent childbearing with child growth and cognitive development, we use data on the Younger Cohort children and their mothers from the four rounds of the study, when the children were around 1, 5, 8, and 12 years old. For our investigation on the incidence and extent of catch-up growth among girls during adolescence we use data on the Older Cohort girls in Rounds 2, 3, and 4 of the survey, when they were around 12, 15, and 19 years old respectively.

Figure 1. *Young Lives cohort design*



2.2 Mother and child nutritional status measures

Nutritional status for Younger Cohort children and their mothers was based on stunting status determined by length and height measures. Height measures were also used to assess catch-up growth among Older Cohort girls during adolescence. Measures of child length for Younger Cohort children at 1 year old, height in subsequent rounds, and height of Older Cohort children at all rounds were obtained using standard techniques (Crookston et al. 2013; Petrou and Kupek 2010). We calculated height-for-age z scores (HAZ) using the 2006 WHO standard for children younger than 5 years old (WHO Multicentre Growth Reference Study Group 2007) and the 2007 WHO reference for children older than 5 (de Onis et al. 2007). Maternal height was measured once, in 2006 (Round 2), when all mothers were adults (between 21 and 48 years old), and HAZ scores were calculated using the 2007 WHO reference for women at age 19 (the maximum age at which WHO standards are available). Stunting for both mothers and children was defined as having a HAZ score that is less than -2 (WHO Multicentre Growth Reference Study Group 2007).

2.3 Adolescent childbearing

We calculated the age of the mother at the birth of the Younger Cohort child using information on her age in completed years at the time of the survey and on the date of birth of the Younger Cohort child. Consistent with previous studies and international definitions, we defined adolescent childbearing as giving birth at the age of 19 years or younger (Fall et al. 2015; WHO 2004).

2.4 Child cognitive achievement measures

Cognitive development of Younger Cohort children was assessed at ages 5, 8, and 12 years using quantitative achievement tests. Tests included the quantitative component of the Cognitive Developmental Assessment (CDA) at age 5 and a mathematics test at ages 8 and 12. The quantitative component of the CDA aims to assess child's understanding of notions such as few, most, half, many, equal, a pair, and so on. In particular, it requires children to indicate which one of a set of pictures fits the description in each of 15 statements, such as 'Point to the plate that has a few cupcakes' (Cueto, Leon, Guerrero, and Muñoz 2009). The mathematics test includes 29 items (except in Ethiopia and Peru at age 12, where 28 and 34 items were administered, respectively) on counting, number discrimination, knowledge of numbers, and basic operations with numbers. Extensive analysis of the psychometric characteristics of these tests indicated high reliability and validity of test items (Cueto and León 2012; Cueto et al. 2009). All tests were administered in the language with which the child felt most comfortable.

2.5 Modelling and estimation

Associations between maternal stunting and adolescent childbearing on the one hand, and child stunting and cognitive achievement on the other, were estimated by Ordinary Least Squares (OLS) using the following specification:

$$HC_{ia} = \beta_0 + \beta_1 d_{i1} + \beta_2 d_{i2} + \beta_3 d_{i3} + \beta_4' CH_i + \varepsilon_{ia} \quad (1)$$

where HC_{ia} is a measure of child i's human capital measure at age a, i.e. stunting status or quantitative achievement score, $\boldsymbol{CH_i}$ is a vector of fixed or pre-determined child, household, and locality characteristics (see Table 1, and Tables A1 and A2 in the appendix for details), and ε_{ia} is an error term capturing the influence of all unobserved factors on child's human capital. The association between child human capital outcomes with maternal stunting and adolescent childbearing is modelled in terms of four dummy variables d_{i1}, d_{i2}, d_{i3}, and d_{i4} that take the value 1 for each combination of the incidence of maternal stunting and adolescent childbearing and are 0 otherwise. In particular, d_{i1} is 1 if the child's mother is stunted and gave birth in adolescence, d_{i2} is 1 if the child's mother is stunted and gave birth after adolescence, and d_{i3} is 1 if the child's mother is not stunted and gave birth in adolescence, and 0 otherwise. The binary indicator d_{i4}, that is 1 when the mother is not stunted and gave birth after adolescence, and is excluded from equation (1), is the reference group relative to which the outcomes of the other three groups are measured (captured by β_1, β_2, and β_3). Linear specifications are appropriate also for a binary outcome in our case, such as child stunting, as our modelling approach, when controls are not included in (1), leads to a saturated model that includes a separate coefficient for every possible combination of values that the set of covariates can take (Angrist and Pischke 2009). The same is not the case when controls are included, but we chose to estimate linear specifications also in this case, as linear regression provides the best linear approximation to the conditional expectation function (Angrist and Pischke 2009) and allows us to compare the results between specifications with and without covariates. In the case of cognitive achievement specifications, the dependent variable was the number of correct answers in each test standardised by age in months, which allows us to adjust for differences in the nature and number of items between the CDA and the mathematics test.

The following specification was used for our analysis related to the estimation of the incidence and extent of catch-up growth among girls during adolescence:

$$H_{ia-1} = \alpha_0 + \alpha_1 H_{ia-1} + \boldsymbol{\alpha_2' CH_{ia-1}^A} + u_{ia} \quad (2) \qquad (2)$$

where H_{ia} is a measure of child i's nutritional status at age a, i.e. height-for-age, H_{ia-1} is the same measure of child i's nutritional status at a younger age $a-1$, $\boldsymbol{CH_{ia-1}^A}$ a vector of child, household, and locality characteristics measured at age $a-1$ or earlier and u_{ia} is an error term. Coefficient α_1 provides an estimate of the extent of persistence in nutritional status between age a-1 and a. Alternatively, it allows us to gauge the extent of catch-up growth in that period, that is given by α_1-1 (Schott, Crookston, Lundeen, Stein, and Behrman 2013). We estimated equation (2) with height-for-age at 19 years as the dependent variable, with height-for-age at age 12 years and 15 years separately as the key causing variables, so that we obtain estimates of the incidence and extent of catch-up growth between age 12 and 19 and between 15 and 19, respectively. Height-for-age was measured in centimetres in order to avoid attenuation in α_1 arising from difference in the standard deviation of the WHO reference distribution at different ages (Leroy, Ruel, and Habicht 2013). Equation (2) can be viewed as the empirical analogue of a dynamic conditional child health demand function (Glewwe and Miguel 2007), which is why the set of covariates included in (2), $\boldsymbol{CH_{ia-1}^A}$, include, among other things, the logarithm of monthly household consumption expenditure excluding expenditure on child's health at the period initial height-for-age was measured (see Table 4 and Table A3 in the appendix for details on all covariates).

Estimation of equation (2) by OLS is expected to lead to biased and inconsistent estimates of α_1 due to endogeneity of H_{ia-1} arising from omitted variables, such as child innate healthiness and parental preferences and measurement error in H_{ia-1}. This is why we also estimate equation (2) using Instrumental Variables (IV) estimation, where instruments for height-for-age were selected from a list of measures of community-level determinants of child health in the initial period that are available in the Young Lives data, such as food and medication prices and aspects of the health environment in the community, such as locality hygiene and health infrastructure. These measures are expected to be valid instruments for child health, as they are excluded from the conditional child health demand function (Glewwe and Miguel 2007). In order to avoid estimation problems arising from many instruments that may be strongly correlated, we used an LM test of instruments' redundancy (Breusch, Qian, Schmidt, and Wyhowski 1999) to identify the two strongest instruments (those that reject most strongly the null hypothesis that the instrument is redundant). This allows us first to minimise concerns related to weak instruments that would render 2SLS estimates less reliable and test for instruments' validity using a Hansen J test for the validity of over-identifying restrictions (Hansen 1982).

The estimation sample excludes children with implausible values of HAZ scores (greater than 5 in absolute value) either for the biological mother, or for the Younger Cohort child at any age (only in child stunting specifications), or for the Older Cohort girls at any age between 12 and 19. In order to maximise the estimation sample, we imputed missing values of the control variables (prevalence 0.004 per cent to 2.8 per cent) with their sample means and pooled the data of the four countries.

3. Results

Table 1 presents descriptive statistics of the characteristics of the sample of Younger Cohort children and their mothers. Mother's stunting is prevalent in one in three mothers in India and Vietnam, and one in two in Peru, although a low share of mothers (6 per cent) are stunted in Ethiopia. In India, 30 per cent of mothers gave birth in adolescence compared to 10 per cent, 13 per cent, and 18 per cent in Vietnam, Ethiopia, and Peru respectively. Figure 2 presents the distribution of mother's age at birth in the pooled sample and indicates that the vast majority of mothers who gave birth before the age of 20, gave birth between 17 and 19 years (around 90 per cent), and nearly half were 19 years old (50 per cent) at birth. Figure 3 presents the prevalence of mother's stunting and adolescent childbearing and indicates that the proportion of children whose mothers are stunted and gave birth to them in adolescence ranged from 1 per cent in Ethiopia to 13 per cent in India.

