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Catching up from early nutritional deficits? Evidence from rural Ethiopia☆

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ABSTRACT

We examine the nutritional status of a cohort of poor Ethiopian children and their patterns of catch-up growth in height-for-age between three key development stages: age one, five and eight. We use ordinary least squares (within community) and instrumental variables analysis. During the earliest period, we find that nutritional catch-up patterns vary substantially across socioeconomic groups: average catch-up growth in height-for-age is almost perfect among children in relatively better-off households, while among the poorer children, relative height is more persistent. Between five and eight years of age, however, we find near-perfect persistence and no evidence of heterogeneity in catch-up growth. Our findings suggest that household wealth, and in particular access to services, can lead to substantial catch-up growth early on in life. However, for our sample, the window of opportunity to catch up appears to close as early as the age of five.

1. Introduction

Childhood undernutrition is of the most pressing issues in current development policy (Grantham-McGregor et al., 2007). Evidence from medical and paediatric research indicates that anthropometric and cognitive development of adults is largely determined during gestation and early childhood, and might be subject to ‘critical periods’. In particular, nutritional inputs during pregnancy and the first two or three years of a child’s life have been documented as crucial in determining later adult height, health and other significant outcomes (Doyle et al., 2009; Victora et al., 2010). Similarly, shocks during these critical developmental periods can have irreversible effects on boys’ and girls’ long-term cognitive abilities, anthropometric status and health.

Recently models of human capital formation that incorporate these insights have become influential in the economics discipline (Cunha et al., 2006; Cunha and Heckman, 2007). A feature of these models is that an efficiency-equity trade-off does not exist in the early years (i.e. early investments are both efficient and equitable), prompting Alderman (2010) to argue persuasively that spending on early childhood nutrition should not be viewed as a redistributional tool but as long-term investments in health, nutritional and cognitive development.

Related to the concept of critical periods is the notion that nutrition and other human capital dimensions might be subject to catch up growth. The medical literature documents that higher than normal height velocity can be achieved following a period of retardation, such that previously lagging individuals might return to the statistically normal growth curve. Catch-up growth is characterised by an improvement in the percentile position in the distribution (Boersma and Wit, 1997). Evidence from animal studies shows that near-perfect catch up is common for mildly undernourished subjects, but stunting might be permanent when nutritional deficits begin early and are prolonged. These studies also show

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that nutritional remediation is effective, and catch up growth is achieved only while the critical period of growth remains open. Evidence on human catchup from the nutrition and health literature shows some similar results: Martorell et al. (1994) survey evidence from medical literature and find evidence of catch up growth when living conditions are improved, especially for younger children. Schroeder et al. (1995) find that nutritional supplementation has a significant impact on growth for under 3 year olds in Guatemala. Adair (1999) finds almost total catch up for children aged 2–12 in the Philippines.

A small literature in economics seeks to quantify catch up growth in child nutrition (Deolalikar, 1996; Fedorov and Sahn, 2005; Alderman et al., 2006; Mani, 2008). While there is agreement that catch up is highest in early childhood, estimates of catch up growth differ widely by age and methods of analysis. A feature of these studies is that they focus on average rates of catch-up across the entire distribution of children, regardless of nutritional status of the child or the economic ability of their families to carry our remedial investments. Yet the medical literature suggests that catch-up growth might be expected among those below the standard growth curve, and only once the original nutritional depravation has been removed (Boersma and Wit, 1997).

In this paper, we analyse nutritional catch-up patterns in a sample of Ethiopian children. We address the shortcomings of the extant literature and explore how household socioeconomic status might influence height velocity, while allowing for catchup rates to vary across the height distribution. Assuming households have homogenous (similar) preferences, children living in relatively rich, less credit constrained households might be able to achieve higher rates of nutritional catch up than their poorer counterparts. We use the Ethiopian Young Lives sample, a longitudinal dataset of relatively poor children, that provides three waves of anthropometric and socioeconomic data measured at key stages of development: at the age of one, five and eight respectively. Exploiting this structure, we can also test whether returns to nutritional investments vary between early childhood (1–5 years) and mid-childhood (5–8 years).

A handful of studies have examined socioeconomic differences in nutritional status, mostly in a developed country context. To our knowledge, our paper is the first to investigate differential patterns of catch up growth for different age groups, and across the socioeconomic distribution. Doyle et al. (2009) review evidence showing that low birth weight in developed countries has clear long-term consequences for human capital, and further find significant differences between high and low socioeconomic groups. Batty et al. (2009) also review several studies that find significant impact of various measures of socioeconomic status on height. Finch and Beck (2011) find significant socioeconomic gradients in the height for age of a cross section of US children aged 2–6 years. Evidence for developing countries is quite scarce. Rona et al. (2003) find cross-sectional socioeconomic differences in height in Trinidad and Tobago, and Webb et al. (2008) provide evidence in several countries of Eastern Europe that adult height is associated with childhood socioeconomic circumstances. Ruel et al. (1995) expand on nutritional effects of the Guatemala study outlined above (Schroeder et al., 1995) and find that girls from poorer backgrounds benefited more from the supplementation than girls from wealthier families.

In our empirical analysis, we estimate a dynamic model of nutritional status and explore whether the gradient of catch-up growth – that is, the coefficient on lagged height-for-age z-scores – varies by socioeconomic status. By documenting the link between early childhood nutritional status and the socioeconomic gradient of catch up our results go beyond the standard findings of the literature. In Section 4, we present non-parametric (graphical) estimates of catch up growth and find that, between the age of one and five, undernourished children from better off households experience higher height velocity than their poorer but equally undernourished counterparts. At the same time, we find little evidence of differential catch up growth across wealth groups for the same children in the period between five and eight years of age, suggesting that nutritional remediation after the age of five might be ineffective.

In Section 5, we revisit these findings in a parametric context, including applying instrumental variables (IV) methods to address endogeneity concerns. We find ordinary least squares and IV methods broadly consistent with the non-parametric analysis. Higher height velocity among relatively rich children implies that catch up growth during early childhood for these children is near total, and the differences between catch up across quartiles of the wealth distribution are statistically significant. To summarise the contribution of the paper, we find non-linear patterns of heterogeneous catch up growth, with height velocity highest amongst undernourished children in relatively wealthy households. This evidence is consistent with compensatory investments under imperfect credit markets, but we cannot rule out that differences are driven by household preferences. Our findings indicate that nutritional interventions for the poorest households, even in very poor settings, could have considerable impact on future human capital and that such interventions would only be effective if targeted at infant children.

The remainder of the paper is structured as follows. In Section 2 we discuss the theoretical background and methodology. In Section 3 we describe our data and provide some descriptive statistics, while Sections 4 and 5 present the core of the analysis. We conclude in Section 6.

2. Methodology

Strauss and Thomas (2008) provide a comprehensive survey of recent developments in applied microeconomic analysis regarding health over the life course, and Almond and Currie (2010) summarise recent empirical evidence on the persistent impact of early life conditions on future outcomes including health, cognitive ability and earnings. A theoretical framework that echoes the nutrition literature and has a focus on "critical period programming" has become influential in economics (Cunha et al., 2006). The technology of skill (or human capital) formation determines complementarity or substitutability of investments in different time periods over time, which crucially underpins the possibility for catch up growth and nutritional remediation. In the extreme case of perfect complementarity, investments in period two (or later) *cannot compensate* for the lack of investment in period one. In sum, early child investments must be distinguished from late child investments, and an equity-efficiency trade-off may exist for "late" investment, but not for "early" investment.

Related to critical periods is the notion that nutrition and other human capital dimensions might be subject to catch up growth. The medical literature referenced in the introduction provides evidence that higher than normal height-for-age growth can be achieved following a period of retardation, leading to catch up growth.[1] Similarly, Almond and Currie (2010) discuss the concept of remediation, or the extent to which a shock experienced in an early developmental period can subsequently be mitigated. The authors offer evidence that shocks cause more long-term damage amongst poorer families, even when facing the same shock.

Whether or not remediation is possible depends on several factors: the total productivity of all combined investments through childhood; the timing and combination of shocks and subsequent investments; and the extent of substitutability/complementarity that may exist at different stages. For example, higher nutritional status in an early period may lead to increased absorption of nutrition in later periods. Almond and Currie (2010) note that it is not necessary to observe all investments and estimate the substitutability coefficient for health production; we may simply observe how a shock or nutritional intervention in the first period affects outcomes in later periods. The reduced form estimation of the health effect of such a shock will not only include the pure biological technological effect but also the effect of the household's responses. Whether parental investments are compensatory or reinforcing will depend on the degree of intertemporal substitution in the health production function but also on the functional form that household preferences take. It remains a question open to empirical investigation.

