Early Divergence: Rural-urban child health inequalities over time in four developing countries

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Abstract

The large literature on health differentials between rural and urban areas relies almost exclusively on cross-sectional data. Bringing together the demographic literature on area-level health inequalities with the economic and bio-physiological literature on children's catch-up growth over time, this paper uses panel data to investigate the stability and origins of rural-urban health differentials. Using data from the Young Lives longitudinal study of child poverty, I present evidence of large level differences but similar trends in rural versus urban children's height for age in four developing countries. Further, children's birthweight and mothers' health endowments indicate that persistently poorer rural health is present to a large extent already at birth, suggesting that initial endowments play a substantial role in explaining large rural-urban child height inequalities in developing countries. The results imply that prioritizing maternal nutrition and health is essential, and that interventions to reduce area-level health inequalities must begin before birth.

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1 Introduction

There is a large literature on health differentials between rural and urban areas in low- and middle-income countries (LMICs). On average, it has been found that health in urban areas is better than health in rural areas (Van de Poel et al., 2007). While these differences may mask large disparities within areas (Montgomery and Hewett, 2005), it is widely recognized that rural dwellers are more likely than urban dwellers to lack access to high quality medical care, nutritional diversity, and secure employment, all of which are important inputs into health. There are three central limitations of this research, however: 1) it almost exclusively employs cross-sectional data which renders the assessment of health trajectories impossible, 2) it very infrequently incorporates data before age 1 (and almost never before birth), making it difficult to identify how early and why health inequalities arise, and 3) very few studies look at height for age after early childhood, limiting our understanding of the persistence of early inequalities. This study addresses these three gaps in the literature.

Using data from the Young Lives study of international child poverty (Young Lives, 2014), collected in four developing countries - Ethiopia, India, Peru, and Vietnam - since 2002, I examine the rural-urban differential in child height for age of children ages 1 to 15 in these very different contexts. I explore whether levels and/or trends over time in height for age are different in rural and urban areas. In the two countries that collected information on birthweight from a sufficiently large proportion of their sample (Peru and Vietnam), I present evidence regarding the extent to which health differentials are present even at birth. To investigate further the health implications of even the children's intrauterine environment, mothers' health-related characteristics are also investigated. Finally, I present regression models controlling for early endowments (including the intrauterine environment) and other time-invariant characteristics of the children that suggest very early emergence of rural-urban health inequality.

Results demonstrate large *level* differences in child height for age in rural and urban areas in all countries, cohorts, and waves, with urban children consistently taller than rural children. Rural-urban differences in height *trajectories*, however, are not significant; rural-urban height differentials arise early and persist throughout childhood and into adolescence. Mean trajectories appear almost entirely parallel, with the exception of the older cohorts in Peru and Vietnam. Early divergence (even before age 1) in height is also reflected in the birthweights of children in Peru and Vietnam, which are significantly higher in urban areas as compared to rural. Mother's own height, weight and body mass index (BMI) are also higher in urban areas, suggesting that rural-urban differentials in child health may begin well before birth. Further evidence for this hypothesis is presented using fixed effects regression models in which rural-urban differentials in height for age are almost exclusively no longer statistically significantly different once early endowments are taken into account.

This paper is the first to cross-nationally assess rural-urban differentials in height trajectories, and to document divergence in levels even prior to birth. This contribution to the literature is made possible by the use of panel data following children until 15 years of age, as well as information on mothers' characteristics. The early emergence of large level differences but stable trajectories in height for age of children in developing countries suggests that "early intervention" to improve health aimed at children already enrolled in school and even those under two years of age may be too late. Investments in maternal and even adolescent health must be prioritized to efficiently and effectively reduce area-level health inequalities.

2 Background

In the study of rural-urban health inequalities, researchers have investigated a wide variety of health outcomes including child mortality (under-1, -2, or -5 years), morbidity indicators such as height- and weight for age z-scores, and even differentials in obesity (Sobngwi et al., 2004), adult mortality (Günther and Harttgen, 2012; Zimmer et al., 2010) and maternal health care (Matthews et al., 2010).

2.1 Rural-urban differentials in mortality

Child mortality is consistently found to be lower in urban than rural areas, and these differentials are often explained by different distributions of population characteristics such as household wealth and maternal education (Saikia et al., 2013); in a multiple regression framework, studies tend to "explain away" rural-urban differentials with individual characteristics like socioeconomic status (Fotso and Kuate-Defo, 2005). Indeed, a study by Bocquier et al. (2011) found that controlling for demographic and socioeconomic correlates of under-5 mortality greatly reduced and sometimes reversed the relationship between urban dwelling and better health in the 1990s. Other empirical work has shown that adult mortality rates (ages 15-45) in 11 of 13 sub-Saharan countries are actually higher in urban than in rural areas (Günther and Harttgen, 2012); whether there is indeed an "urban advantage" in health seems to depend on the population and health indicator under study as well as the covariates available to explain the relationship between residential area and health (Fink et al., 2014).

Another popular empirical approach to explain rural-urban health differentials has been to decompose them into their explanatory factors, generally gender, family's economic status, mother's education, ethnicity, birth order (Pradhan and Arokiasamy, 2010), and community-level variables such as levels of vaccination coverage and access to health care (Saikia et al., 2013), among others. While this approach highlights the relative importance of different predictors, it is not clear whether the remaining unexplained residual represents the *contextual* effect of place or simply unmeasured *compositional* covariates or individual-level attributes (Kawachi et al., 2002). Sastry (1997), for example, investigates in the Brazilian context whether observed child mortality differentials by place of residence "merely reflect manifestations of underlying differences in SES and demographic/reproductive behavior". He finds that the urban advantage cannot be explained by socioeconomic differences alone, but that community characteristics also appear to play an independent and important role, although community influences on child health are not found consistently in the literature (Harttgen and Misselhorn, 2006).

2.2 Rural-urban differentials in morbidity

Studies of child malnutrition generally find that while rural-urban differentials in morbidity may not be as stark as those of mortality, the differentials are often similarly explained by the distribution of individual-level characteristics such as household economic status, parental education and mothers' exposure to media (Kumar and Kumari, 2014). Kennedy et al. (2006), for example, find that in Angola, Central African Republic, and Senegal, a wealth index explained away differences between rural and urban areas in childhood undernutrition, leading the authors to argue that "urban residence itself is not an important determinant of nutritional status, but is reflective of more favorable household conditions, supporting better child growth". Van de Poel et al. (2007) also find, in a larger sample of Demographic and Health Surveys from 47 countries, that when controlling for household wealth in comparing rural and urban stunting and mortality, 29 of the 47 countries under study exhibited no "urban advantage".

Most studies use height for age as their health outcome, which is a widely used proxy for poor health in LMICs and is associated with chronic undernutrition and a poor epidemiological environment. Height for age is associated with sustained food deprivation, repeated illness, or both (Fotso and Kuate-Defo, 2005). In addition to being a marker of deprivation, insufficient height attainment is related to a wide variety later life outcomes such as lower levels of educational attainment and labor force participation; taller populations are better off, live longer and are more productive (Deaton, 2008). For these reasons, stature is an important indicator of the health and well-being of children as well as their potential for human capital accumulation (Steckel, 1995).