Table 1. *Descriptive statistics of outcomes and characteristics of Younger Cohort children and their mothers used in the analysis*

	Ethiopia	India	Peru	Vietnam	Pooled country sample
Stunted mother	0.06	0.39	0.52	0.36	0.34
	(0.25)	(0.49)	(0.50)	(0.48)	(0.47)
Mother gave birth in adolescence	0.13	0.30	0.19	0.10	0.19
	(0.34)	(0.46)	(0.39)	(0.31)	(0.39)
Stunted mother who gave birth in adolescence	0.01	0.13	0.09	0.04	0.07
	(0.10)	(0.34)	(0.29)	(0.20)	(0.26)
Non-stunted mother who gave birth in adolescence	0.12	0.17	0.09	0.06	0.11
	(0.33)	(0.38)	(0.29)	(0.24)	(0.32)
Stunted mother who gave birth in adulthood	0.06	0.26	0.42	0.32	0.27
	(0.23)	(0.44)	(0.49)	(0.47)	(0.44)
Non-stunted mother who gave birth in adulthood	0.81	0.44	0.39	0.58	0.55
	(0.39)	(0.50)	(0.49)	(0.49)	(0.50)
Child stunted at age 1 y	0.40	0.30	0.27	0.20	0.29
	(0.49)	(0.46)	(0.44)	(0.40)	(0.45)
Child stunted at age 5 y	0.31	0.36	0.31	0.26	0.31
	(0.46)	(0.48)	(0.46)	(0.44)	(0.46)
Child stunted at age 8 y	0.22	0.29	0.20	0.20	0.23
	(0.41)	(0.45)	(0.40)	(0.40)	(0.42)
Child stunted at age 12 y	0.28	0.29	0.18	0.19	0.24
	(0.45)	(0.45)	(0.38)	(0.40)	(0.42)
Proportion of correct answers in CDA test at age 5 y	0.58	0.67	0.70	0.70	0.67
	(0.21)	(0.19)	(0.18)	(0.18)	(0.19)
Proportion of correct answers in maths test at age 8 y	0.23	0.42	0.50	0.66	0.46
	(0.19)	(0.22)	(0.20)	(0.21)	(0.25)
Proportion of correct answers in maths test at age 12 y	0.39	0.46	0.56	0.51	0.48
	(0.22)	(0.24)	(0.19)	(0.18)	(0.22)
Male child	0.54	0.53	0.51	0.52	0.52
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
Age of child in 2002 (months)	11.58	11.81	11.55	11.70	11.67
	(3.58)	(3.48)	(3.52)	(3.16)	(3.43)
First-born child	0.20	0.38	0.36	0.45	0.35
	(0.40)	(0.49)	(0.48)	(0.50)	(0.48)
Second-born child	0.20	0.39	0.26	0.36	0.31
	(0.40)	(0.49)	(0.44)	(0.48)	(0.46)
Third- or later-born child	0.61	0.23	0.38	0.19	0.34
	(0.49)	(0.42)	(0.49)	(0.39)	(0.47)
Household wealth index in 2002	0.21	0.41	0.43	0.43	0.38
	(0.17)	(0.20)	(0.24)	(0.22)	(0.23)
Biological mother's schooling (years)	2.92	3.67	7.90	6.84	5.37
	(3.77)	(4.41)	(4.41)	(3.97)	(4.65)
Father's schooling (years)	4.74	5.59	9.16	7.61	6.81
	(4.21)	(5.02)	(3.82)	(3.96)	(4.62)
Urban location in 2002	0.33	0.24	0.70	0.20	0.36
	(0.47)	(0.43)	(0.46)	(0.40)	(0.48)
Number of observations	1497	1791	1662	1708	6658

Notes: Statistics are means with standard deviations in parentheses. Descriptive statistics for mother's ethnicity, region of residence in 2002, and language of administration in each test that were also included in the analysis are reported in Tables A1 and A2.

Figure 2. *Distribution of mother's age at index child's birth in the pooled country sample*

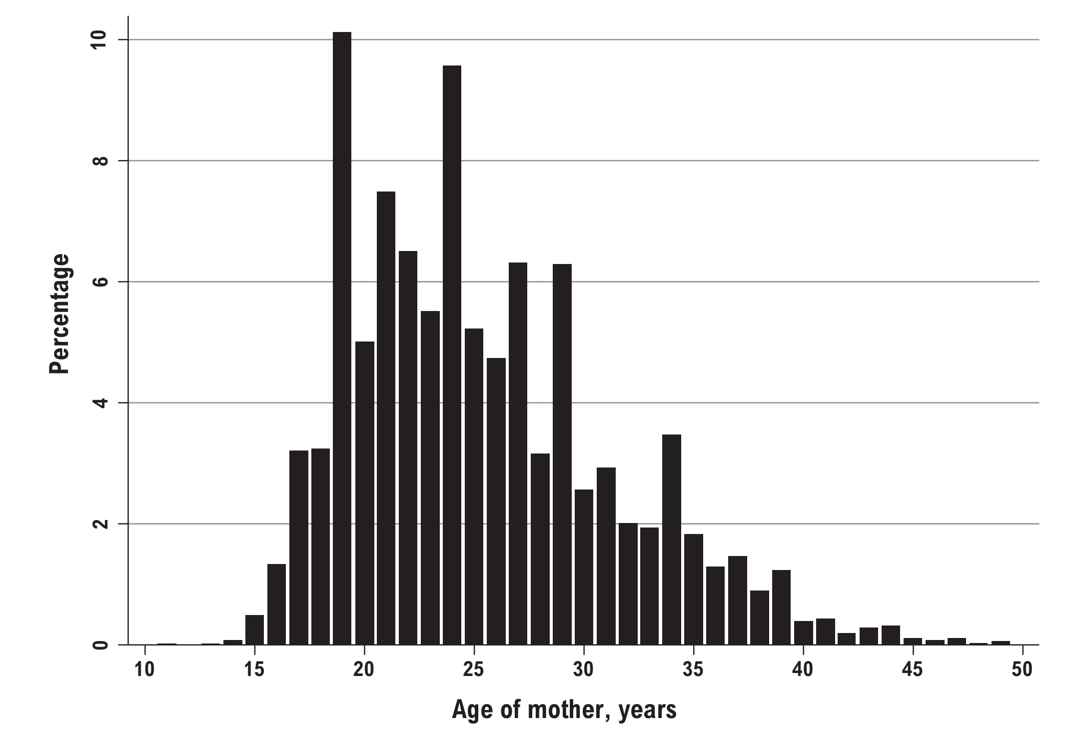


Figure 3. *Prevalence of co-existence of maternal stunting and adolescent pregnancy in the pooled country sample*

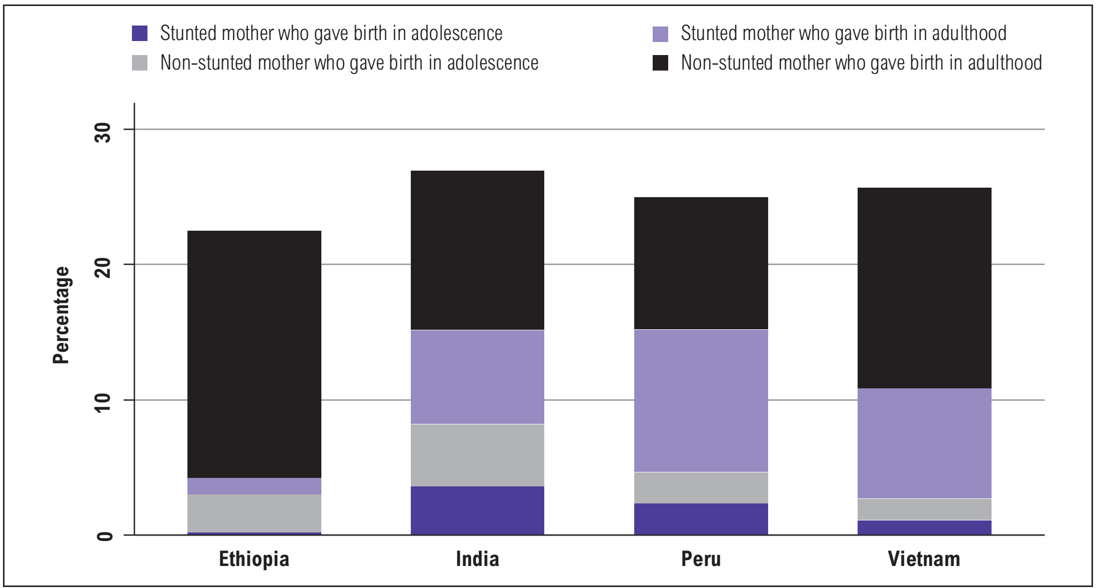


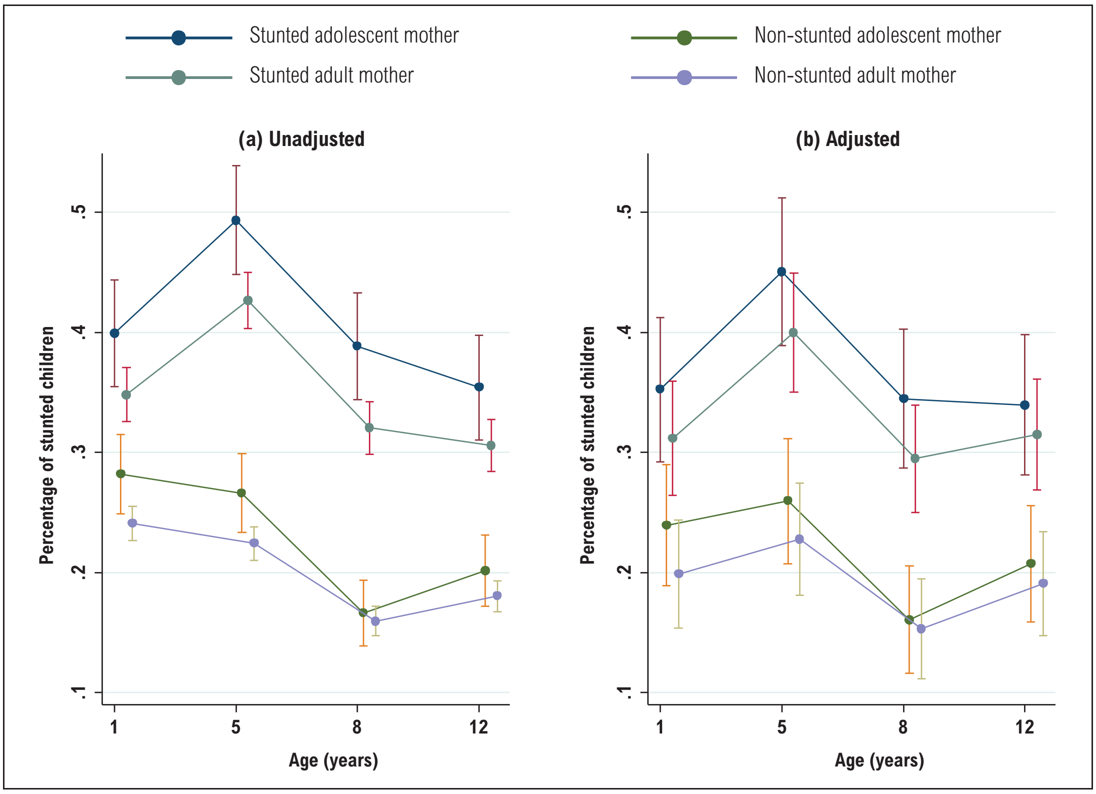
Table 2 reports OLS estimation results for equation (1), where the dependent variable is child stunting at different ages. Associations between child stunting and maternal outcomes are estimated using specifications excluding (unadjusted) and including a range of additional controls (adjusted). Figure 4 presents estimates of the coefficients of the four dummy variables (the estimate of the constant is the coefficient of the reference group) that measure the proportion of stunted children in the four groups defined by the different combinations of the incidence of maternal stunting and adolescent childbearing. Results for the unadjusted models suggest that, relative to the reference group of children whose mothers are not stunted and who gave birth after adolescence, the probability of child stunting at 1 year old was 16 per cent higher among children whose mothers are stunted and gave birth in adolescence, 11 per cent higher for children whose mothers are stunted and gave birth after adolescence, and 4 per cent higher for children with mothers who are not stunted and who gave birth in adolescence. The higher relative risk of stunting persists through adolescence for the two groups whose mothers are stunted. However, the same is not the case for the group of children whose mothers are not stunted and who gave birth in adolescence, among whom the prevalence of stunting is not significantly different from that in the reference group at age 8 and 12 years. Moreover, an F-test of the equality of the coefficients of the two groups of children with stunted mothers, presented in Table 2, suggests that adolescent childbearing exacerbates the risk of stunting among children with stunted mothers.