Empirically, height-for-age *z*-score (HAZ_{it-1}), for child (i) at time (t), can be modelled as a function of lagged height-for-age *z*-score at time ($t-1$), which proxies for previous nutritional investments, and a vector of child and household characteristics (X_{t-1}), which proxy for contemporaneous nutritional investments. Height-for-age might also be affected by unobserved child and household characteristics (μ_i) as well as community unobservables (μ_v).

$$HAZ_{it} = X_{t-1}\beta + HAZ_{it-1}\gamma + \mu_v + \mu_i + v_{it} \quad (1)$$

Several earlier studies noted in the introduction have used variations of Eq. (1) to obtain estimates of catch up growth.[2] When consistently estimated, Eq. (1) provides parameter estimates for the degree of persistence in height-for-age between period t and $t-1$. Under perfect catch up the coefficient on lagged HAZ(γ), would be close to zero, while a coefficient close to unity would be consistent with perfect persistence.

However, while the coefficient on lagged HAZ can provide an estimate of average persistence, it is not clear that this model is sufficiently flexible to capture the complex patterns underlying catch up growth. In particular, it assumes that nutritional investments do not respond to past nutritional status and imposes linearity in the lagged HAZ coefficient. There are two possible reasons why the relationship may be non-linear; first, behavioural responses – parents may compensate or reinforce nutritional deficits that they observe and; second, biological factors may lead to increased growth velocity for children at the lower end of the growth distribution.

The remediation model discussed above in Almond and Currie (2010) would suggest that household nutritional investments will respond to early realisations of nutritional status, resulting in either compensatory or reinforcing actions of parents. Which occurs will depend on technology, preferences and resources. We are unable to directly observe whether parents are able to make compensatory investments but we can hypothesise that for poorer families, this may be more difficult. Behrman et al. (1982) show in a model with more than one child, that even if parents would prefer to accumulate the human capital of the less well-off sibling, it still may not happen if inter-temporal substitution is difficult due to imperfect credit markets.

On the second point, the paediatric and medical literature suggest that higher velocity is likely to happen among children in the most vulnerable positions, and only in so far as nutritional *remediation* takes place. This would suggest that catch up growth should show patterns of heterogeneity across different levels of nutritional investment on the one hand, and non-linearity across the distribution of height on the other. Failing to take these features into account are likely to lead to biases in catch up estimates, and in particular imply that the functional form linking HAZ and lagged HAZ in Eq. (1) might be misspecified.

In this paper, we use non-parametric and parametric methods to address the shortcomings of earlier studies. First, we present kernel smoothing estimates of height-for-age *z*-scores on lagged height-for-age *z*-scores across wealth quartiles. This analysis is sufficiently flexible to allow for non-linearities in the HAZ relationship and across the socioeconomic distribution, and yields the core of our empirical results. Secondly, we apply an array of parametric methods to corroborate the findings of the graphical analysis. We modify Eq. (1) to test whether catch-up growth differs across households from different parts of the wealth distribution by interacting the lagged HAZ coefficient with household wealth.

$$HAZ_{it} = X_{t-1}\beta + \sum_{j=1}^{4} w_{ij} \times HAZ_{it-1}\gamma + \mu_v + \mu_i + v_{it} \quad (2)$$

$$Stunting_{it} = X_{t-1}\beta + \sum_{j=1}^{4} w_{ij} \times Stunting_{it-1}\gamma + \mu_v + \mu_i + v_{it} \quad (2')$$

[1] Boersma and Wit (1997) note that catchup growth may also take the form of an extended period of growth – for example, extending the adolescent growth period.

[2] Several previous studies have specified this model as a growth equation instead, namely $(HAZ_{it} - HAZ_{it-1}) = HAZ_{it-1}\gamma^* +$ covariates. If the relationship between current and lagged height is linear, then the two equations are equivalent, and in comparison with Eq. (1), $\gamma^* = \gamma - 1$. See Fedorov and Sahn (2005) for further discussion of this point.

where $j = 1, 2, 3, 4$ represents four quartiles of the distribution of a composite wealth index. We also test for non-linearities in this relationship by examining the persistence of stunting (a binary variable) as expressed in Eq. (2′).

Our panel dataset contains measurements for each child in three time periods: as a new born (aged 0–1), in early childhood (aged 4–5) and in mid-childhood (aged 7–8). This allows us to test whether the relationship in Eq. (2) is stable over time. The findings of previous studies suggest that from the age of 3–5, catch up growth is substantially lower. We expect a similar pattern regarding the effectiveness of nutritional investments.

Empirical estimates of Eqs. (1) and (2) and, specifically, the relation between nutritional status in two periods are likely to suffer from endogeneity concerns (Hoddinott and Kinsey, 2001; Fedorov and Sahn, 2005; Strauss and Thomas, 2008). Unobserved parental investments, measurement error and genetic potential are among a number of factors that could lead to biased and inconsistent estimates. We saturate the model with a number of child and household characteristics to reduce potential biases from heterogeneity in the error term. In particular, the vector of controls, (X_{t-1}), includes information on pregnancy and child birth experiences, past illness of the child, child characteristics (age, birth order and gender), household demographics and household composition variables as well as parental education. We also include maternal height as a proxy for the genetic potential of the child. Finally, we include a full set of cluster fixed effects to capture unobserved heterogeneity in the patterns of catch up growth across the sample communities.[3]

We address any remaining endogeneity concerns applying instrumental variable (IV) techniques. We estimate determinants of the lagged height-for-age z-scores (HAZ) using instruments (z_{it-1}) that are orthogonal to the error term in the main equation. We incorporate the socioeconomic gradient analysis into the IV technique by estimating the IV model for different quartiles of the distribution.

$$\text{Main-Equation}: \quad \text{HAZ}_{it} = X_{t-1}\beta + \text{HAZ}_{it-1}\gamma + \mu_v + \mu_i + v_{it} \quad \text{if } w_{ij} \leq \tilde{w} \tag{3}$$

$$\text{First-Stage}: \quad \text{HAZ}_{it-1} = X_{t-1}\xi + Z_{it-1}\phi + u_{it-1} \quad \text{if } w_{ij} \leq \tilde{w} \tag{4}$$

whereby $\tilde{w}$ equals 2 and 4. In other words, we obtain IV estimates for the full sample and the bottom half of the wealth distribution separately.

Our choice of instruments is motivated by the demographics and medical literature on the impact of seasonality on birth weight and long-term health. Medical studies document patterns of seasonality in foetal development and birthweight (Van Hanswijck de Jonge et al., 2003; McGrath et al., 2005; Chodick et al., 2007; Torche and Corvalan, 2010), with seasonality varying across countries in different latitudes and level of development (Chodick et al., 2009; Strand et al., 2011). Studies with neonatals also show that seasonality in the availability of nutrients (Doblhammer and Vaupel, 2001) and risk of infection (Costa and Lahey, 2005) in early life, affect the long-term prospects of children. Ethiopian studies have also uncovered substantial seasonality. Dercon and Krishnan (2000) report seasonal variations in the nutritional intake of adults, while Ferro-Luzzi et al. (2001) report strong correlations between diarrheal child morbidity and seasonal patterns of retroviral infections.

We use the quarter of birth as an instrument for height-for-age at the age of 6–18 months. Results for the first-stage regressions indicate that children born in the second quarter of the year and again towards the end of the year have significantly lower HAZ z-scores one year later (see Table A1). We interpret this as indication of nutritional deficiencies suffered by the newborns during the critical period when babies are no longer being breast fed. Children born during the end of the year, will typically stop breast feeding during the main Ethiopian rainy season or *Kremt* (from June to September) – which is the critical food insecure period among rural households as well as the period of maximal exposure to diarrhoeal infections (Ferro-Luzzi et al., 2001). Similarly, children born during the second quarter might be exposed to the second shorter season or Belg that takes place in March and April.