All of the studies reviewed thus far use cross-sectional data and tend to find that favorable socioeconomic conditions among urban residents explain rural-urban differentials in child health at a specific point in time. While one study aggregated many years of cross-sectional data together to illustrate urban-rural differentials between 1985 and 2011 (Paciorek et al., 2013), the use of synthetic cohorts may not be a good substitute for mapping the actual growth trajectories of children. Indeed, very little has been done to investigate rural-urban health inequality using panel data, which is essential for understanding trends, and not simply level differences. Additionally, some evidence of differences in mother's weight and use of prenatal care between rural and urban areas suggests that the urban advantage may develop even before birth (Matthews et al., 2010; Smith et al., 2005). While there is extensive evidence on the connection between early disadvantage and later life outcomes in developed countries, given the scarcity of panel data from developing countries (Currie and Vogl, 2013), no studies, to my knowledge, have assessed the relationship between birthweight and later life health (or even medium-term health) in more than one developing country, and certainly none has looked at this issue through the lens of rural-urban inequality.

2.3 Catch-up growth

However, in the literature on "catch-up" growth, panel data have been used extensively in the study of child height. While catch-up growth lacks an agreed-upon definition, it generally refers to acceleration in growth after a period of growth retardation; it can also refer to complete recovery of growth to initial levels, or, for that matter, any acceleration of growth at all (Adair, 1999). In their canonical article on the topic, Boersma and Wit (1997) define catch-up growth as "a height velocity above the statistical limit of normality for age and/or maturity during a defined period of time, following a transient period of growth inhibition". Catch-up growth can be seen following treatment for a variety of health problems, from hypothyroidism to cystic fibrosis, but most, if not all literature focusing on LMICs concentrates on poverty-related malnutrition and deprivation.

As previously mentioned, sufficient growth in early childhood through adolescence is essential for laying the groundwork of good adult health and also significantly promotes human capital development (Adair et al., 2013). Alderman et al. (2006) estimates that, compared to a well-nourished population, an average loss in stature of just 3.4 centimeters by adolescence (in their sample) would result in a loss of schooling and potential work experience leading to "a loss of lifetime earnings of around 14 percent". Mani (2008) estimates that by adolescence, "a malnourished child, even one who experiences catch-up growth, is likely to complete 0.6 fewer grades of schooling compared to a well-nourished child from the same population".

Researchers studying catch-up growth in children and adolescents have not come to a consensus regarding the age at which the "critical" window closes (Mani, 2008), although they do generally agree that catch-up occurs (Adair, 1999; Fink and Rockers, 2014; Hirvonen, 2014) in certain populations and under the right circumstances (Outes and Porter, 2013). While remediation - or the extent to which a shock experienced in an early developmental period can be subsequently mitigated - is technically possible (Almond and Currie, 2010), it can be difficult to differentiate remediation from regression to the mean (i.e. within-population convergence) (Hirvonen, 2014). Additionally, much of the ambiguity in the catch-up growth literature appears to be due to wide variability in the data used: age ranges, sample sizes, time between survey rounds, research designs, and model specifications (Handa and Peterman, 2009). Very few investigations of catch-up growth focus on impoverished environments in the absence of "extensive and focused interventions" (Handa and Peterman, 2009) or shocks like natural disasters, theft and drought (Frankenberg et al., 2013; Hoddinott and Kinsey, 2001; Woldehanna, 2012); fewer still have looked at differences in catch-up between rural and urban areas (Crookston et al., 2010). This paper brings together the demographic and health literature on rural-urban differentials in child health with the economic and bio-physiological literature on catch-up growth to investigate rural-urban differentials in levels and trends in children's growth in developing countries.

Rather than focusing only on family and community characteristics during early childhood that may explain state dependency in child height (Handa and Peterman, 2009; Pongou et al., 2006), this paper asks the following research question: how early and in what ways do rural-urban child health inequalities manifest, and do early divergences - even before birth - help explain consistent differences in health between these two areas over time? The results presented here provide evidence of large and persistent rural-urban differentials in child health and that controlling for original endowments and other time-invariant characteristics of children render these differences statistically insignificant. Area-level inequalities in health do not only arise from a child's exposure to deprivation, but also their intrauterine experience and the characteristics and experiences of their mother.

Additionally, while there are a number of studies focusing on linear growth after age 5 (Eckhardt et al., 2005; Fink and Rockers, 2014), relatively little is known about inequalities in growth at later ages, or even when they originally emerge. The present study employs data following cohorts of 1-year olds and 8-year olds for 7 years in four different locations - Ethiopia, Andhra Pradesh state in India, Peru, and Vietnam - to characterize the ways in which rural-urban inequalities in child health are manifested. Using data from countries with very different diets, disease environments, and levels of development throws into sharp relief both the similarities and differences in levels and trends of child height in these contexts.

3 Data and Methods

3.1 Data

Young Lives is an international longitudinal study of child poverty run by the University of Oxford in the UK and jointly funded by the Department for International Development (DFID) and the Netherlands Ministry of Foreign Affairs. With their data and the resulting research, the investigators hope to "improve policies and programs for children" in developing countries (Young Lives, 2014). Data collection began in 2002 to follow 12,000 children from Ethiopia, the state of Andhra

Pradesh in India, Peru and Vietnam for 15 years. Two age cohorts of children are followed in each country in order to collect information on each stage of childhood: 2,000 children born between 2001 and 2002 (the "younger" cohort) and 1,000 children born between 1994 and 1995 (the "older" cohort) (Young Lives, 2002). Not surprisingly, the two Young Lives age cohorts display very similar characteristics (Table 1); both age cohorts were sampled at random from the same 20 sentinel sites in each of the four countries. One persistent difference, however, is in height for age: consistent with development progressing apace (Cueto et al., 2011; Dornan, 2011); in all countries, the older cohort is consistently shorter than the younger cohort.

The Young Lives research team has produced reports on sampling and representativeness, which are slightly different in each country. In Ethiopia (Outes-Leon and Sanchez, 2008), Andhra Pradesh state in India (Kumra, 2008), and Vietnam (Nguyen, 2008), a multi-stage, purposive random sampling method was used to select the two age cohorts of children; 20 sentinel surveillance sites were chosen in each country to ensure a balanced representation of the country's "regional diversity as well as rural/urban differences" and children were randomly selected within these sites (Bourdillon, 2012). In Peru, researchers used a multi-stage, cluster-stratified random sampling method to select the two cohorts of children, which randomized households within a site as well as across 20 sentinel site locations. In all countries, only one child was selected per household.

While none of the samples is appropriate for monitoring national-level child indicators, they are all comprised of highly valuable data from which to analyze child health and wellbeing over time (Wilson and Huttly, 2004). In comparisons made between the Young Lives study sample and the nationally representative samples from the Demographic and Health Surveys temporally closest to Young Lives baseline data collection, Young Lives children are comparable on a number of living standards indicators like access to public services and caregiver's education in Peru, slightly poorer in Vietnam and slightly better off in Ethiopia and India (Barnett et al., 2012). Young Lives data have been used previously to investigate the relationship between height and various outcomes including cognition (Crookston et al., 2011; Fink and Rockers, 2014), wealth (Petrou and Kupek, 2010), and community-level indicators like access to health services (Schott et al., 2013).

Finally, there is very limited loss to follow up in the Young Lives data (particularly as compared to other panel surveys undertaken in low resource contexts). As described by Barnett et al. (2012), attrition rates over the three rounds ranged from 2.2 percent in Vietnam to 5.7 percent in Ethiopia in the younger cohort, and from 2.4 percent in Vietnam to 5.0 percent in Peru for the older cohort; there is very little evidence of attrition bias. All analyses presented here include only children sampled at all three waves of data collection who have non-missing data on the dependent variable, which results in sample sizes of 2,726 children in Ethiopia, 2,827 in India, 2,539 in Peru, and 2,872 in Vietnam.