Table 2. *Linear regression estimates of unadjusted and adjusted associations of maternal stunting and adolescent childbearing with child stunting from age 1 to 12*

	Unadjusted				Adjusted			
	Age 1 y	Age 5 y	Age 8 y	Age 12 y	Age 1 y	Age 5 y	Age 8 y	Age 12 y
Stunted mother who gave birth in adolescence	0.158***	0.269***	0.229***	0.174***	0.154***	0.223***	0.192***	0.149***
	(0.024)	(0.024)	(0.023)	(0.023)	(0.025)	(0.025)	(0.024)	(0.024)
Non-stunted mother who gave birth in adolescence	0.041**	0.042**	0.007	0.021	0.041**	0.031*	0.008	0.016
	(0.018)	(0.018)	(0.015)	(0.016)	(0.018)	(0.019)	(0.016)	(0.017)
Stunted mother who gave birth in adulthood	0.108***	0.202***	0.161***	0.126***	0.113***	0.172***	0.142***	0.124***
	(0.014)	(0.014)	(0.013)	(0.013)	(0.013)	(0.014)	(0.013)	(0.013)
Child age in months in 2002					0.018***	-0.003**	-0.002	0.001
					(0.002)	(0.002)	(0.001)	(0.001)
Male child					0.076***	0.023**	0.033***	-0.003
					(0.010)	(0.011)	(0.010)	(0.010)
Second-born child					0.013	0.021	0.033***	0.008
					(0.013)	(0.013)	(0.012)	(0.012)
Third- or later-born child					0.036**	0.056***	0.060***	0.041***
					(0.015)	(0.015)	(0.014)	(0.014)
Household wealth index in 2002					-0.172***	-0.254***	-0.178***	-0.243***
					(0.039)	(0.040)	(0.036)	(0.036)
Biological mother's schooling (years)					-0.006***	-0.005**	-0.004**	-0.001
					(0.002)	(0.002)	(0.002)	(0.002)
Father's schooling (years)					-0.006***	-0.007***	-0.004**	-0.005***
					(0.002)	(0.002)	(0.002)	(0.002)
Urban location in 2002					-0.033**	-0.061***	-0.047***	-0.019
					(0.017)	(0.017)	(0.015)	(0.016)
Constant	0.241***	0.224***	0.159***	0.180***	0.199***	0.228***	0.153***	0.191***
	(0.007)	(0.007)	(0.006)	(0.006)	(0.023)	(0.024)	(0.021)	(0.022)
R-squared	0.015	0.049	0.041	0.023	0.141	0.144	0.124	0.108
Observations	6,413	6,413	6,413	6,413	6,413	6,413	6,413	6,413
P-values of F-tests for equality of coefficients								
Stunted adolescent mother = Non-stunted adolescent mother	0	0	0	0	0	0	0	0
Stunted adolescent mother =Stunted adult mother	0.045	0.010	0.007	0.052	0.112	0.052	0.047	0.322
Non-stunted adolescent mother = Stunted adult mother	0.001	0	0	0	0	0	0	0

Notes: Robust standard errors are in parentheses. *** significant at 1%, ** significant at 5%, * significant at 10%. Regressions adjusting for covariates include controls for region of residence in 2002 and mother's ethnicity, but estimates are not reported. Household wealth index in 2002, mother's years of schooling, and father's years of schooling are expressed as deviations from the median value for the country.

Figure 4. *Unadjusted and adjusted probability of child stunting from age 1 to 12 by group*



Results do not change markedly in models including additional covariates. At 1 year old, being born to a stunted adolescent mother was associated with a 15 percentage point increased risk of being stunted, compared to being born to an older non-stunted mother, having controlled for additional covariates. Coefficients estimates, however, of the three dummy variables reduce slightly and the F-test results indicate no strongly significant differences in the prevalence of stunting from infancy to early adolescence between the two groups of children with stunted mothers. Estimates of the coefficients of additional covariates suggest that the risk of stunting is higher for boys and for children living in rural areas, except at age 12, and for children with at least two older siblings, who live in poorer households and have less educated parents.

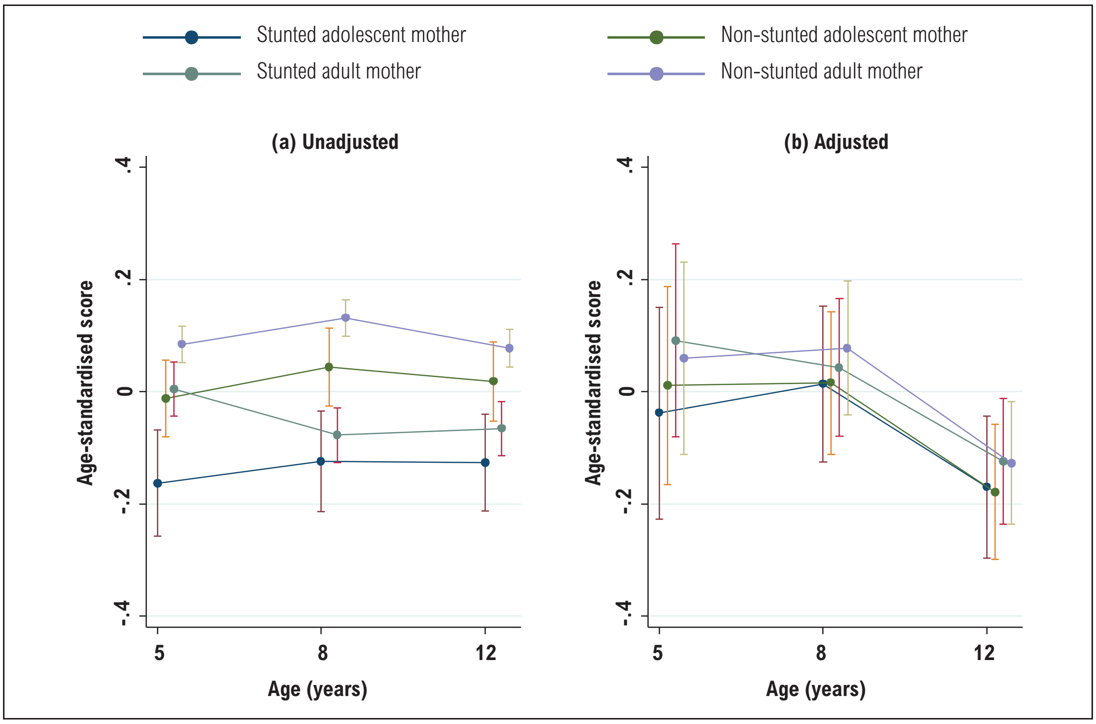
Table 3 presents estimates of the coefficients of equation (1) with the standardised quantitative achievement test score at different ages as the dependent variable, with and without controls, using the pooled sample (Figure 5 presents a graph of the coefficient estimates of the four groups at different ages). In unadjusted models, the patterns are similar to those identified for child stunting; however, differences in performance in the two groups of children with stunted mothers are significant only at 1 year old. After adjusting for confounders, however, no significant differences in achievement are identified across groups, except for a weakly significant difference at 5 years old between the children with stunted mothers who gave birth in adolescence and the reference group. Associations between additional covariates and achievement are similar to those seen for child stunting, indicating strong negative associations between the different measures of household's socio-economic status and test scores, which persist as children grow older.

