Can shorter mothers have taller children?
Nutritional mobility, health equity and the intergenerational transmission of relative height

Amelia B. Finaret*
Assistant Professor
Global Health Studies
Allegheny College, Meadville, PA
*Corresponding author: afinaret@allegheny.edu

William A. Masters
Professor
Friedman School of Nutrition Science and Policy
Tufts University, Boston, MA

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Abstract

This study develops the concept of nutritional mobility, defined here as the probability that a mother ranked low in her cohort's height distribution will have a child who attains a higher rank order. We demonstrate that rank-order regression provides a robust metric of health equity, revealing differences in opportunities for each child to reach their own growth potential. We estimate four indicators of nutritional mobility and test for associations between nutritional mobility and various local economic and environmental factors. Nutritional mobility has improved over time, and the nutrition environment contributes about 2.86 times as much as a mother's height to her child's expected rank in height-for-age. Populations with the least mobility are in Latin America, and the more urbanized areas of Africa and Asia have the most mobility. The results offer valuable insights into the role of socioecological factors in nutrition improvement across generations.

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Introduction

Human development depends on improvements in socioecological conditions, giving children better health outcomes than their parents (Case et al. 2005, Martorell and Zongrone 2012, Thompson 2014). This study explores the individual, local, and national factors associated with whether the children of mothers with shorter-stature can reach their own potential height, indicating greater equality in access to nutritional and other determinants of linear growth. The use of rank-order mobility to measure equality of opportunity across generations was pioneered by Chetty et al. (2014), and has been widely used since then regarding income, wealth and educational attainment. This paper applies the concept to human health, using attained height to measure the degree to which socioecological constraints preserve a population's rank order from generation to generation. Recent work has demonstrated that catch-up in child growth across generations is possible when families migrate to wealthier countries (Alacevich and Tarozzi 2017).

We define *nutritional mobility* as the probability that mothers ranked low in their population's height distribution will have children who attain a higher rank order. Each child's genetic potential is partly inherited from the mother's genetic potential, but the actual attained heights of both mother and child are also influenced by paternal genes, random mutation, care practices and health services as well as environmental factors affecting diet and disease (Emanuel et al. 2004). Transmission of maternal genes implies some transmission of attained height, but observing greater nutritional mobility in some populations than others implies more *equality of opportunity* for each child to reach their own potential height. Some correlation in rank will arise due to inheritance of the mother's genetic potential, and with additional transmission from mothers to children due to shared socioecological constraints such as diet and disease as well as assortive matching of shorter mothers with shorter fathers (Stulp et al. 2017).

Nutritional mobility in rank order allows us to identify change in health equity among individuals from one generation to the next, complementing past work on intergenerational transmission of many different health outcomes such as Johnston et al. (2013). Attained height is well suited to rank order analysis since it varies continuously over a wide range. Rank order mobility in height is also helpful to distinguish changes in health equity from the many other changes in height associated with improved diets, sanitation and disease control, health services and care practices (Fogel 2004, Deaton 2013). Previous work on population heights typically focuses on the prevalence of extremes such as stunting rates, defined as the fraction of children whose height falls below two standard deviations below the median height-for-age of a healthy reference population (HAZ<-2). Many studies also use attained height to identify differential impacts of socioecological conditions, such as sex-specific vulnerability to climate shocks (Mulmi et al. 2016). Our goal is to measure change in health equity, as a distinct dimension of interest to many policymakers (Ottersen et al. 2014), and to do so regarding a health outcome known to be closely associated with many diverse aspects of human development including cognitive ability and future earnings (Case and Paxson 2008).

In our framework, *absolute upward mobility* is the expected height-for-age rank of children whose mothers have a low rank, such as the 25th percentile, and *relative mobility* is the expected difference in rank between children whose mothers are at the bottom and the top of their cohort's distribution. Having taller children is not desirable in itself, but short stature is often a sign of growth retardation associated with many later life outcomes (e.g. Dewey and Begum 2011; Bhalotra & Rawlings 2013; Frongillo et al. 2019), so mobility in attained height could be an important indicator for the intergenerational transmission of well-being in general. Height data also offers some advantages relative to income, expenditure, wealth, or education to quantify a society's equality of opportunity. First, measurement techniques have been subject to a high degree of scrutiny and improvement (Sommerfelt and Boerma 1994) and the data we use were collected using highly standardized methods producing relatively high-quality data (Assaf et al. 2015). Second, potential height is known to have no significant differences across racial or ethnic groups, making it a useful benchmark for health equity (WHO 2006, Garza et al. 2013). Third, heights are measured using continuous variables which helps mitigate empirical challenges with coarse data such as years of schooling (Asher et al. 2017). Fourth, there is no censoring at zero or need to impute values as might arise when studying income or wealth (Chetty et al. 2014). Finally, the mother's measured adult height fully reflects her lifelong attainment (Dewey and Begum 2011), whereas income and wealth fluctuate and are subject to other limitations (Emran and Shipli 2017).

Using changes in rank order of height has some advantageous features but also has limitations of its own. Most importantly, data quality does vary somewhat across surveys (Assaf et al. 2015, Finaret & Hutchinson 2018), so for this study we use only within-country changes in rank order, and do not merge surveys to examine health equity at the global level. Also, the surveys we use are nationally representative but may face selection bias and low power among the most under-served populations (Comandini et al. 2016), so for this study we address only the overall distribution and do not address subgroup differences. Third, there remains the possibility of statistical artifacts associated with the birth dates needed to compare child heights (Agarwal et al. 2017, Larsen et al. 2019, Finaret and Masters 2019a), so for this study we pool all birth months to ensure no effect of artifactual seasonality. A final contribution of our study related to data quality is to test the robustness of rank-order regression compared to direct tests of intergenerational transmission in the level of each variable. For example, Alesina et al. (2019) define upward mobility in education as the likelihood that children will complete primary school given that their parents have not done so. Using height data, we can compare rank-order mobility to other ways of measuring intergenerational transmission, as done by Chetty et al. (2016) in their work on incomes and life expectancy in the United States.

The purpose of our study is to identify local and national factors associated with differences in the intergenerational transmission of nutritional status between mothers and their children. Observed differences in height that persist from one generation to the next are due to the persistence of environmental conditions that constrain linear growth, and breaking that cycle is a precondition for widespread improvement in nutritional status (Garza et al. 2013; Whitaker et al. 2010; Venkataramani 2011). Our explorations are not causal, which would require a focus on a specific region of the world as well as a source of exogenous variation in the child growth environment, such as Bevis and Villa (2019) for the Philippines. Similar to recent explorations of the distribution of body mass index (BMI), we will assess disparities in nutritional mobility within and across cohorts (Krishna et al. 2015). Reaching zero intergenerational correlation is not feasible or desirable (Black and Devereux 2010), but delinking children's outcomes from their parent's status is highly desirable especially in settings where parental heights are likely to have been constrained by socioecological factors. In summary, the rank-order method could have widespread application in public health, allowing researchers to distinguish between genetics and other mechanisms of inheritance.

Background

This study intersects with two areas of literature. The first area of intersection is that of the intergenerational transmission of health status. The second is that of the environmental and genetic determinants of child growth.

Intergenerational transmission of health

Many studies in pediatrics, nutrition, and economics estimate the relationships between parent and child health outcomes. Intergenerational determinants of health refer to the conditions experienced by one generation that relate to the health and development of subsequent generations (Martorell and Zongrone 2012). These linkages are caused by four interrelated factors: genetics, gene-environment interactions, prenatal factors, and the early childhood growth environment. Child growth is jointly determined by genes, the environment, and gene-environment interactions (Addo et al. 2013). Parents pass on their genotypes that may have attributes affecting heights of their children. Parents also pass on aspects of their *phenotypes*, and if parents are exposed to adverse circumstances before or during conception, offspring may be negatively affected (Barker 1990). Finally, parents who have worse nutritional status may face greater constraints to caring for their own children, due to increased morbidity from infectious or non-communicable disease, reduced labor productivity, or cognitive effects (Venkataramani 2011).

Children born into an environment that is not conducive to health are less likely overcome poor maternal health status (Bhalotra and Rawlings 2013). Eriksson et al. (2014) use Blinder-Oaxaca decomposition analysis to measure disparities in intergenerational health transmission between rural and urban areas of China, finding stronger anthropometric associations between parents and children in urban areas. There may be heterogeneity in the transmission of health across groups, but for child heights at birth Addo et al. (2013) find no difference in the linkages between mother height and child height across study sites which included Brazil, Guatemala, India, the Philippines, and South Africa. The present study extends the literature on intergenerational transmission of health and child mortality, which includes investigations of birth weight (Currie and Moretti 2007; Royer 2009), body mass index (Classen and Thompson 2016, Dolton and Xiao 2017; Dolton and Xiao 2015), and heights in Vietnam (Venkataramani 2011).

Existing work on intergenerational transmission of body size has focused more on BMI and weights (Costa-Front and Gil 2013) than the heights of younger children. When child linear growth is the outcome of interest, mid-parental height is used as a main explanatory variable (Wright and Cheetam 1999). *The Young Lives Study* on intergenerational wealth and health transmission found only small effects of improvements in parental consumption and educational attainment on child heights, with models having predictive power ranging from just 17% in Ethiopia to 37% in Peru (Behrman et al. 2017). Given their results, the authors argue that efforts to reduce poverty and improve human capital development will take sustained work over many years, as opposed to being able to spur improvements with a one-time program or project. Other work on intergenerational transmission of health from mothers to children in India focuses on binary outcomes such as mortality, stunting, and wasting, and finds that maternal heights measured in centimeters is negatively associated with child stunting (Subramanian et al. 2009).

Environmental and genetic determinants of child growth

Many characteristics of the human growth environment are confounders of the relationship between parent height and child height, causing challenges for nutritional epidemiology to analyze gene-environment interactions. This study aims to distinguish between the socioeconomic and environmental factors from genetic constraints to child growth by studying children in relation to their peers and separately in relation to their parents. Household, community, and environmental circumstances that are more favorable to child growth would break the intergenerational transmission of nutritional status, leaving only genetic differences to account for similarities in height between parent and child. Normal genetic variation in attained height has been established by the World Health Organization's *Multicenter Growth Reference Study* (MGRS), for which healthy children of diverse parents raised under ideal health-care conditions in various environments around the world were included (WHO 2006; Garza et al. 2013). By exploring transmission of nutritional status within the parent height distribution, changes to child rank can be attributable to the growth environment. Parent height distributions can also be studied within the grandparent height distribution, as in Emanuel et al. (2004) in the U.S. context. Emanuel et al. (2004) find that maternal grandmother's heights is a determinant of maternal height, and use the R^2 values of their models as evidence that the variability in the height outcomes is being captured by all included covariates.

Twin studies, studies of adopted children (Thompson 2014), studies that utilize anthropometric data from extended family members (Black and Devereux 2010), and strategic instrumental variables estimates (Bevis and Villa 2019; Venkataramani 2011) can help address challenges with causal inference for studying intergenerational health (Black and Devereux 2010). Global meta-twin studies have found that the relative contributions of genetics to the environment increases as children age, and that these genetic influences depend on child sex (Dubois et al. 2012, Jelenkovic et al. 2016). At the biochemical level, studies can directly analyze the impacts of genes on child heights (Paternoster et al. 2011) and child weights (Li et al. 2018, Warrington et al. 2013). However, collecting data on twins, adoptees, or of genetic polymorphisms costly and logistically challenging, and datasets do not necessarily include important household and community-level characteristics, which are the main sources of variation in child and adult heights (WHO 2006; Garza et al. 2013). Given current challenges to studying the gene-environment nexus, examining observational data with a new empirical strategy may be helpful and allow for a global perspective.

Data and empirical strategy

We compiled 77 recent DHS surveys from 49 countries around the world, from which we used all mother-child dyads for which heights were measured. The DHS are nationally representative surveys for which the respondent is a woman of childbearing age (ICF International 2005-2018). Detailed information about households, women of childbearing age, and child health and nutrition is collected about every five years in participating countries through a collaboration of national Ministries of Health and the U.S. Agency for International Development (USAID) and distributed by ICF International. To construct the database, we appended the individual datasets together and used the sub-sample of measured children who were at least 24 months of age at the time of measurement and who had mothers without missing anthropometric data.

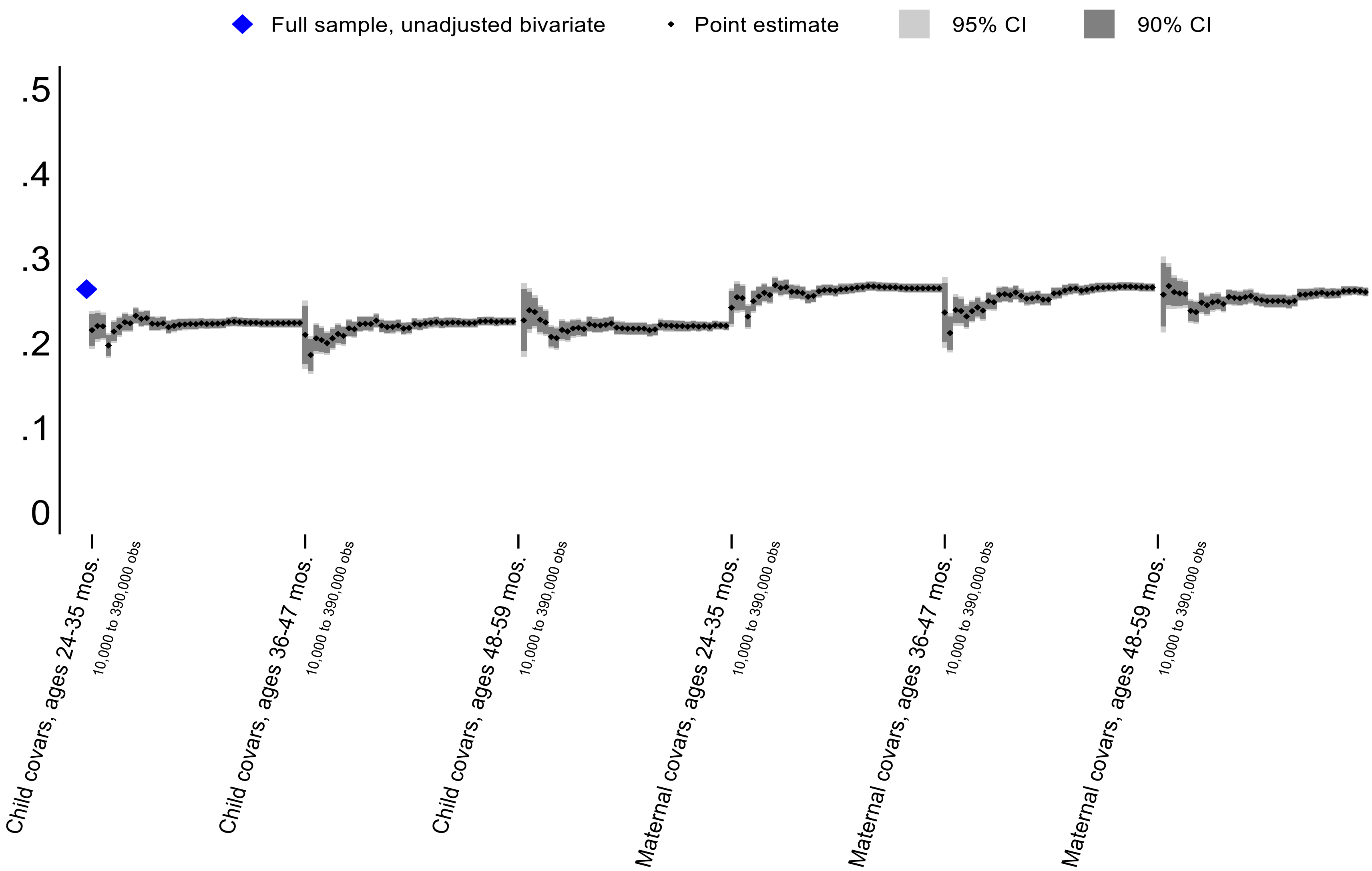
Several variables for children and their mothers were used directly or constructed using the height data available from the DHS to account for both absolute and relative disparities in heights: height in centimeters, the natural logarithm of height in centimeters, height-for-age difference using the WHO child growth reference (Leroy et al. 2015), height-for-age z-scores, the percentile rank in height-for-age z-score within cohorts, and the actual minus the predicted HAZ rank for children. For rankings indicators, children were ranked against others who shared their year and country of birth. Mothers were ranked against other mothers who had children born in the same year and country as their own children. By construction, these percentile-ranking variables have a uniform distribution which ranges from 0-100, where a child ranked at 40, for example, would be taller for their age, sex, birth year, and country of birth than 40 percent of his or her cohort.

The first step for analysis was to explore the sensitivity of intergenerational nutrition mobility estimates to different variable formats and sub-samples. We did this by estimating univariate regressions of the different child height variables on the different maternal height variables under several sub-samples of the dataset. We then calculated the range and standard deviations of the estimated coefficients across these sub-samples and within a given height variable formats. The ranges and standard deviations of the estimated coefficients are an indicator of how sensitive each height variable format is to changes in the sub-sample used. The larger the ranges and standard deviations are, the less stable the coefficient estimates are across different sub-samples and variable definitions.