3.2 Variables

3.2.1 Dependent variable

The outcome of interest is the child's height for age z-score. Height for age z-score, or height for age relative to an international standard of healthy children, reflects past and present inputs into health and provides a cumulative picture of overall health status. The use of a reference population makes possible the comparison of children's height across different ages and contexts (Dibley et al., 1987). For the Young Lives data collection, supine length at age 1 and height thereafter was measured to the nearest 0.1 cm using a height board made for the purpose. Coupled with age of the child in days and the date of interview, these measurements form the inputs into the computation of height for age (Petrou and Kupek, 2010) which is transformed into a standardized z-score based on the 2006 World Health Organization standard (Organization, 2006) in the following way:

$$\text{z-score}_i = \frac{x_i - x_{median}}{\sigma_x} \tag{1}$$

Where x_i is height for age for child i, x_{median} is the median height for age of the reference population of the same age and gender, and σ_x is the standard deviation of height in the reference population (Sahn and Stifel, 2003). The very few questionable z-scores above 6 and below -6 are recoded to missing.

3.2.2 Independent variables

The predictor of interest is whether the child lives in a rural or urban area. Given the different levels of development and urbanization in the four countries, it is important to outline the meaning of these designations in practice. Due to a lack of official statistics in Ethiopia, the distinction between rural and urban areas was made in consultation with local officials in each district (Outes-Leon and Sanchez, 2008). In Andhra Pradesh, sentinel sites were the equivalent of an administrative *mandal* (sub-district comprised of several villages) and were defined as urban if two-thirds of the population lived in an urban area based on the most recent Census (Kumra, 2008). In Peru, the size of the population in each district was used to assign rural/urban status (Escobal and Flores, 2008). The documentation regarding site selection in Vietnam does not contain information on the ways in which rural and urban areas were designated (Nguyen, 2008).

Descriptive statistics comparing rural to urban children on a variety of covariates (Table 2) are consistent with an urban advantage on a range of characteristics associated with child health and wellbeing. On average and across all four countries, urban children are taller, have caregivers with more education, live in households with higher wealth indices, and are surrounded by healthier epidemiological environments. Taking advantage of the longitudinal nature of the data, I find that of the rural-dwelling Young Lives children who are stunted at wave 1, 57 percent are still stunted at wave 3, compared to 41 in urban areas. In contrast, of the Young Lives children who were *not* stunted at wave 1, 16 percent of rural and 7 percent of urban children are stunted by wave 3. There appears to be more churning in height for age in rural areas as compared to urban areas.

Regression models control for whether the child is female as well as their age at the time of the survey. While children in the younger cohort were sampled at approximately 1 year of age and the older cohort at approximately 8 years of age, there is some spread around these target ages. Since growth trajectories are of interest in this study, indicator variables for age in months (in order to allow a non-linear relationship between height and age over time) are constructed and included in all regression models presented here that use more than one wave of Young Lives data. While most of these age indicators denote 1-month categories, ages populated by very few children are combined.

I also investigate the role of mother's education (none, some primary, and completed primary), household wealth,[1] and a community-level index of the epidemiological environment experienced by the child. The dummy variables that comprise this index are whether the household has an earth floor (as compared to cement, wood, tiles, etc.), an "unimproved" source of drinking water (anything other than piped into the home, such as spring water, bore hole, rain water, well, etc.), and an "unimproved" toilet facility (anything other than a septic tank/flush toilet, including no toilet, pit toilet, etc.). The index is constructed for each community within the 20 sentinel sites in each country as the average of the household-level sums of these variables, and ranges from 0-3.[2]

There is a large literature on the importance of early life and even in-utero environment for infant, child and later life health (Currie, 2011). Low birthweight, for example, has been found to indicate a poor intrauterine environment (Martorell, 1999). I use four variables to probe the origins of the rural-urban health differential: mothers' height (in centimeters), weight (in kilograms), and body mass index (body mass index (BMI)), and the child's birthweight (in grams). Analyses using these variables are only performed for the two countries with significant differences in rural-urban height

[1]An average across dummy variables reflecting household assets, quality of housing and access to amenities, including but not limited to number of people per room, consumer durables such as radio, fridge, TV, bike, motor vehicle, etc., whether the dwelling has electricity, cement walls, and a sturdy roof, as well as the material of the floor, the main source of drinking water, the type of toilet facility, and the type of fuel used for cooking.

[2]While Young Lives tracked children who migrated between subsequent waves, it is not possible to compute community-level variables for these children as they no longer lived near other Young Lives participants.

for age when all controls are included in the model (Peru and Vietnam[3]), although mother's height and weight are available only in Peru. BMI is a measure of weight relative to height, and a simple way to assess whether a person's bodyweight departs from what is normal (i.e. in the range of 18.5-25.9 kg/m^2) for their height; it is computed as follows:

$$\text{Body mass index} = \frac{weight(kg)}{height(m^2)} \quad (2)$$

3.3 Analytic approach

Analyses begin with a non-parametric exploration of rural-urban inequalities in height for age, including kernel densities and mean height for age z-score trajectories over time. This is followed by ordinary least squares regression models establishing the absence of statistically significantly different trends in height for age in rural versus urban areas separately for all four countries and both cohorts:

$$Y_{it} = \alpha female_i + \delta age(i,t) + \beta rural(i,t) + \gamma age(i,t)rural(i,t) + e_{it} \quad (3)$$

Where Y_{it} is the height of the i^{th} Young Lives child at time t, $female_i$ is an indicator of whether the child is female, $age(i,t)$ indicates the age category of the Young Lives child (in months) at wave t, and $rural(i,t)$, the covariate of interest, indicates whether the child lives in a rural area (1) or an urban area (0) at time t. This and all following regression models adjust for serial correlation due to multiple observations on the same child over time by clustering the standard errors on the child. I estimate the model without an intercept in order to include all age categories, although the first age category's interaction with residence is excluded. I then rerun this model 1) without the interaction

[3] Additionally, birthweight is missing for 81 percent and 56 percent of Young Lives children in Ethiopia and India, respectively; it is missing only for 12 percent of the children in Peru and Vietnam, another reason that only these countries are used in these further analyses.

terms between age category and residence because they are almost exclusively insignificant at the 0.05 level, 2) with mother's education and household wealth index, and 3) with the variables in 2) plus the community-level index of epidemiological environment. Model 3, the most complex of these specifications, is estimated as follows:

$$Y_{it} = \alpha female_i + \delta age(i,t) + \beta rural(i,t) + \theta ses(i,t) + \lambda epi.env(i,t) + e_{it} \quad (4)$$

Where the dependent variable and covariates are the same as in equation 3 above (without the interaction term), $ses(i,t)$ is a vector of two covariates: mother's education and household wealth index, and $epi.env(i,t)$ is the community's epidemiological environment index.

I then undertake non-parametric and parametric explorations of the possible explanations for persistent significant differences in child health between rural and urban areas in Peru and Vietnam, consisting of comparisons between rural and urban birthweight, and mothers' height, weight, and BMI. I investigate whether rural-urban differences in birthweight explain rural-urban differences in height at age 1, and add mothers' height and weight to subsequent models. The final specification is as follows:

$$\begin{aligned} Y_{i1} = \alpha female_i + \delta age_{i1} + \beta rural_{i1} + \theta ses_{i1} + \lambda epi.env_{i1} + \xi bwght_i + \\ \vartheta momwght_i + \xi momhght_i + e_i \end{aligned} \quad (5)$$

The covariates are the same as in equation 4 above, with the addition of $bwght_i$, the child's birthweight, $momwght_i$, the mothers' weight, and $momhght_i$, the mother's height. These models are only estimated for data from wave 1, as reflected by the dependent variable of Y_{i1}; child i at wave 1.