Table 3. *Linear regression estimates of unadjusted and adjusted associations of maternal stunting and adolescent childbearing with child quantitative achievement scores from age 5 to 12*

	Unadjusted			Adjusted		
	Age 5 y	Age 8 y	Age 12 y	Age 5 y	Age 8 y	Age 12 y
Stunted mother who gave birth in adolescence	-0.247***	-0.256***	-0.204***	-0.098*	-0.064	-0.043
	(0.051)	(0.049)	(0.047)	(0.052)	(0.048)	(0.046)
Non-stunted mother who gave birth in adolescence	-0.096**	-0.087**	-0.059	-0.048	-0.062	-0.051
	(0.039)	(0.039)	(0.040)	(0.040)	(0.038)	(0.039)
Stunted mother who gave birth in adulthood	-0.079***	-0.209***	-0.143***	0.032	-0.034	0.003
	(0.030)	(0.030)	(0.030)	(0.029)	(0.027)	(0.027)
Male child				-0.035	0.040*	-0.029
				(0.023)	(0.022)	(0.022)
Second-born child				-0.002	-0.036	-0.013
				(0.029)	(0.028)	(0.028)
Third- or later-born child				-0.058*	-0.139***	-0.127***
				(0.033)	(0.031)	(0.032)
Household wealth index in 2002				0.563***	0.716***	0.582***
				(0.087)	(0.083)	(0.083)
Biological mother's schooling (years)				0.032***	0.041***	0.041***
				(0.004)	(0.004)	(0.004)
Father's schooling (years)				0.025***	0.033***	0.036***
				(0.004)	(0.003)	(0.004)
Urban location in 2002				0.046	0.118***	0.011
				(0.036)	(0.035)	(0.035)
Constant	0.084***	0.131***	0.077***	0.059	0.077	-0.127**
	(0.017)	(0.017)	(0.017)	(0.087)	(0.061)	(0.056)
R-squared	0.005	0.011	0.006	0.140	0.253	0.235
Observations	6,213	6,213	6,213	6,213	6,213	6,213
P-values of F-tests for equality of coefficients						
Stunted adolescent mother = Non-stunted adolescent mother	0.011	0.004	0.011	0.391	0.969	0.872
Stunted adolescent mother =Stunted adult mother	0.002	0.367	0.228	0.015	0.546	0.332
Non-stunted adolescent mother = Stunted adult mother	0.697	0.005	0.054	0.066	0.503	0.205

Notes: Robust standard errors are in parentheses. *** significant at 1%, ** significant at 5%, * significant at 10%. Dependent variables are age-normalised test scores. Regressions adjusting for covariates include controls for region of residence in 2002, mother's ethnicity, the language of administration of the test, and whether the test was administered in the child's mother tongue, but estimates are not reported. Regressions adjusting for covariates include controls for region of residence in 2002 and mother's ethnicity, but estimates are not reported. Household wealth index in 2002, mother's years of schooling, and father's years of schooling are expressed as deviations from the median value for the country.

Figure 5. *Unadjusted and adjusted mean of age-standardised quantitative achievement scores from age 5 to 12 by group*



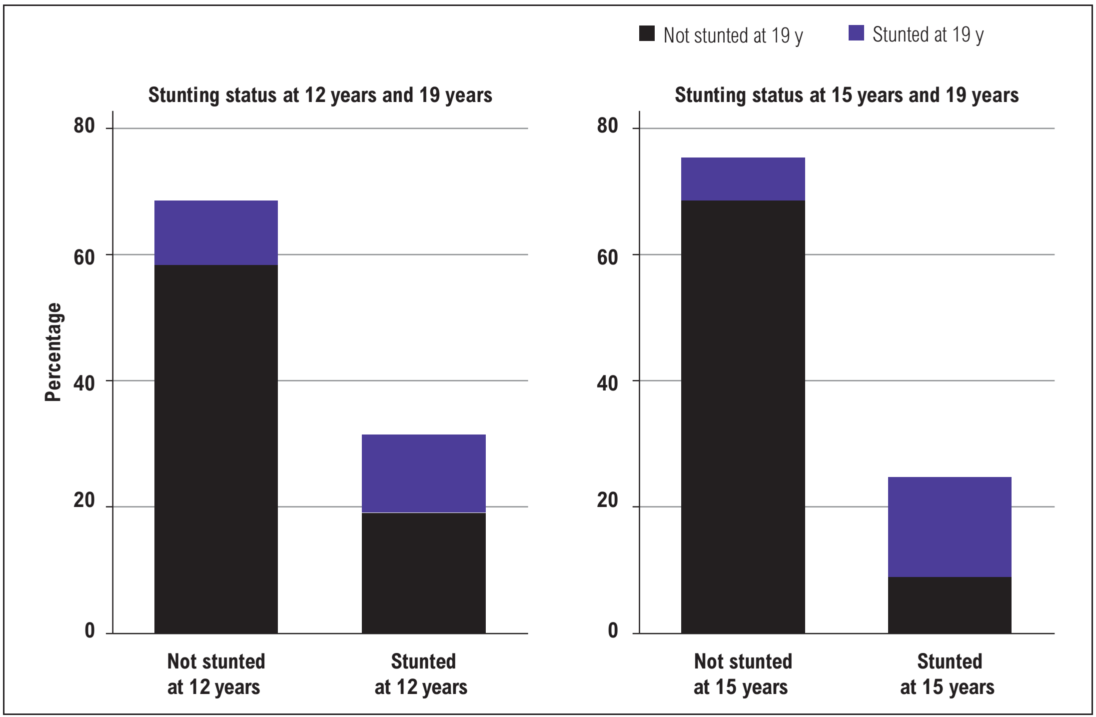
Turning next to the results related to the incidence and extent of catch-up growth during adolescence among Older Cohort girls, Table 4 reports descriptive statistics for the characteristics of Older Cohort girls across countries and in the pooled sample. Average height was more than one standard deviation below the WHO standard at 12 years old, but this difference decreased dramatically by age 19 among girls in Ethiopia and decreased slightly in Vietnam, whereas it increased in Peru and remain relatively stable in India. Figure 6 presents the dynamics of stunting between ages 12 and 19, and 15 and 19. Patterns suggest that the majority of girls who were stunted at 12 years old were not stunted at 19 years old (around 61 per cent), whereas a share of girls who were not stunted by age 12 became stunted at 19 (around 15 per cent). The shares of girls changing stunting status between 15 and 19 years old were around half of those in the respective groups that changed status between 12 and 19.

Table 4. *Descriptive statistics of characteristics of Older Cohort girls used in the analysis by country*

	Ethiopia	India	Peru	Vietnam	Pooled country sample
Height-for-age z-score at age 12 y	-1.37	-1.61	-1.45	-1.39	-1.46
	(1.24)	(1.01)	(0.99)	(1.02)	(1.08)
Height-for-age z-score at age 15 y	-1.04	-1.67	-1.56	-1.39	-1.41
	(1.05)	(0.92)	(0.76)	(0.80)	(0.93)
Height-for-age z-score at age 19 y	-0.61	-1.66	-1.57	-1.25	-1.26
	(0.95)	(0.98)	(0.81)	(0.85)	(1.00)
Age of child in 2002 (months)	94.59	95.71	95.10	95.49	95.25
	(3.56)	(3.78)	(3.85)	(3.39)	(3.65)
First-born child	0.23	0.32	0.31	0.37	0.31
	(0.42)	(0.47)	(0.46)	(0.48)	(0.46)
Second-born child	0.17	0.36	0.25	0.32	0.28
	(0.38)	(0.48)	(0.44)	(0.47)	(0.45)
Third- or later-born child	0.60	0.32	0.44	0.31	0.41
	(0.49)	(0.47)	(0.50)	(0.46)	(0.49)
Child has experienced puberty by age 12	0.03	0.27	0.42	0.20	0.21
	(0.16)	(0.44)	(0.49)	(0.40)	(0.41)
Caregiver's age in 2002 (years)	35.64	30.72	34.81	35.07	33.93
	(9.43)	(6.44)	(8.17)	(6.89)	(7.99)
Caregiver's schooling (years)	2.87	2.91	7.23	6.83	4.75
	(3.55)	(4.09)	(4.43)	(3.87)	(4.45)
Father's schooling (years)	4.34	4.51	9.06	7.88	6.21
	(3.28)	(4.89)	(3.59)	(3.83)	(4.46)
Log household expenditure in 2006 less spending on index child health	4.76	6.78	5.02	5.74	5.66
	(0.59)	(0.57)	(0.72)	(0.54)	(1.00)
Log household expenditure in 2009 less spending on index child health	4.76	6.90	5.22	5.99	5.80
	(0.59)	(0.55)	(0.58)	(0.68)	(1.03)
Urban location in 2002	0.36	0.22	0.74	0.17	0.34
	(0.48)	(0.42)	(0.44)	(0.38)	(0.47)
Number of observations	414	459	279	452	1604

Notes: Statistics are means with standard deviations in parentheses. Descriptive statistics for mother's ethnicity and region of residence in 2002 that were also included in the analysis are reported in Table A3 in the appendix.

Figure 6. *Prevalence of changes in stunting status for girls during adolescence*



Estimation results of equation (2) with height-for-age at age 12 and 15 years respectively as key causing variables are presented in Tables 5 and 6. OLS estimates in Table 5 suggest that, on average, around 55 per cent of the height deficit at age 12 years was recovered by age 19. There are two different 2SLS estimates presented in Table 5, one with the price of salt in the community in 2006 (age 12 years) as the only instrument for height-for-age at age 12 years, and another using this and an indicator of whether garbage in the community in 2006 is collected by truck as an additional instrument. These were the strongest instruments among the set of potential instruments measured by community-level determinants of child health (see Table A9 for the full list and descriptive statistics of these measures). As suggested by 2SLS first-stage estimation results, presented in Table 5, both instruments are strong and significant predictors of height-for-age at 12 years old, and first-stage partial F-statistics are well above the threshold rule of 10, that is typically used as criterion for the instruments' strength in 2SLS estimation (Staiger and Stock 1997). Moreover, the direction of the association of the two instruments with height-for-age is as expected, with the price of salt negatively associated and garbage collection by truck positively associated with height-for-age at age 12. The first-stage results taken together with the results of the Hansen J test, which indicate that the null hypothesis that the over-identifying restriction is valid cannot be rejected, support the validity of 2SLS estimates.