Within rank-order regressions, we also visualized how much the estimated coefficient between mother child height depended on child age, the inclusion of covariates, and the sample size. To do this, we constructed a specification chart (Figure 1) where each black point represents a run of the model with the given features as well as the 90% and 95% confidence intervals around each estimate. This chart was made using code adapted from Hans Sievertsen, which he has generously made available on GitHub[1]. The blue point in the figure is the unadjusted bivariate association between child percentile rank and mother's percentile rank in HAZ. There is a high degree of consistency across model specifications, even for vastly different sample sizes running between 10,000 and 389,000 observations. Confidence intervals are narrower as sample size increases as would be expected, and the estimated beta coefficient between child and maternal rank in HAZ increases slightly in magnitude as maternal controls are added in the latter three models. Estimates of the beta coefficient between child and maternal rank in HAZ have a mean of 0.238 and a standard deviation of 0.020, with a range of 0.185 to 0.267. There are no appreciable differences in estimated coefficients between age groups of children. When measuring child and maternal height by HAZ and not ranks, the standard deviation of the estimated coefficients is greater, at 0.029, and the range is wider, between 0.237 and 0.372 across the same sets of specifications.

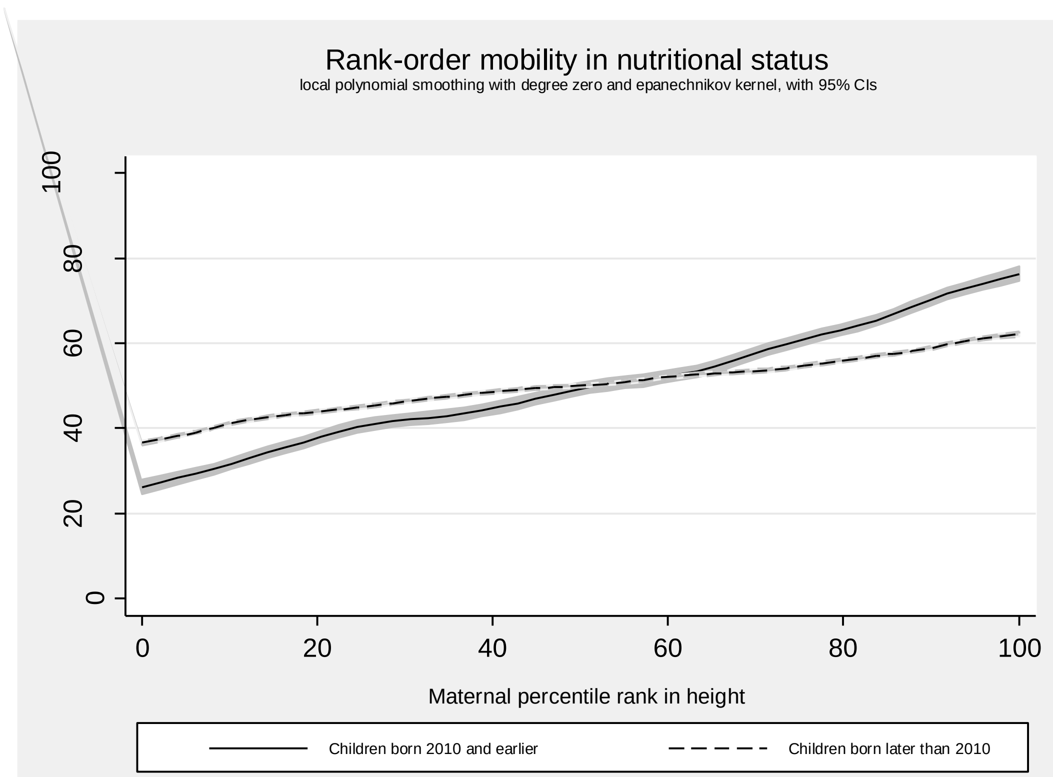
[1] https://github.com/hhsievertsen/speccurve/blob/master/README.md

Figure 1: Specification Chart for 235 specifications across child age groups, included covariates, and number of observations. Within each specification, 39 estimates are made at 10,000 to 390,000 observations at N=10,000 intervals.



The next step was to use the most stable height variable formats – the percentile rank in HAZ for mothers and their children – to construct nonparametric visualizations of nutrition mobility. Using a nonparametric visualization can help determine the best estimator and functional form for subsequent parametric estimates. We construct similar nonparametric charts for other comparisons as described below. The visualizations we use are local polynomial smoothing regressions, to see whether there are differences in nutritional mobility over time in these data. As described in Chetty et al. (2014), a 45-degree line in a chart like Figure 2 would imply that there was a perfect one-to-one matching of a mother's percentile rank in height to a child's percentile rank in height. A horizontal line would imply that maternal and child heights were completely de-linked. Figure 2 is a graphical representation of absolute and relative nutritional mobility across the whole sample, stratified by the period in which the child was born. The sample was split at the median year of birth, which was 2010. Children born earlier had lower absolute nutritional mobility and had heights that were more highly linked to the heights of their mothers, as indicated by the steeper slope in the estimated smoothed polynomial. Children born later had a higher absolute upward mobility and a lower relative mobility, indicated in the shallower slope of the estimated smoothed polynomial.

Figure 2: Rank-order mobility by earlier and later-born children



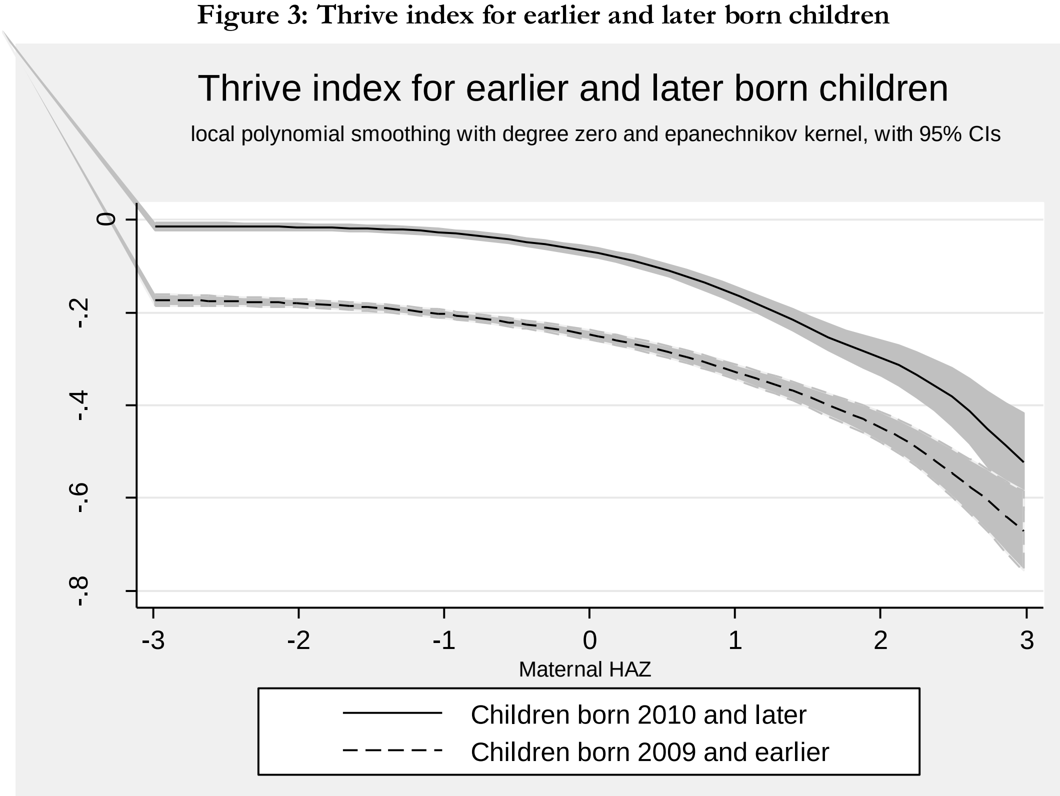
After exploring the stability of the model estimates and the nonparametric relationships between child and mother ranks in HAZ, we constructed an additional indicator of nutritional mobility called the *Child Thrive Index* (CTI). The CTI accounts for regression to the mean in repeated measures data (Equation 1). Intergenerational height data are susceptible to regression to the mean, similarly to repeated measures within the same child such as for measuring catch-up growth (Cameron et al. 2005). The CTI is equal to the actual child HAZ minus the predicted child HAZ given his or her mothers' HAZ.

$$CTI_{ij} = Child\ HAZ_{ij} - \left(\hat{\alpha}_c + \hat{\beta}_c Maternal\ HAZ_{ij}\right) \quad (1)$$

Related work in the pediatric growth literature addresses regression to the mean in child height and weight data in this way (Wright et al. 1994; Cameron et al. 2005). A positive value for the CTI indicates that the child is doing better than expected in terms of his or her linear growth, and a negative value indicates that the child is doing worse than expected for his or her linear growth. In Figure 3, the CTI is visualized across the maternal HAZ gradient, again splitting the sample between earlier- and later-born children. In the rightward extremes of maternal HAZ, the CTI declines sharply which is consistent with regression to the mean. For children born 2009 and earlier, the CTI is strictly negative, indicating that these children were doing worse than expected given their mother's percentile rank in HAZ. In contrast, for children born 2010 and later, the CTI is positive between maternal HAZ of -3 to +2. As would be expected given regression to the mean, the CTI plummets below zero after maternal HAZ equal to about +2 for both earlier-born and later-born children.

A visualization of the relationship between maternal and child HAZ, the fitted values for a linear regression between maternal and child HAZ, and the CTI is provided in Figure S1. That the CTI is not positive even for the shortest mothers indicates regression to the mean is not powerful enough to overcome the biophysical limitations and promote nutritional mobility by itself. Evidence that an additional indicator of nutritional mobility was needed to account for regression to the mean was found by examining the discrepancies between maternal and child heights throughout the maternal HAZ gradient. To do this, we first tabulated the number of children who were within either one or two centile spaces of their own mothers' HAZ, and calculated the average difference between maternal and child HAZ within each maternal HAZ category (Table S1). After calculating the CTI, we estimated summary statistics of the CTI by global region (Table S2).

Figure 3: Thrive index for earlier and later born children



Child-level estimates

Next, we estimate univariate and multivariate regressions of child percentile rank in HAZ on mother percentile rank in HAZ, disaggregated by global region. We first estimate unadjusted associations, then added child-level controls and maternal-level controls. Then, we restrict the model to only the 10^{th} -90^{th} percentiles for child HAZ to explore the sensitivity of this full model to a narrower sub-sample of the data. In the multivariate regressions, we use several key control variables from the DHS into the model that are measured at the child level or the maternal or household level. The control variables we include are child age in linear and quadratic terms, child sex, mother's years of education, number of children in the household under age 5, household wealth, and the year of birth as a time trend. Here, i indexes children and j indexes their country and year of birth cohorts. X is a vector of child- and maternal-level control variables, and μ is an independent and identically distributed error term.

$$Child\ HAZ\ rank_{ij} = \alpha + \beta(Maternal\ HAZ\ rank)_{ij} + \gamma\vec{X}_{ij} + \mu_{ij} \quad (2)$$

Community-level estimates

The next step was to construct summary indicators of nutritional mobility by country and by sub-national region. Examining results by sub-national region is important to understand potential disparities in nutritional mobility within countries. We are interested in nutritional mobility patterns across countries and within countries, with the expectation that there is wide variation in nutritional mobility across both dimensions. When conducting the analysis by subnational region, we excluded subnational regions with fewer than 100 observations. We tabulated results from 50 of the most populous subnational regions in the dataset (Table S6). To construct the four indicators in the columns of Table 2 and Table S6, we followed Chetty et al. (2014) and adapted their methods for use with intergenerational transmission of heights.

First, *absolute upward mobility* is equal to the expected or predicted rank of a child at maternal HAZ rank equal to 25. This variable was constructed by estimating the univariate rank-order HAZ regressions by country for the 49 included countries. For those countries with more than one included DHS survey, all surveys for each given country were included in a single regression, and children were ranked within their birth year cohorts as described above. Therefore, within each country, absolute upward mobility is given by Equation (3), where $\hat{\alpha}$ equals the estimated intercept term and $\hat{\beta}$ equals the estimated coefficient from a univariate regression of child percentile rank in HAZ on mother's percentile rank in HAZ. Here, c indexes countries, country-years or subnational regions depending on the spatial resolution in question.

$$AbsUpMobility_c = \hat{\alpha}_c + \hat{\beta}_c(25) \quad (3)$$

Second, *relative mobility* is defined as the difference in expected child height rank between children with mothers in the 100^{th} percentile of the height distribution and children with mothers in the 0^{th} percentile of the height distribution. The larger this number, the more persistent is nutritional status across generations. This indicator is equal to the slope of the rank-rank regression multiplied by 100 for ease of interpretation.

$$Relative\ Mobility_c = \hat{\beta}_c \cdot 100 \quad (4)$$

Along with the above two indicators of nutritional mobility, we also tabulated two additional indicators in parallel with Chetty et al. (2014). The first indicator was the percentage of children in each country or subnational region who reached the highest (5^{th}) quintile for HAZ given that their mother was in the lowest (1^{st}) quintile for HAZ. The second indicator was the fitted values of a logistic regression of a binary indicator of stunting (HAZ<-2) on maternal HAZ rank at maternal HAZ rank=25, converted from log odds to probabilities. This indicator gives the probability that a child will be stunted given that his or her mother was ranked 25^{th} in the distribution of maternal heights. These two additional indicators of nutritional mobility and are tabulated in the results and may be useful indicators of nutrition mobility at a population level.

The penultimate step in our analysis was to estimate national and subnational correlates of nutritional mobility. To do this, we merge country- and year-level estimates of nutritional mobility with data from The World Bank on GDP per capita, urbanization, the food deficit, access to improved sanitation, and health expenditures as a percentage of GDP. We choose indicators at the national level that were broad metrics of economic resources and public health infrastructure. There were between 259 and 281 country- and year- combinations with sufficient data to conduct these analyses. We estimated univariate OLS regressions between each of the national-level indicators and each of the three indicators of nutritional mobility. Then, we estimated the same nutritional mobility indicators by subnational region to conduct a similar analysis using subnational spatial data provided directly by the DHS (ICF International 2005-2018). The subnational-level factors had a local focus on market access and agricultural production. By subnational region, we estimate the univariate OLS regressions between population density, global human settlement, travel time to the nearest city over 50,000 people, the length of the growing season, the vegetation index, and rainfall with each of the three nutritional mobility indicators.

Finally, we develop a single index that could indicate the degree of nutritional mobility across countries, accounting for several of the indicators developed in this study. To calculate this index, we followed the basic method used for the *Global Hunger Index* which was developed and is calculated annually by Welthungerhilfe and Concern Worldwide (von Grebmer et al. 2018). For the nutritional mobility index, we combined four indicators: Absolute upward mobility, Relative mobility, the probability of a child being stunted given that his or her mother was at HAZ rank equal to 25, and the mean CTI. We first restricted the sample to only the most recent DHS survey in each of the 49 included countries. The original estimates for relative mobility described previously were subtracted from 100 to adjust so that positive values indicate better nutritional mobility, just as for the absolute upward mobility indicator. Similarly, the probability that a child was stunted given that his or her mother had HAZ rank equal to 25 was constructed for the index as follows in Equation (5).

$$(1 - Prob(Stunted|Maternal\ HAZ\ rank = 25)) \cdot 100 \qquad (5)$$

In this way, we calculated the probability that a child was not stunted given that his or her mother was at HAZ rank equal to 25, so that again larger values indicate better nutritional mobility as with the other three indicators. Finally, we re-scaled the mean CTI within each country to be between 0-100 for ease of aggregation with the other indicators. The nutritional mobility index itself is equal to an evenly weighted sum of the four indicators and as described in Equation (6).

$$\frac{1}{4} \cdot AbsoluteUpwardMobility + \frac{1}{4} \cdot (100 - RelativeMobility) + \cdots \frac{1}{4} P(not\ stunted\ | Mat\ HAZ\ rank = 25) + \frac{1}{4} Mean\ CTI. \tag{6}$$

Therefore, the index as a whole is bounded between 0 and 100, and larger numbers indicate better overall nutritional mobility in the country.

Results

This section presents empirical estimates of nutritional mobility around the globe. The final database contained anthropometric information for 383,289 children in 49 countries born between 2005 and 2016. The subsample relevant to this study was for children aged 24 months and older and their mothers with complete anthropometric data in the DHS. This subsample was contained within 77 DHS surveys. Globally, four countries were represented in Europe and Central Asia (ECA), five countries in Latin America & the Caribbean (LAC), two countries in the Middle East and North Africa (MENA), six countries in South and Southeast Asia (SEA), five countries in Central Africa (CA), eleven countries in West Africa (WA), seven countries in East Africa (EA), and seven countries in Southern Africa (SA). Table S1 in the supplemental materials compiles summary statistics by survey on sample sizes, child age in months, as well as several measures of child and maternal height used for analysis.

