Age-Profile Estimates of the Relationship Between Economic Growth and Child Health

Draft Version

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Abstract

For the last several years, there has been a debate in the academic literature regarding the association between economic growth and child health in under-developed countries, with many arguing the association is strong and robust and several new papers arguing the association is weak or nonexistent. Focusing on child growth faltering as a process that unfolds over the first several years of life, we provide new evidence tracing out the relationship between macroeconomic trends and the trajectory of child growth through age 5. Using two novel regression models that each harness different kinds of within- and between-country variation, and data on over 600,000 children from 38 countries over more than 20 years, our estimates of the association are relatively small but precise, and are consistent across both estimators. We estimate that a 10% increase in GDP around the time of a child's birth is associated with a decrease in the rate of loss of HAZ of about 0.002 SD per month over the first two years of life, which generates a cumulative effect of around 0.04 SD by age 3 that then persists through age 5. Our estimates are small compared to most previously published statistically significant estimates, more precisely estimated than previous insignificant estimates, and relate to a broader population of children than previous estimates focused on dichotomous outcomes.

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1 Introduction

Economic growth is valuable insofar as it improves human wellbeing, and long-term development has clearly generated large improvements in the welfare of millions of people. Yet even with steady growth in the global economy over the last several decades, child physical growth stunting induced by chronic under-nutrition and heavy disease burden still affects over 150 million children worldwide.[1] Stunted growth in childhood leads to decreased wages and worsened health outcomes in later life, and contributes to the inter-generational persistence of poverty (Behrman et al., 2009; Hoddinott et al., 2008). It is also, by definition, around 98% preventable by raising children in households with moderate income in safe public health environments, making its prevalence both a disheartening fact about the world and a useful statistical measure of the health dimensions of child welfare. Stunted growth is both a marker of the cumulative effects of chronic nutrient deficiency and poor health on physical development and a physical manifestation of stunted human potential.

Despite the major differences in stunting rates and mean height-for-age z-score (HAZ) between children in developed and developing countries, several recent papers have argued that there is a surprisingly weak correlation between medium-term economic growth and nutritional status within less-developed countries (Subramanyam et al., 2011; Vollmer et al., 2014). These papers stand in contrast to previous cross-country work that estimated relatively robust effects of macroeconomic conditions on child anthropometric outcomes (Smith and Haddad, 2002; Haddad et al., 2003; Klasen, 2008; Harttgen et al., 2013). We argue that the regression models used in the newer studies aggregate over important heterogeneities in the magnitude of the correlation between GDP and HAZ that develop as children age. Correlations of medium-term growth and HAZ start small but grow steadily over the first few years of life. Aggregating the magnitude of the correlation across all ages thus reduces point estimates relative to the magnitude that is relatively persistent from age 3 onwards. Given

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[1] UNICEF data, Date Accessed: 07/12/2016: http://data.unicef.org/nutrition/malnutrition.html

that stunting is generally understood as the result of the process of growth faltering, and that this process unfolds primarily over the first two years of life (Victora et al., 2010; Rieger and Trommlerová, 2016), the correlation between GDP and HAZ at ages 3-5 is likely more informative than the average correlation over the first five years. Though not intrinsically biased, previous models produce estimates that are needlessly imprecise in terms of statistical power and difficult to interpret given the biological realities of child growth faltering.

We develop two novel regression models that estimate the effects of GDP changes at various points in a child's development on survey-time anthropometric outcomes using both within- and between-country variation. The two models, though conceptually and statistically quite distinct, produce similar estimates. Using our survey-level outcome and regression model, we estimate that exposure to a 10% increase in GDP during early childhood is associated with a decrease in the rate of loss of HAZ relative to the World Health Organization (WHO) reference median by 0.002 sd/month. This adds up to an effect of around 0.05 sd by the child's third birthday. Similarly, our age-profile fixed-effect model estimates a statistically, biologically and economically insignificant association before a child's first birthday, but that by age three a 10% increase in GDP is associated with a cumulative effect of 0.03-0.04 sd that persists through age 5.

Our models specifically address both the timing of exposure to economic growth relative to a child's development and the age at which a child is measured, while controlling for both growing up to age A in country C (country-specific age profiles) and growing up between the years of T and T+A (a child's lifespan). We interpret the identifying variation in both models in terms of within- and between-country variation in GDP exposure history and the shape of the HAZ-age profile, and we relate this interpretation to previous models employed in the literature. Like previous fixed-effects models, our coefficient estimates are identified from relative changes in GDP and HAZ over space and time. However, unlike previous work that estimates a level effect of economic growth on child nutritional status, we model how changes in GDP tied to specific points in a particular cohort's development are associated with changes in average child growth trajectory. Said another way, we estimate the associations between a country's history of economic growth and the shape of its HAZ-age profile.

Beyond their desirable econometric properties, our models are inspired by, and clearly interpretable within, the framework of dynamic health capital accumulation theory. As in classic health capital models, households choose an optimal stream of investment in child health inputs given their preferences and subject to a budget constraint and a health production function. The optimal level of inputs varies with standard microeconomic forces (prices, budget constraints) and public goods (including environment and infrastructure), and choosing optimal input levels implies an optimal health level for the child. This allows us to interpret HAZ, a measure of cumulative health inputs since birth, as carrying information on the entire history of that optimally chosen stream of inputs up to the moment the child is measured. We model changes in GDP as altering public goods availability and household income, thus altering the optimal stream of investments in child health inputs, and thus affecting a child's physical growth trajectory (HAZ). The age-profile analyses we conduct are fully consistent with the set of potential effect heterogeneities across child development predicted by the abstract model. More than that, specific predictions about the heterogeneous effects of input timing or effect-persistence can be tested by comparing coefficient estimates across child ages.

Our goals in this work are two-fold. First, we argue that we provide more precise and interpretable estimates of the relationship between medium-term economic growth and child height than have previously been available. Second, we demonstrate how an econometric framework focused on the HAZ-age profile, instead of simply mean HAZ or stunting probability, can allow for both more precise and more nuanced estimates, regardless of the covariate of interest. Models such as those developed here may allow researchers to better trace out how inputs and investments at different ages differentially affect child development. Such analyses, exploiting spatio-temporal variation in exposure and repeated cross-sectional or panel outcome data, could help generate a deeper understanding of both human development itself and the effectiveness of interventions and policies aimed at improving developmental outcomes.

2 Background

2.1 Spatio-Temporal Variation: Within- v. Between-Country

Cross country studies of the effects of macroeconomic growth on child anthropometric outcomes have estimated strong relationships between contemporary GDP and child wasting or undernutrition. Smith and Haddad (2002) and Headey (2013) find that a 10% increase in GDP is associated with decreases in undernutrition rates of 6.3% and 1.8pp respectively. Haddad et al. (2003) estimates a much bigger cumulative effect, finding that a 10% increase in GDP is associated with decreases in undernutrition of 32pp over two decades.

While multi-country studies have found robust effects when relying primarily on across-country variation and aggregate outcome measures, within-country studies using individual-level data have also found strong associations (or causal effects) between HAZ and changes in household income measures and the availability of public goods. Jensen (2000) and Hoddinott and Kinsey (2001) show that droughts in Ivory Coast & Zimbabwe (respectively) increased malnutrition of children. Similarly, Maluccio et al. (2005) shows that a sharp reduction in coffee prices in Nicaragua increases malnutrition in children from households dependent on coffee plantations for their livelihoods. Pongou et al. (2006) show that after controlling for health seeking behavior by mothers, a reduction in socio economic status of households in Cameroon increases malnutrition.

Despite the seeming volume of evidence, two recent papers have provided important reasons to worry that some of those estimates may be misleading. Subramanyam et al. (2011) finds that province level per capita GDP does not have any impact on the nutritional status of children in India. Vollmer et al. (2014) uses cross country height and weight scores from 126 DHS surveys and find for the most part statistically, economically and biologically insignificant associations.