Table 5. *OLS and 2SLS estimates of height-for-age persistence between age 12 and 19 among Older Cohort girls*

	OLS Height-for-age at 19y	First stage Height-for-age at 12y	2SLS Height-for-age at 19y	First stage Height-for-age at 12y	2SLS Height-for-age at 19y
Height-for-age at 12 y	0.454*** (0.022)		0.560*** (0.183)		0.603*** (0.157)
Age of child in 2002 (months)	0.102*** (0.036)	-0.142*** (0.046)	0.117** (0.046)	-0.143*** (0.046)	0.123*** (0.044)
Second-born child	0.867*** (0.317)	-0.679 (0.425)	0.936*** (0.337)	-0.729* (0.425)	0.965*** (0.333)
Third- or later-born child	0.210 (0.329)	-0.463 (0.437)	0.261 (0.345)	-0.499 (0.435)	0.281 (0.345)
Child has experienced puberty by age 12	-3.430*** (0.352)	5.010*** (0.430)	-3.965*** (1.001)	4.919*** (0.429)	-4.183*** (0.874)
Caregiver age in 2002 (years)	-0.007 (0.018)	0.060** (0.024)	-0.013 (0.021)	0.060** (0.024)	-0.016 (0.021)
Caregiver's schooling (years)	0.110*** (0.042)	0.136** (0.054)	0.095* (0.048)	0.134** (0.053)	0.089* (0.046)
Father's schooling (years)	0.002 (0.040)	0.110** (0.051)	-0.011 (0.044)	0.104** (0.051)	-0.016 (0.043)
Log household expenditure in 2006 less spending on index child health	0.232 (0.249)	1.659*** (0.300)	0.054 (0.386)	1.628*** (0.297)	-0.018 (0.363)
Urban location in 2002	-0.783** (0.367)	1.411*** (0.500)	-0.863** (0.400)	0.333 (0.693)	-0.895** (0.403)
Community price of salt in 2006 (local currency)		-0.514*** (0.107)		-0.459*** (0.108)	
Truck for garbage disposal available in community in 2006				1.600** (0.654)	
R-squared	0.445	0.233	0.434	0.236	0.423
Observations	1,604	1,604	1,604	1,604	1,604
Under-identification test p-value			0		0
Weak identification test: Kleibergen-Paap rK Wald F-statistic			23.30		15.24
Hansen J-statistic p-value			.		0.616

Notes: Robust standard errors are in parentheses. *** significant at 1%, ** significant at 5%, * significant at 10%. Height-for-age is measured in cm. All regressions include controls for region of residence in 2002 and mother's ethnicity, but estimates are not reported.

Table 6. *OLS and 2SLS estimates of height-for-age persistence between age 15 and 19 among Older Cohort girls*

	OLS Height-for-age at 19y	First stage Height-for-age at 15y	2SLS Height-for-age at 19y	First stage Height-for-age at 15y	2SLS Height-for-age at 19y
Height-for-age at 15 y	0.730*** (0.023)		0.997*** (0.233)		0.994*** (0.215)
Age of child in 2002 (months)	0.033 (0.027)	0.008 (0.043)	0.031 (0.029)	0.007 (0.043)	0.031 (0.028)
Second-born child	0.631** (0.248)	-0.049 (0.396)	0.643** (0.266)	-0.061 (0.396)	0.643** (0.265)
Third- or later-born child	0.096 (0.256)	-0.251 (0.384)	0.160 (0.280)	-0.238 (0.384)	0.159 (0.276)
Child has experienced puberty by age 12	-0.849*** (0.231)	-0.232 (0.408)	-0.787*** (0.243)	-0.266 (0.408)	-0.788*** (0.239)
Caregiver age in 2002 (years)	-0.017 (0.014)	0.057*** (0.020)	-0.033 (0.021)	0.056*** (0.020)	-0.032* (0.019)
Caregiver's schooling (years)	0.058* (0.033)	0.182*** (0.050)	0.009 (0.055)	0.180*** (0.050)	0.010 (0.053)
Father's schooling (years)	0.020 (0.030)	0.087* (0.047)	-0.003 (0.038)	0.080* (0.047)	-0.002 (0.035)
Log household expenditure in 2009 less spending on index child health	-0.099 (0.159)	0.488** (0.244)	-0.224 (0.204)	0.487** (0.244)	-0.222 (0.211)
Urban location in 2002	-0.399 (0.285)	-0.150 (0.436)	-0.397 (0.305)	0.225 (0.458)	-0.397 (0.304)
Community price of salt in 2009 (local currency)		0.230*** (0.086)		0.224*** (0.087)	
Community price of salt in 2006 (local currency)				-0.291*** (0.104)	
R-squared	0.670	0.147	0.612	0.152	0.613
Observations	1,604	1,604	1,604	1,604	1,604
Underidentification test p-value			0.007		0.001
Weak identification test: Kleibergen-Paap rK Wald F-statistic			7.095		7.491
Hansen J-statistic p-value			.		0.989

Notes: Robust standard errors are in parentheses. *** significant at 1%, ** significant at 5%, * significant at 10%. Height-for-age is measured in cm. All regressions include controls for region of residence in 2002 and mother's ethnicity, but estimates are not reported.

In particular, 2SLS estimates suggest that, on average, among girls whose height was below the WHO standard at 12 years old, between 40 to 44 per cent of the height deficit was recovered by age 19 and that OLS estimates overestimate the extent of catch-up growth. The latter is the case also for the period between 15 and 19, as suggested by estimates in Table 6, with 2SLS estimates being consistent with no catch-up growth. Based on the 2SLS first-stage partial F-statistic results, however, we cannot rule out the possibility that instruments are weak in this case, and thus that 2SLS estimates of the coefficient of height-for-age at age 15 years and its standard error are biased.

Results in Tables 5 and 6 suggest that the girls experiencing puberty after age 12 are shorter at 12 years old compared to girls experiencing puberty before this age (first-stage results), but then grow faster between 12 and 19 years old, and particularly between 12 and 15.

4. Discussion and conclusions

Maternal undernutrition during pregnancy and adolescent childbearing are endemic and pose major threats to offspring health and development in low- and middle-income countries. It has been suggested that these two risks factors are likely to coexist and reinforce each other, with persistent implications for offspring growth and cognitive development. No study has investigated the interaction of these two risk factors in low- and middle-income countries. Moreover, very little is known about the extent to which maternal undernutrition, typically measured by height, can be attributed to growth failure in early life ("the first 1,000 days") as opposed to adolescence, as both periods have been highlighted as critical for nutrition and growth. This working paper addresses these gaps using longitudinal data on a cohort of young children and their mothers in Ethiopia, India, Peru, and Vietnam, and another cohort of girls from these countries who were followed during adolescence. We estimate associations of maternal stunting and adolescent childbearing with their offspring's stunting and cognitive achievement from early childhood to early adolescence. We also infer the extent to which maternal chronic undernutrition reflects undernutrition during adolescence through IV estimation of the extent of catch-up growth during adolescence among Older Cohort girls. This estimation strategy corrects for bias in OLS estimates arising from the endogeneity of initial height-for-age.

We find that mother's stunting has a positive and significant association with offspring's stunting in infancy, and this association persists through to age 12. Mother's adolescent childbearing is positively and significantly associated with the probability that her offspring is stunted in infancy, but this association is weaker than that between mother and offspring stunting and does not persist in magnitude and significance through to age 12. We find no evidence that, after adjusting for covariates, mother's adolescent childbearing significantly and systematically exacerbates the risk of stunting among children of stunted mothers, or that mother's stunting and adolescent childbearing are significantly associated with offspring's performance in quantitative tests. Separate analysis by gender, however, suggests that among boys, those with stunted mothers who gave birth in adolescence have systematically lower scores in quantitative achievement at all ages compared to those whose mother is not stunted and who gave birth after adolescence (see Tables A4 and A5 for all results by gender). One potential explanation of the weaker and non-persistent association between maternal adolescent childbearing and child outcomes is that the majority of mothers in our sample gave birth in late adolescence, between 17 and 19 years old, with a large share (50 per cent) giving birth at 19, when the risk of adverse pregnancy and delivery outcomes is lower relative to early adolescence (WHO 2004). Additional analysis on the sensitivity of our results to lowering the cut-off age used to define adolescent childbearing (see Tables A6 and A7 for details) provided some support to this hypothesis. In particular, we find that child outcomes tend to be worse the younger the mother is at birth, particularly when children were 1 year old, but our results were very unstable and imprecise due to the small number of mothers in our sample who gave birth very young. Moreover, a potential explanation of our finding that mother's stunting is strongly and significantly associated with offspring stunting, but not with offspring cognitive achievement, could be that changes in the offspring's environment not related to nutrition may compensate for cognitive deficits arising from early undernutrition, even if they do not improve child nutrition. This is supported by studies (Mendez and Adair 1999; Sudfeld et al. 2015), which produce evidence that over time improvements in the access and quality of schooling and learning may attenuate the effects of early undernutrition on cognition.

Another and probably the most important result of our study is that we find evidence of catch-up growth among girls in adolescence and in particular that around 40 per cent of the height deficit among girls with height lower than the WHO standard at 12 years old was recovered by age 19. Moreover, our findings, although not conclusive, seem to suggest that the largest share of catch-up growth occurred in early adolescence, between the ages of 12 and 15 years old. Additional patterns in our data, in particular in Ethiopia, are also supportive of catch-up growth during adolescence. The first is that, among Older Cohort girls in Ethiopia, average height-for-age increased by around 50 per cent between 12 and 19 years old. This could be explained in terms of delayed onset of puberty, as only 3 per cent have experienced puberty by age 12, compared to at least 20 per cent of girls in the other countries. Several studies have suggested that pubertal delay provides an opportunity for more catch-up growth prior to skeletal maturity (Adair 1999). Delayed onset of puberty, however, cannot explain our regression-based estimates of catch-up growth, as the timing of the onset of puberty is included among the controls.