Table 1 below presents the preliminary estimates of relative nutritional mobility under different variable definitions as indicated in the row headings and different samples as indicated in the column headings. Relative mobility has a minimum of 0.027 when measuring heights using centimeters and restricting to the 25th-75th percentiles. The maximum relative mobility estimate in this table is 0.331 when using the natural logarithm of heights in centimeters as the variable measures and restricting the sample to female children only. Overall, these estimates are relatively similar in magnitude to the rank-order results for income mobility found by Chetty et al. (2014). The smallest ranges and standard deviations of the estimated coefficients across samples is achieved when using rank-order regressions. When comparing results after restricting to less extreme values for height, such as just within the 25th to 75th percentiles for child height, we can observe the nonlinearities in the maternal-child height relationship. Across all variable definitions, the most substantial deviations from other estimates occurs when restricting the sample to between the 25th and 75th percentiles of children and their mothers. However, the change in coefficients across samples is lessened when using rank-order regressions. Just as found for income mobility by Chetty et al. (2014), the relationship between mother and child heights is nonlinear and therefore mobility estimates are sensitive to the point at which they are measured in the height distribution.

Table 1: Global relative nutritional mobility estimates under different variable definitions

Child height units	Maternal height units	(1) Full sample	(2) Poorest wealth quintile	(3) Richest wealth quintile	(4) Males	(5) Females	(7) Restricted to 25th-75th percentiles	(7) Restricted to 10th-90th percentiles	(8) Restricted to 5th-95th percentiles	(9) Birth cohort 2005-2010	(10) Birth cohort 2011-2016	(11) Sample stats of estimated coefficients (range) (sd)
cm	cm	0.188***	0.171***	0.185***	0.181***	0.196***	0.0267**	0.115***	0.155***	0.148***	0.166***	0.169
		(0.002)	(0.004)	(0.005)	(0.003)	(0.003)	(0.008)	(0.003)	(0.0100)	(0.00274)	(0.0027)	0.050
Log(cm)	Log(cm)	0.316***	0.290***	0.306***	0.302***	0.331***	0.0449**	0.192***	0.259***	0.245***	0.283***	0.286
		(0.0032)	(0.0062)	(0.0087)	(0.0045)	(0.0046)	(0.0137)	(0.0052)	(0.0165)	(0.0046)	(0.0046)	0.085
HAD	cm	0.197***	0.184***	0.193***	0.191***	0.204***	0.0575***	0.136***	0.169***	0.204***	0.219***	0.162
		(0.0013)	(0.0026)	(0.0035)	(0.0019)	(0.0019)	(0.0052)	(0.0016)	(0.0112)	(0.0019)	(0.0020)	0.047
HAZ	HAZ	0.293***	0.271***	0.289***	0.288***	0.299***	0.0779***	0.197***	0.247***	0.290***	0.324***	0.246
		(0.0020)	(0.0039)	(0.0053)	(0.0029)	(0.0029)	(0.0072)	(0.0024)	(0.0166)	(0.0029)	(0.0030)	0.072
Rank (HAZ)	Rank (HAZ)	0.263***	0.228***	0.238***	0.264***	0.262***	0.167***	0.192***	0.222***	0.256***	0.271***	0.104
		(0.0016)	(0.0031)	(0.0039)	(0.0022)	(0.0022)	(0.0294)	(0.0019)	(0.0087)	(0.0022)	(0.0022)	0.035
Rank (HAZ)	Rank(cm)	0.263***	0.227***	0.238***	0.264***	0.262***	0.168***	0.192***	0.222***	0.256***	0.271***	0.103
		(0.0016)	(0.0031)	(0.0039)	(0.0022)	(0.0022)	(0.0294)	(0.0019)	(0.0087)	(0.0022)	(0.0022)	0.034
Rank (cm)	Rank (cm)	0.237***	0.208***	0.215***	0.236***	0.237***	0.144***	0.167***	0.196***	0.235***	0.240***	0.096
		(0.0016)	(0.0031)	(0.0040)	(0.0022)	(0.0022)	(0.0251)	(0.0020)	(0.0073)	(0.0022)	(0.0022)	0.033
	N	383289	98493	56278	195189	188100	249485	249485	249485	194829	188460	N/A

Notes: This table recreates Table I of Chetty et al. (2014) for international height data. Models are univariate OLS regressions with constant terms not shown. This table reports only the estimated coefficient and its standard error on mother's height under various variable definitions. Ranks for children are defined within their birth cohort year and country. Ranks for mothers are defined within the set of other mothers who have children from the same birth cohort (by year) and country. Rankings do not change with sub-group analyses in columns 2-9. Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

One interesting global comparison is that between the Latin America and Caribbean region (LAC) with the rest of the world. Nutritional mobility is systematically worse in the LAC region compared with the rest of the world. Out of the 10 countries with the lowest absolute upward mobility, five are located in the LAC region (Table 2). Children surveyed in LAC have heights that are more closely linked to their mothers' heights.

Figure 4. Latin America and the Caribbean vs. Rest-of-world

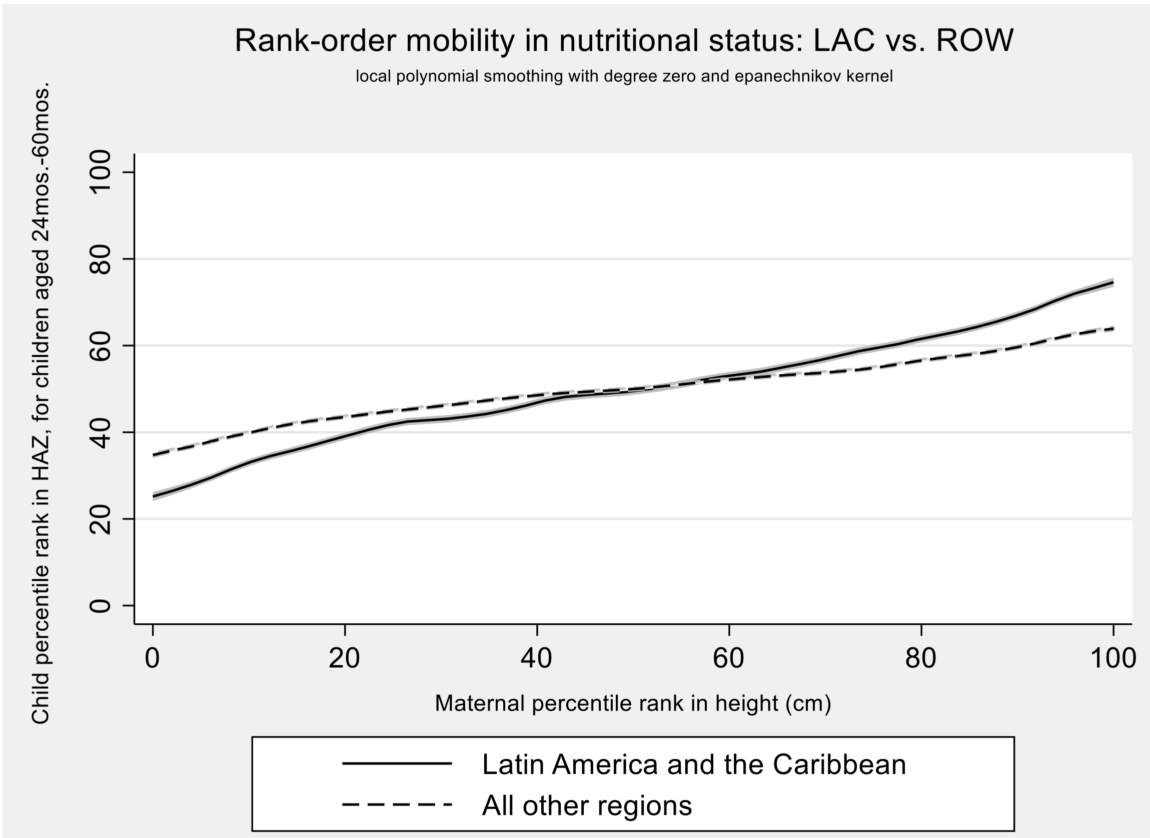


Table 2 presents estimates of global variation in nutritional mobility in more detail, recreating the structure of Table III of Chetty et al. (2014) but for international height data. The table shows nutritional mobility indicators for the 49 included countries, ranked from lowest absolute upward mobility to highest absolute upward mobility. The five countries with the lowest absolute upward mobility – Guatemala, Honduras, Guyana, Colombia, and Bolivia – are all located in the LAC region. Across all countries, there is little variation in the Column 3 results, which calculate the probability that a child born to a mother in the 1st quintile of the height distribution will reach the 5th quintile of the height distribution. These estimates range from 0.60% in Guatemala to 3.60% in Benin. Column 4 presents estimates of the probability that a child will be stunted (with HAZ <-2), given that his or her mother was in the 25th percentile of the height distribution. These estimates have a much wider range, from a low of 8.02% in the Dominican Republic to a high of 73.28% in Burundi. Relative mobility declines as absolute upward mobility increases, and ranges from 0.52 in Guatemala to just 0.05 in Benin. Countries with higher relative mobility have children whose heights are more tightly linked to the height of their mothers, and therefore in those regions there are more substantial intergenerational disparities across the height distribution for children in Guatemala compared to children in Benin, for example. The five countries in our dataset with the highest absolute upward mobility are Albania, Comoros, Madagascar, Mali, and Benin. The difference between absolute upward mobility in Benin and Guatemala is 11.83 rank-order positions in the height distribution.

The standard deviation of absolute upward mobility across countries in is 2.183. By construction, the standard deviation of the child percentile rank in HAZ variable is equal to that of the uniform distribution, or $\sqrt{\frac{(100-0)^2}{12}}$ in the case of a variable ranging from 0 to 100. This standard deviation equals about 28.94 for each of the year of birth and country level HAZ rankings, or 2.894 when relative mobility is measured by the raw slope before it is multiplied by 100. Therefore, a one standard deviation improvement in the nutritional circumstances within a country, indicated by absolute upward mobility, results in a $\frac{2.183}{2.894} = 0.754$ standard deviation improvement in the expected HAZ rank of children whose mothers were in the 25th percentile for HAZ. To compare, a direct improvement in maternal HAZ rank of one standard deviation is associated with a 0.263 standard deviation improvement in the expected HAZ rank of children, which is given by the relative mobility estimate for the whole sample together as presented in Column 1 of Table 2. Therefore, the national nutrition environment is about $\frac{0.754}{0.263} = 2.86$ times as powerful as a mother's individual height for promoting nutritional mobility in children. This finding is consistent with the evidence that linear growth retardation in low- and middle-income countries is driven mainly by the nutrition environment (Perkins et al. 2016). This finding is also consistent with the WHO MGRS, which found that children from all over the world have the same growth potential if raised in a healthy nutrition environment (WHO 2006).

However, this finding is in contrast with work using twin studies to examine the relative contributions of genetics and the environment to linear growth. In the human biology literature, heritability estimates range from about 0.6 to 0.9, three to four times as large as the relationship between maternal rank in HAZ and child rank in HAZ found in this study (Jelenkovic et al. 2016; Wehkalampi et al. 2008). This difference may arise because older children, adolescents, and adults are studied more in the human biology literature, whereas children younger than age 5 are studied more in the nutrition literature, and the relative contributions of genetics and the environment differ at different ages, as found for example by Dubois et al. (2012). The other possible reason is that studies of linear growth retardation are focused on regions of the world where it is an issue of public health concern and the nutrition environment is not ideal for child growth. Existing twin studies have been conducted mainly in higher-income countries like Sweden, Finland and Denmark, where the nutrition environment is already sufficient to promote healthy linear growth in children. Therefore, the estimated contributions of the environment compared to genetics is lower due to diminishing marginal returns.

In this example, it is important to remember that individual mother's heights are determined by her cumulative nutritional investment over her lifetime, which may include genetic, epigenetic, and environmental factors, and so this analysis can disentangle genetic from environmental influences on health at the child level but not the maternal level. The present findings that the environment matters more for nutritional mobility than maternal nutritional status are opposite to those for income mobility by Chetty et al. (2014), who found that the quality of a commuting zone for promoting income mobility provided about 60 percent as large of an improvement as parental income itself in determining a child's future income. In the case of income, parent outcomes are more significant predictors of child outcomes than the quality of the commuting zone. In contrast, the quality of the nutrition environment is a more significant predictor of child heights than mother's heights alone.

Table 2: Global variation in nutritional mobility

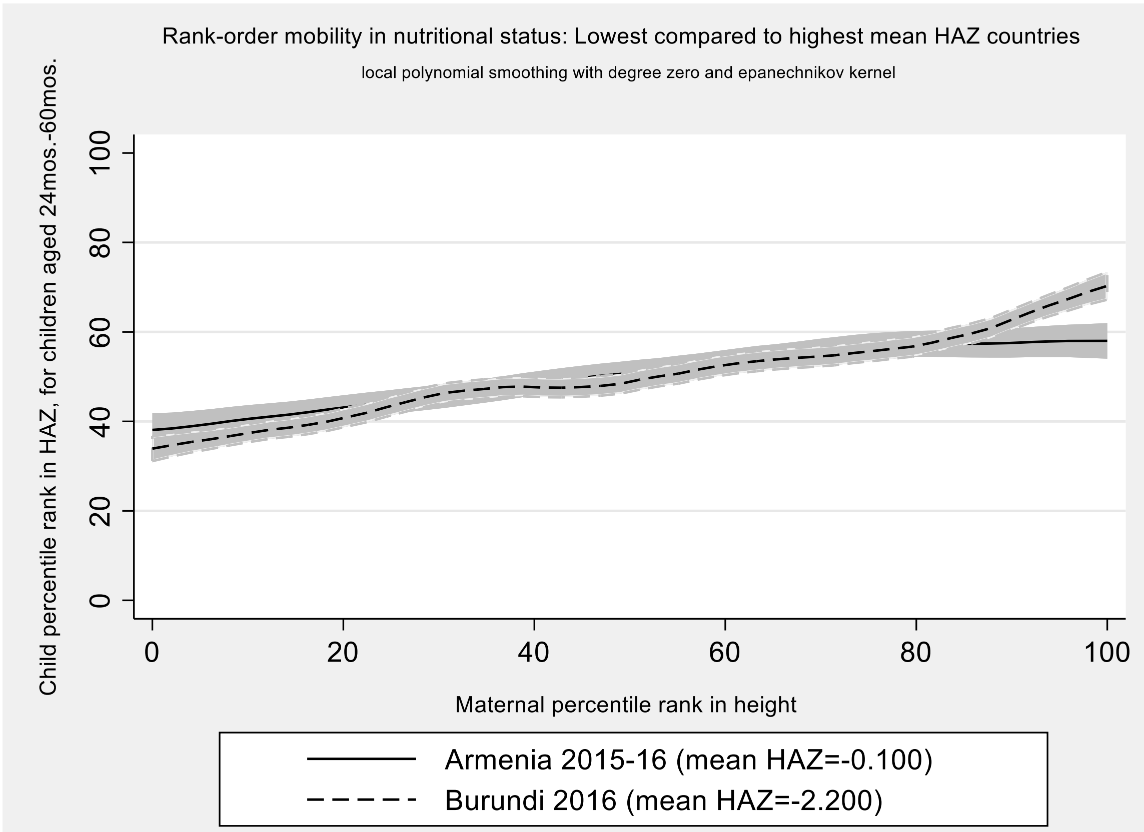
(1) Country Name	(2) Absolute Upward Mobility	(3) % Child in Q5 | Mother in Q1	(4) % Stunted	(5) Relative mobility/100
Guatemala	36.99	0.60	68.32	0.52
Honduras	37.80	0.99	46.06	0.49
Guyana	38.36	1.14	33.60	0.47
Colombia	39.39	0.98	23.11	0.42
Bolivia	40.60	1.33	41.92	0.38
Gabon	41.54	1.56	32.81	0.34
Swaziland	41.77	1.81	37.29	0.33
Rwanda	42.04	1.59	57.36	0.32
Burundi	42.28	1.77	73.28	0.31
Bangladesh	42.30	2.05	56.78	0.31
Cambodia	42.47	2.13	56.87	0.30
Dominican Republic	42.62	1.62	8.02	0.29
Uganda	42.69	2.02	45.45	0.29
Zimbabwe	42.86	1.89	41.53	0.28
Haiti	42.92	2.28	34.62	0.28
Tanzania	42.95	1.90	47.24	0.28
Myanmar	42.98	2.03	48.70	0.28
Mozambique	43.03	2.43	53.51	0.28
Cote d'Ivoire	43.08	2.20	44.93	0.28
Nepal	43.16	2.22	64.26	0.27
Jordan	43.21	2.02	14.43	0.27
India	43.22	2.24	52.24	0.27
Zambia	43.36	2.47	54.19	0.26
Lesotho	43.38	2.29	54.93	0.26
Malawi	43.41	1.90	54.04	0.26
Kyrgyz Republic	43.50	1.94	26.54	0.26
Ghana	43.63	2.45	35.43	0.25
Kenya	43.73	2.13	40.52	0.25
Cameroon	43.90	1.91	47.39	0.24
Senegal	43.91	1.85	38.84	0.24
Armenia	43.92	2.54	8.97	0.24
Tajikistan	43.94	2.50	29.91	0.24
DR-Congo	44.03	2.27	63.39	0.24
Namibia	44.16	1.66	41.36	0.29
Togo	44.43	2.58	42.56	0.22
Burkina Faso	44.55	2.19	47.94	0.22

Ethiopia	44.71	2.35	55.87	0.21
Nigeria	44.82	2.80	50.66	0.20
Guinea	45.14	2.79	46.37	0.19
Egypt	45.28	2.38	22.76	0.19
Liberia	45.28	2.61	52.16	0.19
Sierra Leone	45.71	2.60	48.15	0.17
East Timor	45.73	3.25	62.85	0.17
Chad	45.81	2.96	59.27	0.17
Albania	45.83	1.97	16.65	0.17
Comoros	46.07	1.96	31.94	0.16
Madagascar	46.11	2.95	60.00	0.16
Mali	46.31	2.58	49.44	0.15
Benin	48.82	3.60	51.41	0.05
Mean	43.42	2.128	44.41	0.263
Standard Deviation	2.183	0.571	14.91	0.087

Notes: This table recreates Chetty et al. (2014) for international height data. The table shows nutritional mobility across 49 countries between 2005-2017. Countries are ranked by Column 2, from lowest to highest. Column 2 contains Absolute upward mobility, which is calculated as the fitted values at maternal HAZ rank =25 on the univariate rank-rank regressions. Column 3 is the percentage of children out of the sample within the country who reached the 5th (highest) quintile for HAZ given that their mother was in the 1st (lowest) quintile for HAZ. Column 4 are the fitted values of a logistic regression of a binary indicator of stunting (HAZ<-2) on maternal HAZ rank at maternal HAZ rank =25, converted from log odds to probabilities. Column 5 is relative mobility, or the slope of the estimated rank-rank relationship within each country.