The impact of Subramanyam et al. (2011) and Vollmer et al. (2014) on the academic debate was large, sparking a series of both positive and less positive responses in various journals (Singh, 2014; Alderman et al., 2014; Bershteyn et al., 2015; Joe et al., 2016; O'Connell and Smith, 2016; Lange and Vollmer, 2017). This was not simply because their estimates were somewhat out of line with previous research, but because these out-of-line estimates were the first to apply spatio-temporal econometric models that could estimate the effect of within-country economic growth while still controlling non-parametrically for secular time trends. This methodological improvement came with an important statistical critique of previous research similar to the arguments in favor of the so-called "difference-in-difference" type fixed effect models widely used in applied microeconometrics.

A version of the statistical critique goes as follows: previous studies have relied almost exclusively on one of two types of "identifying variation" in the variables of interest. Cross-country studies rely on "between country" variation; the model implicitly compares the GDP levels of countries J and K with their average HAZ. These regressions tell us how countries that have grown differently in the past have experienced different health improvement trajectories, but they cannot tell us how growth in some particular country affects the nutritional status of children. The model will pick up any effect of GDP on HAZ, but also any effects of anything else that is more conducive to child physical growth in richer as compared to poorer countries.

Exploiting "within country" variation comes with its own concerns. If we consider only country-level macro-economic conditions, then within a country the only variation in GDP comes from across birth cohorts - from children born in different years and thus exposed to the stream of GDP realizations at different points in their development. The sacrifice to be made to estimate within-country effects is that one must choose a parametric specification for the effects of secular improvement over time, and with only a few survey rounds this becomes a potentially insurmountable econometric problem.

Spatio-temporal fixed-effects models, on the other hand, exploit both within- and between-country variation in GDP growth and child growth. These models make assumptions about the effects of place and time that allow for group/region level effects that are persistent across time, and simultaneously allow for arbitrary secular trends that are common across groups. Whereas within-country models compare changes in GDP to changes in HAZ, these "difference-in-difference" type models compare how much more or less change in HAZ high growth countries experienced relative to low growth countries. Differential changes in HAZ that are uncorrelated with differential changes in GDP are then ascribed to the unobserved time effect and not, as in the pure within-country model, ascribed to GDP growth itself.

2.2 Outcome Measurement: Height v. Weight; HAZ v. Stunting; HAZ-age Profile v. HAZ

Height-for-age Z-score (HAZ) is an age- and gender-normalized measure of child height relative to the median height of a population of well-nourished and healthy children. The anthropometric standards provided by the WHO reflect the highest potential for physical growth and human development. The standards were derived from growth curves that were estimated from children between the ages of 0 to 5 years olds in six countries –United States, Oman, Norway, Brazil, Ghana and India. In order to capture the anthropometry measures of well fed children, the WHO collected data on children from higher socio economic groups who were breast fed up to at least 12 months after they were born by non smoking mothers who lived within a sub set of locations in these countries.

Alongside determining the standards, a WHO expert working committee argued that height–for–age (HAZ), weight–for–age (WAZ), weight–for–height (WHZ) z-scores best reflected the interaction between social determinants of health and the physical development of children (World Health Organization, 1995). They determined that indicators that used weight could accurately predict malnourishment within a population at a given time. However, since weight is highly responsive to food and nutrition availability in the short-term, weight measures should not be used predict the effect of past input streams on the current or future health and productivity of an individual. On the other hand, HAZ scores can be interpreted as capturing the cumulative effects of the stream of biological inputs over the course of the child's development. Other work has shown that HAZ predicts lower productivity in adults (Glewwe and Miguel, 2007; Hoddinott et al., 2008) and can predict two year future mortality risk in young children (World Health Organization, 1995). The authors of the WHO report also cautioned that any study that used HAZ as an outcome would be confounded by its relationship with age if this relationship was not accounted for properly.

Figure 1 shows survey-round mean HAZ from 126 Demographic and Health Surveys (DHS) across 38 countries, comparing HAZ and GDP in year of survey. The upper panel of Figure 1 shows how mean HAZ for a country correlates with the level of GDP in the survey year. The correlation in the raw data is statistically significant and the coefficient is of a similar magnitude to our final estimates - a 0.1 log point change in GDP is associated with a 0.03 sd increase in HAZ. The bottom panel in the graph shows changes in HAZ against changes in GDP, and the point estimates are similarly sized and also precisely estimated. Figure 1, though, fails to capture the underlying biological process of child growth.

To represent the population-level association between HAZ and GDP in a manner more true to the process of growth faltering, we present the HAZ-age profiles from our sample countries in Figure 2, plotting mean HAZ across child age. In the top panel, we aggregate countries based on being above or below median GDP for countries in our sample[2]. A very clear pattern emerges. Children in both groups of countries start at similar HAZ at birth (just below 0) and then grow more slowly than the children in the well nourished, healthy WHO

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[2] We use average GDP over the study period to divide countries into the two groups

reference group. Mean child HAZ is then essentially constant from age 2 through age 5.[3]

The second key insight taken from the graph is that it is the rate of loss of HAZ, and not HAZ at birth, that drives the differences in the HAZ-age profiles across GDP levels. At the left edge of the graph, poorer and richer countries (graded from cyan to magenta) are intermingled, with a slight tendency for poorer countries to have a lower intercept. However, by the age of 5, the HAZ-age profiles have essentially sorted themselves along GDP rank. This is the result of increased severity of growth faltering in the poorer countries. Despite the fact that children in relatively richer and poorer countries were born with similar length, the children in the poorer countries grow much slower.

If the defining characteristic of the association between economic conditions and child height is the process of growth faltering, then clearly the use of mean HAZ or stunting as a measure, as compared to age-specific HAZ, is averaging across the exact effect it is hoping to capture. The probability of stunting is non-linear and strongly increasing over the first two years of life and any effect of GDP growth on stunting at age 2 is being averaged with much smaller effects for an otherwise similar child measured at 4 months. Limiting the sample to younger children (as Subramanyam et al., 2011 and Vollmer et al., 2014 both do to increase sample size) only exacerbates the problem.

2.3 Timing of Exposure: Cohort v. Survey

While Figure 2 is a conceptual improvement over Figure 1, they both aggregate over another important dimension of the analysis - the timing of changes in GDP relative to the development of a child. That is, in Figure 2 countries are categorized as simply above or below the median for the sample; and in Figure 1 they are assigned the GDP that corresponds with the timing of the survey. This second strategy, of merging GDP level with survey-time is common to almost all of the cross-country literature on macroeconomic conditions and

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[3] There is some visual evidence that the gap in HAZ between richer and poorer countries may close slightly by age 5 (so called "catch–up" growth).

child health. Indeed, our survey-level aggregate models tie exposure to survey time, though mostly because they use data on only the two most recent annual cohorts of children, and so the choice of merging strategies makes little difference.

But once we concede that the age-profile representation is more accurate than the scatter-plot representation, we are also conceding that the timing of inputs matters, and that experiencing GDP growth as a 4 year old has different effects than being born following several years of economic growth. Our fixed effects analyses thus merge GDP exposure to child cohort, not to survey dates. We also vary this "age-at-exposure" to test how coefficients change when input-timing is allowed to adjust. Though the serial correlation in GDP over time makes separately identifying the effects of each age-at-exposure from each age-at-measure impossible, the exercise is still valuable. We discuss the details of the empirical issues in our discussion of the econometric models, but in the next section we show that only by tying exposure to cohort instead of survey can we remain faithful to the underlying heath capital accumulation theory.

3 Health Capital Accumulation

3.1 Model Structure

We begin with an abstract and stylized inter-temporal household utility optimization problem, drawing from health capital models such as Grossman (1972) and Becker (1962). Household decision makers have preferences for their own consumption (C) and for their children's health (H).

$$\sum_{T} U_t(H_t^a, C_t) \tag{1}$$

Child health is super-scripted 'a' to re-enforce the link between calendar time 't' and child age once a child is born. This becomes important because while setting t=0 normalizes the relationship between "time" and "age" for that child, exposures in the world must be indexed in "calendar time" not "age time".