Finally, in order to take full advantage of the longitudinal nature of the Young Lives data and the multiple measures over time of children's height for age, and to address the many indications that very early life circumstances - even before birth - may shape child health differentials, I present fixed effects regression models for each country separately. The general structure of these models is as follows:

$$Y_{it} = \beta_1 rural_{it} + \beta_2 age_{it} + \alpha_i + e_{it} \tag{6}$$

Where Y_{it} is the height for age of child i at time t, $rural_{it}$ is an indicator for whether child i is living in a rural area at time t, α_i is the unobserved, time-invariant child "effect", and e_{it} is the error term. Fixed effects regression models control for individual-specific and time invariant unobservable heterogeneities that affect child height (Dasgupta, 2012), and while they do not require the rather intensive assumptions of random effects models (in this case the assumption that the child-specific effect is uncorrelated with the independent variables), they do require the covariate of interest - in this case, "rural" - to vary with time. Between waves 1 and 2, 370 Young Lives children (3.3 percent of the sample) move between rural and urban areas; between waves 2 and 3 219 Young Lives children (2.0 percent of the sample) move.

I also include the wealth index in the fixed effects models because the socioeconomic status of movers (between waves 1 and 2) and non-movers significantly differs in Ethiopia and Peru; the wealth index of movers and non-movers between waves 2 and 3 differ only in Peru. Finally, while fixed effects models do not allow for the estimation of the effect of time-invariant covariates, nor do they fully solve the potential problem of omitted variables bias, their ability to control for these unobserved characteristics (which include, but are not limited to, early life exposures) is attractive. Fixed effects models have been used previously in the investigation of the importance of early life exposures for child health (Currie et al., 2009).

All analyses were done using R version 3.0.3 (R Core Team, 2014). Formal human subjects approval was obtained from the Princeton University Institutional Review Board.

4 Results

4.1 Rural-urban height differentials over time

Figure 1 displays kernel densities of child height for age in each country and for each cohort separately. Urban children's height curves dominate rural children's in almost all cases, with the exception being the older cohort in the third wave of data collection in Ethiopia and Vietnam; height for age differences in these graphs are most pronounced in Peru. Relative consistency across cohorts, countries, and time is striking. To further investigate whether differences in height for age in rural and urban areas change over time, mean height trajectories are constructed and presented in Figure 2, which provides evidence consistently - across countries and cohorts - of level differences in height for age between rural and urban areas but an almost complete lack of differences in trajectories. Mean trajectories are almost entirely parallel, with the exception of the older cohorts in Peru and Vietnam (and the first year of life, which is not available in the data). This suggests that rural-urban inequalities in height for age are largely determined very early, even before age 1. That inequalities are present so early and persist over time across all countries and almost all cohorts - in spite of the regions' very different nutritional patterns, disease environments, and levels of development more broadly - is striking, but is consistent with the very few other studies of this phenomenon, many of which use synthetic cohorts from cross-sectional surveys (Paciorek et al., 2013). Also consistent with previous research is the dip in height for age after age 1, when breastfeeding generally either stops (Lauer et al., 2004) or becomes nutritionally insufficient in terms of energy content, although this could also be due to 1-year olds' height being measured while lying down and 5-year olds' height being measured while standing up.

Regression models confirm significant differentials in levels but not trends in height for age in all countries and cohorts. While I present only the association between living in a rural area and height for age (Model 1 in Table 3), given the large number of indicator variables for age (and the equally large number of interactions with rural dwelling), their message is clear: while age indicators are generally statistically significant (reflecting changes in height for age z-score with age), interaction terms between these age indicators and rural dwelling are almost exclusively insignificant, indicating that height trajectories do not differ between rural and urban areas. Model 2 in Table 3 shows the coefficients on rural from regression models for each country and cohort, but without the interaction terms between rural dwelling and age. Height for age is statistically significantly lower in rural as compared to urban areas in all countries and cohorts. In standard deviation terms, these coefficients range from a difference of 72 percent of a standard deviation in height for age z-score between rural and urban children in the younger cohort in Peru to a 30 percent difference in the younger cohort in Ethiopia. The large differences in Peru are consistent with very large rural-urban health inequities reported by van de Poel et al. (2007).

4.2 Explaining the differential

I then add both household wealth index and mothers' education to the regression models to investigate whether the coefficient on rural becomes insignificant with the inclusion of household socioeconomic status, as has been found in other studies on this topic. Coefficients from these models are presented in Model 3 in Table 3; for only Ethiopian children and the younger cohort in India are rural-urban differences "explained away" by the household's wealth index and the mother's education, although the other coefficients are reduced substantially. Not surprisingly, both mothers' education and household wealth index are strongly associated with children's height for age. Table 4 presents the "full" regression model that also includes the community-level epidemiological environment index. Interestingly, in these models, the rural-urban differential among the younger cohort in India becomes significant at the 0.05 level, and is positive, suggesting that when controlling for socioeconomic status and the disease environment, rural children are better off than urban children. This is consistent with the importance of and interaction between open defecation (Spears, 2013; Spears et al., 2013), population density, and infectious disease dynamics in determining child health. Rural-urban differentials remain significant and negative, however, among the younger age cohorts in Peru and Vietnam, despite the statistical significance of the epidemiological environment in these models.

4.3 Early origins

To begin to unpack just how early children may be placed on their more or less parallel height trajectories, I present both non-parametric and parametric analyses. While there is significant heaping of birthweight in both Peru and Vietnam, as shown in Figure 3, t-tests indicate that children's birthweight is statistically significantly lower in rural than in urban areas (Peru: t-statistic = 5.6278, p-value = <0.001; Vietnam: t-statistic = 3.7313, p-value = <0.001). Additionally, the more obvious differences in birthweight between rural and urban areas in Peru as compared to Vietnam are consistent with the very pronounced differences in the kernel density graphs of height for age from Peru (Figure 1), and other literature on this topic (Van de Poel et al., 2007). These findings indicate that rural-urban differentials are present even at birth, and that area-level health inequalities may be established very early on in life.

Just how early on? Even mothers' weight, height, and BMI are higher in urban than in rural Peru (Figure 4), and these differences are all statistically significant at the 5 percent level (weight: t-statistic = 7.6214, p-value = <0.001; height: t-statistic = 10.8697, p-value = <0.001, BMI: t-statistic = 8.4854, p-value = <0.001), suggesting rural-urban inequality even in the intrauterine environment. Table 5 presents models of height for age in wave 1; the inclusion of birthweight in Model 1 renders rural-urban differentials statistically insignificant in Vietnam, and the inclusion of mothers' height and weight renders the differentials insignificant in Peru. Higher birthweight is associated with higher height for age z-score at 1 year in both countries; taller mothers on average have taller children in Peru.

Given the evidence presented here regarding the very early onset and persistence of health inequalities between rural and urban areas and the importance of the intrauterine environment and mothers' physical characteristics, the final models consist of fixed effects regressions with a child fixed effect introduced as an indicator for each child. These models, like all others, are run separately for each country and cohort. Child fixed effects used in this way control for both observed and unobserved time-invariant "characteristics" of the children, including fetal exposures, mothers' health during pregnancy, and her household's wellbeing during the pregnancy, to name a few. As can be seen in Table 6, rural-urban health differentials are no longer statistically significant at the 0.05 level in any country or cohort (with the exception of the older age cohort in Vietnam), suggesting that initial endowments and/or time-invariant characteristics of the children or their community play a substantial role in explaining the large and persistent inequalities in child health between rural and urban areas in developing countries. Both rural and urban height trajectories change over time in the Vietnamese older cohort and appear not to be as well explained in the fixed effects models as in the other countries and cohorts.