We also found that only 6 per cent of mothers of Younger Cohort children in Ethiopia are stunted in adulthood, and we believe this could be suggestive of catch-up growth after early childhood rather than low stunting prevalence in early childhood among these mothers. This is because of the evidence that stunting prevalence among children below age 5 in Ethiopia has been extremely high during the period these mothers were in childhood (Christiaensen and Alderman 2004). We also believe that low stunting rates among mothers cannot be explained by sample selection, as, although the Young Lives sample in Ethiopia is not representative, urban households in the study were, on average, poorer than those in representative samples, whereas rural households were slightly better off than rural households in representative samples (Outes-Leon and Sanchez 2008). Therefore, our estimates of catch-up growth suggest a large share of maternal undernutrition is likely to reflect environments and experiences during adolescence. This result is consistent with several studies that documented growth plasticity during adolescence (Coly et al. 2006; Prentice et al. 2013) including one using Young Lives data (Fink and Rockers 2014) and with other studies highlighting the importance of adolescent girls' diet and micronutrient intake for their offspring's growth and development (Black et al. 2013; Dominguez-Salas et al. 2014; Martorell and Zongrone 2012). Our result, however, differs from the latter studies in that it highlights that improvements in mother's nutrition during adolescence may generate gains in her offspring's growth through the offspring's life course by promoting catch-up growth in the mother.

Our analyses have several limitations. First, we do not have linear growth measures for mothers from birth to the time growth is terminated in our sample and thus we cannot investigate directly the implications of growth failure at different periods of the mother's life for her offspring's growth and development. Nevertheless, indirect evidence of these is produced by our analysis in the sample of Older Cohort girls who were followed during adolescence. Second, potential problems related to weak instruments in our 2SLS estimation do not allow us to produce precise and unbiased estimates of the extent of catch-up growth during late adolescence, that is, between 15 and 19 years old. Third, because of the nature of our sample, our estimates of associations of maternal adolescent childbearing and child outcomes largely reflect associations of child outcomes with mother's childbearing in late adolescence.

Overall, our findings reinforce concerns over the long-term implications of mother's nutritional circumstances for their children's healthy growth. An important implication of these findings is that interventions that aim to delay childbearing and promote catch-up growth among adolescent girls, particularly in early adolescence, may be effective in breaking the intergenerational cycle of stunting in low- and middle-income countries.

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Appendix

Table A1. *Descriptive statistics of region of residence in 2002 and mother's ethnicity of Younger Cohort*

	Ethiopia	India	Peru	Vietnam
Region of residence in 2002				
Addis Ababa	0.13 (0.34)			
Amhara	0.20 (0.40)			
Oromia	0.20 (0.40)			
SNNP	0.24 (0.43)			
Tigray	0.23 (0.42)			
Coastal Andhra		0.35 (0.48)		
Rayalaseema		0.31 (0.46)		
Telangana		0.35 (0.48)		
Coast			0.36 (0.48)	
Mountain			0.49 (0.50)	
Jungle			0.15 (0.36)	
Northern Uplands				0.20 (0.40)
Red River Delta				0.19 (0.39)
Central Coastal				0.41 (0.49)
Mekong River Delta				0.20 (0.40)
Mother's ethnicity				
Amhara	0.28 (0.45)			
Gurage	0.07 (0.26)			
Hadiya	0.05 (0.21)			
Oromo	0.20 (0.40)			
Sidama	0.05 (0.23)			
Tigrian	0.24 (0.43)			

	Ethiopia	India	Peru	Vietnam
Wolayta	0.06 (0.24)			
Scheduled castes		0.18 (0.38)		
Scheduled tribes		0.13 (0.33)		
Other backward classes		0.49 (0.50)		
Quechua			0.18 (0.39)	
White			0.04 (0.19)	
Mixed ethnicity	0.00 (0.00)	0.00 (0.00)	0.73 (0.44)	0.00 (0.00)
Kin'h	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.86 (0.35)
Hmong	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.06 (0.23)
Other ethnicities	0.04 (0.20)	0.21 (0.41)	0.05 (0.22)	0.09 (0.28)
Number of observations	1497	1791	1662	1708

Notes: Statistics are means with standard deviations in parentheses.

Table A2. *Descriptive statistics of language of administration of quantitative achievement tests for Younger Cohort*

	Ethiopia	India	Peru	Vietnam
Child's mother tongue				
Amharic	0.44 (0.50)			
Oromiya	0.24 (0.43)			
Tigrigna	0.19 (0.39)			
Other Ethiopian languages	0.13 (0.34)			
Telugu		0.92 (0.27)		
Kannada		0.04 (0.19)		
Other Indian languages		0.04 (0.20)		
Spanish			0.90 (0.30)	
Quechua			0.10 (0.30)	
Other Peruvian languages			0.00 (0.02)	
Vietnamese				0.81 (0.39)
H'mong				0.04 (0.20)
Other Vietnamese languages				0.15 (0.36)
Language of administration of cognitive tests				
CDA test at 5y administered in mother tongue	0.99 (0.10)	0.96 (0.20)	0.97 (0.17)	0.97 (0.17)
Maths test at 8y administered in mother tongue	0.61 (0.49)	0.75 (0.43)	0.91 (0.28)	0.82 (0.39)
Maths test at 12y administered in mother tongue	0.51 (0.50)	0.92 (0.27)	0.90 (0.30)	0.81 (0.39)
Number of observations	1265	1731	1610	1607

Notes: Statistics are means with standard deviations in parentheses.

Table A3. *Descriptive statistics of region of residence in 2002 and mother's ethnicity of Older Cohort*

	Ethiopia	India	Peru	Vietnam
Region of residence in 2002				
Addis Ababa	0.14 (0.35)			
Amhara	0.21 (0.41)			
Oromia	0.21 (0.40)			
SNNP	0.22 (0.42)			
Tigray	0.22 (0.41)			
Coastal Andhra		0.36 (0.48)		
Rayalaseema		0.29 (0.45)		
Telangana		0.36 (0.48)		
Coast			0.41 (0.49)	
Mountain			0.43 (0.50)	
Jungle			0.16 (0.37)	
Northern Uplands				0.23 (0.42)
Red River Delta				0.22 (0.42)
Central Coastal				0.35 (0.48)
Mekong River Delta				0.20 (0.40)
Mother's ethnicity				
Amhara	0.32 (0.47)			
Gurage	0.06 (0.24)			
Hadiya	0.03 (0.18)			
Oromo	0.20 (0.40)			
Sidama	0.05 (0.21)			
Tigrian	0.25 (0.43)			
Wolayta	0.06 (0.24)			
Scheduled castes		0.20 (0.40)		
Scheduled tribes		0.12		

	Ethiopia	India	Peru	Vietnam
		(0.32)		
Other backward classes		0.48 (0.50)		
Quechua			0.76 (0.43)	
White			0.16 (0.37)	
Mixed ethnicity			0.05 (0.22)	
Kin'h				0.08 (0.27)
Hmong				0.88 (0.33)
Other ethnicities	0.03 (0.17)	0.20 (0.40)	0.03 (0.17)	0.04 (0.20)
Number of observations	414	459	279	452

Notes: Statistics are means with standard deviations in parentheses.

Table A4. *Linear regression estimates of adjusted associations of maternal stunting and adolescent childbearing with child stunting from age 1 to 12, by child gender*

	Boys				Girls			
	Age 1 y	Age 5 y	Age 8 y	Age 12 y	Age 1 y	Age 5 y	Age 8 y	Age 12 y
Stunted mother who gave birth in adolescence	0.180***	0.212***	0.204***	0.178***	0.121***	0.237***	0.181***	0.116***
	(0.035)	(0.035)	(0.033)	(0.033)	(0.035)	(0.037)	(0.035)	(0.035)
Non-stunted mother who gave birth in adolescence	0.017	0.032	0.022	0.015	0.069***	0.035	-0.001	0.021
	(0.026)	(0.027)	(0.024)	(0.024)	(0.026)	(0.027)	(0.022)	(0.026)
Stunted mother who gave birth in adulthood	0.105***	0.156***	0.139***	0.127***	0.121***	0.191***	0.148***	0.123***
	(0.019)	(0.020)	(0.018)	(0.018)	(0.019)	(0.020)	(0.018)	(0.018)
Child age in months in 2002	0.018***	-0.002	-0.003	0.005**	0.019***	-0.004**	-0.001	-0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Second-born child	-0.000	0.015	0.042**	0.014	0.025	0.030	0.023	0.002
	(0.019)	(0.019)	(0.017)	(0.017)	(0.018)	(0.019)	(0.017)	(0.018)
Third- or later-born child	0.015	0.039*	0.070***	0.046**	0.056***	0.073***	0.048**	0.037*
	(0.021)	(0.022)	(0.020)	(0.020)	(0.021)	(0.022)	(0.019)	(0.021)
Household wealth index in 2002	-0.186***	-0.260***	-0.169***	-0.260***	-0.147***	-0.250***	-0.188***	-0.223***
	(0.056)	(0.056)	(0.051)	(0.049)	(0.054)	(0.057)	(0.052)	(0.054)
Biological mother's schooling (years)	-0.006**	-0.004	-0.005**	-0.001	-0.005**	-0.006**	-0.002	-0.002
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)
Father's schooling (years)	-0.005**	-0.004	-0.001	-0.003	-0.008***	-0.009***	-0.007***	-0.007***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)
Urban location in 2002	-0.039	-0.080***	-0.076***	-0.016	-0.030	-0.039	-0.016	-0.024
	(0.024)	(0.024)	(0.022)	(0.022)	(0.023)	(0.024)	(0.021)	(0.022)
Constant	0.285***	0.268***	0.195***	0.203***	0.190***	0.208***	0.141***	0.171***
	(0.032)	(0.033)	(0.029)	(0.030)	(0.032)	(0.033)	(0.030)	(0.031)
R-squared	0.142	0.135	0.128	0.110	0.133	0.162	0.125	0.116
Observations	3,346	3,346	3,346	3,346	3,067	3,067	3,067	3,067
P-values of F-tests for equality of coefficients								
Stunted adolescent mother = Non-stunted adolescent mother	0	0	0	0	0.181	0	0	0.015
Stunted adolescent mother = Stunted adult mother	0.040	0.117	0.063	0.143	0.993	0.223	0.368	0.830
Non-stunted adolescent mother = Stunted adult mother	0.002	0	0	0	0.070	0	0	0

Notes: Robust standard errors are in parentheses. *** significant at 1%, ** significant at 5%, * significant at 10%. Regressions include controls for region of residence in 2002 and mother's ethnicity, but estimates are not reported. Monthly age of child in 2002, household wealth index in 2002, mother's years of schooling, and father's years of schooling are expressed as deviations from the median value for the country.