The evolution of child height is modeled by an age-specific human capital production function that also takes inputs from calendar-time features of the world:

$$H_t^a = f^a(H_{t-1}^{a-1}, I_{t-1}, G_{t-1}; \delta^a) \tag{2}$$

Household's can purchase inputs I that increase child health (food, medicine), and children are affected by the general public health environment and availability of public health goods and services such as water and sanitation, health knowledge, clinic and market access (G).

Given their preferences and the nature of $f^a()$, household's optimally purchase consumption and child health investments (I) to maximize Equation 1 over the course of their expected lifetimes subject to a period-specific budget constraint:

$$W_t = P_t.C_t + I_t^a \tag{3}$$

In every period households earn income W_t and they spend all of it on either personal consumption or health investment in the child. Households gain current period utility from private consumption and a stream of future utility if they invest in their child's health. Given standard parameter restrictions including decreasing marginal utility of consumption and concavity of the human capital production function, household's will optimally proportion their period specific income with positive purchases of both C and I, and will trade off on the margin if relative prices or the efficiency of human capital production change. The addition of common modeling complications such as inter-temporal borrowing, endogenous earnings or later life wealth transfers from children to parents do not change these basic conclusions. However, non-concavities in the human capital production function could easily change these predictions, and we address that to some degree below.

3.2 Optimal Investment and Comparative Age Dynamics

Fix the initial conditions: a child is born. This child is born into a household in year t with health status H_t^0 and family wealth W_t. This implies, for the first period, an optimal $I_t^{*0}(H_t^0, G_t; W_t; P_t; \delta^1)$, and thus implies an optimal $H_{t+1}^{*1}(H_t^0, G_t, W_t; P_t, \delta^1)$

Differences across countries in GDP, and changes within a country, are likely to affect two elements in the determinants of optimal child health investment and thus in future child health. First, increases in GDP lead to improvements in the labor market. During times of GDP growth, households are more likely to find employment, and conditional on finding employment, likely to receive more income (Topel, 1999). Second, increases in GDP are likely to increase the provision of public goods (G). Public goods, broadly construed, work here as a sort of in-kind transfer from the government that pays in child health. If we want to know how a change in W or G at birth affects health status at age 2, we have to trace its effect through optimal investment decisions in period 1 and the development of G and W over time.

Consider the effect of an increase in household wealth generated by improved economic conditions, which a household experiences in year t when a child is born. At age 1, the effect of this input on child height comes from an increase in I_t^{*0} (since increased wealth goes partially to investment) and any increase in public goods G_t made possible by increases in governmental revenue (which directly enters the human capital production function as an input).

The effect by age 2, though, is not the same as it was at age 1. Instead, the change in H^{*1} generates changes in both I^{*1} relative to what it would have been had the household not experienced the wealth transfer in year t, and in the effectiveness of the inputs themselves (via $f^a()$). The effect of improvements in W and G experienced in the first period of ones life will have differential effects that may either fade-out or be reinforced over the child's life depending on all of biology, household decision-making and the future strength of the macroeconomy.

The above discussion highlights model predictions across age-at-measure, while fixing age-at-exposure. But the model makes predictions across as second dimension of child age as well. For a 4 year old, the effect of an input at age 2 compared to age 3 has two different components. First, there are the fundamental differences in the human capital production function over child age, for instance if there are critical periods to child development where inputs have a larger effect than in other periods. Secondly, re-optimization of household decision making in each period means that if unexpected external forces increase child health, households may have incentives to invest differently than they previously would have because the child is already healthier than they anticipated it being. By focusing on age-at-exposure, conditional on age-at-measure, researchers can investigate how the timing of inputs over the course of a child's lifespan (up to measurement date) differentially impact attained height at age A.

The simple framework presented here generates two dimensions of age heterogeneities, each with both a biological and behavioral affect on child height (either directly via the human capital production function or indirectly via behavioral choices regarding optimal investment). Our econometric framework is designed to address and estimate, in as least restrictive a manner as possible, both of these dimensions of age-heterogeneity.

4 Econometric Models

We develop two methods for estimating the relationship between GDP and child growth rates. The first method uses each individual DHS survey as a single observation of an HAZ-age profile. This provides two-parameters (intercept and slope) that summarize the relationship between GDP growth and how quickly children in developing countries lose height relative to the WHO reference population of healthy, well-nourished children. The second method uses fixed-effects models developed to specifically control for both the average HAZ-age profile for the child's country and the experience of growing from age 0 to age A during the years T to T+A. This allows us to (in theory) identify the effects of all permutations of age-at-measure and age-at-exposure.

4.1 Rate of Loss of HAZ

Recall the common defining feature of the HAZ-age profiles presented in Figure 2. The loss of HAZ experienced by children in developing countries is rapid and relatively linear over the first two years of life. The age profile then becomes essentially flat (or slightly positively inclined) from ages 2 through 5. We define two parameters to characterize this empirical regularity: a) we define α as the *intercept of the HAZ-age profile on the Y-axis*, that is, the implied length-for-age Z-score (LAZ) at birth; b) we define β as the *rate of loss of HAZ from birth to age 2*, that is, how much more slowly are children growing than the WHO reference median child (in units of standard deviations of the reference population). As simple as they are, these summary measures provide a relatively complete characterization of the HAZ-age profile over the first two years of life in country J from calendar years Y-A to Y[4].

We estimate these parameters separately for each survey round in each country as an OLS regression of HAZ for child i measured at age A for the entire set of surveys S:

$$HAZ^s_{iA} = \alpha^s + \beta^s_{age} * Age^s_{iA} + u^s_{iA} \qquad \forall s \in S \tag{4}$$

Equation 4 allows us to estimate $\hat{\alpha}^s$, a country by time period specific estimate of the LAZ at birth and $\hat{\beta}^s$, an estimate of the rate of loss from that initial birth LAZ over the first two years

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[4] Where Y is the Survey Year.

of life. We then take the estimates $\hat{\alpha}^s$ and $\hat{\beta}^s$ and turn them into $\hat{\alpha}_{jy}$ and $\hat{\beta}_{jy}$, observations from country J in survey year Y for a second stage regression on the determinants of the shape of the HAZ-age profile over the first two years of life. The second stage regressions treat $\hat{\alpha}_{jy}$ and $\hat{\beta}_{jy}$ as the outcomes of interest. We merge this data with a panel of (log) per capita GDP measures from the World Bank, generating an unbalanced panel of observations at the country-year level that include the parameter estimates of the first-stage regressions and the GDP data from the World Bank panel[5].

The second stage regression takes a form involving some or all of the elements of the fully saturated regression model below, for country J in year Y:

$$\hat{P}_{jy} = \delta.GDP_{jy} + \gamma_j + \lambda_y + \eta_{jy} \tag{5}$$

$\hat{\delta}$, divided by 1,000[6], can be interpreted as the effect of a 10% change in GDP on HAZ. Variants of this equation, keeping or dropping different elements, allow us to estimate the effect of GDP growth on the parameters of the HAZ-age profile using fundamentally different types of identifying variation. Without γ_j and λ_y, the equation reduces to the OLS estimate of the association between economic growth and HAZ. $\hat{\delta}$ is the estimate of the effect of GDP on the outcome $\hat{P}_{jy}$ (either $\hat{\alpha}$ or $\hat{\beta}$). This version of the regression model treats every observation as independent from the others, as though an observation from Armenia in 2000 can be naively compared to an observation from Zimbabwe in 2010. In that sense, the equation fully exploits both within- and across-country variation, but does not do so

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[5] In this specification, we merge GDP from the survey year with the outcome data. This means that children who are infants in our regressions are being given a measure of GDP associated with their year of birth, but children who are two years old are being given GDPs that they experience at age 2. In the next section we more strictly link GDP measure to year of birth for all children, but in this section we simply note that, given both the relatively small changes in GDP across one or two years, and the high serial-correlation in GDP over time within a country, this should make little difference to our estimates. Furthermore, this set of estimates abstracts away from the fact that children of different ages are living through periods of growth at different points in their development, but since we are taking each survey as a single observation at one point in time, this seems natural to the empirical environment, and is consistent with the previous literature.