Figure 5 compares nutritional mobility in the country with the highest mean HAZ in the dataset, which was Armenia in 2016, to the country with the lowest mean HAZ in the dataset, which was Burundi in 2016. Visualizations using nonparametric smoothing indicate that there is are no substantial differences in the relationship between maternal and child height rank between the two countries, except for the top fifth of mothers in the maternal height distribution. These results suggest that nutritional mobility is measuring a different aspect of nutritional status than just mean HAZ alone.

Figure 5: Armenia 2016 (highest mean HAZ) compared with Burundi 2016 (lowest mean HAZ)



We further demonstrate that mobility is a different phenomenon than mean HAZ by comparing nutritional mobility in two countries that had the same mean HAZ at the time the DHS was implemented there: Benin in 2011-2012 and Guatemala in 2014-2015. Despite that these countries had the same mean HAZ at the time of the DHS survey, nutritional mobility in Benin is much better than in Guatemala. In Guatemala, children are much more highly linked to the heights of their mothers, whereas in Benin the heights of mothers and children are de-linked.

Figure 6: Comparison of nutritional mobility between two countries with the same mean HAZ: Benin in 2011-2012 and Guatemala in 2014-2015.

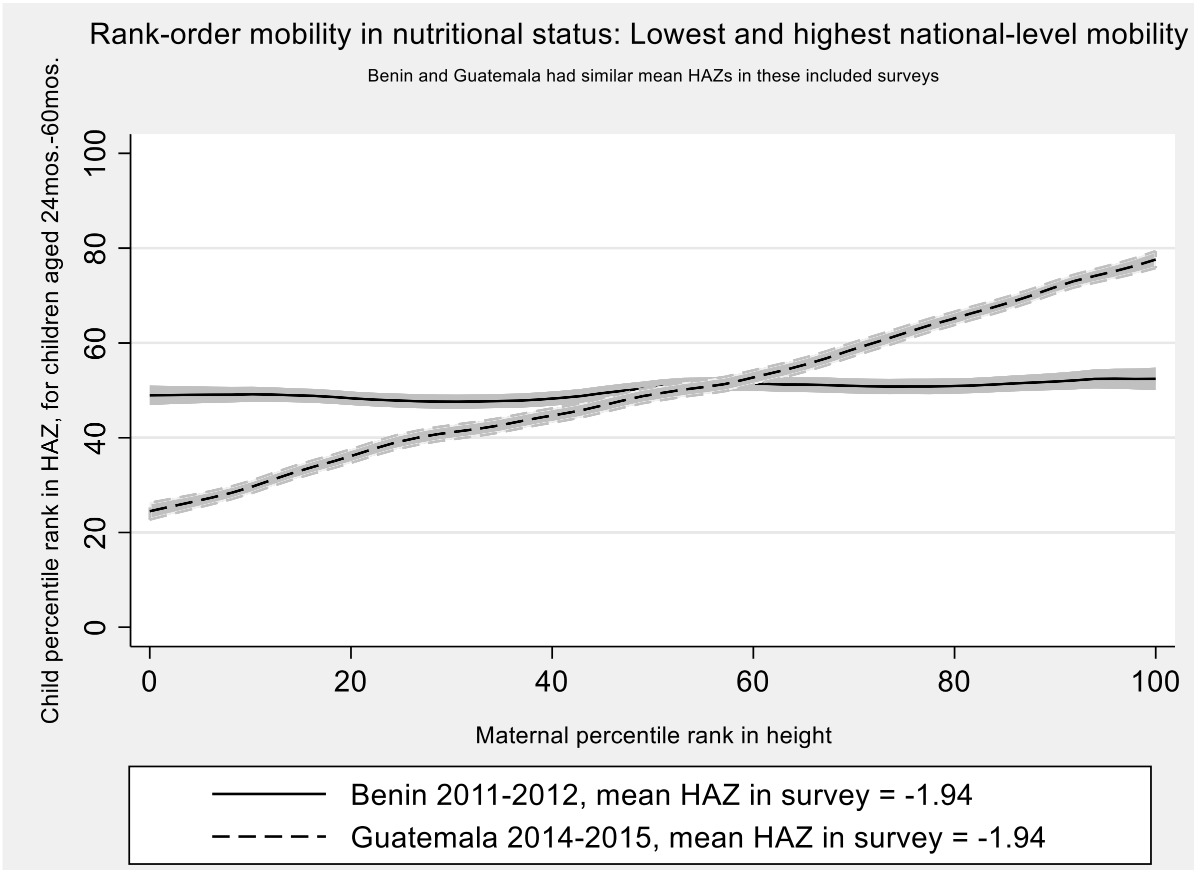


Table 3 presents our main results for the determinants of nutritional mobility under different variable definitions. Column 5 of Table 3 is the preferred specification for estimating the association between maternal heights and child heights. In this model, the association between maternal percentile rank in HAZ and child percentile rank in HAZ is 0.202 (S.E. 0.0017). Column 6 of this table presents the associations between the CTI and various child and maternal characteristics. There is no maternal height variable in this model because maternal height is incorporated into the CTI as indicated above in Equation 1. The CTI is lower for male children and is higher for children of mothers with more years of education and wealth. The CTI is higher for later born children, but only later born children in rural areas, not urban areas. In rural areas, being born one year later is associated with a 0.03 HAZ point increase in the CTI. The CTI is negatively associated with the number of children under age 5 living in the household, and not associated with child age in months. Further analysis if the determinants of the CTI split by global region can be found in Table S2 in the Supplemental Materials.

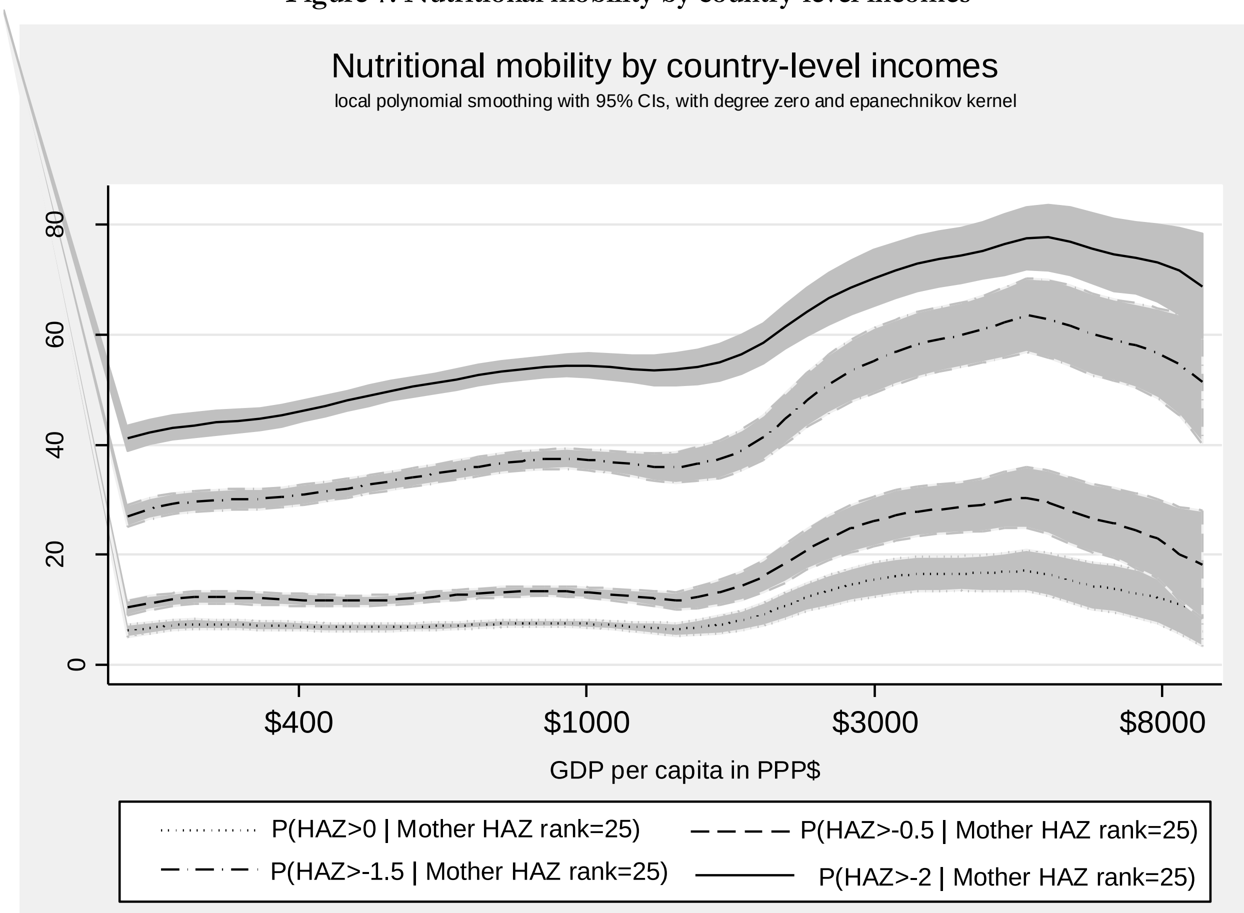
Table 3: Nutritional mobility under different variable definitions and incorporating covariates

	(1)	(2)	(3)	(4)	(5)	(6)
Child height variable	cm	Ln(cm)	HAD	HAZ	Pctile Rank	CTI
Maternal height variable	cm	Ln(cm)	cm	HAZ	Pctile Rank	-
Maternal height variable	0.173***	0.294***	0.173***	0.262***	0.202***	-
	(0.0017)	(0.0029)	(0.0017)	(0.0026)	(0.0017)	
Child age in months	0.787***	0.0101***	-0.173***	-0.0204***	-0.259***	-0.0204***
	(0.0082)	(0.0001)	(0.0082)	(0.0021)	(0.0403)	(0.0021)
(Child age in months)^2	-0.00283***	-0.0000495***	0.00107***	0.000212***	0.00181***	0.000212***
	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.0005)	(0.0000)
Child is male	0.887***	0.00991***	0.0192	-0.0537***	-1.021***	-0.0542***
	(0.0186)	(0.0002)	(0.0186)	(0.0048)	(0.0917)	(0.0048)
Mother's education (years)	0.0811***	0.000886***	0.0809***	0.0207***	0.443***	0.0190***
	(0.0029)	(0.0000)	(0.0029)	(0.0007)	(0.0143)	(0.0007)
Number of children (count of <5yrs in hhld)	-0.146***	-0.00162***	-0.148***	-0.0390***	-0.914***	-0.0379***
	(0.0106)	(0.0001)	(0.0106)	(0.0027)	(0.0521)	(0.0027)
Household wealth categorical (1=poorest, 5=richest)	0.486***	0.00530***	0.486***	0.124***	2.756***	0.118***
	(0.0115)	(0.0001)	(0.0115)	(0.0029)	(0.0564)	(0.0029)
Year of birth (time trend)	-0.251***	-0.00269***	-0.249***	-0.0608***	-1.322***	-0.0606***
	(0.0185)	(0.0002)	(0.0185)	(0.0047)	(0.0909)	(0.0047)
N	383087	383087	383087	383087	383086	383086

Notes: Data are OLS regressions of where the outcome variables is child height measured in several different ways as indicated. Each regression was estimated using fixed-effects of the survey cluster. The explanatory variables are a binary indicator of child sex, age in months, a quadratic term for age in months, the year of birth for a time trend, a categorical indicator of wealth which is calculated by the DHS within survey strata, maternal education in single years, and the count of the number of children under age 5 living in the household. Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The maternal height variable is incorporated into the calculation of the CTI and is therefore not included as a covariate in Column 6.

While using ranked-order regression is helpful for improving the stability of coefficient estimates, changes in HAZ rank can be difficult to interpret given differences in the distribution of child height across cohorts and countries. To obtain a visualization of the national-level results, we calculated the probabilities for each birth year and country cohort to be at HAZ>0.00, HAZ>-0.50, HAZ>-1.50, and HAZ>2.00 given that their maternal HAZ rank was equal to 25. We obtained these probabilities from a logistic regression where the binary outcome variable was equal to one if the given HAZ condition was met and zero otherwise. The dotted line shows the probability that a child will have HAZ>0 if his or her mother had an HAZ ranking equal to 25, across the GDP per capita gradient for all the year-of-birth and country combinations available in the dataset, of which there were 281. Similarly, the solid line shows the probability that a child will not be stunted, given that his or her mother had an HAZ rank equal to 25. Each of the nonparametric functions are positively associated with GDP per capita after about $1,500 per person per year. In the poorest countries in the dataset, a child born to a mother at HAZ rank equal to 25 has about a 40 percent chance of not being stunted. In the richest countries in this dataset with GDP per capita of between $7,000 and $8,000, a child born to a mother at HAZ rank equal to 25 has a 75% to 80% chance of not being stunted. Compared to milder manifestations of linear growth retardation, the probability of avoiding worse stunting outcomes such as HAZ<-2 or HAZ<-1.5 have stronger associations with national-level incomes across the spectrum of GDP per capita. This indicates that improvements to intergenerational mobility happen easier for the most at-risk children, but also implies that improvements to milder forms of linear growth faltering may be harder to achieve simply with income growth.

Figure 7: Nutritional mobility by country-level incomes



We now turn to empirical results that measure the associations between spatially aggregated measures of nutritional mobility and various economic and environmental factors. Table 4 presents the associations between three indicators of nutritional mobility and various national-level economic and environmental factors. For these estimates, mobility indicators are calculated at the country-year level, and these indicators were then merged with data from The World Bank on GDP, urbanization, food deficits, sanitation, and health expenditures. Absolute upward mobility is negatively correlated with GDP and with the percent of the population with access to basic sanitation. This indicates that, as countries get richer and more families have access to basic sanitation, the expected gains made in child growth across generations shrinks. The magnitude of the associations found is not very large, especially considering that the range of absolute upward mobility estimates by country were between about 36 and 48 in Table 2.

That the absolute upward mobility is negatively associated with national incomes may be due to diminishing marginal returns of GDP on nutritional improvement. For countries towards the bottom of the income distribution, improvements in intergenerational transmission of nutritional status will come much more quickly than for countries towards the top of the income distribution. After a certain point, absolute upward mobility in human height is not a public health concern because there is already drastically less linear growth retardation. Although height is good proxy for wealth in many ways, it does have the limitation that, after a certain point, people will not care to accumulate more height, and more even more height after that point can be detrimental to cardiovascular health in particular. There is no similar threshold effect for incomes or wealth.

Relative mobility is positively associated with GDP per capita, urbanization, and sanitation. A 10 percent increase in GDP per capita is associated with a 35.6 increase in relative mobility and a ten percent increase in sanitation use is associated with a 9.78 increase in relative mobility. Going back to the technical definitions, the difference in HAZ rank between a child born to a mother in the 100^{th} percentile for HAZ and a child born to a mother in the 0^{th} percentile for HAZ increases with GDP per person and sanitation. The magnitudes estimated here are not large, but the results indicate increasing disparities between children of the tallest mothers and children of the shortest mothers as national incomes grow. This indicates that an understanding how increases in GDP are distributed in the population will be essential for characterizing the intergenerational nutritional risks.