The credibility of the IV technique relies on the 'validity' and 'strength' of our instruments. Although the structure of the YL sample does not allow us to apply Household/Mother Fixed Effects IV methods, as used for example in Alderman et al. (2006) – we apply Cluster Fixed Effects IV methods instead –, we believe that our set of instruments are truly orthogonal to the error term in Eq. (2). In order to be a valid instrument, seasonality should not be correlated with any unobserved nutritional investments. A concern over the validity of the exogeneity restriction, is whether households plan the season of birth of their children (as was evidenced in sub-Saharan Africa by Artadi, 2005). Households that do so might also differ in other ways, such that the timing of birth might also be correlated with nutritional investments or parental preference. However, we find no evidence that household characteristics are linked to season of birth.[4]

An additional concern in applying IV methods relates to how informative, or strong, the instruments are. Finite-sample theory suggests that IV estimation with weak instruments can lead to very misleading results. Weak IVs provide not only biased point estimates – towards OLS –,

[3] In the Section 5, we also report evidence for Eqs. (1) and (2) where the X_{t-1} vector is omitted and only include cluster dummies as controls. We report this model for comparison purposes. The evidence confirms our original suspicion that omission of covariates might bias estimates of catch up and socioeconomic gradients, although the implied bias is mos is more modest than what we would have expee would have expected.

[4] More specifically, we estimate a probit model of the season of birth dummy on the vector of controls (X_{t-1}) and village fixed effects, and found little correlation between household characteristics and the quarter of birth. Some of the household demographic variables were significant (e.g. household size, number of brothers), however, we would argue that these are not obviously correlated with any decisions by the household to space births in a particular season. See Table A2.

but standard errors are understood to be biased downwards, increasing the possibility of accepting significance of a substantially biased estimate (Stock and Yogo, 2002; Murray, 2006). We use the Stock–Yogo (2002) critical values to asses whether the IVs in the first-stage regressions are sufficiently strong. To ensure that any biases are minimal, we report Fuller IV estimates. The Fuller estimator belongs to a family of weak-IV robust estimators, shown to perform better than standard IV methods – such as 2SLS or GMM methods (Murray, 2006). Though the season of birth is highly significant in Eq. (3) we find that our instruments are marginally weak, but the point estimates are robust.

Given the weak IV issues with the estimation, some uncertainty around the magnitude of the true estimate remains. Recent studies have proposed Anderson–Rubin and CLR Moreira confidence intervals, which have been shown to be *fully* robust to the presence of weak-IVs (Yogo, 2004; Andrews et al., 2006). These statistics provide a robust indication – regardless of the exact coefficient magnitude – of whether the effects studied are non-spurious. The tests support our suggestion that in spite of relatively weak instruments, the catch up estimates are sufficiently robust.

Finally, note that in our parametric analysis we control for potential correlation the error term across members of the same community. In particular, shocks common at the level of the village as well as seasonal shocks might affect standard inference methods. Throughout the paper we report cluster corrected standard errors at the level of the community and the quarter of birth.

3. Data and descriptive statistics

The data are from the first three rounds of the Ethiopia Young Lives survey, an ongoing longitudinal study of child poverty. The baseline year was 2002, and the study is planned to continue over a period of fifteen years.[5] Ethical concerns informed all stages of the data collection process.[6] 100 children aged 6–18 months were randomly sampled in each of 20 purposely chosen sites, yielding a cohort of just under 2000 children (1999 to be precise) which have been followed in subsequent follow up rounds in 2006 and 2009.[7]

Ethiopia is a country that is known for pervasive malnutrition and persistent hunger (Alderman and Christiaensen, 2001). Major famines in 1974, 1984 and in the past ten years[8] make the study of nutrition and child development a pertinent issue. The Ethiopian economy has experienced growth in the past two decades, but seasonal hunger continues to be an endemic feature of life in many rural areas.

We calculate the height-for-age *z*-score for children in the sample (HAZ). HAZ score is a measure of child development that has been shown to correlate with long-run investments in child nutrition (i.e. the 'stock' of health). It shows the height of the child relative to an international reference group of healthy children. We use the latest version of the height distributions, known as the WHO Reference 2007.[9] The international standard allows our study to be compared with other studies, and also allows an analysis of children of different ages, compared to the norm for their exact age in months. Stunting is defined as a HAZ of -2 or less, and severe stunting as HAZ below -3.

We focus our analysis on children located in the rural sentinel sites (just over half the children). Around 85% of the population of Ethiopia live in rural areas and undernutrition is more prominent. Further, our IV strategy outlined in Section 3 above uses seasonal variation in nutrition, which is more pertinent for the rural sample.

Attrition in the Young Lives sample is low in the international comparison with other longitudinal studies (Outes and Dercon, 2008). In the second round, attrition was 4.5% – 61 children had died, and 29 were untraceable or did not wish to participate – leading to a loss of just 48 children from the rural sample. Outes and Dercon (2008) study attrition bias in round two and conclude that while sample attrition – mainly mortality – in Ethiopia was linked to poor health and nutrition, the magnitude of these effects would not lead to estimation biases in a health equation similar to the one estimated here. Attrition in round three was even lower, at just over 1%, or thirteen children for the rural sample, which suggests that attrition bias is of little concern in our analysis.[10]

Table 1a presents the mean and standard deviation for the variables in our sample in the analysis. Common to other studies, we find that the anthropometric status of children – as measured by height-for-age – deteriorates between the time of birth and 3 years of age (e.g. de Onis et al., 2007). At the age of 6–18 months in round one (2002), the average YL child had a HAZ *z*-score of -1.13.[11] Four years later the average HAZ *z*-score was -1.6. By 2009, it recovered slightly to -1.38. 34% of the children were stunted in 2002, falling to 24% in 2009.

We measure wealth using an index constructed by the Young Lives team. The Wealth Index is a composite variable of housing quality, local services and durable assets standardised across the YL sample that arguably

[5] See www.younglives.org.uk for an overview of the Young Lives project, which also operates in India, Peru, and Vietnam. See Outes and Sanchez (2008) for an assessment of the sample used.

[6] For a detailed discussion of the research ethics, methods and training of the research team, including issues arising over the course of the longitudinal research, and ongoing informed consent, see Morrow (2009).

[7] Wilson and Huttly (2004) present a justification of this sampling procedure. The five regions selected (Addis Ababa, Amhara, Oromia, SNNP and Tigray) account for 96% of the population of the country. Note though, that this coverage excludes pastoralist communities of Afar and Somaliland.

[8] See the many useful references in Harvey (Ed., 2009).

[9] Raw data at http://www.who.int/growthref/ last accessed February 23rd 2010. Also see de Onis et al. (2004, 2007) and Garza and de Onis (1999) for discussion of the latest standards for child growth.

[10] We perform similar attrition bias tests as in Outes and Dercon (2008) for round 3 and find no evidence of non-random attrition. Results not reported here.

[11] Mekonnen et al. (2005) provide a fuller descriptive analysis of the nutritional status of the cross-section of this group of children in 2002, and find strong correlations between wealth and stunting amongst other things.

Table 1a
Summary of descriptive statistics.

	Mean	Std. Dev.	Nr Observ.
Height-for-Age z-score, 2009, Age 7–8 yr	−1.375	1.031	903
Height-for-Age z-score, 2006, Age 4–5 yr	−1.603	1.079	913
Height-for-Age z-score, 2002, Age 0–1 yr	−1.134	2.027	913
Stunted, HAZ < −2.0, 2009, Age 7–8 yr	0.244	0.430	903
Stunted, HAZ < −2.0, 2006, Age 4–5 yr	0.364	0.481	913
Stunted, HAZ < −2.0, 2002, Age 0–1 yr	0.341	0.474	913
Stunted, HAZ < −3.0, 2009, Age 7–8 yr	0.060	0.237	903
Stunted, HAZ < −3.0, 2006, Age 4–5 yr	0.096	0.295	913
Stunted, HAZ < −3.0, 2002, Age 0–1 yr	0.147	0.354	913
Sex of the Child, Female = 1, 2002	0.471	0.499	913
HH Head Sex, Female = 1, 2002	0.080	0.271	913
HH Size, 2002	5.715	2.071	913
Nr HH Adults, 2002	2.346	0.825	913
Nr Male members, 2002	2.892	1.474	913
Nr Brothers, 2002	1.317	1.315	913
HH Wealth Index, 2002	0.087	0.091	913
Caregiver reads, With difficulty = 1, 2002	0.112	0.315	913
Caregiver reads, Easily = 1, 2002	0.147	0.354	913
Any Schooling?, HH Head, Yes = 1, 2002	1.817	0.387	913
Age of Mother, 2002	27.467	6.165	913
Maternal Height, in CM, 2002	158.504	5.738	913

Table 1b
The Wealth Index and its components.