[6] HAZ is measured as the WHO score*100, which is how it is provided in the DHS. The calculation above is based on a change of 0.1 in the log of GDP .

in ways that are not immediately interpretable relative to actual changes in macroeconomic conditions in the world.

In order to address more carefully the question of whether medium-term economic growth is correlated with improvements in child health, we then specify a country level fixed effects model. By including γ_j and thus de-meaning the outcome variable and the GDP time-series within a country, $\hat{\delta}$ estimates how changes in GDP within a country over time affect LAZ at birth and the rate of loss of GDP over the first two years. Our identifying variation within a country comes not from one calendar year to the next, but from one survey year to the next, an average time difference of about 6 years. The between country identifying variation comes from binning surveys into 3 year survey-time bins.[7] Symmetrically, we might want to focus only on the across-country differences, even if only to understand any potential differences between the OLS results and the within-country estimates. We show this by including λ_y while dropping γ_j. This between country model estimates $\hat{\delta}$ by averaging correlations across countries at each point in time.

The single fixed-effects estimates in the preceding paragraph are regression analogues of single-difference estimators. Exploiting both across- and within-country variation in a "difference-in-difference" framework allows us to partially address the problems of omitted variables (across-country) and secular trends (within-country). With the inclusion of both λ_y and γ_j, the model now implicitly compares changes in the HAZ-age profile in a country with low growth to changes in the profile in a country with high growth. The secular trend in improvement is thus differenced out, and the model estimates based on how much more improvement in the parameters of the age profile there was in the high growth countries compared to the low growth countries.

We offer two strategies for estimation of standard errors for $\hat{\delta}$. First, we provide analytic

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[7] Technically, it is possible to include individual survey year dummies into the regression. However, since surveys for different countries occur at different times, this forces the year dummies to identify off a small and changing set of countries in each potential survey year. We thus bin time into 3 calendar-year bins, chosen so that no country appears in the same temporal bin twice. Results are generally robust to the use of individual year dummies.

standard errors clustered by country, following standard practice for spatio-temporal fixed-effects models. These standard errors are likely biased towards 0 relative to the true sampling distribution of $\hat{\delta}$, since they do not account for the uncertainty in the left-hand side variables (Elbers et al., 2005). To account for this, we provide a second set of standard errors estimated from a 2-stage bootstrap procedure. In that procedure, we first choose (with replacement) 38 countries, and give each observation a new ID number. We then bootstrap sample by the interaction of primary sampling unit (PSU) and survey round within each ID number, and jointly estimate $\hat{\alpha}$ and $\hat{\beta}$ for each survey replacing country based fixed effects with ID based fixed effects. We repeat the double bootstrap sampling 500 times and report the standard deviation of the estimates as the bootstrap standard error estimate of $\hat{\delta}$. Empirically, the large sample sizes from each survey seem to make this secondary source of variation rather small, and the two standard error estimates are similar.

Unlike the age-profile estimates in the next section, each parameter in the first stage regression is estimated from a regression weighted by the probability weights provided by the DHS. These weights make the age-profile parameter estimates representative of the population distribution of the country at the time of the survey. Since each parameter is estimated from only one survey, applying the weights is easy and the interpretation of their function in clear. However, the second stage regressions of the parameters on GDP are not weighted, and each survey is given an implicit weight of 1. The age-profile fixed-effects models in the next section, which are estimated directly on the pooled data, are also not weighted.[8]

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[8] We refer primarily to (Solon et al., 2015) for justification. DHS weights are designed to generate nationally-representative estimates of population means and proportions. Any reweighing of repeated cross-sections of the DHS from different countries requires deeply subjective choices about the target population of interest. After relative probability weights are applied, the sum of those weights within a survey round could be weighted equally across all surveys, by sample size, by country population (repeated or broken up over survey rounds), or by some optimal variance minimizing quantity. We choose instead to simply let each observation represent one observation, and concede that we have already assumed away heterogeneity in impact by estimating a single parameter for each age (one that does not vary by individual type or sub-group).

4.2 Age-Profile Fixed-Effect Models

Our second method implements a novel fixed effects specification that isolates the effect of inputs at various ages on the entire HAZ-age profile. The intuition for the fixed-effects models we estimate below can be motivated by a simple thought experiment. Suppose a researcher has a set of cross-sectional surveys with HAZ measurements from different countries covering a number of survey rounds in each country. Collapsing this data down into country-year observations generates a country-year panel dataset. The insight we exploit is simply that this same procedure can apply even if we keep only the observations from any particular round that are children of age A. The following equation represents the regression analogue of this thought-experiment, containing observations for only children aged A:

$$HAZ_{icj}^{A} = X_{ijc}'\beta^{A} + \delta^{A} * GDP_{cj} + \mu_{j}^{A} + \lambda_{c}^{A} + \zeta_{icj}^{A} \tag{6}$$

This equation reduces to the standard "quasi-difference-in-difference" method employed using panel or repeated cross-sectional methods on mean impacts, but estimates the coefficients only on children of age A. There is no reason this regression cannot then be repeated for children aged A+1, A-1, A+2... etc. A two year old child in country J born in 2000 would be compared to a two year old born in Country J in 1995. Simultaneously, the 2 year old born in 2000 in Country J is compared to a 2 year old born in 2000 in Country K. More than that, each age-group is identified off different (though correlated) variation because each cohort was born into the GDP stream experienced by their country at a different point in calendar time. If the coefficient off 2 year olds is identified off the GDP values from 1995 and 2000, the coefficient on 3 year olds is identified off GDP values from 1994 and 1999 (and the change in the value).

We generalize the above thought experiment and regression equation into a multi-age framework where we can estimate δ^{A} simultaneously for children of all ages. We generalize the above function by allowing μ_j^A and λ_c^A to become μ_{ja} and λ_{ca}, that is, we interact country and cohort with age, generating fixed-effects for the country-specific HAZ-age profiles (λ_{ac}) and child's lifespan (μ_{ja}).

$$HAZ_{ijca} = X'_{ijca}\beta + \sum_a \delta^A * GDP_{jc} + \mu_{ja} + \lambda_{ca} + \epsilon_{ijca} \tag{7}$$

This regression again has both within- and between-country comparison analogs, but these comparisons are now made only within a particular country's children of the same age, or across children who have lived the same "lifespan". Our "within" variation comes from comparing children of age A in country J and born in cohort C, with children of the same age A and same country J but born in cohort C'. That is, we difference out the average effect (over the whole sample period) of growing up to age A in Country J. The remaining variation in GDP and HAZ for a cohort in Country J then contains three components: exogenous noise (by assumption), any effect of GDP, and the secular improvement in HAZ that would have occurred over time even absent changes in GDP.

Since HAZ is not an instantaneous outcome, the calendar date on which one is measured can only affect HAZ by, in combination with cohort, fixing the calendar time through which an individual child grows; that is, by being a proxy for the time into which you were born and through which you grew up. Our "between" variation (λ_{ca}) then comes from comparing children who were born at the same time and measured at the same age (who lived the same "lifespan" over calendar time), but in different countries. All children who lived the same lifespan experienced secular changes in life-improving technologies over the exact same points in their human development. Given the remaining variation in GDP after de-meaning by country-age, the component of the secular time trend that is common across countries for children of that cohort measured at that age can be purged from the remaining variation by simultaneously estimating indicator variables for each lifespan permutation (age-cohort-period) realized in the data. Interpreted in terms of allowing for idiosyncratic time trends, controlling for child lifespan allows the non-parametric secular time trends to themselves vary non-parametrically by age.[9]

5 Data

For the outcome variables and other covariates, we use data from 126 demographic health surveys (DHS) from 38 countries surveyed between the years 1986 and 2013 (I C F, 2011). The DHS are nationally representative multi stage cluster surveys that provide health, demographic and socioeconomic information of women (15-49 years) and children (0-5 years). The surveys are generally conducted every few years in a given country, and can be weighted to be nationally representative. A two stage sampling format is used where countries are divided into regions based on political and geographical criteria and each region is classified into urban and rural areas. Within these strata, enumeration areas called the primary sampling units (PSU) are chosen such that the probability of being chosen is equal to the proportion of the population in the PSU to the total population from the census data. In the second stage, 25 households from each PSU are randomly selected for the survey. The surveys include information on anthropometry, household wealth, and other health care seeking behaviors of households. Eligible respondents are women between the ages of 15 to 49, and information is collected on the household and on children under the age of 5.[10] We use the (2005) WHO referenced HAZ scores that are the secondary HAZ measures in the DHS. For DHS surveys completed before the 2005 WHO references were adopted, we merge back in the DHS-computed WHO z-scores from the auxiliary files online.