The CTI is positively associated with GDP per capita, urbanization, and sanitation. A 1 percent increase in GDP per capita is associated with a 0.360 increase in the CTI, a relationship that is relatively small in magnitude. A 10 percent increase urban population is associated with a 0.15 increase in the CTI. The CTI is negatively associated with the food deficit. A deficit of 100 kcal per person per day is associated with a -0.127 reduction in the CTI. This is a relatively substantial relationship, given that the mean values of the CTI ranged from -0.554 in CA to 0.841 in MENA. This indicates that food availability per capita at the national-level is still a major determinant of whether children can reach their growth potential.

Table 4: National-level economic and health correlates of nutritional mobility

Correlate	(1) GDP Per Capita	(2) Urbanization	(3) Food Deficit	(4) Sanitation	(5) Health expenditure
Units	Log of Expenditure-side real GDP at chained PPPs (in mil. 2011US$), per capita	% of population living in urban areas	Kcal/person/day	% of population using at least basic sanitation services	Health expenditure as a % of GDP
Outcome: Absolute upward mobility	-0.892***	-0.0183*	0.00272*	-0.0244***	-0.105
	[-1.199,-0.584]	[-0.033,-0.003]	[0.000,0.005]	[-0.034,-0.015]	[-0.224,0.013]
Constant	49.49***	44.07***	42.89***	44.39***	44.07***
	[47.391,51.593]	[43.486,44.661]	[42.369,43.408]	[43.947,44.842]	[43.306,44.831]
*Outcome: Relative mobility*100*	3.569***	0.0735*	-0.0109*	0.0978***	0.420
	[2.334,4.804]	[0.013,0.135]	[-0.021,-0.001]	[0.060,0.136]	[-0.057,0.897]
Constant	1.867	23.54***	28.30***	22.26***	23.59***
	[-6.573,10.308]	[21.184,25.904]	[26.214,30.390]	[20.463,24.057]	[20.529,26.654]
Outcome: CTI	0.360***	0.0154***	-0.00127***	0.0117***	0.0139
	[0.316,0.404]	[0.013,0.018]	[-0.002,-0.001]	[0.010,0.013]	[-0.009,0.037]
Constant	-2.469***	-0.559***	0.209***	-0.480***	-0.104
	[-2.770,-2.168]	[-0.650,-0.468]	[0.122,0.297]	[-0.543,-0.418]	[-0.251,0.043]
N	281	281	259	281	272

Notes: Models are univariate estimates of the associations between the listed national-level economic and social factors with absolute upward mobility, relative mobility, and the CTI. Absolute upward mobility is defined as the fitted values for expected child rank in HAZ given his or her mother is in the 25th percentile for HAZ. Relative mobility, or the slope coefficient in the estimated rank-rank regressions, is equal to the difference in mean child HAZ rank between children with mothers in the 100th percentile for HAZ and children with mothers in the 0th percentile for HAZ. The CTI is defined as the difference between actual child HAZ and predicted child HAZ given maternal HAZ. All models are estimated with standard errors clustered by country. There are 49 included countries. Environmental variables are means of the DHS-clusters for each subnational region; data come from the DHS Spatial Correlates Database, documentation here. 95% confidence intervals in brackets; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

There are 555 unique subnational regions that constitute the final dataset, and about 480 of the regions had subnational spatial covariates available for analysis. Table 5 presents the associations between three indicators of nutritional mobility and various sub-national environmental and agricultural factors: Population density, human settlement, travel time to the nearest city, the length of the growing season, the vegetation index, and rainfall per year. For these estimates, the three mobility indicators are calculated at the subnational level. Absolute upward mobility is positively associated with population density and human settlement. It is negatively associated with the travel time to the nearest city over 50,000 people and the vegetation index. Relative mobility is not associated with these sub-national factors. The CTI is positively associated with population density and human settlement, and negatively associated with travel time to the nearest city. Rainfall is not significantly associated with any of the mobility indicators. These results, combined with those at the country-level in Table 4, indicate that nutritional mobility is better in areas of denser human settlement, such as urban areas.

Table 5: Subnational-level environmental and agricultural correlates of nutritional mobility

	(1)	(2)	(3)	(4)	(5)	(6)
Correlate	Population density	Global human settlement	Travel time	Length of growing season	Vegetation index	Rainfall
Units	1000s of people/km	Continuous: 1=extremely urban, 0=extremely rural	Log(Minutes to nearest city of >=50,000)	Categorical, groups of 30 days	Log(Continuous: 10000=most vegetation, 0=least vegetation)	Log(Millimeters/year)
Outcome: Absolute upward mobility	0.787*** [0.535,1.039]	14.77*** [11.59,17.96]	-9.352*** [-12.51,-6.199]	-0.240* [-0.438,-0.0424]	-3.894*** [-6.102,-1.686]	-0.486 [-1.242,0.270]
Constant	43.21*** [42.38,44.04]	42.77*** [41.80,43.73]	59.39*** [54.51,64.28]	46.50*** [44.76,48.24]	75.43*** [57.92,92.95]	47.77*** [42.71,52.83]
*Outcome: Relative mobility*100*	-0.0000460 [-0.000,0.000]	-0.260 [-7.749,7.229]	-0.510 [-2.423,1.403]	1.054* [0.247,1.861]	7.715* [1.139,14.292]	2.683 [-0.248,5.614]
Constant	24.92*** [21.651,28.192]	24.65*** [21.290,28.011]	27.44*** [17.925,36.951]	15.18*** [7.922,22.448]	-36.97 [-89.165,15.223]	5.698 [-14.627,26.024]
Outcome: CTI	0.0000431*** [0.000,0.000]	1.004*** [0.704,1.303]	-0.184*** [-0.275,-0.093]	0.0207 [-0.028,0.069]	0.0137 [-0.326,0.354]	0.00477 [-0.195,0.205]
Constant	-0.132* [-0.260,-0.005]	-0.158* [-0.283,-0.033]	0.881*** [0.410,1.353]	-0.236 [-0.685,0.213]	-0.160 [-2.883,2.563]	-0.0842 [-1.523,1.354]
N	472	484	476	484	484	484

Models are univariate estimates of the associations between the listed national-level economic and social factors with absolute upward mobility, relative mobility, and the CTI. Absolute upward mobility is defined as the fitted values for expected child rank in HAZ given his or her mother is in the 25th percentile for HAZ. Relative mobility, or the slope coefficient in the estimated rank-rank regressions, is equal to the difference in mean child HAZ rank between children with mothers in the 100th percentile for HAZ and children with mothers in the 0th percentile for HAZ. The CTI is defined as the difference between actual child HAZ and predicted child HAZ given maternal HAZ. All models are estimated with standard errors clustered by country. There are 49 included countries. Environmental variables are means of the DHS-clusters for each subnational region; data come from the DHS Spatial Correlates Database, documentation here. 95% confidence intervals in brackets; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Conclusion

Many projects, programs and policies aim to stop the intergenerational transmission of malnutrition. However, the degree of economic and social change needed to break intergenerational malnutrition linkages is likely more intensive than the set of individual health promotion programs can provide, so understanding the joint roles of local and national factors at modifying the intergenerational links between parents and their children is essential. The intergenerational transmission of health is itself a biologically and socially plausible mechanism for the transmission of socioeconomic outcomes, and therefore necessitates a close look (Ahlburg 1998; Venkataramani 2011). Using rank-order regression improves the stability of coefficient estimates for the intergenerational transmission of nutritional status. Rank-order regressions have more stability than regressions of child HAZ on maternal HAZ. Nutritional mobility is a separate phenomenon to average heights. Countries with similar mean HAZ for children under age five can have very different degrees of nutritional mobility, and countries with very different mean HAZs can have similar degrees of nutritional mobility.

The LAC region has some of the largest gaps in child HAZ between children of the tallest and shortest mothers. There is wide variation in nutritional mobility across and within countries, and the gap in HAZ between children born to the shortest mothers and children born to the tallest mothers increases with GDP per capita. Access to populated areas that have hospitals and markets is positively associated with nutritional mobility. The length of the growing season and the amount of vegetation in a sub-national region is negatively associated with nutritional mobility. Children born between 2005 and 2009 have worse nutritional mobility compared to children born between 2010 and 2018, indicating that nutritional mobility on average is improving over time. The quality of the national nutrition environment is about 2.86 times as powerful as an individual mother's height at determining a child's HAZ ranking. Previous analyses of the DHS have found that decreases in mean HAZ as children age are the results of shifts of the whole HAZ distribution and not driven by the extremes in HAZ, which is evidence for addressing the nutrition environment to improve child linear growth (Roth et al. 2017).

The strengths of this study include its newly developed indicators of nutritional mobility, the use of an empirical strategy that provides stability in coefficient estimates, the disentanglement of genetic from environmental determinants of child nutrition, and its global focus. This analysis was not designed to elicit causality but instead to develop a method to provide more stable estimates of the associations between parent and child health outcomes. Further work is needed to understand how to promote nutritional mobility within populations, so that children can escape from malnutrition traps. Obtaining data on local factors at a fine resolution, including factors like food prices and local weather patterns, may help improve understanding of nutritional mobility. Additional work to understand whether there are additional child-level determinants of nutritional mobility would also be useful, such as exploring the role of birth order, care practices, and gender.

There are two main policy implications of this work. First, raw data on current child nutrition indicators in a country is not necessarily sufficient for understanding nutritional status in that country. A more detailed approach would incorporate aspects of nutritional mobility to understand how local and national environments influence the intergenerational transmission of nutritional status within a country, even without interventions or policy initiatives. Studying intergenerational transmission in nutritional status is a useful way to use cross-sectional data to explore an arguably longitudinal and long-term outcome, which is especially valuable in settings without longitudinal data collection for child nutritional status. Understanding nutritional mobility can help determine which local populations are at higher risk of remaining trapped in a cycle of malnutrition across generations, and can be prioritized for intervention. Second, low nutritional mobility in many parts of the world necessitates that policymakers are not only aggressive with their efforts to improve child nutritional status but also persistent over time, because adverse nutritional circumstances can affect populations for generations. Observing progress at improving child linear growth will take time, and articulating this to funding bodies this will allow policymakers around the world to argue for sustained and improved nutrition programming in their countries.

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Supplemental Materials

Table S1: Summary statistics by included survey

Region	Country	Year	N	Child age (months)	Child height (cm)	HAD	HAZ	CTI (HAZ)	Maternal height (cm)	Maternal HAZ
Europe & Central Asia	Albania	2008	864	42.63	97.04	-2.37	-0.58	0.62	160.73	-0.50
				10.19	9.77	7.59	1.93	1.91	6.20	1.04
	Albania	2017	1,516	41.06	96.62	-1.81	-0.53	0.72	159.85	-0.65
				10.54	8.60	5.58	1.42	1.42	6.15	1.03
	Armenia	2015	945	41.23	98.19	-0.36	-0.16	1.10	159.90	-0.64
				10.48	8.73	6.07	1.55	1.52	5.70	0.96
	Kyrgyz Republic	2012	2,265	40.55	93.69	-4.41	-1.13	0.17	159.13	-0.77
				10.30	7.62	4.62	1.19	1.16	5.41	0.91
	Tajikistan	2012	2,655	40.35	92.91	-5.06	-1.32	0.00	158.69	-0.84
				10.49	8.23	5.34	1.38	1.35	5.52	0.93
	Tajikistan	2017	3,504	40.89	94.18	-4.14	-1.12	0.23	158.22	-0.92
				10.24	7.82	5.06	1.28	1.25	5.54	0.93
Latin American & Caribbean	Bolivia	2008	4,504	41.24	92.83	-5.71	-1.45	-0.70	151.52	-2.04
				10.39	7.66	4.60	1.17	2.11	5.61	0.94
	Colombia	2009	9,369	41.44	94.98	-3.68	-0.94	0.59	155.25	-1.42
				10.40	7.70	4.22	1.08	0.98	6.23	1.04
	Dominican Republic	2013	1,854	41.59	97.43	-1.33	-0.34	0.97	158.89	-0.81
				10.45	8.17	4.46	1.14	1.09	6.34	1.06
	Guyana	2009	963	40.85	94.27	-3.99	-1.02	0.53	154.77	-1.50
				10.68	8.60	5.40	1.39	1.25	7.56	1.27
	Guatemala	2014	6,371	41.23	90.92	-7.62	-1.94	-0.03	148.63	-2.53
				10.26	7.60	4.72	1.18	1.04	6.02	1.01
	Haiti	2012	2,191	40.70	93.14	-5.02	-1.29	0.02	158.92	-0.80
				10.47	8.24	5.11	1.30	1.25	6.22	1.04
	Honduras	2011	5,630	41.21	92.84	-5.69	-1.44	0.24	152.49	-1.88
				10.39	7.61	4.65	1.17	1.03	6.34	1.06
Middle East & North Africa	Egypt	2014	7,895	40.67	95.89	-2.30	-0.59	0.69	159.33	-0.73
				10.15	9.52	7.18	1.84	1.81	5.45	0.91
	Jordan	2007	2,684	41.27	95.41	-3.14	-0.79	0.56	158.19	-0.92
				10.36	8.34	5.77	1.49	1.48	6.14	1.03
	Jordan	2012	3,864	41.61	96.45	-2.34	-0.59	0.77	157.97	-0.96
				10.36	7.70	4.29	1.08	1.03	5.73	0.96
South & Southeast Asia	Bangladesh	2007	3,143	41.37	90.69	-7.93	-2.00	-0.21	150.66	-2.18
				10.42	7.74	5.01	1.25	1.19	5.46	0.92
	Bangladesh	2011	8,836	41.74	91.80	-7.07	-1.79	-0.02	151.05	-2.12

				10.29	7.79	5.11	1.28	1.23	5.49	0.92
	Cambodia	2005	4,339	41.47	90.56	-8.13	-2.06	-0.37	152.42	-1.89
				10.41	7.44	5.05	1.25	1.20	5.27	0.88
	Cambodia	2014	2,503	41.40	91.97	-6.66	-1.68	0.16	152.97	-1.80
				10.55	7.44	4.71	1.19	1.69	5.19	0.87
	East Timor	2009	4,784	41.15	89.27	-9.19	-2.34	-0.54	150.59	-2.20
				10.29	8.13	6.09	1.56	1.56	5.30	0.89
	East Timor	2016	3,608	41.36	91.90	-6.73	-1.76	-0.04	151.89	-1.98
				10.24	9.23	7.44	1.90	1.89	5.49	0.92
	India	2015	137,306	41.48	92.00	-6.71	-1.69	0.03	151.82	-1.99
				10.31	8.17	5.92	1.50	1.46	5.88	0.99
	Myanmar	2015	2,512	41.32	91.92	-6.69	-1.70	0.00	152.24	-1.92
				10.21	7.49	4.52	1.14	1.10	5.28	0.89
	Nepal	2006	3,223	41.46	89.70	-8.96	-2.27	-0.48	150.76	-2.17
				10.48	7.46	4.86	1.19	1.15	5.38	0.90
	Nepal	2011	1,435	41.28	90.59	-8.01	-2.03	-0.28	151.32	-2.08
				10.20	7.53	4.87	1.21	1.17	5.29	0.89
	Nepal	2016	1,390	41.40	91.77	-6.89	-1.81	-0.06	151.47	-2.05
				10.30	7.62	4.87	1.20	1.15	5.51	0.92
Central Africa	Burundi	2010	1,953	40.73	89.12	-9.12	-2.35	-0.86	155.84	-1.32
				10.15	7.53	5.11	1.29	1.23	6.22	1.04
	Burundi	2016	3,471	41.79	89.76	-9.10	-2.35	-0.85	155.53	-1.37
				10.64	7.53	5.10	1.24	1.17	6.07	1.02
	Cameroon	2011	2,719	40.84	91.94	-6.32	-1.63	-0.40	160.23	-0.58
				10.45	8.57	5.91	1.51	1.46	6.21	1.04
	Chad	2014	5,887	41.85	90.71	-8.19	-2.09	-0.97	162.11	-0.27
				10.42	9.10	7.00	1.77	1.75	6.21	1.04
	DR-Congo	2007	1,858	40.60	89.75	-8.36	-2.13	-0.74	157.48	-1.04
				10.43	8.47	6.76	1.71	1.66	7.48	1.25
	DR-Congo	2013	4,585	41.06	89.98	-8.43	-2.14	-0.71	156.83	-1.15
				10.38	8.18	6.58	1.64	1.60	6.97	1.17
	Gabon	2012	1,797	40.41	93.52	-4.47	-1.15	0.21	158.00	-0.96
				10.41	8.39	5.28	1.37	1.30	6.28	1.05
West Africa	Benin	2011	4,494	41.47	90.99	-7.71	-1.94	-0.58	160.07	-0.61
				10.24	9.62	8.23	2.09	1.38	6.48	1.09
	Burkina Faso	2010	3,788	40.78	91.62	-6.64	-1.72	-0.58	161.83	-0.32
				10.31	8.40	5.49	1.41	1.38	5.84	0.98
	Cote d'Ivoire	2011	1,729	39.94	91.66	-6.06	-1.59	-0.28	158.88	-0.81
				10.22	8.07	5.45	1.41	1.36	6.00	1.01
	Ghana	2008	1,359	41.29	92.75	-5.81	-1.49	-0.19	159.12	-0.77
				10.45	8.19	5.43	1.37	1.35	6.30	1.06
	Ghana	2014	1,534	40.75	93.34	-4.90	-1.26	0.03	159.23	-0.75
				10.45	7.87	4.49	1.15	1.10	5.90	0.99