5 Discussion

This paper is the first to illustrate almost entirely parallel and highly unequal height trajectories in rural versus urban areas in four very different developing country contexts. The findings presented here also suggest that differential endowments - even those before birth - may help set rural and urban children on these different height and therefore health courses. Low height for age in rural areas (and in LMICs in general) has sizeable implications for the wellbeing of children and the development process more broadly.

While there is somewhat of a consensus regarding the capacity of children to catch up in height, even until adolescence (Fink and Rockers, 2014), the parallel trajectories in rural and urban areas shown here do not indicate that, on average, rural children will ever become as tall as their urban counterparts. Golden (1994) outlines two possible explanations for persistent lack of catch-up in height among children lagging behind - either they are set on an early trajectory that is immutable, or the conditions surrounding the child do not sufficiently improve over time so as promote growth. While the evidence presented here suggests the former in the case of rural as compared to urban children, it is not clear to what extent these early disadvantages might have been mitigated by intervention or improvement in circumstances, had improvements occurred. Interestingly, however, on average, Young Lives children living in both rural and urban areas saw their household's socio-economic status improve between waves 1 and 3, and this increase was more pronounced in rural than in urban areas (Table 7). Largely reflecting a small base and more room for improvement in rural areas, the percentage increase is remarkable nonetheless (over 100 percent in rural Ethiopia). It is concerning, therefore, that average rural-urban height for age inequalities did not narrow significantly during this time, although these findings are consistent with recent evidence that economic growth (on a national level) is not generally associated with reduced child undernutrition (Vollmer et al., 2014).

Finally, a note on the limitations of this study. First, fixed effects models do not solve the problem of omitted variables. While I hypothesize that it is differential endowments that are driving the results, it is not impossible that other unobserved, time-invariant characteristics may be responsible. Second, the models presented here and the data they are based on can unfortunately give no insight into the mechanisms underlying the findings. Third, while patterns of growth significantly differ across childhood and adolescence, the sample of rural-urban movers is unfortunately too small to include an interaction term between area and age in the fixed effects model. Fourth, while it would be ideal not simply to the cluster standard errors on the child, but to cluster them on the sentinel site in which the Young Lives child lives, this cannot be done while simultaneously including rural-urban migrants in the models. When the migrants move out of their original sentinel sites they are not assigned a new site; if models clustered the standard errors on the sentinel site, all migrants - for whom this value is missing - would be dropped and fixed effects models could not be estimated.

In sum, the consignment of rural children to lives of poorer health and therefore reduced wellbeing, educational attainment, and productivity, as compared to their urban counterparts, must be addressed, as the early emergence and persistence of poor health among disadvantaged children has implications for their entire life course (Alderman et al., 2006). While rural areas are on average poorer than urban areas, and the literature does indicate that poorer children tend to have more trouble bouncing back from episodes of poor health (Hoddinott and Kinsey, 2001; Outes and Porter, 2013), simply tackling inequalities in child malnutrition as a problem of childhood poverty may not be sufficiently nuanced. Given that inequalities appear already at birth, intervention must begin earlier than nutritional supplements in school or cash payments for clinic visits and immunization completion. Prioritizing maternal nutrition and health is essential; the spatial and environmental aspects (Tu et al., 2012) of these differentials must be addressed.

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6 Graphs and Tables

Table 1: Descriptive of the study population by age cohort

Variable name	Ethiopia			India			Peru			Vietnam		
	Younger	Older	p-value	Younger	Older	p-value	Younger	Older	p-value	Younger	Older	p-value
Height for age	-1.37 (1.39)	-1.41 (1.26)	0.224	-1.45 (1.19)	-1.58 (1.03)	<0.001	-1.33 (1.16)	-1.46 (0.99)	<0.001	-1.18 (1.12)	-1.45 (0.99)	<0.001
Rural	0.61 (0.49)	0.61 (0.49)	0.757	0.76 (0.44)	0.76 (0.43)	0.217	0.30 (0.46)	0.25 (0.43)	<0.001	0.80 (0.40)	0.80 (0.40)	0.564
Wealth index	0.28 (0.18)	0.29 (0.18)	<0.001	0.46 (0.20)	0.47 (0.20)	0.188	0.48 (0.230	0.52 (0.22)	<0.001	0.51 (0.21)	0.52 (0.20)	0.009
Caregiver's education (%)												
None	53.3	51.9		53.6	63.1		8.7	11.0		16.0	17.3	
Some primary	30.7	29.6	0.028	19.1	17.5	<0.001	41.6	44.1	<0.001	45.4	42.1	0.627
> primary	16.0	18.5		27.3	19.4		49.6	45.0		38.5	40.6	
Female (%)	47.4	48.9	0.189	46.5	50.2	0.001	49.6	47.1	0.058	49.0	50.3	0.271
Epidemiological environment	2.70 (0.35)	2.70 (0.34)	0.697	1.90 (0.58)	1.90 (0.58)	0.860	1.75 (0.58)	1.63 (0.69)	<0.001	1.64 (0.69)	1.66 (0.70)	0.388
Birthweight	-	-	-	-	-	-	3204.1 (509.1)	-	-	3100.1 (447.1)	-	-
Mothers' height	-	-	-	-	-	-	150.1 (5.4)	-	-	-	-	-
Mothers' weight	-	-	-	-	-	-	56.0 (9.6)	-	-	-	-	-
Mothers' BMI	-	-	-	-	-	-	24.8 (3.8)	-	-	-	-	-
N	1,678	800	-	1,868	952	-	1,880	645	-	1,906	963	-

Table 2: Descriptive statistics of the study population by rural-urban status

Variable name	Ethiopia			India			Peru			Vietnam		
	Urban	Rural	p-value	Urban	Rural	p-value	Urban	Rural	p-value	Urban	Rural	p-value
Height for age	-1.12 (1.26)	11.55 (1.38)	<0.001	-1.20 (1.12)	-1.61 (1.12)	<0.001	-1.12 (1.06)	-1.95 (1.05)	<0.001	-0.77 (1.05)	-1.40 (1.06)	<0.001
Wealth index	0.44 (0.14)	0.18 (0.12)	<0.001	0.66 (0.13)	0.40 (0.17)	<0.001	0.58 (0.19)	0.27 (0.14)	<0.001	0.71 (0.14)	0.47 (0.19)	<0.001
Caregiver's education (%)												
None	29.5	67.9	<0.001	27.8	66.6	<0.001	3.6	23.3	<0.001	5.9	19.1	<0.001
Some primary	42.3	22.6		24.1	16.7		34.6	60.9		30.3	47.8	
> primary	28.2	9.5		48.1	16.8		61.8	15.7		63.8	33.1	
Female (%)	50.0	47.1	0.088	45.8	48.4	0.041	48.2	50.8	0.040	48.4	49.7	0.353
Epidemiological environment	2.33 (0.27)	0.08 (2.94)	<0.001	1.06 (0.39)	2.18 (0.28)	<0.001	1.42 (0.57)	2.46 (0.30)	<0.001	0.47 (0.39)	1.92 (0.36)	<0.001
Birthweight	-	-	-	-	-	-	3,247.9 (503.3)	3,091.6 (507.1)	<0.001	3,174.4 (426.4)	3,079.1 (450.8)	<0.001
Mothers' height	-	-	-	-	-	-	150.7 (5.450	148.6 (5.06)	<0.001	-	-	-
Mothers' weight	-	-	-	-	-	-	57.4 (10.0)	52.4 (7.5)	<0.001	-	-	-
Mothers' BMI	-	-	-	-	-	-	25.2 (4.04)	23.7 (2.88)	<0.001	-	-	-
N	909	1,569		691	2,129		1,760	765		555	2,314	