Our estimation sample includes children between the ages of 0 to 60 months with valid HAZ scores which were referenced to the WHO 2005 values. Only countries with at least

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[9] A graphical representation of both the within- and between-country variation in the age-profile fixed-effects models is presented in Figure A1, which plots the HAZ and GDP time series for three countries over several survey rounds.

[10] Sometimes the sampling frame includes any children under 5 and sometimes only children of the respondent, but this varies from country to country and over time

2 surveys in which all the ages were available were used for the analysis[11]. Anthropometry scores between -6 and 6 were considered valid and included in the analysis per the WHO recommendations (World Health Organization, 2006)[12]. Our regressions include only those individuals with complete information on sex, their mother's education level & age and type of residence (urban or rural). After following this inclusion criteria, our estimation sample consists of a total of 685,075 children in 38 countries. The consort diagram (Figure 3) shows the sample selection criteria and loss of sample size at each stage.

GDP per capita (adjusted for 2005 USD) time-series for individual countries were downloaded from the World Bank Databank.[13] The data for GDP is merged to individual observations by cohort and country. However, given that survey timing within the calendar year is not constant across survey rounds and almost never covers the entire calendar year, we make a slight adjustment. For each age of child (0, 1,..4), we calculate the modal birth year for children measured in that survey round and of that age, and we assign this as the"merge" year. This has a motivation in statistical theory - it removes the possibility of identifying effects of GDP on HAZ off of "December-January" babies. That is, if we allowed children from one cohort (defined as combination of country, survey round, and age group) to have multiple values of GDP, our model would then derive identifying variation off comparing children born in December with those born in January. If a survey takes place in other months, the children from December will be measured at an older age than the children in January, and since GDP tends to increase over time, younger children (with higher HAZ) will be associated with (on average) higher GDP from the next calendar year. By defining cohort in the manner that we do (constant within round-country-age bin) our fixed-effects models do not identify off within-cohort variation in a way that can cause the bias described

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[11] For example, India was dropped from the analysis since 2 out of the 3 surveys did not have children between the ages of 3 to 4.

[12] The DHS multiplies standard WHO scores by 100, and we maintain this convention to make coefficients more easily interpretable, so in practice our analysis includes those that range from -600 to 600 in the DHS surveys

[13] Economic Indicators from http://databank.worldbank.org/; Accessed Dec 2014

in Cummins (2013) or that relies on spurious variation across two children born just one month apart.

Summary information on the countries used, the survey years, characteristics of the households and children and the outcome and GDP measure can be found in Table 1. The mean age of the children is about 29 months and is evenly split by gender. 36% of the children live in urban areas. Mothers are on average 29 years old, 36% of them have no education and 35% of them have at least primary education. The average GDP per capita experienced by children in our sample is around 721 USD. The average HAZ score for all children in the sample is -144, meaning the average child in our sample is 1.4 standard deviations below the WHO reference for the median healthy and well-nourished child of that age and gender.

Table 1 contains the entire (small) set of covariates used in our analysis. By controlling for the sex of the child, the maternal age and education and the type of residence, we are able to control for some of the main determinants of the differences in HAZ scores that come from heterogeneity within the population. We limited the number of covariates in order to maximize the final sample size and limit the potential for bias induced by differential omission from the analysis set[14]. Our analysis files make it possible to easily add or remove covariates in order to test the robustness of the estimates, but in general we find that covariates do not strongly influence estimated effect size conditional on the fixed-effects specification.

6 Results

6.1 Rate of Loss of HAZ

Table 2 presents results from estimating Equation 5 on the parameter estimates from Equation 4. The α columns show the coefficient estimates of GDP on the implied length-for-age

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[14] This parsimonious set of controls that was chosen such that the information was available in all survey rounds in the DHS and the coding of the variables was consistent across DHS questionnaires.

z scores (LAZ) estimates, and the β columns show the coefficients on the estimates of the rate of loss of HAZ. The first specification provides the OLS estimate (excluding both γ_j and λ_y) of the coefficients on $\hat{\alpha}$ and $\hat{\beta}$ (obtained from Equation 4). The "between" specification includes γ_j, the "within" specification includes λ_y, and the "DnD" columns present estimates when both are included.

The coefficient estimates on α are generally small, highly variable across specifications and imprecisely estimated. Taken at face value to assess potential magnitude, the point estimate on the OLS coefficient implies that a 10% increase in GDP is associated with an approximately 0.1sd increase in length-at-birth z-score. The coefficient magnitude increases to almost 0.4 sd for the within estimate (with a confidence interval approximately that wide), but the preferred difference-in-difference estimate puts the magnitude around 0.02 sd (with a similarly wide confidence interval).

The coefficient estimates on β, on the other hand, are robust across specifications and fairly precise. A 10% increase in GDP is associated with around a 0.002 sd decrease in the rate of loss of HAZ. In a country whose median child becomes exactly stunted on their second birthday after being born 0.25sd below the reference children (reasonable given Figure 2), the rate of loss would be around 0.07 sd/month, making that a 3% change off the base. Cumulatively, a change in the rate of loss of HAZ of 0.002 sd would generate a 0.05 sd effect by the time the child reached their 3rd birthday.

6.2 Age Profile Fixed Effects Results

6.2.1 Birth Year GDP by Age-at-Measure

Figure 4 graphs, across child age, the coefficients and confidence intervals from the regressions outlined in Equation 6, where separate regressions are run on children at each age in years. The coefficient estimate on children under age 1 is small and statistically indistinguishable from zero. However, as the child reaches age two, the effect size has grown and the confidence interval remains of similar magnitude. By age 3, a 10% increase in birth year GDP is associated with a 0.04 sd increase in HAZ.

Table 3 provides the regression estimates from the simultaneous estimation strategy described in Equation 7. The specification in column 1 has only country and survey fixed effects. Column 2 includes country-age with survey fixed effects and column 3 includes country fixed effects with lifespan fixed effects. The specification in column 4 includes both the country-age and lifespan fixed effects. The estimates are stable across specifications and similar in magnitude and precision to those graphed in Figure 4.

6.3 Effect at Age A by Age at Exposure

Figure 5 presents coefficient estimates from a series of regressions that shift the timing of GDP relative to the child's cohort, presented separately for children measured at ages 3 and 4. Each dot represents the estimate on $\hat{\delta}$ from a regression where the GDP exposure is tied to a particular point in the child's delveopment, from three years before their birth up to two or three years after they were measured. The strong serial correlation in GDP (and in changes in GDP) means that many of the estimates are statistically significant. However, estimates from merges of the GDP stream to years between the birth of the child and the date they were measured generate the largest coefficient estimates and have lower bounds much further above the estimates those from estimates based on years before the child was born or after they were measured.

6.4 Simultaneous Estimation of Age-at-Exposure Effects by Age-at-Measure

Figure 6 presents estimates, separately for each age-at-measure, of the association between GDP exposure at each period from a child's birth until the age at which they were measured. Essentially, Equation 7 is re-conceived so that δ^A references heterogeneous effects across age-at-exposure while holding age-at-measure fixed.