Sub-Indices Items		Wealth Index			
		First Quartile	Second Quartile	Third Quartile	Fourth Quartile
Housing Quality	None	99.1%	80.3%	24.6%	5.7%
	One	0.4%	19.7%	56.1%	35.5%
	Two or More	0.4%	0.0%	19.3%	58.8%
Consumer Durables	None	100.0%	46.5%	80.7%	24.6%
	One	0.0%	52.6%	6.1%	44.3%
	Two or More	0.0%	0.9%	13.2%	31.1%
Services	None	100.0%	100.0%	82.5%	41.2%
	One	0.0%	0.0%	17.5%	42.1%
	Two or More	0.0%	0.0%	0.0%	16.7%
Nr Observations		229	228	228	228

Notes: Cells refer to the percentage of households in each quartile (first being the bottom quartile, and fourth the top) who own items as indicated. Housing Quality items: wall, roof, floor of good durability, or if the house has more than one room; Consumer Durables include 11 items such as radio, fridge, bicycle, table. Services Index comprises access to electricity, (clean, piped) water, sanitation (pit latrine or flush toilet) and cooking fuel (not wood or dung).

captures the socio-economic status of the households.[12] Housing Quality comprises an average of four dummies equal to one if the wall, roof, floor are of good durability, or if the house has more than one room; Consumer Durables include 11 items such as radio, fridge, bicycle, table. Services Index comprises averaged dummies for if the household has access to electricity, (clean, piped) water, sanitation (pit latrine or flush toilet) and cooking fuel (not wood or dung). Each sub-index is scored, and then the three are averaged to calculate the final index. The range of the wealth index is then from 0 to 1, and we divide households into quartiles of the wealth distribution across the sample.

We provide a disaggregation of the wealth index into the three components of services, consumer durables, and housing in Table 1b. We show for each quartile the percentage of households with no items, one or more items, and two or more items in each sub index. It is immediately apparent that this is an extremely poor sample. In the bottom quartile (column 1), households basically have none of the items in any sub-index. In terms of housing, the number of improved housing materials increases steadily across quartiles, though no household in the sample has a floor made of anything other than earth. In the top quartile, more than half have two or more of improved roof, wall or more than one room. There is not a great deal of variation across the sample in terms of consumer durables owned, as most households are poor and own very few. In the top quartile just under a third own one or two items. In terms of

[12] See Ethiopia Preliminary country report round one on www.younglives.org.uk for further details.

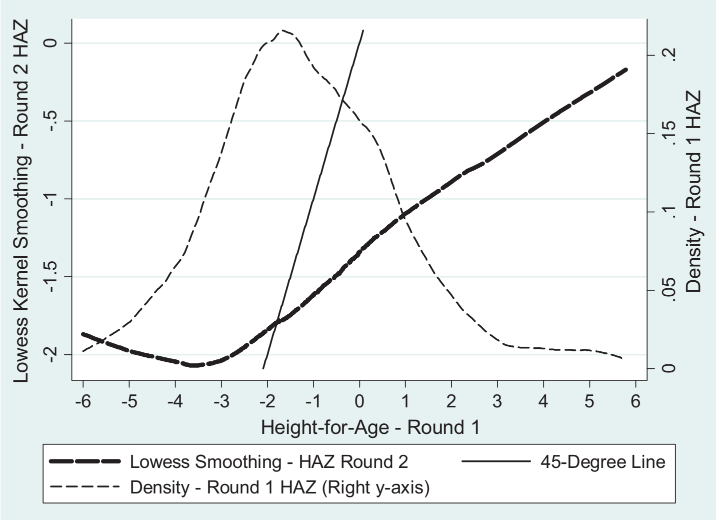

Fig. 1. Average catch up in early childhood. Nonparametric estimates of height-for-age round 2 (2006) on round 1 (2002). *Notes*: Dashed line depicts the kernel density function of height-for-age *z*-scores in round 1 (2002) when children were aged 6–18 months. Thick long dashed line is the lowess kernel smoothing estimate of height-for-age *z*-score in round 2 (2006) against the height for age in round 1. The figure includes data for 913 children. For reference the solid line stands for the 45° line.

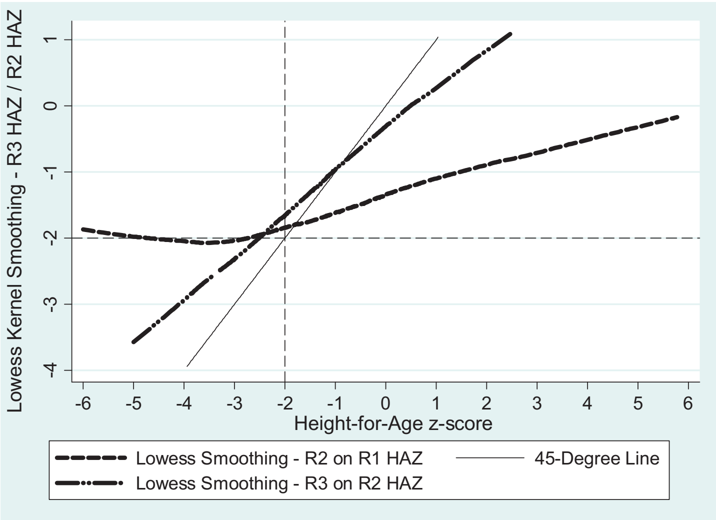

Fig. 2. Average catch up. Non-parametric relation between HAZ and HAZ lagged for early and mid-childhood periods. *Notes*: Dashed line depicts the kernel density function of height-for-age *z*-scores in round 1 (2002) when children were aged 6–18 months. Bold curves are lowess kernel smoothing estimates of height-for-age *z*-score and height-for-age *z*-score lagged. The 'longdash' line represents the relation between HAZ in round 2 (4–5 years) and HAZ in round 1 (0–1 years), while the 'longdash-dot-dot' line represents the relation between HAZ in round 3 (7–8 years) and HAZ in round 2 (4–5 years). Each kernel curve includes data for 913 and 903 children respectively. For reference the solid line stands for the 45° line.

services, the bottom two quartiles have none. In the third quartile, 17% of households have one item (predominantly a pit latrine), and nobody has more than one service. In the top quartile, 42% have one service, and 16% have two services (mainly pit latrine plus electricity).

Fig. A2 depicts the kernel density function of the wealth index variable. While this is a substantially skewed distribution, we find that a quartile analysis captures well the variation in wealth. This is not the case for the sub-indices, which in some cases only take a limited number of values, consequently in later analysis, where we decompose the effect of the wealth index into its sub-indices, we use the categorical variables reported in Table 1b instead.

4. Catch up growth and household wealth

In Fig. 1 we graphically depict the relation between height-for-age *z*-scores at age 6–18 months and aged 4–5 years. The graph shows bivariate lowess kernel smoothing estimates with round 1 HAZ in the *x*-axis and round 2 HAZ in the *y*-axis. This graphical technique allows us to plot the two periods of nutrition against each other, and create a "smooth" line that depicts the shape of the relationship, without assuming any functional form (for example that it is a straight line). If nutrition in period one is the same as period two, the relationship would simply be a straight line (with a 45° angle). For most of the values of HAZ at the age of 0–1, the relation is linear. Moreover, the slope of the