Table A5. *Linear regression estimates of adjusted associations of maternal stunting and adolescent childbearing with child quantitative achievement scores from age 5 to 12, by child gender*

	Boys			Girls		
	Age 5 y	Age 8 y	Age 12 y	Age 5 y	Age 8 y	Age 12 y
Stunted mother who gave birth in adolescence	-0.155**	-0.125*	-0.130**	-0.041	-0.010	0.051
	(0.073)	(0.067)	(0.064)	(0.075)	(0.069)	(0.066)
Non-stunted mother who gave birth in adolescence	-0.056	-0.085	-0.080	-0.031	-0.045	-0.024
	(0.054)	(0.054)	(0.055)	(0.059)	(0.053)	(0.057)
Stunted mother who gave birth in adulthood	0.031	-0.023	-0.023	0.033	-0.050	0.032
	(0.041)	(0.038)	(0.039)	(0.041)	(0.039)	(0.039)
Second-born child	-0.013	-0.054	-0.055	0.005	-0.023	0.030
	(0.040)	(0.039)	(0.039)	(0.042)	(0.040)	(0.040)
Third- or later-born child	-0.100**	-0.175***	-0.188***	-0.017	-0.106**	-0.071
	(0.047)	(0.044)	(0.044)	(0.047)	(0.045)	(0.045)
Household wealth index in 2002	0.358***	0.545***	0.535***	0.779***	0.898***	0.643***
	(0.122)	(0.114)	(0.116)	(0.125)	(0.120)	(0.119)
Biological mother's schooling (years)	0.035***	0.039***	0.044***	0.029***	0.044***	0.039***
	(0.005)	(0.005)	(0.005)	(0.006)	(0.005)	(0.005)
Father's schooling (years)	0.029***	0.035***	0.037***	0.022***	0.031***	0.035***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Urban location in 2002	0.052	0.139***	-0.037	0.035	0.092*	0.052
	(0.051)	(0.049)	(0.050)	(0.051)	(0.049)	(0.049)
Constant	0.059	0.103	-0.107	0.048	0.102	-0.168**
	(0.117)	(0.081)	(0.077)	(0.129)	(0.089)	(0.078)
R-squared	0.143	0.234	0.230	0.144	0.282	0.250
Observations	3,255	3,255	3,255	2,958	2,958	2,958
P-values of F-tests of equality of coefficients						
Stunted adolescent mother = Non-stunted adolescent mother	0.219	0.589	0.493	0.912	0.640	0.318
Stunted adolescent mother = Stunted adult mother	0.0130	0.137	0.103	0.342	0.578	0.775
Non-stunted adolescent mother = Stunted adult mother	0.144	0.298	0.341	0.314	0.936	0.365

Notes: Robust standard errors are in parentheses. *** significant at 1%, ** significant at 5%, * significant at 10%. Dependent variables are age-normalised test scores. Regressions include controls for region of residence in 2002, mother's ethnicity, the language of administration of the test, and whether the test was administered in the child's mother tongue, but estimates are not reported. Household wealth index in 2002, mother's years of schooling, and father's years of schooling are expressed as deviations from the median value for the country.

Table A6. *Linear regression estimates of adjusted associations of maternal stunting and adolescent childbearing with child stunting from age 1 to 12, using different threshold ages to define adolescent pregnancy*

	Age 1 y	Age 5 y	Age 8 y	Age 12 y	Age 1 y	Age 5 y	Age 8 y	Age 12 y	Age 1 y	Age 5 y	Age 8 y	Age 12 y
Stunted mother who gave birth by 18 y	0.165***	0.218***	0.191***	0.152***								
	(0.033)	(0.033)	(0.033)	(0.033)								
Non-stunted mother who gave birth by 18 y	0.059**	0.024	0.009	0.024								
	(0.027)	(0.027)	(0.023)	(0.025)								
Stunted mother who gave birth after 18 y	0.113***	0.174***	0.147***	0.125***								
	(0.013)	(0.013)	(0.012)	(0.012)								
Stunted mother who gave birth by 17 y					0.165***	0.204***	0.171***	0.106***				
					(0.041)	(0.041)	(0.040)	(0.040)				
Non-stunted mother who gave birth by 17 y					0.105***	0.025	0.027	0.044				
					(0.036)	(0.035)	(0.030)	(0.032)				
Stunted mother who gave birth after 17 y					0.116***	0.176***	0.151***	0.130***				
					(0.013)	(0.013)	(0.012)	(0.012)				
Stunted mother who gave birth by 16 y									0.191***	0.184***	0.235***	0.117**
									(0.056)	(0.057)	(0.059)	(0.056)
Non-stunted mother who gave birth by 16 y									0.198***	0.058	0.032	0.083
									(0.065)	(0.064)	(0.053)	(0.062)
Stunted mother who gave birth after 16 y									0.115***	0.177***	0.149***	0.128***
									(0.012)	(0.013)	(0.012)	(0.012)
Child age in months in 2002	0.018***	-0.003**	-0.002*	0.001	0.018***	-0.003**	-0.002*	0.001	0.018***	-0.003**	-0.002*	0.001
	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
Male child	0.076***	0.023**	0.033***	-0.003	0.076***	0.023**	0.033***	-0.003	0.077***	0.024**	0.034***	-0.002
	(0.010)	(0.011)	(0.010)	(0.010)	(0.010)	(0.011)	(0.010)	(0.010)	(0.010)	(0.011)	(0.010)	(0.010)
Second-born child	0.012	0.017	0.030**	0.007	0.012	0.014	0.029**	0.004	0.009	0.013	0.029**	0.004
	(0.013)	(0.013)	(0.012)	(0.012)	(0.013)	(0.013)	(0.012)	(0.012)	(0.013)	(0.013)	(0.012)	(0.012)
Third- or later-born child	0.032**	0.048***	0.056***	0.039***	0.032**	0.044***	0.054***	0.036***	0.027*	0.042***	0.054***	0.035***
	(0.015)	(0.015)	(0.013)	(0.014)	(0.014)	(0.015)	(0.013)	(0.014)	(0.014)	(0.014)	(0.013)	(0.013)
Household wealth index in 2002	-0.172***	-0.255***	-0.178***	-0.243***	-0.173***	-0.256***	-0.179***	-0.245***	-0.173***	-0.257***	-0.179***	-0.244***
	(0.039)	(0.040)	(0.036)	(0.036)	(0.039)	(0.040)	(0.036)	(0.036)	(0.039)	(0.040)	(0.036)	(0.036)
Biological mother's schooling (years)	-0.006***	-0.005***	-0.004**	-0.001	-0.006***	-0.005***	-0.004**	-0.001	-0.006***	-0.005***	-0.004**	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Father's schooling (years)	-0.006***	-0.007***	-0.004**	-0.005***	-0.006***	-0.007***	-0.004**	-0.005***	-0.006***	-0.007***	-0.004**	-0.005***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Urban location in 2002	-0.034**	-0.062***	-0.047***	-0.019	-0.033**	-0.062***	-0.047***	-0.019	-0.033**	-0.062***	-0.047***	-0.019
	(0.017)	(0.017)	(0.015)	(0.016)	(0.017)	(0.017)	(0.015)	(0.016)	(0.016)	(0.017)	(0.015)	(0.016)
Constant	0.203***	0.236***	0.156***	0.193***	0.204***	0.239***	0.156***	0.194***	0.208***	0.240***	0.157***	0.195***
	(0.023)	(0.023)	(0.021)	(0.022)	(0.022)	(0.023)	(0.021)	(0.022)	(0.022)	(0.023)	(0.020)	(0.022)
R-squared	0.141	0.144	0.124	0.108	0.142	0.144	0.124	0.109	0.142	0.144	0.124	0.108
Observations	6,413	6,413	6,413	6,413	6,413	6,413	6,413	6,413	6,413	6,413	6,413	6,413
P-values of F-tests for equality of coefficients												
Stunted adolescent mother = Non-stunted adolescent mother	0.009	0	0	0.001	0.248	0.001	0.003	0.207	0.934	0.135	0.010	0.681
Stunted adolescent mother = Stunted adult mother	0.126	0.195	0.190	0.426	0.228	0.504	0.616	0.548	0.173	0.901	0.149	0.846
Non-stunted adolescent mother = Stunted adult mother	0.053	0	0	0	0.764	0	0	0.010	0.199	0.064	0.029	0.474

Notes: Robust standard errors are in parentheses. *** significant at 1%, ** significant at 5%, * significant at 10%. Regressions include controls for region of residence in 2002 and mother's ethnicity, but estimates are not reported. Monthly age of the child in 2002, household wealth index in 2002, mother's years of schooling, and father's years of schooling are expressed as deviations from the median value for the country.