We present the estimates for completeness, and to show two aspects of the analysis. First, the estimates are incredibly noisy and they have overly large coefficients that tend to cancel one another out. This is certainly due in large part to the serial-correlation in GDP over time, but that may be less of a problem in other empirical contexts. Second, for every age group, the contemporary, survey-time coefficient dominates the other input periods. We leave it to future researchers to determine whether this result is meaningful or informative, or simply the result of contemporary GDP being the only exposure-year for which each cohort experiences it in the same calendar year. Since the regressions are run separately by age, it could simply be an improbable "draw" on the joint HAZ/GDP distribution in that particular set of calendar years and countries. Though we do not pool data across measurement ages and thus estimate each of these parameters simultaneously, such specifications follow naturally, with Equation 7 updated again to have a double summation of coefficients over both exposure and measurement age, covering whatever subset of permutations are relevant and interpretable.

6.5 Public Health Mechanisms

As discussed in the conceptual model, economic growth can impact the health of a child either through private investments made by households or through public health channels. In terms of household earnings and labor supply, the DHS does not provide appropriate measures that are comparable across surveys. In the case of the latter, though, several comparable measures are provide. However, since this information is only collected relative to the moment at which the survey was conducted, we can only trace out how economic growth is correlated with changes in the aggregate public health environment, and not relate this association to individual children or cohorts.

We find some evidence that increases in GDP improve the overall health services (Table 4). In Table 4. A 10% increase in GDP is associated with increased vaccination rates (Cols 1 & 2) of around 1.3*pp*. Point estimates on access to within house sanitation facilities (Cols 7 & 8) are positive but not statistically significant. Point estimates on traditional births, i.e births taking place outside formal health institutions (Cols 3 & 4) and access to health cards (Cols 5 & 6) are negative but not statistically significant. We find little evidence (in our sample) that GDP growth is associated with improvements in the health environment. In Table 5, our estimates imply that a 10% increase in GDP is associated with increases in fever of about 1pp, with no clear association with frequency of coughs or diarrhea.

7 Discussion & Conclusions

Prior studies that have estimated the relationship between economic growth and child health have often assumed away the actual process of child development, preferring instead static measures of population average health. In this paper we set out to develop new conceptual and methodological tools to capture the dynamic effects of health inputs on children's growth trajectory. We parametrically model the HAZ-age profiles from 126 DHS surveys and interpret our results as evidence that the relationship between economic growth and child health is more apparent in the rate of loss of HAZ than in length at birth. In the aggregate, richer countries, and countries that grow richer, raise children that grow faster than those in poorer countries and those that did not experience recent growth.

We also make strides towards separately identifying differences across permutations of "age at measure" and "age at exposure" relevant to estimating the age-dynamic parameters of an optimal health investment model. We introduce age-profile fixed-effects models that exploit variation within and across countries and cohorts to capture the impact of medium term economic growth on child growth trajectory. Similar to the magnitudes from the aggregate regressions, we find that a 10% increase in medium term GDP is associated with an almost 0.04 sd increase in HAZ by the time a child reaches the age of 3. Though the least-squares estimation we use in this paper may be insufficiently structured to identify all the potential exposure-by-measurement age permutations, we believe the econometric framework we lay out here can be greatly improved upon in terms of variance for the willingness to trade off small amounts of bias by placing prior restrictions on the coefficient dynamics across age (at exposure and measurement).

Finally, we hope that our demonstration convinces readers of the value of such an age-profile perspective in empirical contexts such as this where pseudo-panel outcome data is merged to aggregate spatio-temporal variation and an age-determined outcome of interest. Averaging effects across age can lead to misleading estimates that are not as directly interpretable relative to the world as they may seem, and failure to account for the age-cohort relationship can lead to bias as seen in Cummins (2013). Such age-aggregated models also needlessly obscure nuances in human development that are revealed in our analysis without large losses in statistical precision. We hope that more researchers will consider making the HAZ-age profile, and not simply mean HAZ or stunting rates, their object of investigation.