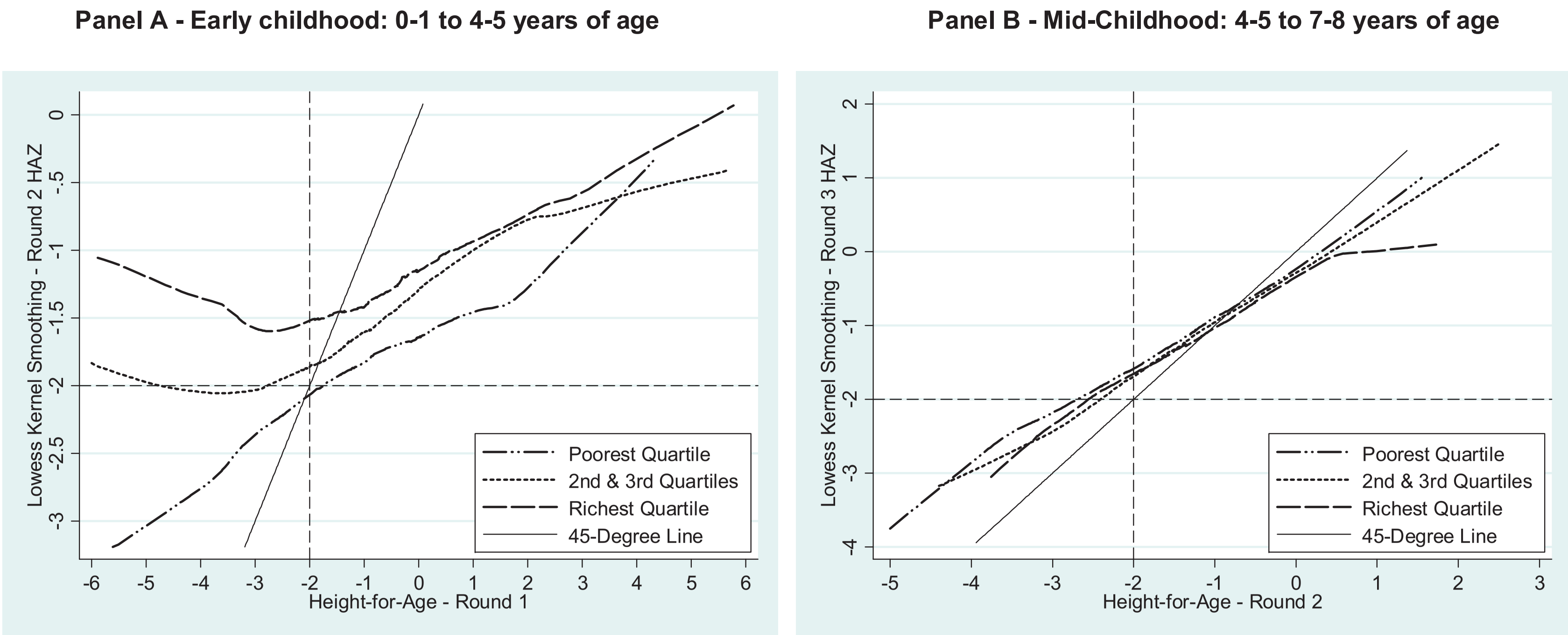

Fig. 3. Non-parametric estimates of catch-up by wealth quartiles. *Notes*: Curves are lowess kernel smoothing estimates of height-for-age *z*-score and height-for-age lagged for different wealth quartiles. The 'longdash' line represents the top quartile of wealth, the 'shortdash' line combines the second and third quartiles, while the 'longdash-dot-dot' line represents the bottom wealth quartile. Panel A reports the relation between round 1 (0–1 years) HAZ and round 2 (4–5 years) HAZ while panel B reports the relation between round 2 (4–5 years) and round 3 (7–8 years) HAZ. The measure of wealth is an index comprised of three items: housing quality index, local services index and consumer durables index, all measured in round 1 (2002). Panels A and B include data for 913 and 903 children respectively across all wealth quartiles. For reference the solid line stands for the 45° line.

relation suggests a substantial degree of catch-up (as the slope is flatter than the 45° line shown on the graph). There is also a marked non-linear effect at the lower end-tail of the HAZ distribution. Early measures of HAZ below −2 (stunted) are linked to higher levels of catch-up growth – in other words, children with particularly low levels of HAZ appear to experience faster catch-up growth than other children. This is consistent with the definition of catch up in Boersma and Wit (1997), discussed above. Fig. 2 incorporates the relation between height at 4–5 years and 7–8 years. The relationship is much closer to the 45° line, indicating that children's position in the height distribution appears to be more 'fixed' and that – unlike in the earlier period – height at 4–5 years is a strong predictor of height three years later.[13]

Fig. 3 further explores whether catch up growth differs across wealth categories. Again we present lowess kernel smoothing estimates and now split the original sample between children living in households in the bottom, top and middle-two quartiles of the round 1 wealth index (see above for description, panel A depicts the early childhood relationship and panel B the later period). Panel A is striking in two respects. First, the locus of round 1 HAZ and round 2 HAZ is vertically shifted when moving from lower to higher wealth index quartiles. This suggests that children from poorer households will accumulate a growth deficit vis-à-vis wealthier children *with a similar initial level of nutrition*.

Secondly, the original non-linear relationship between early and later HAZ appears to be present only among the relatively wealthy households. While children in households from the bottom quartile of the wealth index experience catch-up rates that remain constant throughout the entire nutritional distribution, better-off children experience increased catch-up growth if their HAZ measure in round 1 was low.

The graph in Fig. 3(A) provides compelling evidence that – to the extent that catch-up growth is taking place between the ages of 0–1 and 4–5, it is children in relatively well-off families that are benefiting most. The comparison with the later period (between age 4–5 and 7–8) is also striking. Fig. 3(B) shows no clear differences between any of the wealth categories, and again the slopes of the lines converge at a much steeper gradient. In the early years, household wealth appears to enable nutritional catch up, however, by the age of five the window of opportunity for effective nutritional remediation appears to be closed, though it may open again in the adolescent years.

We cannot conclude using non-parametric analysis that the observed catch-up is not driven by problems of endogeneity. Measurement error, unobserved child ability and household heterogeneity are well understood causes of statistical bias that will affect the average rate of catch up growth. In our parametric analysis we apply IV methods to address these issues, however, at least, in their conventional formulation, these confounding mechanisms are unlikely to have generated the pattern of heterogeneous catch up growth that we observe in Fig. 3.

Measuring the height of small children can be imprecise, especially when babies are too small to stand alone. Our sample includes children aged 6–17 months, so we might expect the noise-to-signal ratio to be larger among the youngest in the cohort, as these were all measured lying down, whereas in the later rounds, the children are old enough to stand for measurement. We do find evidence that HAZ in the first wave has a higher variance among younger children (aged 6–11 months), however, their *z*-scores are higher than the average. Nevertheless, even if younger children were to be concentrated in the lower section of the HAZ distribution, it is not clear why attenuation bias should exclusively affect richer children – as is implied by the convexity of the top and middle quartiles but not the bottom wealth quartile in Fig. 3.

Panel attrition could potentially be generating heterogenous catch up. If attrition due to death is concentrated among children with poor health and nutrition, surviving children in the lower section of the HAZ distribution are likely to have higher innate health. To the extent that children with better innate health experience higher catch up growth, attrition bias could create the illusion that catch up is higher among stunted children. Low HAZ has indeed been found to be correlated with attrition in the second wave, however, the small incidence of attrition implies that attrition bias can be expect to be minimal (Outes and Dercon, 2008). Again, this phenomenon cannot explain why catch up is largest among the richer children, and if anything, we would expect attrition bias to be highest among the poorest households.

Finally, children in richer families might differ in their innate health; wealthier families over generations might have cumulated a better genetic pool (for a discussion see Deaton, 2007). Accordingly, wealthier families with possibly taller mothers might have children with higher height potential (Bhalotra and Rawlings, 2011). In this case, children who are temporarily stunted in the early period, from richer backgrounds, may simply be reaching their higher underlying potential height, rather than being more heavily invested in. In our subsequent parametric analysis we include information on maternal height and maternal education to control for this mechanism.

5. Parametric analysis

In this section we report an array of econometric methods to substantiate the findings of the non-parametric analysis. Table 2 shows community fixed-effects (OLS) estimates of HAZ on lagged HAZ for early childhood and mid-childhood separately. Columns (1) and (3) are the naïve specifications with only community fixed effects as controls, whilst columns (2) and (4) include full controls; household characteristics that are likely to influence future nutritional status (household composition, assets, mother's height, literacy of the mother). The top panel of the table assumes homogeneity in the lagged HAZ coefficient. The first two columns in this panel show a

[13] Fig. A1 in the annex shows the kernel density estimates of the three rounds of data. Clearly the early years (round 1) are more spread out, which we would expect at this age group, but there is a striking similarity between rounds 2 and 3.

Table 2
Catch up growth by age period: Height-for-Age z-scores at age 4–5 and 7–8 years, OLS estimates.

OLS Estimates	Dependent variable: HAZ (t), Age 4–5 yr ($t-1$)^ = Age 0–1		Dependent variable: HAZ (t), Age 7–8 yr ($t-1$)^ = Age 4–5	
	No Controls	Full Controls	No Controls	Full Controls
	(1)	(2)	(3)	(4)
Average Catch Up Model				
Height-for-Age ($t-1$)^	0.236***	0.239***	0.711***	0.693***
	(0.019)	(0.020)	(0.028)	(0.024)
Full Controls	No	Yes	No	Yes
Community Fixed Effects	Yes	Yes	Yes	Yes
R-Squared	0.295	0.384	0.540	0.574
Nr Observations	913	913	903	903
Wealth Interaction Model				
Height-for-Age ($t-1$)^	0.295***	0.295***	0.693***	0.667***
	(0.034)	(0.032)	(0.045)	(0.046)
(HAZ ($t-1$)) × (Quartile 2, Wealth Index)	−0.042	−0.035	0.045	0.074
	(0.053)	(0.050)	(0.050)	(0.057)
(HAZ ($t-1$)) × (Quartile 3, Wealth Index)	−0.070	−0.069	0.040	0.039
	(0.052)	(0.043)	(0.052)	(0.056)
(HAZ ($t-1$)) × (Quartile 4, Wealth Index)	−0.128**	−0.101**	−0.010	−0.009
	(0.052)	(0.049)	(0.061)	(0.063)
Wealth Quartile Dummies	Yes	Yes	Yes	Yes
Full Controls	No	Yes	No	Yes
Community Fixed Effects	Yes	Yes	Yes	Yes
R-Squared	0.306	0.386	0.542	0.577
Nr Observations	913	913	903	903