	Guinea	2012	1,718	40.78	92.08	-6.19	-1.59	-0.34	159.96	-0.63
				10.05	8.45	6.24	1.58	1.56	6.12	1.03
	Liberia	2006	2,439	41.06	90.80	-7.62	-1.95	-0.52	156.75	-1.17
				10.34	8.42	6.44	1.62	1.61	6.06	1.02
	Liberia	2013	1,736	41.38	91.94	-6.70	-1.72	-0.28	156.82	-1.15
				10.36	8.11	5.64	1.43	1.40	6.14	1.03
	Mali	2006	5,987	40.59	91.14	-6.99	-1.80	-0.63	161.30	-0.40
				10.22	9.32	6.88	1.77	1.75	6.23	1.04
	Mali	2012	2,649	41.69	91.91	-6.92	-1.78	-0.66	162.21	-0.25
				10.19	8.93	6.83	1.73	1.72	6.21	1.04
	Nigeria	2008	10,975	40.74	91.14	-7.08	-1.82	-0.46	158.12	-0.94
				10.22	9.46	7.37	1.90	1.88	6.59	1.11
	Nigeria	2013	14,059	41.14	91.81	-6.66	-1.71	-0.38	158.61	-0.85
				10.39	9.36	7.10	1.81	1.77	6.02	1.01
	Senegal	2010	1,951	40.28	92.49	-5.44	-1.41	-0.35	163.21	-0.08
				10.36	8.52	5.79	1.49	1.46	6.22	1.04
	Sierra Leone	2008	1,068	39.72	91.32	-6.25	-1.62	-0.13	155.91	-1.31
				10.13	9.33	7.53	1.96	1.98	10.34	1.73
	Sierra Leone	2013	2,390	40.41	91.81	-6.18	-1.59	-0.22	157.90	-0.97
				10.27	9.09	6.99	1.83	1.80	6.37	1.07
	Togo	2013	1,825	41.19	92.23	-6.26	-1.58	-0.28	159.05	-0.78
				10.20	7.71	5.07	1.27	1.25	6.00	1.01
East Africa	Comoros	2012	1,375	41.19	93.53	-4.98	-1.28	0.16	156.70	-1.17
				10.20	8.87	6.66	1.69	1.69	6.11	1.02
	Ethiopia	2010	5,829	41.19	90.58	-7.94	-2.05	-0.66	157.56	-1.03
				10.22	8.41	5.98	1.53	1.50	6.37	1.07
	Ethiopia	2016	5,091	41.00	91.83	-6.57	-1.74	-0.39	158.23	-0.92
				10.36	8.81	6.31	1.59	1.56	6.58	1.10
	Kenya	2008	2,966	41.17	92.42	-6.07	-1.57	-0.31	159.64	-0.68
				10.34	8.57	5.80	1.49	1.46	6.47	1.09
	Kenya	2014	5,301	40.99	93.09	-5.29	-1.36	-0.12	160.05	-0.61
				10.21	8.02	5.15	1.32	1.28	6.23	1.04
	Madagascar	2008	2,913	41.50	90.63	-8.08	-2.05	-0.42	153.40	-1.73
				10.39	8.30	6.64	1.68	1.67	5.76	0.96
	Rwanda	2010	4,582	40.92	90.98	-7.37	-1.89	-0.47	156.99	-1.13
				10.32	7.63	4.83	1.23	1.16	6.14	1.03
	Tanzania	2015	4,901	40.95	92.12	-6.22	-1.66	-0.24	157.09	-1.11
				10.48	7.88	4.84	1.23	1.18	6.04	1.01
	Uganda	2006	1,317	40.82	91.29	-6.98	-1.80	-0.50	159.11	-0.77
				10.32	8.02	5.55	1.43	1.39	6.47	1.09
	Uganda	2011	1,138	40.96	92.01	-6.37	-1.66	-0.38	159.42	-0.72
				10.06	8.25	5.33	1.37	1.33	6.22	1.04
	Uganda	2016	2,502	40.88	93.13	-5.15	-1.40	-0.12	159.35	-0.73

				10.54	8.35	5.08	1.30	1.24	6.22	1.04
Southern Africa	Lesotho	2009	870	41.51	91.24	-7.46	-1.90	-0.49	157.28	-1.08
				10.60	7.48	4.89	1.23	1.21	6.14	1.03
	Lesotho	2014	702	40.54	91.17	-6.88	-1.78	-0.39	157.42	-1.06
				10.51	7.88	4.77	1.23	1.18	6.04	1.01
	Malawi	2010	2,667	41.15	90.65	-7.83	-2.00	-0.55	156.40	-1.23
				10.30	7.94	5.42	1.38	1.35	6.03	1.01
	Malawi	2015	3,029	41.09	92.01	-6.42	-1.69	-0.22	156.12	-1.27
				10.21	7.63	4.95	1.25	1.21	5.67	0.95
	Mozambique	2011	5,186	40.80	91.29	-6.98	-1.78	-0.28	155.64	-1.35
				10.22	8.30	5.54	1.42	1.38	5.96	1.00
	Namibia	2006	1,876	40.74	92.55	-5.68	-1.47	-0.23	160.22	-0.58
				10.20	8.07	5.14	1.31	1.25	6.93	1.16
	Namibia	2013	896	40.03	92.50	-5.25	-1.37	-0.17	160.85	-0.48
				10.36	8.04	4.80	1.25	1.21	6.79	1.14
	Swaziland	2006	1,104	40.96	92.80	-5.53	-1.43	-0.13	159.12	-0.77
				10.48	8.15	4.46	1.16	1.11	5.75	0.96
	Zambia	2007	2,898	40.81	90.76	-7.50	-1.92	-0.54	157.76	-1.00
				10.28	8.22	5.82	1.49	1.45	6.44	1.08
	Zambia	2013	6,757	41.52	91.84	-6.86	-1.76	-0.36	157.46	-1.05
				10.42	8.48	5.59	1.43	1.39	6.11	1.03
	Zimbabwe	2005	2,227	41.54	92.49	-6.23	-1.59	-0.34	160.01	-0.62
				10.50	8.17	5.27	1.37	1.34	5.95	1.00
	Zimbabwe	2010	2,212	40.55	91.63	-6.47	-1.67	-0.43	160.13	-0.60
				10.40	8.28	4.56	1.20	1.17	5.94	1.00
	Zimbabwe	2015	2,826	41.19	93.55	-4.94	-1.34	-0.13	160.62	-0.52
				10.39	8.37	4.71	1.20	1.14	6.16	1.03

Figure S1: Regression to the mean in intergenerational height data

Figure S1 is a visualization of the construction of the CTI. The blue line is a nonparametric regression of child HAZ on maternal HAZ. The dotted red line are the fitted values for a univariate OLS regression of child HAZ on maternal HAZ. The purple line is the CTI, which equals actual child HAZ – predicted HAZ.

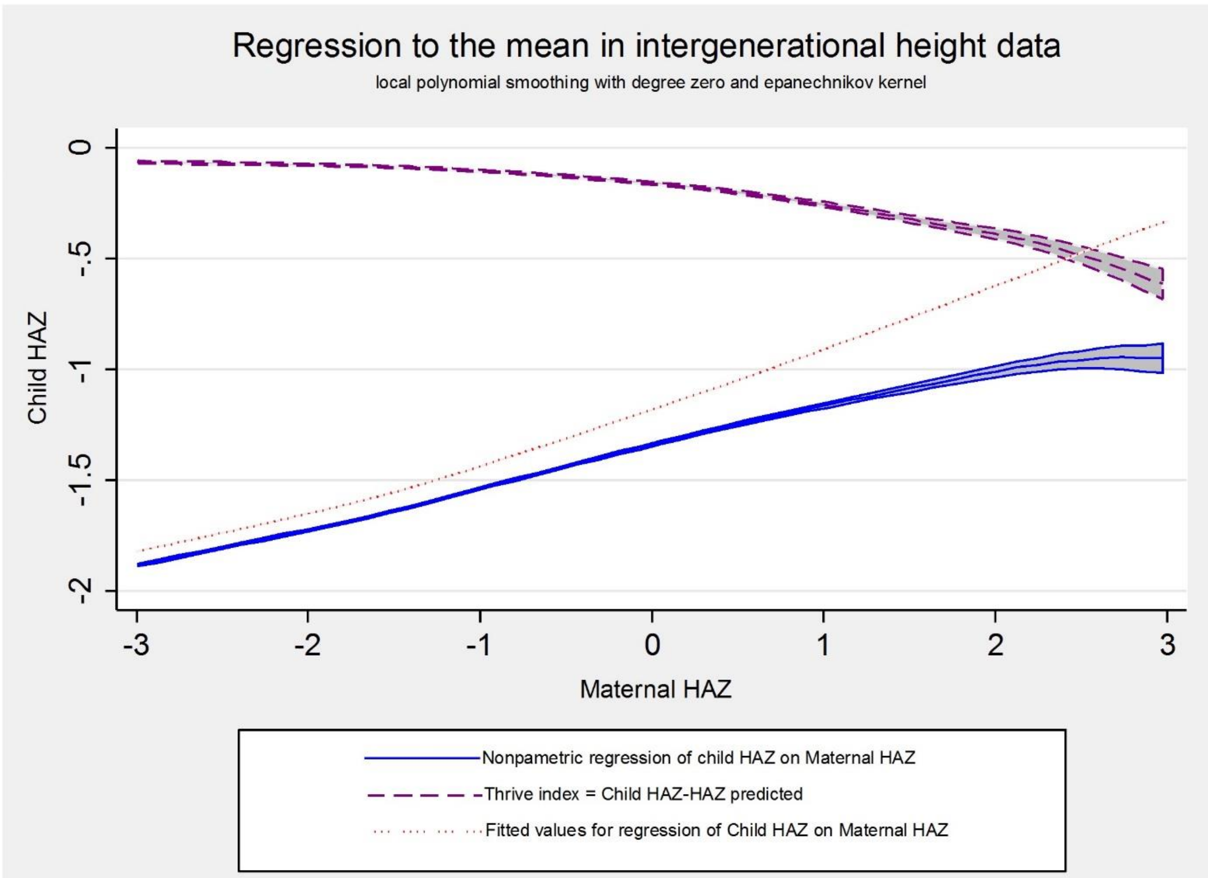

Table S1: Discrepancy between child and maternal heights by maternal HAZ

		HAZ Difference	>1 centile space (0.67 SD)		>2 centile spaces (1.33 SD)		Child Thrive Index (CTI)
Maternal HAZ	Number	Difference between child and maternal HAZ: *Mean (SD)*	Below maternal HAZ (% of children)	Above maternal HAZ (% of children)	Below maternal HAZ (% of children)	Above maternal HAZ (% of children)	HAZ, adjusted for regression to the mean *Mean (SD)*
<-3	32,512	1.131 (1.432)	8.98	62.91	3.48	41.06	-0.121 (1.399)
>=-3 to <-2	93,252	0.498 (1.431)	18.46	43.22	8.70	24.37	<0.001 (1.421)
>=-2 to <-1	125,633	-0.124 (1.478)	33.55	26.70	18.35	13.63	0.351 (1.465)
>=-1 to <0	87,757	-0.793 (1.571)	52.88	14.90	34.18	7.47	0.354 (1.557)
>=0 to <1	33,688	-1.555 (1.620)	72.53	7.11	54.90	3.51	-0.049 (1.606)
>=1 to <2	7,296	-2.308 (1.744)	85.27	3.87	72.46	1.99	-0.124 (1.728)
>=2 to <3	933	-3.317 (1.853)	94.53	1.29	87.89	0.54	-0.445 (1.838)
>=3	407	-5.063 (2.042)	0.00	0.00	0.00	0.00	-1.641 (1.765)
Total (N)	381,478	-0.201 (1.710)	140,224	110,058	86,899	61,078	<-0.001 (1.592)

Notes: This table reproduces Table 1 from Wright and Cheetham (1999) using the DHS data for child and maternal heights. The means within maternal HAZ categories for the CTI are smaller and tighter around zero than the means for the raw difference in HAZ between mothers and their children, which indicates that the procedure for adjusting for regression to the mean was successful (Wright et al. 1994).

Table S1 begins an analysis of regression to the mean in these intergenerational height data, with a reproduction of Table 1 from Wright and Cheetham (1999) using DHS data for child and maternal heights. Of the 32,512 children with mothers having HAZ<-3, only 8.98% of them had HAZ below the maternal HAZ and 62.91% of them had HAZ above maternal HAZ. A similar pattern can be seen throughout the table as maternal HAZ increases as defined in the rows. As maternal HAZ increases to a median of zero, the percent of children below their mother's HAZ rises and the percent of children above their mother's HAZ falls until the pattern is reversed after maternal HAZ becomes positive. For mothers with positive HAZ values, far greater percentages of children have HAZ below that of their mothers, while fewer children have HAZ above that of their mothers. Further, the HAZ difference, defined as the mean difference between maternal and child HAZ, declines as maternal HAZ increases. The mean difference in HAZ between children and mothers ranges from +1.13 for the shortest mothers to -5.06 for the tallest mothers. This table shows that the distribution of child heights around maternal height varies throughout the height distribution, just as shown by Wright and Cheetham (1999). Regression to the mean is of course expected in repeated measures data or intergenerational data such as these. This table indicates that another nutritional mobility indicator is necessary to overcome conflation of real results with the simple phenomenon of regression to the mean. The last column in this table is the CTI, calculated as the adjusted mean expected HAZ of children of mothers with HAZ given by the rows. The mean HAZs for the CTI are smaller and tighter around zero compared with the HAZ difference column, which indicates that adjustment for regression to the mean was successful (Wright and Cheetham 1999). As would be expected, the CTI equals approximately zero for the sample as a whole.

Table S2: Summary Statistics for the Child Thrive Index (CTI) by global region

	Europe & Central Asia	Latin America & Caribbean	Middle East & North Africa	South/ Southeast Asia	Central Africa	West Africa	East Africa	Southern Africa
CTI Mean	0.4810	0.4345	0.8411	0.0695	-0.5543	-0.2828	-0.2014	-0.1921
CTI SD	1.3980	1.1082	1.5762	1.4382	1.5520	1.7264	1.4111	1.3143
% of children in each category of CTI, by region								
<-2	4.15	1.79	3.97	6.47	16.76	15.54	9.46	7.63
<=-2- to -1	7.44	7.26	5.98	13.87	21.32	16.44	16.83	16.77
<=-1 to 0	22.24	24.57	15.67	28.97	27.44	24.74	30.43	32.51
<=0 to 1	33.51	36.74	29.95	28.79	20.08	23.01	26.34	28.02
<=1 to 2	21.58	22.43	26.39	13.91	9.57	12.14	11.34	10.45
<=2 to 5	10.59	7.16	16.60	7.49	4.58	7.55	5.39	4.43

Notes: Data are means, standard deviations, and percentages for the CTI by global region as indicated in the columns. Columns may not sum exactly to 100 due to rounding.

Table S2 presents summary statistics by global region for the CTI. These values are tighter around zero than raw mean HAZs, and range from -0.55 HAZ in CA to 0.84 HAZ in MENA. The MENA region has the most rightward skew of the CTI, where 72.94 percent of children have positive values of the CTI, indicating that they are doing better than expected given their mothers' position in the height distribution. Regions of Africa appear to have the most leftward skews of the CTI, where between 65.52 percent in CA and 56.72 percent of children in WA and EA are doing worse than expected given their mothers' positions in the height distribution. In LAC, 33.62 percent of children are doing worse than expected, and 66.33 percent of children are doing better than expected given their mothers' positions in the height distribution. In ECA, 33.83 percent of children are doing worse than expected, and 65.68 percent of children are doing better than expected.