Figure 1: Probability density functions of height for age

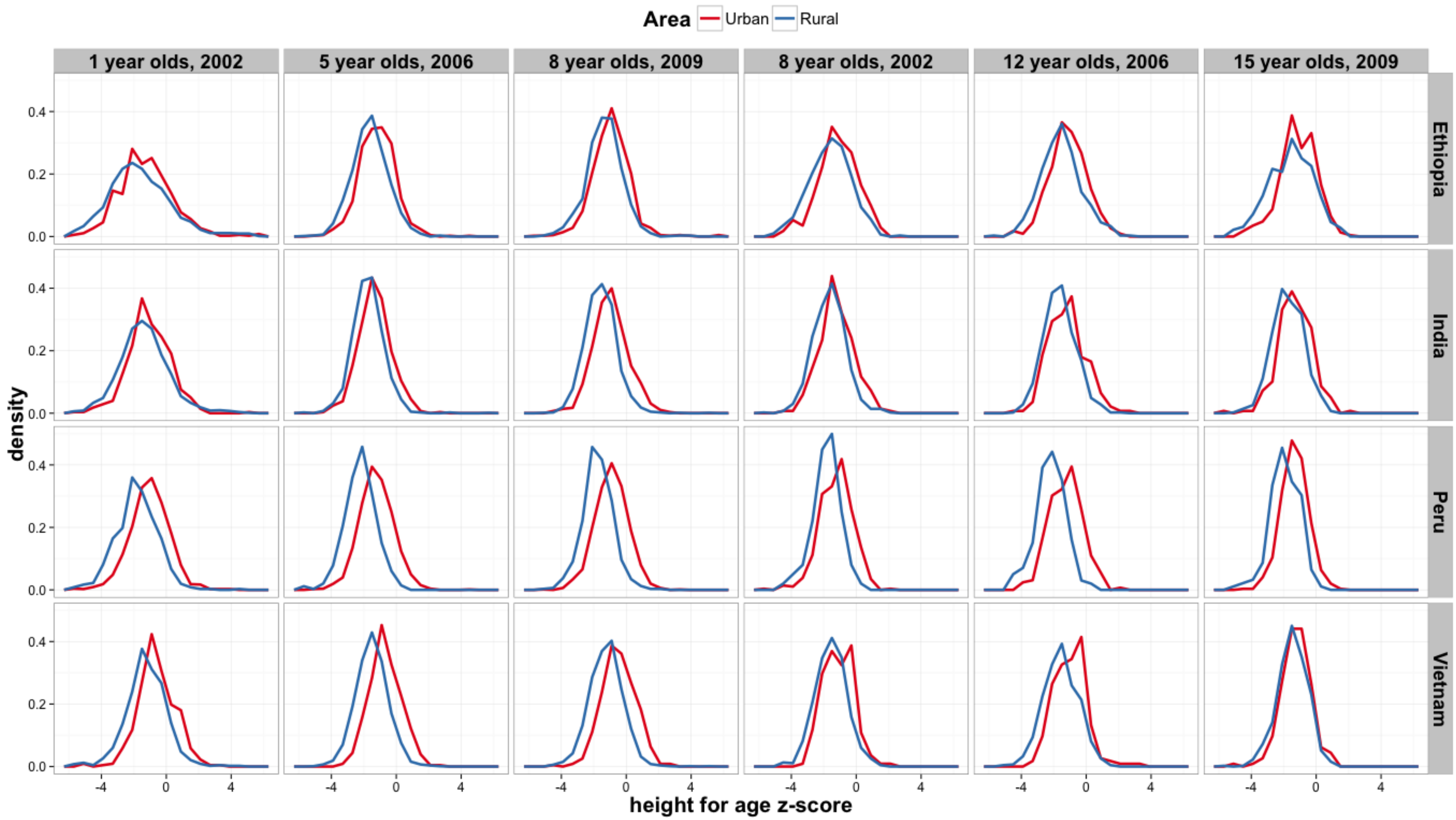

Figure 2: Mean trajectories of height for age

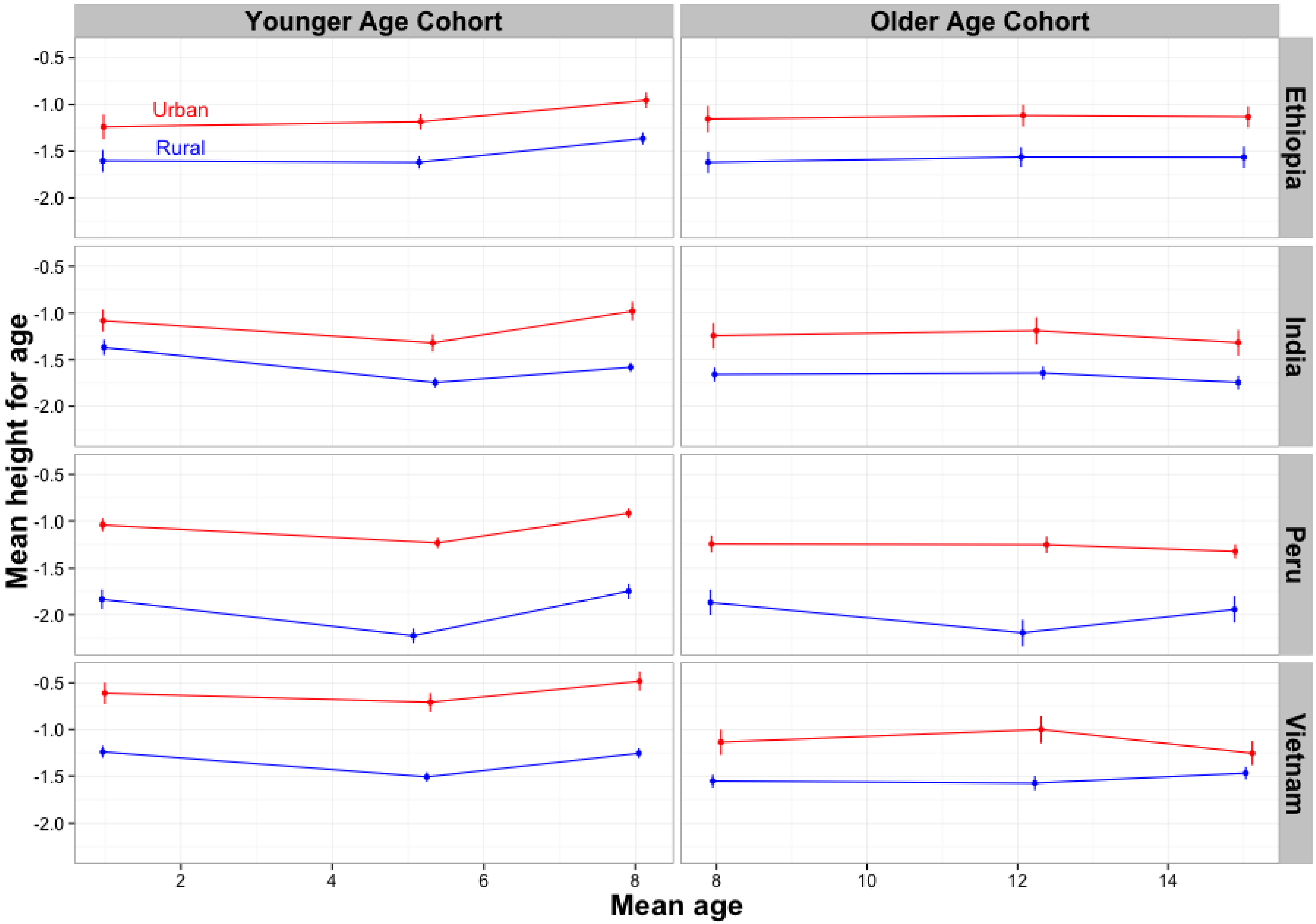

Table 3: Main effects from linear regression models of height for age including interaction terms between rural and age groups (Model 1) and not including interaction terms between rural and age groups (Model 2); Model 3 includes more control variables