Notes: *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. ^For each model, HAZ ($t-1$) refers to the height-for-age *z*-score of the child in the previous period. All estimates are Ordinary Least Squares with community fixed effects. Full controls include information on household characteristics (including caregiver gender, height, health, household wealth and demographics), mother and child information, as well as dummies for age in months, ethnic group and birth order. The lower panel of the table shows the interaction of the lagged HAZ with the wealth quartile (bottom quartile omitted) measured in round one. When interacting by wealth quartiles household wealth is excluded from the core controls. Standard errors are clustered at the community and quarter of birth level.

strong correlation between early nutritional status at the age of 0–1 and later height attainment at the age of 4–5 years of age, with a significant and positive coefficient on the early child height. The point estimate for the lagged dependent variable of 0.23 during this period shows substantial but only partial catch up. If persistence in height-for-age were perfect, we would expect a coefficient that is close to one. Columns (3) and (4) use the same specifications, but move on one period; the relation between height-for-age at the age of 4–5 and 7–8 years is assessed. The coefficients are now much higher, closer to 0.7, replicating the high degree of correlation that was shown in panel B of Fig. 3.

In terms of the full set of control variables (reported in Table A1), we found that the wealth index was significant in determining HAZ in the early period, but not later. Maternal height (our control for genetic factors), literacy of the mother, the number of household members and the health of the child during early years were also significant – though less so for the later period. Beyond the reported controls the model specification also includes information on a range of household, mother and child characteristics, as well as a set of community, household ethnicity and month of birth dummies. In a robustness check we trimmed the top and bottom 5% HAZ scores, removing potential outliers, and results remained largely unchanged.

In the lower panel of Table 2, we explore the interaction of wealth and lagged height to examine whether the relationship between early child height and subsequent height differ significantly depending on the wealth of the household. Columns (1) and (2) report results for the early period, and columns (3) and (4) for the later period. We include individual wealth quartile dummies and interact the HAZ in the previous period with each of these quartiles, omitting the poorest quartile. Taking the early period first, the interaction terms are highly significant.[14] We find that persistence of nutritional status is significantly lower for the top quartile than for the bottom quartile, while point estimates indicate that the magnitude of the catch up growth increases with wealth. This evidence suggests that catch-up growth is stronger for children from relatively wealthier households. Belonging to the top quartile of wealth reduces the persistence coefficient by 0.13 points. In contrast, there are no significant differences for the later period (column 3 and 4), indicating that the wealth differential in the early period has now disappeared.

[14] HAZ levels in the current period do not appear to increase with wealth quartiles and are not reported to keep the tables parsimonious – possibly because any level effects are already being captured by HAZ status in round 1.

Table 3
Non-linear catch up growth: Stunting at age 4–5 and 7–8 years, Linear Probability Model.

Linear Probability Model	Dependent variable: Stunting (t), Age 4–5 yr (t − 1)^ = Age 0–1		Dependent variable: Stunting (t), Age 7–8 yr (t − 1)^ = Age 4–5	
	Stunted (HAZ < −2.0) (1)	Stunted (HAZ < −3.0) (2)	Stunted (HAZ < −2.0) (3)	Stunted (HAZ < −3.0) (4)
Stunted (t − 1)^	0.363***	0.196**	0.471***	0.236***
	(0.052)	(0.088)	(0.047)	(0.062)
(Stunted (t − 1)) × (Quartile 2, Wealth Index)	0.028	−0.094	0.023	0.193*
	(0.085)	(0.089)	(0.064)	(0.099)
(Stunted (t − 1)) × (Quartile 3, Wealth Index)	−0.026	−0.130	0.029	−0.128
	(0.090)	(0.095)	(0.065)	(0.123)
(Stunted (t − 1)) × (Quartile 4, Wealth Index)	−0.173**	−0.217**	0.005	0.039
	(0.085)	(0.085)	(0.078)	(0.149)
Wealth Quartile Dummies	Yes	Yes	Yes	Yes
Full Controls	Yes	Yes	Yes	Yes
Community Fixed Effects	Yes	Yes	Yes	Yes
R-Squared	0.106	0.025	0.283	0.138
Nr Observations	913	913	903	903

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Dependent variable is binary (0,1) which is positive if child is stunted, defined as HAZ < −2.0 (columns 1 and 3) or HAZ < −3.0 (columns 2 and 4). ^ For each model, Stunted (t − 1) refers to stunting status of the child in the previous period. All estimates are Linear Probability Model with community fixed effects and full controls. Full controls include information on household characteristics (including caregiver gender, height, health and demographics), mother and child information, as well as dummies for age by month, ethnic group and birth order. Columns (1) and (2) estimate the relation between stunting at the age of 0–1 and 4–5 years, columns (3) and (4) explore the relation for the later period from 4–5 to 7–8 years of age. Standard errors are clustered at the community and quarter of birth level.

In Table 3 we further explore the possible nonlinear relationship between HAZ in the two earlier periods. To do this we fit a linear probability model of the likelihood of being stunted (HAZ < −2.0)[15] and severely stunted (HAZ < −3.0), in the early and later periods separately, as a function of household, maternal and child controls, as well as the stunting status in the previous period. We find that the likelihood of stunting persisting into the next period is higher in later childhood than earlier. Further, persistence of stunting appears higher for the poorer children, whilst 36% of poor children remain stunted from age 6–18 months through to age 4–5, only 19% of the previously stunted wealthy children do so. These patterns are similar for the case of severe stunting. Consistent with the previous results, the wealth differentials disappear in the later period. This evidence supports the suggestive patterns of catch-up depicted in Fig. 3, namely that in the early period, relatively wealthy children with early nutritional deficiencies appear to achieve higher catch-up growth than equally stunted but poorer children. In the later period, no significant differences emerge.

5.1. Instrumental variables estimation[16]

Despite the careful selection of control variables, we are unable to allay the concern that unobserved factors might determine both nutritional attainment in the early stage of life, and subsequent nutritional development in the second stage of life. OLS estimates of the relation between lagged HAZ and current HAZ could be driven by these unobserved factors and therefore be spurious. Note however, that as discussed in the previous section there is no clear reason why endogeneity would cause a spurious disparity in catch up across the wealth distribution.

IV Fuller estimates for height-for age *z*-scores in the early childhood period are presented in Table 4 following the system of Eqs. (3) and (4). Column (1) reports IV results for the full sample, while columns (2) and (3) show estimates for the bottom half of the wealth distribution, using wealth index and maternal height respectively as the wealth indicator. For the full sample, we find that Fuller estimates yield a parameter estimate on lagged HAZ similar to OLS estimates (0.25). Estimates for the bottom half of the wealth distribution are substantially higher than the full sample coefficients. For the bottom half of the wealth index, the persistence parameter is 0.42, with a similarly high coefficient for the bottom half of the maternal height distribution. The bottom panel in Table 4 also report IV estimates on stunting status. Estimates show a substantial increase in the coefficient on lagged height, with parameter estimates of 0.68 for the full sample, and 0.90 – effectively suggesting full persistence – among the poorest households. This may be due to a higher level of measurement error in the binary model – but it could be due to the poorer fit of the first-stage.

In all models, the coefficient for the poorer group is more precisely estimated than for the full group, which goes some way to dispel the concern that the wealth differences in catch up were driven by unobservables causing an upward bias; it appears that if anything, the

[15] As noted in Section 3, WHO standard (5 cm and 9 cm below the mean for a one and five year old boy respectively). Note also that we ran a probit model on this variable which showed very similar results, but we report here the linear probability model, as we use a linear model to fit the IV later on in the paper.

[16] As there is little variation in the height for age between the two later periods of mid-childhood, we present the IV analysis for the first two periods only.

Table 4
Summary of catch up effects: IV Fuller and OLS Estimates, Age 4–5 years.