Table S3: Summary statistics by included survey

Region	Country	Year	N	Child age (months)	Child height (cm)	HAD	HAZ	CTI (HAZ)	Maternal height (cm)	Maternal HAZ
Europe & Central Asia	Albania	2008	864	42.63	97.04	-2.37	-0.58	0.62	160.73	-0.50
				10.19	9.77	7.59	1.93	1.91	6.20	1.04
	Albania	2017	1,516	41.06	96.62	-1.81	-0.53	0.72	159.85	-0.65
				10.54	8.60	5.58	1.42	1.42	6.15	1.03
	Armenia	2015	945	41.23	98.19	-0.36	-0.16	1.10	159.90	-0.64
				10.48	8.73	6.07	1.55	1.52	5.70	0.96
	Kyrgyz Republic	2012	2,265	40.55	93.69	-4.41	-1.13	0.17	159.13	-0.77
				10.30	7.62	4.62	1.19	1.16	5.41	0.91
	Tajikistan	2012	2,655	40.35	92.91	-5.06	-1.32	0.00	158.69	-0.84
				10.49	8.23	5.34	1.38	1.35	5.52	0.93
	Tajikistan	2017	3,504	40.89	94.18	-4.14	-1.12	0.23	158.22	-0.92
				10.24	7.82	5.06	1.28	1.25	5.54	0.93
Latin American & Caribbean	Bolivia	2008	4,504	41.24	92.83	-5.71	-1.45	-0.70	151.52	-2.04
				10.39	7.66	4.60	1.17	2.11	5.61	0.94
	Colombia	2009	9,369	41.44	94.98	-3.68	-0.94	0.59	155.25	-1.42
				10.40	7.70	4.22	1.08	0.98	6.23	1.04
	Dominican Republic	2013	1,854	41.59	97.43	-1.33	-0.34	0.97	158.89	-0.81
				10.45	8.17	4.46	1.14	1.09	6.34	1.06
	Guyana	2009	963	40.85	94.27	-3.99	-1.02	0.53	154.77	-1.50
				10.68	8.60	5.40	1.39	1.25	7.56	1.27
	Guatemala	2014	6,371	41.23	90.92	-7.62	-1.94	-0.03	148.63	-2.53
				10.26	7.60	4.72	1.18	1.04	6.02	1.01
	Haiti	2012	2,191	40.70	93.14	-5.02	-1.29	0.02	158.92	-0.80
				10.47	8.24	5.11	1.30	1.25	6.22	1.04
	Honduras	2011	5,630	41.21	92.84	-5.69	-1.44	0.24	152.49	-1.88
				10.39	7.61	4.65	1.17	1.03	6.34	1.06
Middle East & North Africa	Egypt	2014	7,895	40.67	95.89	-2.30	-0.59	0.69	159.33	-0.73
				10.15	9.52	7.18	1.84	1.81	5.45	0.91
	Jordan	2007	2,684	41.27	95.41	-3.14	-0.79	0.56	158.19	-0.92
				10.36	8.34	5.77	1.49	1.48	6.14	1.03
	Jordan	2012	3,864	41.61	96.45	-2.34	-0.59	0.77	157.97	-0.96
				10.36	7.70	4.29	1.08	1.03	5.73	0.96
South & Southeast Asia	Bangladesh	2007	3,143	41.37	90.69	-7.93	-2.00	-0.21	150.66	-2.18
				10.42	7.74	5.01	1.25	1.19	5.46	0.92
	Bangladesh	2011	8,836	41.74	91.80	-7.07	-1.79	-0.02	151.05	-2.12
				10.29	7.79	5.11	1.28	1.23	5.49	0.92

	Cambodia	2005	4,339	41.47	90.56	-8.13	-2.06	-0.37	152.42	-1.89
				10.41	7.44	5.05	1.25	1.20	5.27	0.88
	Cambodia	2014	2,503	41.40	91.97	-6.66	-1.68	0.16	152.97	-1.80
				10.55	7.44	4.71	1.19	1.69	5.19	0.87
	East Timor	2009	4,784	41.15	89.27	-9.19	-2.34	-0.54	150.59	-2.20
				10.29	8.13	6.09	1.56	1.56	5.30	0.89
	East Timor	2016	3,608	41.36	91.90	-6.73	-1.76	-0.04	151.89	-1.98
				10.24	9.23	7.44	1.90	1.89	5.49	0.92
	India	2015	137,306	41.48	92.00	-6.71	-1.69	0.03	151.82	-1.99
				10.31	8.17	5.92	1.50	1.46	5.88	0.99
	Myanmar	2015	2,512	41.32	91.92	-6.69	-1.70	0.00	152.24	-1.92
				10.21	7.49	4.52	1.14	1.10	5.28	0.89
	Nepal	2006	3,223	41.46	89.70	-8.96	-2.27	-0.48	150.76	-2.17
				10.48	7.46	4.86	1.19	1.15	5.38	0.90
	Nepal	2011	1,435	41.28	90.59	-8.01	-2.03	-0.28	151.32	-2.08
				10.20	7.53	4.87	1.21	1.17	5.29	0.89
	Nepal	2016	1,390	41.40	91.77	-6.89	-1.81	-0.06	151.47	-2.05
				10.30	7.62	4.87	1.20	1.15	5.51	0.92
Central Africa	Burundi	2010	1,953	40.73	89.12	-9.12	-2.35	-0.86	155.84	-1.32
				10.15	7.53	5.11	1.29	1.23	6.22	1.04
	Burundi	2016	3,471	41.79	89.76	-9.10	-2.35	-0.85	155.53	-1.37
				10.64	7.53	5.10	1.24	1.17	6.07	1.02
	Cameroon	2011	2,719	40.84	91.94	-6.32	-1.63	-0.40	160.23	-0.58
				10.45	8.57	5.91	1.51	1.46	6.21	1.04
	Chad	2014	5,887	41.85	90.71	-8.19	-2.09	-0.97	162.11	-0.27
				10.42	9.10	7.00	1.77	1.75	6.21	1.04
	DR-Congo	2007	1,858	40.60	89.75	-8.36	-2.13	-0.74	157.48	-1.04
				10.43	8.47	6.76	1.71	1.66	7.48	1.25
	DR-Congo	2013	4,585	41.06	89.98	-8.43	-2.14	-0.71	156.83	-1.15
				10.38	8.18	6.58	1.64	1.60	6.97	1.17
	Gabon	2012	1,797	40.41	93.52	-4.47	-1.15	0.21	158.00	-0.96
				10.41	8.39	5.28	1.37	1.30	6.28	1.05
West Africa	Benin	2011	4,494	41.47	90.99	-7.71	-1.94	-0.58	160.07	-0.61
				10.24	9.62	8.23	2.09	1.38	6.48	1.09
	Burkina Faso	2010	3,788	40.78	91.62	-6.64	-1.72	-0.58	161.83	-0.32
				10.31	8.40	5.49	1.41	1.38	5.84	0.98
	Cote d'Ivoire	2011	1,729	39.94	91.66	-6.06	-1.59	-0.28	158.88	-0.81
				10.22	8.07	5.45	1.41	1.36	6.00	1.01
	Ghana	2008	1,359	41.29	92.75	-5.81	-1.49	-0.19	159.12	-0.77
				10.45	8.19	5.43	1.37	1.35	6.30	1.06
	Ghana	2014	1,534	40.75	93.34	-4.90	-1.26	0.03	159.23	-0.75
				10.45	7.87	4.49	1.15	1.10	5.90	0.99
	Guinea	2012	1,718	40.78	92.08	-6.19	-1.59	-0.34	159.96	-0.63

				10.05	8.45	6.24	1.58	1.56	6.12	1.03
	Liberia	2006	2,439	41.06	90.80	-7.62	-1.95	-0.52	156.75	-1.17
				10.34	8.42	6.44	1.62	1.61	6.06	1.02
	Liberia	2013	1,736	41.38	91.94	-6.70	-1.72	-0.28	156.82	-1.15
				10.36	8.11	5.64	1.43	1.40	6.14	1.03
	Mali	2006	5,987	40.59	91.14	-6.99	-1.80	-0.63	161.30	-0.40
				10.22	9.32	6.88	1.77	1.75	6.23	1.04
	Mali	2012	2,649	41.69	91.91	-6.92	-1.78	-0.66	162.21	-0.25
				10.19	8.93	6.83	1.73	1.72	6.21	1.04
	Nigeria	2008	10,975	40.74	91.14	-7.08	-1.82	-0.46	158.12	-0.94
				10.22	9.46	7.37	1.90	1.88	6.59	1.11
	Nigeria	2013	14,059	41.14	91.81	-6.66	-1.71	-0.38	158.61	-0.85
				10.39	9.36	7.10	1.81	1.77	6.02	1.01
	Senegal	2010	1,951	40.28	92.49	-5.44	-1.41	-0.35	163.21	-0.08
				10.36	8.52	5.79	1.49	1.46	6.22	1.04
	Sierra Leone	2008	1,068	39.72	91.32	-6.25	-1.62	-0.13	155.91	-1.31
				10.13	9.33	7.53	1.96	1.98	10.34	1.73
	Sierra Leone	2013	2,390	40.41	91.81	-6.18	-1.59	-0.22	157.90	-0.97
				10.27	9.09	6.99	1.83	1.80	6.37	1.07
	Togo	2013	1,825	41.19	92.23	-6.26	-1.58	-0.28	159.05	-0.78
				10.20	7.71	5.07	1.27	1.25	6.00	1.01
East Africa	Comoros	2012	1,375	41.19	93.53	-4.98	-1.28	0.16	156.70	-1.17
				10.20	8.87	6.66	1.69	1.69	6.11	1.02
	Ethiopia	2010	5,829	41.19	90.58	-7.94	-2.05	-0.66	157.56	-1.03
				10.22	8.41	5.98	1.53	1.50	6.37	1.07
	Ethiopia	2016	5,091	41.00	91.83	-6.57	-1.74	-0.39	158.23	-0.92
				10.36	8.81	6.31	1.59	1.56	6.58	1.10
	Kenya	2008	2,966	41.17	92.42	-6.07	-1.57	-0.31	159.64	-0.68
				10.34	8.57	5.80	1.49	1.46	6.47	1.09
	Kenya	2014	5,301	40.99	93.09	-5.29	-1.36	-0.12	160.05	-0.61
				10.21	8.02	5.15	1.32	1.28	6.23	1.04
	Madagascar	2008	2,913	41.50	90.63	-8.08	-2.05	-0.42	153.40	-1.73
				10.39	8.30	6.64	1.68	1.67	5.76	0.96
	Rwanda	2010	4,582	40.92	90.98	-7.37	-1.89	-0.47	156.99	-1.13
				10.32	7.63	4.83	1.23	1.16	6.14	1.03
	Tanzania	2015	4,901	40.95	92.12	-6.22	-1.66	-0.24	157.09	-1.11
				10.48	7.88	4.84	1.23	1.18	6.04	1.01
	Uganda	2006	1,317	40.82	91.29	-6.98	-1.80	-0.50	159.11	-0.77
				10.32	8.02	5.55	1.43	1.39	6.47	1.09
	Uganda	2011	1,138	40.96	92.01	-6.37	-1.66	-0.38	159.42	-0.72
				10.06	8.25	5.33	1.37	1.33	6.22	1.04
	Uganda	2016	2,502	40.88	93.13	-5.15	-1.40	-0.12	159.35	-0.73
				10.54	8.35	5.08	1.30	1.24	6.22	1.04

Southern Africa	Lesotho	2009	870	41.51	91.24	-7.46	-1.90	-0.49	157.28	-1.08
				10.60	7.48	4.89	1.23	1.21	6.14	1.03
	Lesotho	2014	702	40.54	91.17	-6.88	-1.78	-0.39	157.42	-1.06
				10.51	7.88	4.77	1.23	1.18	6.04	1.01
	Malawi	2010	2,667	41.15	90.65	-7.83	-2.00	-0.55	156.40	-1.23
				10.30	7.94	5.42	1.38	1.35	6.03	1.01
	Malawi	2015	3,029	41.09	92.01	-6.42	-1.69	-0.22	156.12	-1.27
				10.21	7.63	4.95	1.25	1.21	5.67	0.95
	Mozambique	2011	5,186	40.80	91.29	-6.98	-1.78	-0.28	155.64	-1.35
				10.22	8.30	5.54	1.42	1.38	5.96	1.00
	Namibia	2006	1,876	40.74	92.55	-5.68	-1.47	-0.23	160.22	-0.58
				10.20	8.07	5.14	1.31	1.25	6.93	1.16
	Namibia	2013	896	40.03	92.50	-5.25	-1.37	-0.17	160.85	-0.48
				10.36	8.04	4.80	1.25	1.21	6.79	1.14
	Swaziland	2006	1,104	40.96	92.80	-5.53	-1.43	-0.13	159.12	-0.77
				10.48	8.15	4.46	1.16	1.11	5.75	0.96
	Zambia	2007	2,898	40.81	90.76	-7.50	-1.92	-0.54	157.76	-1.00
				10.28	8.22	5.82	1.49	1.45	6.44	1.08
	Zambia	2013	6,757	41.52	91.84	-6.86	-1.76	-0.36	157.46	-1.05
				10.42	8.48	5.59	1.43	1.39	6.11	1.03
	Zimbabwe	2005	2,227	41.54	92.49	-6.23	-1.59	-0.34	160.01	-0.62
				10.50	8.17	5.27	1.37	1.34	5.95	1.00
	Zimbabwe	2010	2,212	40.55	91.63	-6.47	-1.67	-0.43	160.13	-0.60
				10.40	8.28	4.56	1.20	1.17	5.94	1.00
	Zimbabwe	2015	2,826	41.19	93.55	-4.94	-1.34	-0.13	160.62	-0.52
				10.39	8.37	4.71	1.20	1.14	6.16	1.03

Table S4: Global nutritional mobility transition matrix for HAZ between mothers and children

		Mother decile									
Child decile		1	2	3	4	5	6	7	8	9	10
	N	*39,293*	*38,749*	*38,208*	*38,801*	*38,314*	*37,850*	*38,336*	*37,918*	*38,063*	*37,757*
1	*38,709*	20.0%	14.3%	11.7%	10.6%	9.2%	8.6%	7.6%	6.7%	6.0%	5.3%
2	*38,450*	16.7%	13.9%	12.0%	11.2%	10.1%	9.2%	8.2%	7.5%	6.4%	5.0%
3	*38,370*	14.1%	12.9%	12.1%	11.3%	10.2%	9.5%	9.2%	8.0%	7.0%	5.7%
4	*38,350*	11.7%	12.0%	11.6%	11.1%	10.8%	10.1%	9.6%	9.1%	7.8%	6.2%
5	*38,375*	9.5%	10.7%	10.5%	10.7%	10.7%	10.4%	10.3%	10.0%	9.3%	7.9%
6	*38,204*	8.2%	9.4%	10.1%	10.6%	10.7%	10.6%	10.7%	10.6%	10.1%	9.0%
7	*38,275*	6.8%	8.4%	9.2%	10.1%	10.2%	10.5%	11.1%	11.3%	11.6%	10.7%
8	*38,181*	5.6%	7.1%	8.1%	9.3%	10.0%	10.3%	11.5%	11.8%	13.1%	13.3%
9	*38,141*	5.0%	6.4%	7.4%	8.5%	9.3%	9.9%	11.2%	12.3%	13.9%	16.1%
10	*38,234*	4.8%	6.0%	6.8%	8.0%	8.7%	9.7%	10.8%	11.7%	14.1%	19.4%

Notes: This table recreates Table II of Chetty et al. (2014) for international child height data. Each cell contains the percentage of children with HAZ in the decile listed in the rows, given that his or her mother had HAZ within the decile listed in the columns. Decile 1 is the 0^{th}-10^{th} percentile, and Decile 10 is the 90^{th}-100^{th} percentile.

This is the transition matrix for HAZ between mothers and children. This analysis follows Chetty et al. (2014). The transition matrix contains child deciles of HAZ in the rows and maternal deciles of HAZ in the columns. Each cell of the matrix contains the percentage of children with HAZ in the decile listed in the rows, given that his or her mother had HAZ within the decile given by the columns. Using this matrix, the distributions of child heights within each decile of maternal heights can be seen at-a-glance. The decile transition matrix indicates the probability that a child is in decile *n* of the child height distribution if his or her mother is in decile *m* of the mother height distribution. A child born to a mother in the 1^{st} decile of the height distribution has a 4.8 percent chance to reach the top 10^{th} decile of the height distribution. A child born to a mother in the 10^{th} decile of the height distribution has a 19.4 percent chance of also being in the 10^{th} decile of the height distribution, and a 5.3 percent chance of being at the 1^{st} decile of the height distribution. The results in this table reflect the inevitable regression to the mean, and also indicate that very only about 37 percent of children with mothers in the bottom three deciles of the height distribution end up reaching the top half of the child height distribution.