8 Figures & Tables

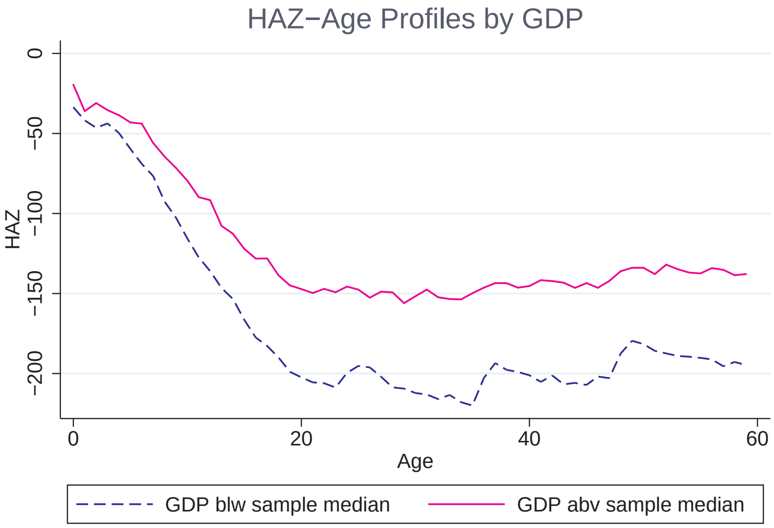
GDP Level and HAZ

OLS estimates, Beta = 33.8, p<0.01

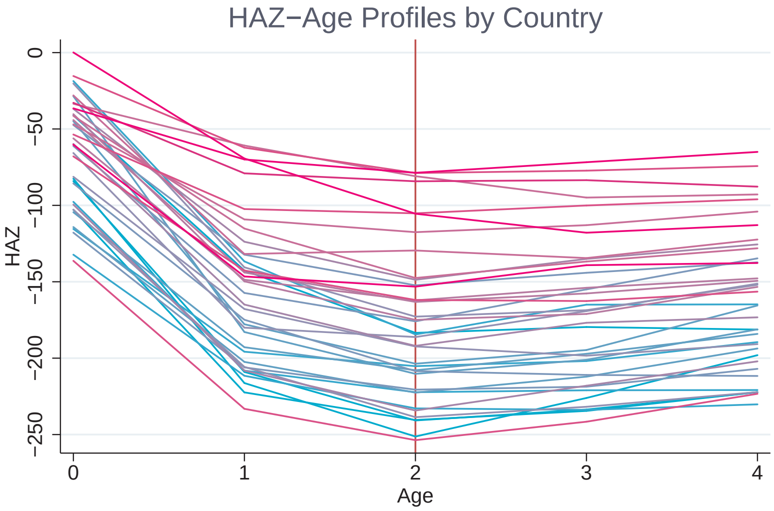
Changes in GDP and HAZ

OLS estimates, Beta = 34.6, p<0.01

Figure 1: Birth Year GDP and Child HAZ

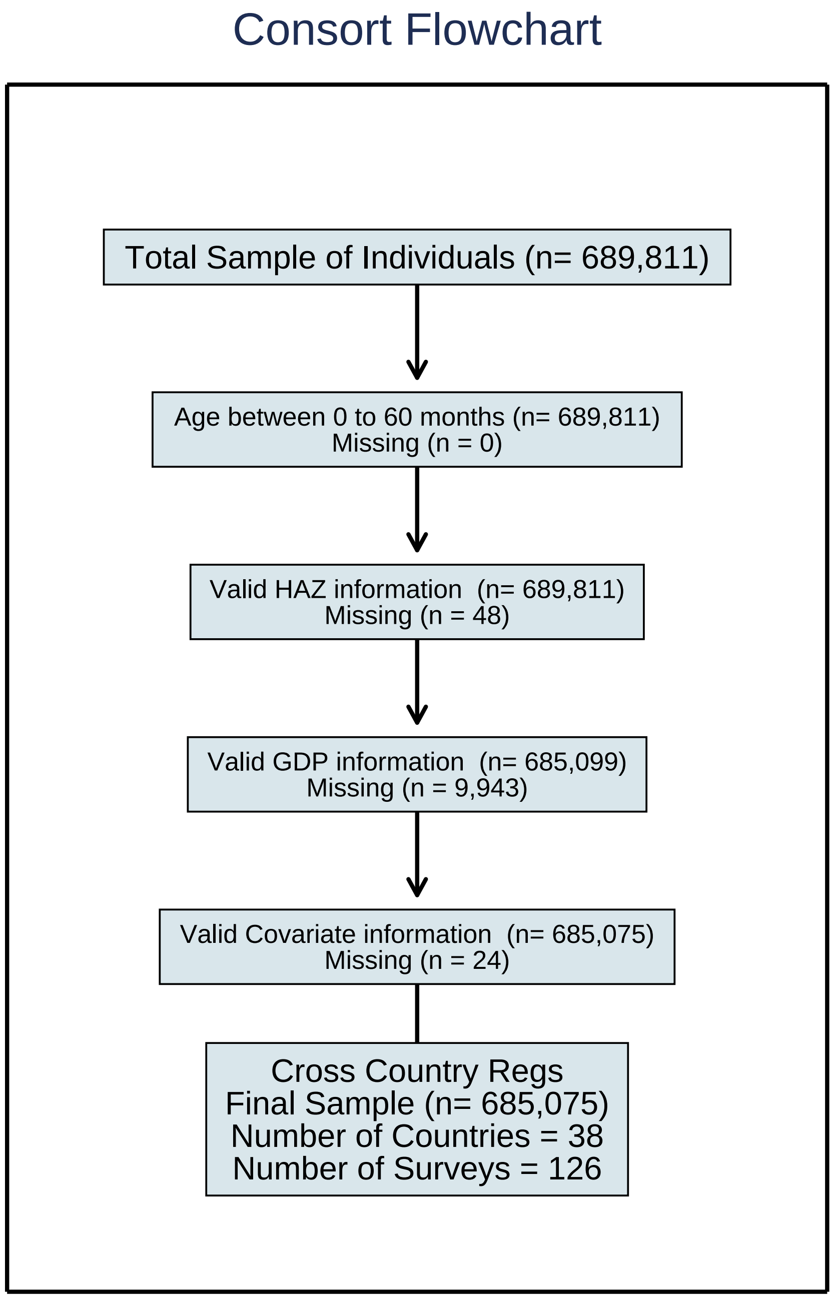


All countries in the sample are developing countries



Cyan to Magenta imply we are moving from countries with GDP in the bottom decile to countries in the top decile of the sample

Figure 2: HAZ Age Profiles



Adapted from: www.consort−statement.org/consort−statement/flow−diagram

Figure 3: CONSORT Diagram

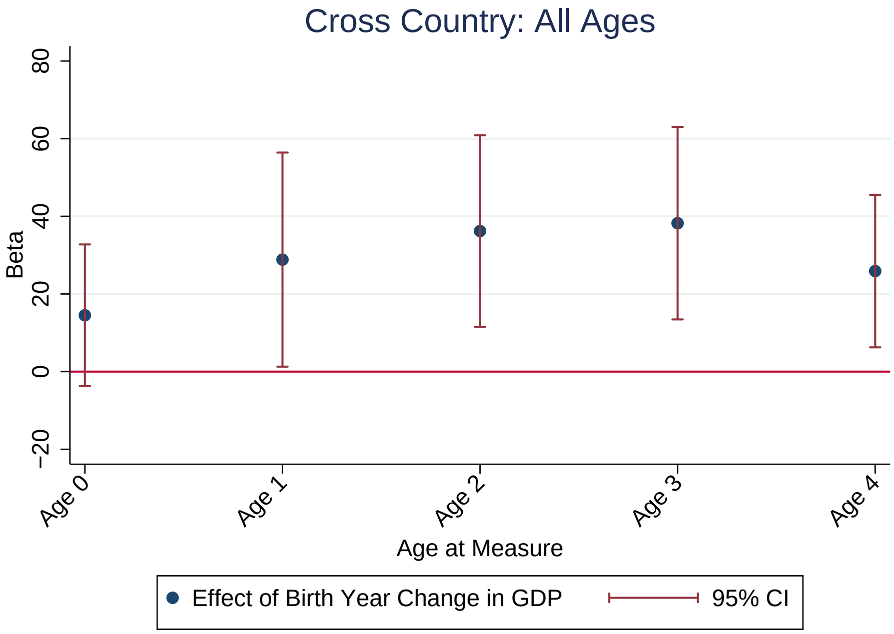
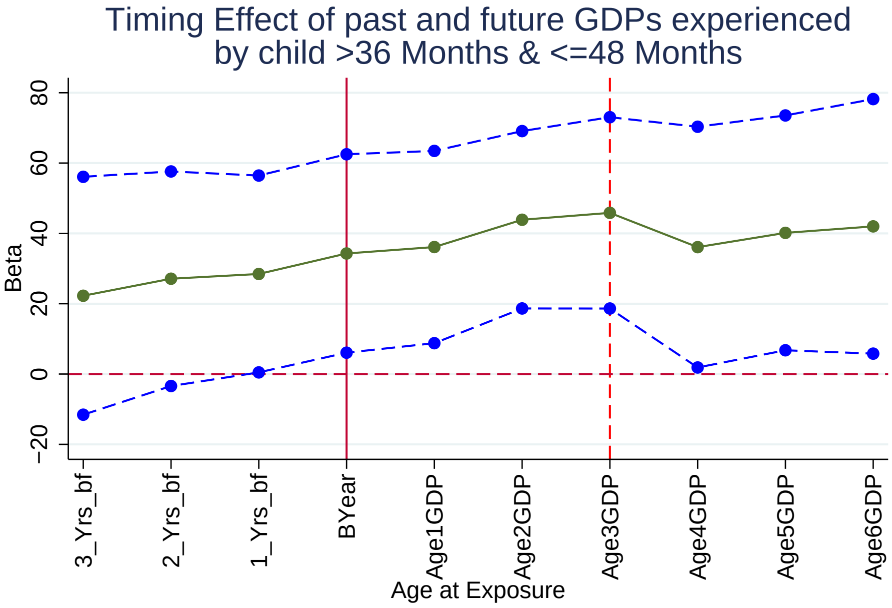
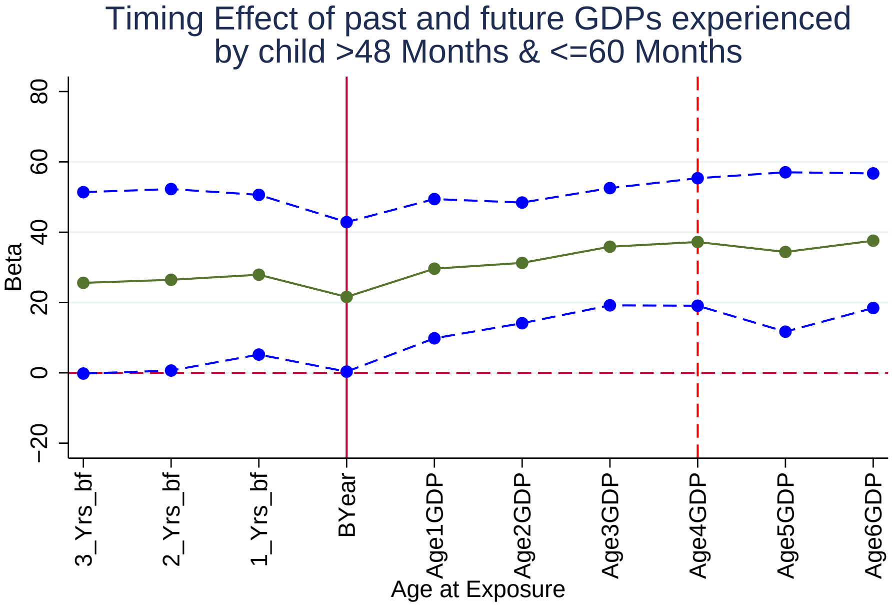


Figure 4: Results: Age-Specific Effects of GDP on HAZ


Timing Effect of past and future GDPs experienced by child >36 Months & <=48 Months

BYear is Birth Year; bf is before birth; Age3GDP is the GDP experienced by the three year old


Timing Effect of past and future GDPs experienced by child >48 Months & <=60 Months

BYear is Birth Year; bf is before birth; Age4GDP is the GDP experienced by the four year old