	Full Sample	Bottom Half Wealth Index	Bottom Half Maternal Height
	(1)	(2)	(3)
Dependent Variable: Height-for-Age (t), 4–5 years of age			
OLS – HAZ ($t-1$), Age 0–1 years	0.239***	0.270***	0.223***
	(0.020)	(0.031)	(0.026)
IV Fuller – HAZ ($t-1$), Age 0–1 years	0.250**	0.419***	0.368***
	(0.122)	(0.149)	(0.125)
First-Stage: IV *F*-Statistic	7.158	10.496	7.032
Anderson–Rubin *p*-value	0.280	0.059	0.032
Nr Observations	913	457	457
Instrument	Season	Season	Season
Dependent Variable: Stunted (t), (HAZ < −2.0), 4–5 years of age			
OLS – Stunting ($t-1$), Age 0–1 years	0.326***	0.363***	0.339***
	(0.034)	(0.047)	(0.044)
IV Fuller – Stunting ($t-1$), Age 0–1 years	0.676**	0.911***	0.906***
	(0.277)	(0.315)	(0.271)
First-Stage: IV *F*-Statistic	5.253	8.304	4.044
Anderson–Rubin *p*-value	0.024	0.009	0.001
Nr Observations	913	457	457
Instrument	Season	Season	Season

Notes: *$p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All estimates include full controls and community fixed-effects. Full controls include information on household characteristics (including caregiver gender, height, health and demographics), mother and child information, as well as dummies for age by month, ethnic group and birth order. Instrumental variable 'season' takes a value of one for children born in the second and fourth quarter. IV estimates obtained using weak-IV robust k-class Fuller estimator. First-stage *F*-Statistic reports results for Kleibergen–Paap test of weak identification. Standard errors are clustered at the community and quarter of birth level.

opposite may be true. IV estimates support (and strengthen) our earlier OLS findings: catch up rates are larger among wealthier children and this effect primarily takes place among undernourished children.

Table 4 also provides information on the strength of our instruments. We compare the *F*-Statistics of the first-stage explanatory power of the excluded instruments reported at the bottom of the table with the Stock and Yogo (2002) weak-IV test critical values. The Kleibergen–Paap *F*-Statistic for our IV estimates ranges from 7 to 10.5, marginally passing the weak-IV rule-of-thumb of a value of 10 suggested by Staiger and Stock (1997). Stock and Yogo critical values suggest that our Fuller estimates may contain a 30% bias or more. Though the remaining bias can not be disregarded, it is understood to be towards the OLS estimates; IV Fuller estimates can therefore be interpreted as lower bounds to the true coefficient.[17] However, instrument weakness also affects inference testing, rendering standard errors invalid. Table 4 reports the implied *p*-values from fully robust Anderson–Rubin 95% confidence intervals.[18]

We find that among the poorest households, the lagged HAZ coefficient is significantly different from zero at the 10% level (with a robust weak-IV *p*-value of 6%). However, the estimated coefficient on persistence for the full sample appears to be insignificant.[19] Consequently, even with some uncertainty around average catch up parameter we can be confident to conclude that the bottom and top half households in the wealth distribution experience significantly different levels of catch up growth, with the poorer half experiencing partial catch up while the richer half appear to experience near perfect catch up rates.

Estimates of the degree of catch up growth in height among children vary significantly in the literature. Using experimental data, Ruel et al. (1995) obtain estimates of persistence in height of 0.75 and 0.61 for boys and girls respectively for the period between 3 years of age and adolescence. When using IV methods, Hoddinott and Kinsey (2001) report point estimates of 0.56 on lagged height for children 12–36 months old, but a coefficient as small as 0.19 for the same age group when applying mother fixed effect methods. Fedorov and Sahn (2005), using yet again a different method – IV Arellano-Bond GMM methods – obtain estimates of 0.20 for children from 0 to 76 months of age. Our full sample IV estimates contribute to this literature. The persistence parameter estimate of 0.25 for 4–5 year olds is closest to Fedorov and Sahn study, though we cannot totally rule out the possibility that catch up is complete.

[17] When we use a GMM/LIML estimator, which arguably carries a smaller OLS bias, but is less robust to the effect of weak instruments, we find indeed coefficient estimates are higher, supporting the theory that the reported Fuller estimates represent a lower bound to the true parameter.

[18] Under the just-identified case in our analysis, Conditional Likelihood Ratio Moreira (2003) and Anderson-Rubin tests yield identical results.

[19] Note that instrument weakness is higher for the full sample than the bottom half sample. Implying that the difference in catch up rates found in the IV estimates could be driven by differences in the weak-IV bias. Results from the AR confidence intervals dispel this possibility and indicate that difference persistent when the effect of any weak instruments is removed.

Table 5
Channels of nutritional remediation: Disaggregating Wealth Index, OLS Estimates.

OLS Estimates	Dependent variable: HAZ, Aged 4–5			Dependent variable: Stunted (HAZ < −2.0), Aged 4–5		
	Nr of Items by Wealth Sub-Index			Nr of Items by Wealth Sub-Index		
	Housing Quality Sub-Index	Consumer Durables Sub-Index	Services Sub-Index	Housing Quality Sub-Index	Consumer Durables Sub-Index	Services Sub-Index
	(1)	(2)	(3)	(4)	(5)	(6)
Height-for-Age ($t-1$), 0–1 years	0.264***	0.251***	0.257***			
	(0.027)	(0.022)	(0.020)			
Stunted ($t-1$) (HAZ < −2.0), 0–1 years				0.375***	0.344***	0.350***
				(0.048)	(0.034)	(0.036)
(HAZ/Stunted) × (Sub-Index, Items: One)	−0.040	−0.044	−0.074*	−0.069	−0.043	−0.168**
	(0.038)	(0.032)	(0.042)	(0.079)	(0.060)	(0.070)
(HAZ/Stunted) × (Sub-Index, Items: Two or More)	−0.055	0.014	−0.130**	−0.163	−0.073	−0.359***
	(0.047)	(0.037)	(0.058)	(0.104)	(0.108)	(0.093)
Full Controls	Yes	Yes	Yes	Yes	Yes	Yes
Community Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Dummies for Nr of Items by Wealth Sub-Indices	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.197	0.200	0.198	0.106	0.100	0.104
Nr Observations	913	913	913	913	913	913

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All estimates include full controls and community fixed-effects. Full controls include information on household characteristics (including caregiver gender, height, health and demographics), mother and child information, as well as dummies for age by month, ethnic group and birth order, dummies for the wealth index quartiles and its components. Subindices for the wealth index are explained and decomposed in Table 1b. Stunting models are estimated using a Linear Probability Model. Standard errors are clustered at the community and quarter of birth level.

We show that average catch up rates can mask substantial heterogeneity affected by nutritional remediation. Differences in catch up rates between the bottom and top halves of the wealth distribution can be substantial, 0.42 versus an implied value of 0.08 respectively.[20] Moreover, allowing for the non-linear nature of health – by analysing stunting status – further increases the disparity in catch up rates: a gap of 0.47 between bottom (0.91) and top (0.441) halves of wealth. This evidence suggests that targeted nutritional remediation in early childhood can be very effective, and in the absence of such investments, height is likely to experience only limited catch up. In fact, stunted children in relatively poor households have little chance of catching up with their healthy peers.

The IV and OLS results on wealth differentials in the early years are robust to different methodologies. Indeed we find that OLS estimates underestimate the socio-economic gradient of catch up growth. Similarly, we consider that the significant difference between the early and mid-childhood OLS estimates – in particular that the economic gradient disappears – offers convincing evidence that the opportunities for catch up growth are better in the earlier years, and that nutritional remediation after the age of five might be too late.

5.2. Channels of nutritional remediation

In this section, we investigate the wealth differentials in more detail. Our composite wealth variable outlined in Section 3 comprises three sub-indices: *housing quality*, *services index* (water, sanitation, electricity and cooking fuel), and *consumer durables*. To further investigate the channels through which wealth impacts on catch up in the early period, we re-estimate Eq. (2) for each sub-index independently. Because sub-indexes can be very discrete in their distribution, we use indicator variables to capture its variation instead of the quartile analysis. Table 1b showed a detailed descriptive breakdown of the wealth index and the indicator variables.[21]

Table 5 reports a summary of our findings. Among the three components, *access to services* appears to be the most important. Having one of the four services increases catch up growth by 7% and having two or more services by 13% (column 3). In terms of stunting, one (two or more) service(s) reduces the probability by 17 (35)%. We interpret these results as evidence that services that improve the child's environment have complementary (and possibly separate) impacts on nutritional intake in terms of ability to catch up from nutritional shocks at an early age, for example through reduced infections and illnesses (Burger and Esrey, 1995; Alderman et al., 2003; Merchant et al., 2003). Increased *consumer durables* and *housing quality* do not have significant impacts on their own. However, as we would expect and just as they do for the services sub-index, coefficient estimates are negative and increase in magnitude with the number of items (see the columns (4) and (5) in particular), suggesting that housing quality and consumer durables capture distinct nutritional effects.