Table S5: Regional nutritional mobility estimates

Outcome: Child percentile rank in HAZ	(1) Univariate	(2) Child controls	(3) Full controls	(4) Full controls Excludes <10th & >90th percentiles
Globe				
Maternal rank in HAZ	0.263***	0.263***	0.225***	0.160***
	(0.0016)	(0.0016)	(0.0015)	(0.0014)
Constant/intercept	36.81***	40.68***	281.2***	218.1***
	(0.0896)	(0.7778)	(29.2396)	(26.6226)
N	383288	383288	383086	306209
Europe & Central Asia				
Maternal rank in HAZ	0.229***	0.229***	0.212***	0.161***
	(0.0090)	(0.0090)	(0.0090)	(0.0082)
Constant/intercept	38.52***	40.14***	99.18	28.11
	(0.5163)	(4.4272)	(183.3638)	(164.7914)
N	11749	11749	11657	9305
Latin America & Caribbean				
Maternal rank in HAZ	0.432***	0.431***	0.344***	0.229***
	(0.0051)	(0.0051)	(0.0050)	(0.0049)
Constant/intercept	28.40***	30.88***	-110.6	2.152
	(0.2953)	(2.5567)	(129.6316)	(124.8854)
N	30882	30882	30880	24668
Middle East & North Africa				
Maternal rank in HAZ	0.226***	0.226***	0.215***	0.148***
	(0.0081)	(0.0081)	(0.0081)	(0.0074)
Constant/intercept	38.70***	39.11***	250.4	210.4
	(0.4659)	(4.0758)	(202.0985)	(182.6994)
N	14443	14443	14441	11541
South/Southeast Asia				
Maternal rank in HAZ	0.270***	0.270***	0.219***	0.163***
	(0.0023)	(0.0023)	(0.0023)	(0.0021)
Constant/intercept	36.49***	41.19***	256.2***	158.3**
	(0.1331)	(1.1645)	(55.0830)	(50.0979)
N	173079	173079	173066	138409

Central Africa				
Maternal rank in HAZ	0.245***	0.245***	0.207***	0.144***
	(0.0065)	(0.0065)	(0.0064)	(0.0059)
Constant/intercept	37.73***	46.37***	-366.3*	-256.2
	(0.3738)	(3.2198)	(145.0374)	(132.9525)
N	22270	22270	22253	17785
West Africa				
Maternal rank in HAZ	0.184***	0.184***	0.149***	0.106***
	(0.0040)	(0.0040)	(0.0039)	(0.0036)
Constant/intercept	40.77***	45.57***	341.3***	227.4**
	(0.2311)	(1.9790)	(88.8386)	(80.3055)
N	59701	59701	59654	47668
East Africa				
Maternal rank in HAZ	0.245***	0.245***	0.239***	0.163***
	(0.0050)	(0.0050)	(0.0049)	(0.0045)
Constant/intercept	37.72***	38.56***	105.9	65.26
	(0.2863)	(2.4823)	(96.7712)	(88.1498)
N	37915	37915	37892	30281
Southern Africa				
Maternal rank in HAZ	0.275***	0.275***	0.250***	0.175***
	(0.0052)	(0.0052)	(0.0052)	(0.0048)
Constant/intercept	36.34***	36.39***	112.2	70.09
	(0.3023)	(2.6162)	(93.4558)	(85.0545)
N	33249	33249	33243	26646

Notes: Estimates are OLS regressions where the outcome variable in each model is the child's percentile rank in HAZ, estimated by his or her country and year of birth, and the main coefficient of interest is the maternal rank in HAZ. Coefficient estimates for control variables are not shown. Column 1 is a univariate estimate. Column 2 has controls for child age in months, child age in months squared, and child sex. Column 3 includes all child controls, plus maternal education in single years, the number of children under age 5 years in the household, the relative wealth quintile of the household, a binary indicator of rural residence, and the year of birth of the child for a time trend. Column 4 has the same controls as Column 3, and also excludes children who are below the 10th percentile for their rank in HAZ or greater than the 90th percentile for their rank in HAZ. Estimates are given for the whole sample and then split into eight global regions. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table S5 includes control variables in the intergenerational mobility estimates and splits the analysis up by global region. The models presented in this table use only rank-order specifications. Given the results of Table 2 and 3, our preferred specification uses percentile rank in HAZ for both mothers and their children for measuring heights. The intercept term is included in this table because it is needed to calculate absolute upward mobility for Columns 1 and 2. When restricting the sample to within the 10^{th} and 90^{th} percentiles, relative mobility estimates are lower across all sub-samples, suggesting the influence of regression to the mean, consistent with preliminary results. Relative mobility also declines slightly as controls are added, indicating that some of the variation in child heights is explained by other factors besides maternal height. Children born to mothers at height extremes are more likely to be closer to the mean of their own cohorts, and excluding these children and their mothers attenuates the remaining association between mother and child heights

Column 1 reports results from the univariate estimates as in previous tables, to compare mobility across global regions. Relative nutritional mobility for the world as a whole is equal to 0.263, and ranges across regions from 0.184 in WA to 0.432 in LAC. This indicates that there is greater inequality between children born of the tallest mothers and the shortest mothers in LAC compared to other regions, especially WA. In WA, this nutritional inequality is very low compared to the rest of the world. Global absolute upward nutritional mobility, defined as the predicted rank of a child given that his or her mother was in the 25^{th} percentile for height, is equal to 43.38. Absolute upward mobility in most sub-regions of the world is all relatively similar, ranging from between 43.22 in SA to 44.39 in MENA. The only real outlier here at a regional level is the LAC region, where absolute upward mobility is only 39.2. The phenomenon of systematically lower nutritional mobility in the LAC region is investigated further using Wald Tests in Table S2.

Table S6: Nutritional mobility in the 50 largest subnational regions by DHS population

(1) Country	(2) Region	(3) DHS population	(4) Absolute upward mobility	(5) Pct. (Child Q5 | Mother Q1)	(6) % Stunted	(7) Relative mobility
Egypt	Lower Egypt - Rural	1,300,000	49.23	2.25	20.75	0.19
Bangladesh	Dhaka	1,100,000	44.56	2.52	54.72	0.29
Egypt	Upper Egypt-Urban	1,100,000	40.26	2.28	25.58	0.12
Bangladesh	Chittagong	789,241	39.87	1.73	60.21	0.31
Nigeria	Southeast	661,457	37.41	2.75	64.66	0.08
Nigeria	North Central	506,966	51.90	1.95	45.45	0.21
Bangladesh	Rangpur	443,396	42.00	1.95	57.07	0.33
Bangladesh	Rajshahi	389,931	46.89	2.95	50.35	0.31
Bangladesh	Sylhet	355,098	35.41	1.68	64.86	0.30
Nigeria	Northeast	350,063	56.00	3.76	39.65	0.19
Bangladesh	Khulna	305,304	48.10	1.76	48.35	0.31
Nigeria	Northwest	281,613	57.27	2.97	39.26	0.23
Bangladesh	Barisal	277,015	40.97	1.69	58.99	0.25
Tajikistan	Districts of Republican Subordination	216,092	42.67	2.09	37.08	0.27
Egypt	Urban governorates	203,987	51.45	2.18	17.52	0.14
Rwanda	West	197,997	36.64	1.00	73.29	0.29
Nepal	Hills	186,836	42.68	2.84	74.40	0.29
Malawi	Southern	182,998	42.45	1.97	65.31	0.29
Nigeria	South South	178,623	41.27	2.74	61.33	0.12
Nigeria	Southwest	171,325	46.22	2.88	54.84	0.21
Rwanda	South	157,472	42.81	1.45	64.42	0.33
Kenya	Western	146,231	43.09	1.51	50.65	0.21
Jordan	Central	146,124	43.67	1.78	15.11	0.24
Kenya	Nyanza	141,951	41.71	1.77	50.94	0.24
Benin	Ouémé	140,677	53.77	5.33	43.41	-0.06
Guatemala	Suroccidente	126,908	36.54	0.56	69.16	0.48
Rwanda	North	123,107	38.48	0.86	71.88	0.28
Tajikistan	Sughd	118,730	42.40	2.57	38.31	0.27
Colombia	Central	115,138	45.19	1.33	16.95	0.40
Nepal	Terai	114,672	46.24	2.69	69.11	0.29
Malawi	Central	112,647	43.04	1.67	61.54	0.23
Rwanda	East	104,546	43.33	2.07	65.15	0.31
Jordan	North	100,188	42.56	1.88	12.98	0.34
Mali	Bamako	99,531	59.98	2.96	32.33	0.16

Zambia	Lusaka	98,659	46.81	2.47	58.16	0.26
Cambodia	Phnom Penh	95,580	53.07	1.18	51.37	0.33
Colombia	Bogota	89,380	39.12	0.41	19.85	0.31
Ethiopia	Southern Nations, Nationalities, and People's Region	88,501	44.68	3.79	56.60	0.14
Egypt	Upper Egypt- Rural	88,190	40.86	2.86	27.66	0.12
Haiti	Metropolitan area	88,094	48.11	2.84	28.10	0.32
Rwanda	Kigali	86,315	57.13	3.22	49.96	0.33
Nepal	Mountain	85,789	44.70	2.13	70.51	0.27
Guatemala	Metropolitana	85,564	53.14	0.94	44.83	0.42
Kenya	Northeastern	84,068	46.21	2.01	39.85	0.18
Zimbabwe	Harare	78,961	42.81	1.68	49.82	0.32
Colombia	Atlantica	77,593	35.96	0.54	27.13	0.42
Egypt	Lower Egypt - Urban	73,857	48.84	2.57	20.76	0.15
Madagascar	Analamanga	67,723	48.88	2.58	63.52	0.16
DR-Congo	Kinshasa	65,088	59.33	0.86	33.88	0.32
Colombia	Pacifica	64,309	41.53	0.94	22.14	0.42
Mean	-	245,271	45.51	2.10	47.36	0.26
Standard deviation	-	280,529	6.28	0.96	17.85	0.10

Notes: This table shows the 50 subnational regions in the dataset with the largest "DHS Populations." There are 555 total subnational regions in the dataset. DHS survey-specific region names are given. "DHS Population" tabulated in Column 3 is equal to the sum of population living within 2 km (urban) or 10km (rural) of DHS survey clusters within a subnational region. Column 4 is absolute upward mobility, which is calculated as the fitted values at maternal HAZ rank =25 on the univariate rank-rank regressions. Column 5 is the percentage of children out of the sample within the subnational region who reached the 5th (highest) quintile for HAZ given that their mother was in the 1st (lowest) quintile for HAZ. Column 6 are the fitted values of a logistic regression of a binary indicator of stunting (HAZ<-2) on maternal HAZ rank at maternal HAZ rank =25, converted from log odds to probabilities. Column 7 is relative mobility, or the slope of the estimated rank-rank relationship within each subnational region. This is same analysis as from Table 5 in the main text, except for subnational regions within countries. As might be expected, variation in absolute upward mobility and the other nutritional mobility indicators is higher when comparing sub-national regions than when comparing countries, indicated by the standard deviations presented at the bottom of the table. For this table, the 50 subnational DHS regions with the largest DHS populations were selected. The DHS population is defined by the DHS as the sum of the population living within 2 kilometers of urban clusters or 10 kilometers of rural clusters within a subnational region. The DHS subnational regions with the largest populations were chosen to highlight because there is wide variation in sample sizes across subnational regions, and due to the Law of Large Numbers, subnational regions with smaller sample sizes ended up in the extremes of the mobility estimates. Many of the included subnational regions are capital city metro areas, including Bamako, Phnom Penh, Bogota, Kigali, Lusaka, Kinshasa, and Harare. Across subnational regions, absolute upward mobility ranges from 59.98 in Bamako, Mali to 35.41 in Sylhet, Bangladesh. The probability of a child with a mother in the 1st quintile of the height distribution reaching the 5th percentile of the height distribution ranges from 0.41 in Bogota, Colombia to 5.33% in Ouémé, Benin. The probability of a child being stunted given that his or her mother was in the 25th percentile of the height distribution ranges from 74.4 in the Hills region of Nepal to 12.98 in the northern region of Jordan. Relative mobility ranges from 0.48 in the Southwest region of Guatemala to -0.06 in Ouémé, Benin. In this highly populated region of Benin, the relationship between maternal and child heights is relatively flat. This is consistent with the finding presented in Table 5 that, in Benin, the nutritional environment is about 15 times as powerful as a mother's individual height at determining child HAZ ranking.

Table S7: Nutritional Mobility Index

(1) Country	(2) Absolute upward mobility	(3) 100-Relative Mobility	(4) P(Not stunted | Maternal HAZ rank 25)	(5) CTI	(6) Nutrition Mobility Index
Burundi	41.93	67.80	25.65	3.87	34.81
Guatemala	36.99	47.90	31.44	41.33	39.41
DRC	44.10	76.50	36.47	10.94	42.00
Chad	45.81	83.40	40.60	0.00	42.46
Rwanda	42.04	68.20	42.25	22.77	43.82
Lesotho	43.05	72.50	47.99	26.87	47.60
Zambia	43.32	73.50	47.20	28.09	48.03
Mozambique	43.03	72.20	46.07	31.29	48.15
Burkina Faso	44.55	78.40	51.84	19.08	48.47
Madagascar	46.11	84.40	39.70	24.12	48.58
Ethiopia	44.53	78.20	47.93	26.85	49.38
Honduras	37.80	51.30	53.43	55.91	49.61
Cameroon	43.90	75.80	52.07	27.12	49.72
Mali	46.63	86.70	50.64	15.04	49.75
Bangladesh	42.40	69.70	44.93	42.45	49.87
Malawi	42.80	71.40	51.36	34.56	50.03
Nigeria	44.46	78.00	50.24	27.56	50.07
Tanzania	42.95	71.90	52.56	33.78	50.30
CIV	43.08	72.50	54.54	32.63	50.69
Nepal	43.18	73.00	47.51	40.58	51.07
Benin	48.82	95.38	48.53	12.47	51.30
Cambodia	42.59	70.60	50.60	43.22	51.75
Liberia	44.85	79.60	52.07	31.64	52.04
India	43.22	72.90	47.46	45.43	52.25
Uganda	41.91	67.80	58.76	40.56	52.26
Guinea	45.14	80.80	53.63	29.83	52.35
Myanmar	42.98	72.20	50.95	44.04	52.54
Swaziland	41.77	67.30	62.11	39.82	52.75
Senegal	43.91	75.70	61.16	30.55	52.83
East Timor	45.47	81.90	42.82	41.75	52.99
Togo	44.43	78.00	57.12	32.50	53.01
Sierra Leone	45.35	81.50	50.82	34.97	53.16
Zimbabwe	41.76	67.20	64.22	40.25	53.36
Namibia	43.15	72.80	63.49	38.62	54.52
Bolivia	40.60	62.40	57.60	57.91	54.63
Kenya	43.53	74.40	61.66	40.87	55.11
Haiti	42.92	71.90	64.78	47.13	56.68
Guyana	38.36	53.40	66.24	70.67	57.17
Ghana	42.54	70.30	69.13	47.92	57.47

Gabon	41.54	66.20	66.86	56.18	57.70
Kyrgyz Republic	43.50	74.20	73.18	54.43	61.33
Colombia	39.39	57.70	76.52	73.57	61.79
Tajikistan	43.94	75.90	72.79	57.22	62.46
Comoros	46.07	84.50	67.96	53.35	62.97
Jordan	41.64	66.70	88.00	83.73	70.02
Egypt	45.28	81.20	77.10	80.14	70.93
Albania	45.80	83.30	85.02	81.70	73.95
Dominican Republic	42.62	70.70	91.89	93.40	74.65
Armenia	43.92	75.70	90.89	100.00	77.63
min	**37.0**	**47.9**	**25.6**	**0.0**	**34.8**
max	**48.8**	**95.4**	**91.9**	**100.0**	**77.6**
mean	**43.3**	**73.2**	**56.9**	**41.8**	**53.8**
stdev	**2.2**	**8.8**	**14.6**	**21.8**	**8.6**
median	**43.2**	**72.9**	**52.6**	**40.3**	**52.3**

Notes: Data are four nutrition mobility indicators aggregated into one index in Column 6 and the table is sorted by lowest to highest on this nutritional mobility index. These indicators were calculated using only the most recent available survey in each included country. Column 2 are the estimates for absolute upward mobility. Column 3 are the estimates for relative mobility where the original measure was subtracted from 100 to ensure that positive values indicate better nutritional mobility, just as for the absolute upward mobility indicator. Similarly, in Column 4 the probability that a child is not stunted given that his or her mother had HAZ rank equal to 25 was constructed as previously described for Tables 5 and 6 but constructed as:

$(1 - Prob(Stunted|Maternal\ HAZ\ rank = 25)) \cdot 100$. Finally, Column 5 is equal to the mean CTI for each country in the given country's most recent DHS survey, re-scaled to be between 0-100 for ease of aggregation with the other indicators. Column 6 is the aggregate of the four indicators and equals $\frac{1}{4} \cdot AbsoluteUpwardMobility + \frac{1}{4} \cdot (100 - RelativeMobility) + \frac{1}{4} P(not\ stunted\ |Mat\ HAZ\ rank = 25) + \frac{1}{4} Mean\ CTI$. Larger values of the nutritional mobility index indicate better nutritional mobility.

In Table S7, the Nutrition Mobility Index (NMI) aggregates four key indicators of nutritional mobility for cross-country comparisons. The mean NMI is equal to 53.8, with a standard deviation of 8.6. The five countries with the lowest NMI are Burundi, Guatemala, the Democratic Republic of the Congo, Chad, and Rwanda. These low NMI values are driven mainly by low CTI scores and low probabilities that a child is not stunted given that his or her mother was at HAZ rank equal to 25. The five countries with the highest NMI scores are Armenia, the Dominican Republic, Albania, Egypt, and Jordan. These countries are mainly from ECA and MENA, except for the Dominican Republic. The Dominican Republic scored relatively low when countries were ranked strictly by their absolute upward mobility, similar to other countries in the LAC region. However, children in the Dominican Republic have a much higher CTI on average, meaning that their linear growth is better than expected after accounting for regression to the mean. Further, children in the Dominican Republic have a very good chance, 93.40 percent, of not being stunted even if their mother has an HAZ rank equal to 25. The higher score for the aggregate NMI in the Dominican Republic is driven by these values. There are slight geographic patterns found in the NMI, but not as strong as may have been hypothesized given raw data on nutritional status in many of these countries. Understanding the relationship of additional country- and local-level correlates of nutritional mobility is essential for improving the likelihood that children can overcome their mother's poor nutritional status around the world.