Variable Name	Ethiopia		India		Peru		Vietnam	
	Younger	Older	Younger	Older	Younger	Older	Younger	Old
(Model 1)								
Rural	-0.706** (0.227)	-0.929*** (0.244)	-0.228 (0.210)	-0.364† (0.208)	-0.828*** (0.179)	-0.116 (0.218)	-1.232*** (0.321)	-0.353 (0.508)
Female	0.199*** (0.037)	0.413*** (0.048)	0.125*** (0.031)	-0.081* (0.038)	0.100*** (0.028)	-0.026 (0.043)	0.084** (0.029)	0.136*** (0.037)
R^2	0.538	0.591	0.623	0.718	0.644	0.725	0.576	0.699
(Model 2)								
Rural	-0.416*** (0.038)	-0.429*** (0.049)	-0.434*** (0.036)	-0.435*** (0.045)	-0.840*** (0.032)	-0.683*** (0.050)	-0.735*** (0.036)	-0.433*** (0.046)
Female	0.201*** (0.037)	0.394*** (0.048)	0.124*** (0.031)	-0.078* (0.038)	0.100*** (0.028)	-0.033 (0.043)	0.087** (0.029)	0.134*** (0.037)
R^2	0.533	0.585	0.625	0.715	0.642	0.720	0.572	0.696
(Model 3)								
Rural	0.007 (0.053)	-0.109 (0.068)	-0.029 (0.044)	-0.189*** (0.056)	-0.250*** (0.038)	-0.187*** (0.060)	-0.349*** (0.040)	-0.187*** (0.052)
Wealth index	1.358*** (0.152)	1.168*** (0.200)	1.178*** (0.105)	0.610*** (0.129)	1.130*** (0.083)	1.546*** (0.131)	1.053*** (0.095)	0.894*** (0.125)
Mothers' education	0.133*** (0.028)	0.070* (0.034)	0.127*** (0.020)	0.128*** (0.026)	0.392*** (0.025)	0.094** (0.036)	0.252*** (0.024)	0.185*** (0.029)
Female	0.216*** (0.037)	0.401*** (0.047)	0.121*** (0.030)	-0.085* (0.038)	0.095*** (0.027)	-0.018 (0.041)	0.096*** (0.028)	0.115** (0.036)
R^2	0.542	0.592	0.641	0.722	0.680	0.746	0.605	0.714

All models cluster standard errors at the child level and include indicator variables for monthly age categories
† p ‹ .10; * p ‹ .05; ** p ‹ .01; *** p ‹ .00

Table 4: Linear regression models of height for age, including household wealth, mothers' education, and a community-level index of the epidemiological environment, coefficient(standard error)

Variable Name	Ethiopia		India		Peru		Vietnam	
	Younger	Older	Younger	Older	Younger	Older	Younger	Old
Rural	0.094 (0.077)	-0.016 (0.097)	0.246*** (0.064)	-0.170* (0.086)	-0.203*** (0.041)	-0.067 (0.068)	-0.129* (0.065)	-0.014 (0.092)
Wealth index	1.310*** (0.155)	1.115*** (0.203)	1.022*** (0.108)	0.598*** (0.135)	1.011*** (0.092)	1.319*** (0.145)	0.858*** (0.105)	0.752*** (0.140)
Mothers' education	0.127*** (0.028)	0.068* (0.034)	0.117*** (0.020)	0.128*** (0.027)	0.379*** (0.026)	0.074* (0.036)	0.239*** (0.024)	0.172*** (0.029)
Female	0.217*** (0.037)	0.399*** (0.047)	0.121*** (0.030)	-0.170* (0.038)	0.096*** (0.027)	-0.017 (0.041)	0.096*** (0.028)	0.113** (0.036)
Epidemiological environment index	-0.168 (0.107)	-0.179 (0.133)	-0.290*** (0.050)	-0.020 (0.067)	-0.094** (0.031)	-0.179*** (0.050)	-0.189*** (0.045)	-0.140* (0.061)
R^2	0.545	0.592	0.643	0.712	0.681	0.747	0.606	0.715

All models cluster standard errors at the child level and include indicator variables for monthly age categories