Table A7. *Linear regression estimates of adjusted associations of maternal stunting and adolescent childbearing with child quantitative achievement scores from age 5 to 12, using different threshold ages to define adolescent pregnancy*

	Age 5 y	Age 8 y	Age 12 y	Age 5 y	Age 8 y	Age 12 y	Age 5 y	Age 8 y	Age 12 y
Stunted mother who gave birth by 18 y	-0.138*	0.004	0.074						
	(0.071)	(0.064)	(0.057)						
Non-stunted mother who gave birth by 18 y	-0.084	-0.087	-0.011						
	(0.057)	(0.054)	(0.057)						
Stunted mother who gave birth after 18 y	0.023	-0.040	-0.005						
	(0.027)	(0.026)	(0.026)						
Stunted mother who gave birth by 17 y				-0.181**	-0.013	0.060			
				(0.090)	(0.078)	(0.072)			
Non-stunted mother who gave birth by 17 y				-0.125*	-0.170***	-0.059			
				(0.074)	(0.064)	(0.070)			
Stunted mother who gave birth after 17 y				0.020	-0.039	-0.003			
				(0.027)	(0.026)	(0.026)			
Stunted mother who gave birth by 16 y							-0.132	0.026	0.106
							(0.120)	(0.097)	(0.092)
Non-stunted mother who gave birth by 16 y							-0.130	-0.231**	-0.040
							(0.133)	(0.111)	(0.110)
Stunted mother who gave birth after 16 y							0.016	-0.034	-0.000
							(0.027)	(0.025)	(0.025)
Male child	-0.035	0.040*	-0.030	-0.035	0.040*	-0.030	-0.037	0.039*	-0.030
	(0.023)	(0.022)	(0.022)	(0.023)	(0.022)	(0.022)	(0.023)	(0.022)	(0.022)
Second-born child	-0.001	-0.029	0.005	0.001	-0.034	-0.001	0.012	-0.027	0.002
	(0.028)	(0.027)	(0.028)	(0.028)	(0.027)	(0.028)	(0.028)	(0.027)	(0.027)
Third- or later-born child	-0.053*	-0.127***	-0.101***	-0.050	-0.133***	-0.109***	-0.035	-0.123***	-0.104***
	(0.032)	(0.030)	(0.030)	(0.031)	(0.030)	(0.030)	(0.031)	(0.029)	(0.029)
Household wealth index in 2002	0.563***	0.721***	0.589***	0.563***	0.720***	0.588***	0.568***	0.720***	0.588***
	(0.087)	(0.083)	(0.083)	(0.087)	(0.083)	(0.083)	(0.087)	(0.083)	(0.083)
Biological mother's schooling (years)	0.032***	0.041***	0.042***	0.032***	0.041***	0.042***	0.033***	0.041***	0.042***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Father's schooling (years)	0.025***	0.033***	0.036***	0.025***	0.033***	0.036***	0.025***	0.033***	0.036***
	(0.004)	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)
Urban location in 2002	0.046	0.118***	0.013	0.046	0.118***	0.012	0.047	0.119***	0.013
	(0.036)	(0.035)	(0.035)	(0.036)	(0.035)	(0.035)	(0.036)	(0.035)	(0.035)
Constant	0.055	0.067	-0.148***	0.049	0.071	-0.143***	0.037	0.061	-0.147***
	(0.087)	(0.060)	(0.055)	(0.086)	(0.060)	(0.055)	(0.087)	(0.059)	(0.055)
R-squared	0.140	0.253	0.235	0.140	0.253	0.235	0.139	0.253	0.235
Observations	6,213	6,213	6,213	6,213	6,213	6,213	6,213	6,213	6,213
P-values of F-tests for equality of coefficients									
Stunted adolescent mother = Non-stunted adolescent mother	0.524	0.249	0.255	0.617	0.105	0.214	0.990	0.076	0.297
Stunted adolescent mother = Stunted adult mother	0.025	0.500	0.170	0.027	0.746	0.381	0.219	0.536	0.252
Non-stunted adolescent mother = Stunted adult mother	0.070	0.407	0.919	0.057	0.048	0.438	0.275	0.080	0.718

Notes: Robust standard errors are in parentheses. *** significant at 1%, ** significant at 5%, * significant at 10%. Dependent variables are age-normalised test scores. Regressions include controls for region of residence in 2002, mother's ethnicity, the language of administration of the test, and whether the test was administered in the child's mother tongue, but estimates are not reported. Monthly age of the child in 2002, household wealth index in 2002, mother's years of schooling, and father's years of schooling are expressed as deviations from the median value for the country.

Table A8. *Descriptive statistics of community characteristics for the Older Cohort girls*

	Ethiopia	India	Peru	Vietnam	Total
Air pollution is a severe problem in the community in 2006	0.58	0.56	0.34	0.12	0.40
	(0.49)	(0.50)	(0.47)	(0.33)	(0.49)
Water pollution is a severe problem in the community in 2006	0.58	0.85	0.64	0.44	0.63
	(0.49)	(0.36)	(0.48)	(0.50)	(0.48)
Piped water available in community in 2006	0.93	0.98	0.99	0.81	0.92
	(0.25)	(0.13)	(0.12)	(0.39)	(0.27)
Improved sanitation available in community in 2006	1.00	0.93	0.98	1.00	0.98
	(0.00)	(0.25)	(0.13)	(0.00)	(0.15)
Truck for garbage disposal available in community in 2006	0.21	0.26	0.72	0.35	0.35
	(0.41)	(0.44)	(0.45)	(0.48)	(0.48)
Community price of coffee in 2006 (local currency)	14.67	114.78	9.50	15.47	42.64
	(7.81)	(44.38)	(3.13)	(18.26)	(52.58)
Community price of sugar in 2006 (local currency)	8.28	19.83	2.03	9.50	10.84
	(0.79)	(1.64)	(0.16)	(1.28)	(6.34)
Community price of oil in 2006 (local currency)	9.22	53.84	3.96	17.56	23.42
	(5.68)	(4.28)	(0.41)	(1.94)	(20.18)
Community price of salt in 2006 (local currency)	1.79	5.80	0.58	1.41	2.62
	(2.86)	(1.83)	(0.16)	(0.50)	(2.71)
Community price of staple food in 2006 (local currency)	2.47	11.66	1.73	5.15	5.73
	(0.90)	(2.22)	(0.18)	(0.55)	(4.17)
Air pollution is a severe problem in the community in 2009	0.57	0.59	0.42	0.17	0.44
	(0.50)	(0.49)	(0.49)	(0.38)	(0.50)
Water pollution is a severe problem in the community in 2009	0.47	0.70	0.71	0.26	0.52
	(0.50)	(0.46)	(0.46)	(0.44)	(0.50)
Piped water available in community in 2009	0.83	0.79	1.00	0.98	0.89
	(0.37)	(0.41)	(0.00)	(0.12)	(0.31)
Improved sanitation available in community in 2009	0.87	0.98	0.99	0.95	0.95
	(0.34)	(0.12)	(0.08)	(0.22)	(0.23)
Truck for garbage disposal available in community in 2009	0.11	0.25	0.75	0.54	0.38
	(0.31)	(0.44)	(0.43)	(0.50)	(0.49)
Community price of coffee in 2009 (local currency)	38.30	208.86	12.55	60.03	88.75
	(9.71)	(74.02)	(4.04)	(23.06)	(88.17)
Community price of sugar in 2009 (local currency)	14.40	34.05	2.00	15.27	18.11
	(0.65)	(2.86)	(0.21)	(1.06)	(11.25)
Community price of oil in 2009 (local currency)	20.09	56.74	5.89	26.59	29.94
	(3.04)	(9.64)	(0.54)	(3.98)	(19.18)
Community price of salt in 2009 (local currency)	3.08	8.00	0.82	4.45	4.48
	(0.56)	(2.04)	(0.14)	(2.77)	(3.14)
Community price of staple food in 2009 (local currency)	6.71	20.37	2.05	8.61	10.34
	(0.98)	(5.03)	(0.20)	(2.06)	(7.33)
Number of observations	414	459	279	452	1604

Notes: Statistics are means with standard deviations in parentheses. Community prices are the means across all local currencies: Birr in Ethiopia, Rupees in India, Pesos in Peru, and '000 VND in Vietnam. The item used as staple food varies across countries: in Ethiopia, it is the price of cereals, in India and Vietnam, the price of rice, whereas in Peru, it is the average of the prices of rice, potatoes, and pasta.

Maternal Undernutrition and Childbearing in Adolescence and Offspring Growth and Development in Low- and Middle-Income Countries: Is Adolescence a Critical Window for Interventions Against Stunting?

Maternal undernutrition and adolescent childbearing are prevalent in low- and middle-income countries and have harmful consequences for children. However, less is known on whether these implications persist throughout the offspring's life course. Moreover, although adult nutritional status has been suggested to largely reflect conditions during the period from conception to 2 years old ("the first 1,000 days"), others have argued that adolescence is an equally important period for nutrition. This is not well established, however, and there is less evidence on the relative importance of conditions during the first 1,000 days of a girl's life, versus during adolescence, for her nutritional status during pregnancy.

This working paper addresses these gaps through two interrelated investigations. First, we document associations of mothers' stunting and adolescent childbearing with their children's developmental outcomes from infancy through early adolescence, using data on a cohort of children and their mothers from Ethiopia, India, Peru, and Vietnam. Second, in order to infer whether maternal adult undernutrition may reflect undernutrition during adolescence, we use data from another cohort of girls in each of these countries who were surveyed throughout adolescence to estimate the extent of catch-up growth during adolescence.

The results suggest that maternal stunting and adolescent childbearing are both associated with offspring stunting at infancy, that the association between the mother's and offspring's stunting persists through the offspring's early adolescence, and that the two maternal outcomes are not systematically associated with offspring cognitive achievement. For example, taking account of many variables which could affect children's stunting, we find that being born to a stunted adolescent mother was associated with a 15 percentage point increased chance of child being stunted, compared with being born to a non-stunted older mother. We also find that among adolescent girls with height below the WHO standard at 12 years old, on average, 40 per cent of the height deficit was recovered by age 19. As most of this change is likely to have occurred during early adolescence (in this data 12-15 years old), this may be a particularly promising time for interventions to take place.

Overall, the findings reinforce concerns over the long-term implications of mother's nutritional circumstances for their children's healthy growth. An important implication of these findings is that interventions that aim to delay childbearing and promote catch-up growth among adolescent girls, particularly in early adolescence, may be effective in breaking the intergenerational cycle of stunting in low- and middle-income countries.

Young Lives

An International Study of Childhood Poverty

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, Ethiopia*
- *Centre for Economic and Social Studies, Hyderabad, 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*
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