[20] The implied coefficient for the top half is calculated using the point estimates for the average and that of the bottom half of the sample.

[21] Using the quartile analysis for the sub-indices yields similar results to the analysis discussed here, though substantially less precise.

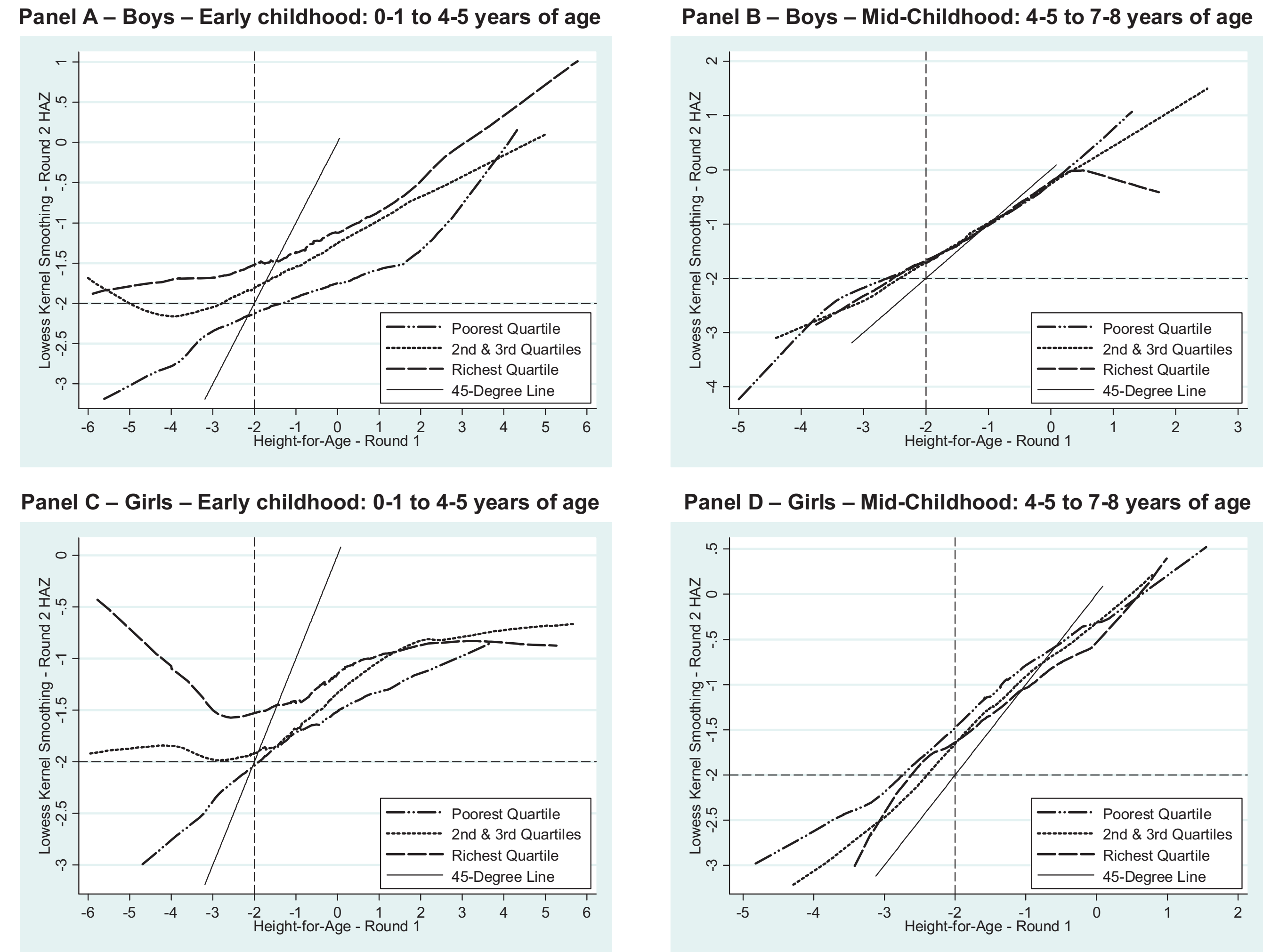

Fig. 4. Non-parametric estimates of catch-up by gender and wealth. *Notes*: The 'longdash' line represents the top quartile of wealth, the 'shortdash' line combines the second and third quartiles, while the 'longdash-dot-dot' line represents the bottom wealth quartile. Panels A and C include data for 483 and 430 boys and girls respectively while panels B and D include data for 478 and 425 boys and girls respectively. Solid line stands for the 45° line.

We are also interested in whether early life nutrition has different consequences for boys and girls – differences may be driven by behavioural factors – such as a pro-boy bias in the intra-household allocation of resources – or biological (or both). Studies of animals (e.g. rats, see summaries in Boersma and Wit, 1997) have shown that females have higher potential for catchup growth. Also in a well-known Guatemalan nutrition study Ruel et al. (1995) found that a nutritional supplement had a higher impact for girls of lower socio-economic status at age 3, which persisted into adolescence. Deolalikar (1996) in a Kenyan study found higher rates of catchup for girls in terms of weight (though did not test across socioeconomic status), especially at younger ages.

The four panels in Fig. 4 provide lowess estimates similar to Fig. 3 for each gender separately. It becomes apparent that nutritional remediation is different across genders. Girls benefit more from living in wealthier households than their equally undernourished male counterparts. Table A5 reports OLS parametric estimates split by gender. Whilst there are not many significant differences, girls have significantly higher rates of catch up in the top wealth quartile (0.16 lower than the average coefficient of 0.27). Indeed for boys, nutritional remediation appears to be ineffective. Consistent with earlier findings, we also find that in mid-childhood nutritional investments are no longer effective for either gender. Nevertheless, with our data we are not able to test whether these gender patterns are because in early childhood girls' nutrition is more sensitive to other inputs such as sanitation or that in credit-constrained or poorer households, girls are allocated less food.

6. Conclusion

Examining a group of poor rural Ethiopian children, we find a clear relationship between nutritional status measured at age 6–18 months and nutritional status four years later. We find that malnourished children in the richer households do experience significantly higher catch up rates than malnourished children in the bottom quartile of the wealth distribution. We find evidence that catch up among wealthier girls is substantially higher than the poorer girls, whereas the socioeconomic status of the household does not appear to affect catch up growth of boys. Considering that our sample is pro-poor from a very poor country, the results are quite alarming – even in this context, being poorer seems to indicate fewer possibilities to catch up from negative shocks in early life. Examining the same children during the 5–8 years period, HAZ position in the distribution is very persistent, and does not vary by household wealth, nor by gender.

We cannot distinguish between several competing explanations in terms of why there is differential catch up by wealth in the early period. Both richer and poorer households may wish to compensate for poor endowments, but richer households may be more successful as they have more resources available. Our findings indicate that it is through access to essential services such as sanitation and electricity that wealth has a strong effect on nutritional catch up.

We cannot fully rule out the influence of unobservable characteristics of households. Significant differences across the wealth distribution could possibly arise because richer and poorer households have different preferences (for example poorer households simply prefer to reinforce sibling differences in endowments). Rosenzweig and Wolpin (1980) show that there is an under identification problem in terms of distinguishing between parameters of the child nutrition ''production function'' and the preferences of the household (though in the context of cognitive ability). Another possibility that we cannot exclude is that richer households may have unobserved ability (beyond their education which is factored into our model) that allows them to compensate and achieve catch up growth, additional to their extra wealth (e.g. noticing malnutrition sooner due, or knowing that if the child is small then feeding more/improving nutritional intake will help the child, and which foods are better suited to this purpose). Or, richer households may have access to better investment 'technology' that is more effective in improving nutritional outcomes for a given amount of expenditure over and above improved water and sanitation that is included in our wealth measure (for example, purchasing food with a higher nutritional content).

A priori, it seems to us unlikely that poorer households would have completely different preferences, and rather more likely that the marginal benefit of investing in an undernourished child has higher opportunity cost in terms of other households members' nutrition. Whether or not there is more than one channel of impact, the outcome is clear: that early life chances are considerably lowered for under nourished children from poorer households. Further, if this is not addressed before the age of five, then the window of opportunity for catch up may have closed. Moreover, other evidence in the literature shows that even in developed countries, health differentials that manifest in the early years appear to be exacerbated as children get older (Case et al., 2002). This suggests that in the absence of other interventions, future surveys of Young Lives children in Ethiopia may find increasing disparities in nutritional outcomes and other measures of child development as the children age.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ehb.2012.03.001.

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