†p ‹ .10; *p ‹ .05; **p ‹ .01; ***p ‹ .001

Figure 3: Probability density functions of Young Lives' children's birthweight

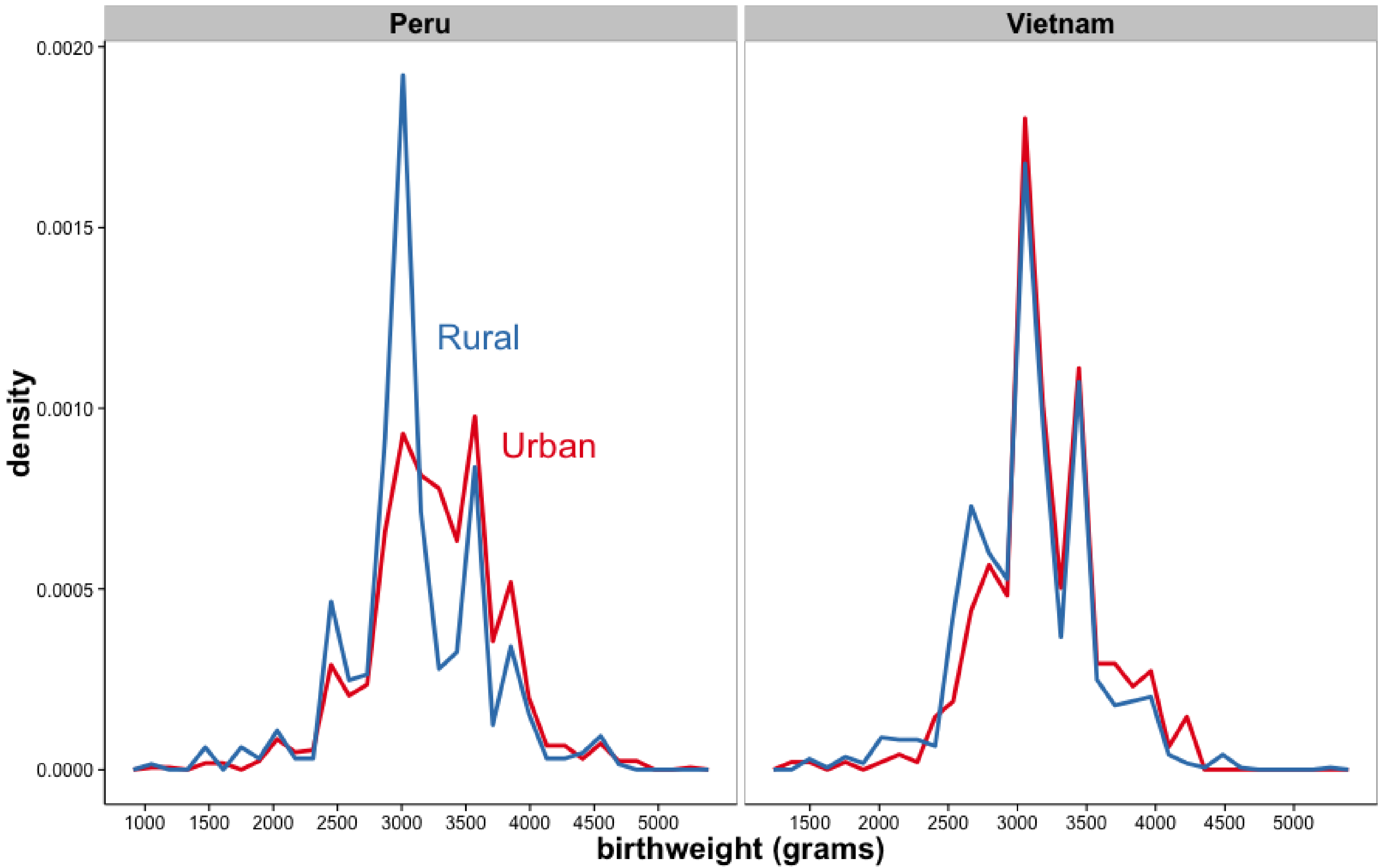

Figure 4: Probability density functions of Young Lives' children's birthweight

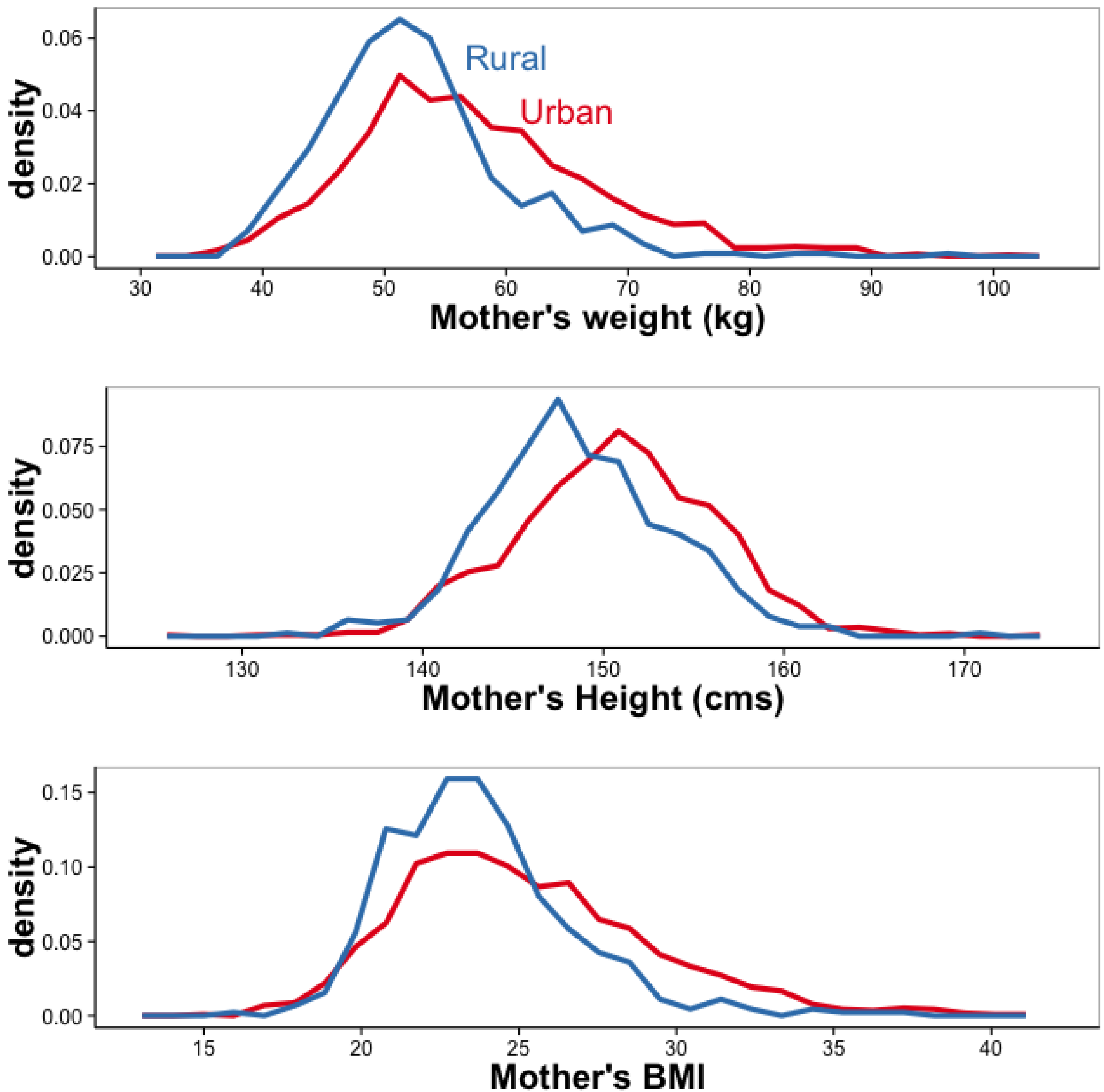

Table 5: Regression models of height for age in wave 1 including all control variables plus the Young Lives child's birthweight (Model 1) and their mothers' height and weight (Model 2)

	Model 1		**Model 2**
Variable names	**Peru**	**Vietnam**	**Peru**
Rural	-0.199* (0.089)	-0.132 (0.146)	-0.137 (0.089)
Birthweight (per 100 grams)	0.659*** (0.055)	0.629*** (0.062)	0.598*** (0.055)
Mother's height	-	-	0.052*** (0.005)
Mother's weight	-	-	-0.001 (0.003)
Wealth index	0.669*** (0.180)	0.548** (0.212)	0.522** (0.176)
Mothers' education	0.357*** (0.054)	0.085* (0.042)	0.274*** (0.053)
Female	0.307***	0.242 (0.054)	0.269*** (0.053)
Epidemiological environment index	-0.090 (0.071)	-0.103 (0.103)	-0.152* (0.069)
R^2	0.624	0.515	0.646

All models cluster standard errors at the child level and include indicator variables for monthly age categories

†p ‹ .10; *p ‹ .05; **p ‹ .01; ***p ‹ .001

Table 6: Fixed effects regression models of height for age z-scores in each country and cohort, coefficient(standard error)

	Ethiopia		India		Peru		Vietnam	
	Younger	Older	Younger	Older	Younger	Older	Younger	Older
Rural	-0.019 (0.229)	-0.006 (0.172)	0.033 (0.309)	-0.166 (0.321)	0.063 (0.118)	-0.037 (0.136)	-0.096 (0.214)	-0.422** (0.113)
N	1,801	925	1,875	952	1,886	653	1,907	965

All models control for age of the child and wealth index in addition to including a fixed effect for each child; standard errors are clustered on the child.
†p < .10; *p < .05; **p < .01; ***p < .001

Table 7: Changes in wealth index over time

Country	Cohort	wave 1	wave 1 p-value	wave 3	wave 3 p-value	% increase
Ethiopia	Urban	0.393	<0.001	0.474	<0.001	20.6
	Rural	0.118		0.244		107.2
India	Urban	0.644	<0.001	0.685	<0.001	6.4
	Rural	0.332		0.462		39.2
Peru	Urban	0.534	<0.001	0.633	<0.001	18.5
	Rural	0.221		0.346		56.8
Vietnam	Urban	0.687	<0.001	0.803	<0.001	16.9
	Rural	0.378		0.564		49.3