Figure 5: Results: Age-Specific Inputs of GDP on HAZ

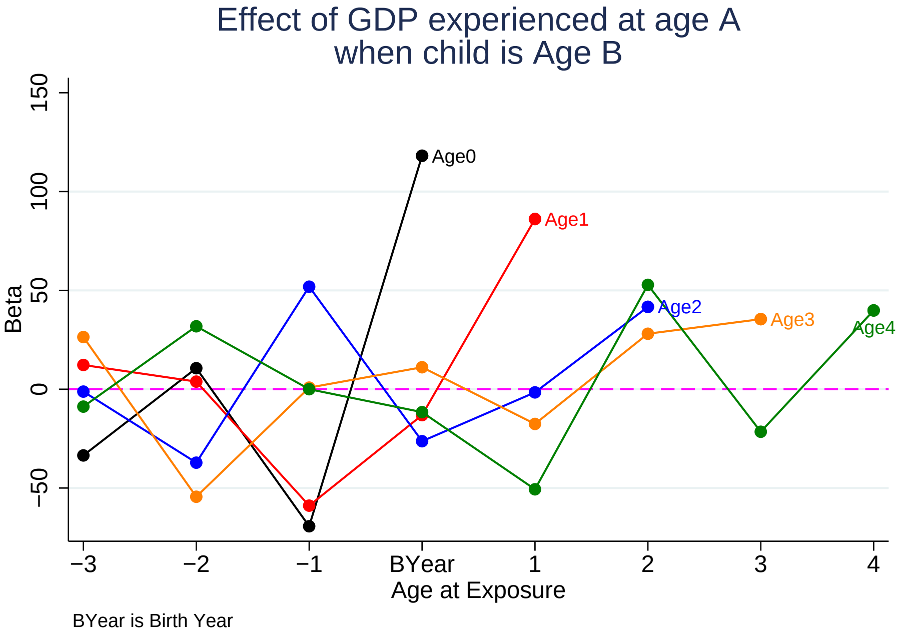


Figure 6: Simultaneous Estimation Across Age-at-Exposure, by Age-at-Measure

Table 1: Summary Statistics: Covariates

Variable	Mean	SD
HAZwho	-143.89	168.16
Child age (months)	28.40	17.17
GDP per capita (log)	6.58	0.92
Survey Year Gap (years)	5.98	2.28
Covariates		
female (%)	0.50	0.50
Maternal Age (years)	28.80	6.83
Maternal Education		
No Education (%)	0.36	0.48
Primary Education (%)	0.35	0.48
Secondary Education (%)	0.24	0.42
urban (%)	0.36	0.48
N	685075	

Table 2: Results: Rate of HAZ Loss and LAZ

	OLS		Between		Within		DnD	
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
	b/se/bse	b/se/bse	b/se/bse	b/se/bse	b/se/bse	b/se/bse	b/se/bse	b/se/bse
GDP	9.00	1.68***	10.0^{+}	1.65***	36.4*	2.21*	2.08	2.34*
	(5.54)	(0.33)	(5.33)	(0.33)	(17.8)	(0.93)	(15.7)	(0.90)
	[5.60]	[0.35]	[5.40]	[0.36]	[18.4]	[0.99]	[20.6]	[1.15]
Mean	-19.7	-7.6						
Survey FE			✓	✓			✓	✓
Country FE					✓	✓	✓	✓
r2	0.04	0.36	0.15	0.37	0.08	0.08	0.23	0.10
N	126	126	126	126	126	126	126	126

$^{+}$ 0.10, * 0.05, ** 0.01, *** 0.001; Robust standard errors clustered at the country level for 41 countries; For each specification columns represent results for children under 2, the first column presents values of the average LAZ scores (α) and the second column presents values for the rates of loss of HAZ (β) from Equation 5; Analytic cluster standard errors in ( ), 2-stage Bootstrap SE in [ ].

Table 3: Results: Age Specific HAZ Outcomes

	(1) HAZ b/se	(2) HAZ b/se	(3) HAZ b/se	(4) HAZ b/se
Age 0	8.8	3.2	12.8	14.5
	(10.5)	(10.4)	(9.6)	(9.3)
Age 1	28.8***	30.3**	32.5***	28.9**
	(10.5)	(13.4)	(10.0)	(14.1)
Age 2	33.6***	38.8***	36.7***	36.2***
	(10.7)	(13.1)	(10.0)	(12.6)
Age 3	31.3***	38.6***	34.2***	38.2***
	(10.6)	(11.0)	(9.9)	(12.6)
Age 4	28.8***	24.8**	31.9***	25.9**
	(10.5)	(9.5)	(9.6)	(10.0)
Urban	31.9***	32.0***	31.9***	32.0***
	(2.0)	(2.1)	(2.0)	(2.1)
Mat. Age	0.8***	0.8***	0.8***	0.8***
	(0.1)	(0.1)	(0.1)	(0.1)
Female	14.3***	14.3***	14.3***	14.3***
	(1.2)	(1.2)	(1.2)	(1.2)
Sample Mean	-143.91			
Survey FE	✓	✓		
Country FE	✓		✓	
Country-Age		✓		✓
Lifespan			✓	✓
r2	0.119	0.049	0.120	0.049
Obs	685075	685075	685075	685075

Ordinary Least Squares, All Controls Included, Regressions clustered by country, controls also include dummies for maternal education

Table 4: Results: Access to Health Care Services

	(1) Vax b/se	(2) Vax b/se	(3) Trad b/se	(4) Trad b/se	(5) Card b/se	(6) Card b/se	(7) Sani b/se	(8) Sani b/se
GDP at Birth	0.13*	0.13	-0.13	-0.12	0.0024	-0.017	0.0058	0.0069
	(0.07)	(0.08)	(0.08)	(0.08)	(0.07)	(0.07)	(0.06)	(0.07)
Urban	0.066***	0.066***	-0.15***	-0.15***	0.075***	0.075***	0.20***	0.20***
	(0.009)	(0.009)	(0.02)	(0.02)	(0.01)	(0.01)	(0.04)	(0.04)
Mat. Age	0.0013***	0.0013***	0.00076	0.00076	0.00065	0.00066	0.0013***	0.0013***
	(0.0004)	(0.0004)	(0.0005)	(0.0005)	(0.0007)	(0.0007)	(0.0004)	(0.0004)
Female	-0.0014	-0.0015	0.0048***	0.0048***	-0.0017	-0.0018	0.0015**	0.0015**
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.0007)	(0.0007)
Sample Mean	.69		.29		.82		0.16	
Country FE	✓		✓		✓		✓	
Country-Age		✓		✓		✓		✓
Lifespan	✓	✓	✓	✓	✓	✓	✓	✓
r2	0.158	0.042	0.076	0.076	0.055	0.050	0.186	0.186
Obs	681610	681610	671787	671787	685075	685075	676084	676084

Ordinary Least Squares, All Controls Included, Regressions clustered by country, controls also include dummies for maternal education

Table 5: Results: Age Specific Morbidity

	(1) Cough b/se	(2) Cough b/se	(3) Fever b/se	(4) Fever b/se	(5) Diarrhea b/se	(6) Diarrhea b/se
Age 0	0.04	0.05	0.09*	0.1**	-0.02	-0.003
	(0.05)	(0.06)	(0.05)	(0.05)	(0.02)	(0.03)
Age 1	0.06	0.07	0.09*	0.1*	-0.02	-0.004
	(0.05)	(0.06)	(0.05)	(0.07)	(0.02)	(0.04)
Age 2	0.06	0.07	0.09*	0.09	-0.02	-0.005
	(0.05)	(0.06)	(0.05)	(0.06)	(0.02)	(0.02)
Age 3	0.06	0.04	0.10*	0.07	-0.01	-0.03
	(0.05)	(0.06)	(0.05)	(0.06)	(0.02)	(0.02)
Age 4	0.06	0.07	0.1**	0.08	-0.01	0.010
	(0.05)	(0.05)	(0.05)	(0.05)	(0.02)	(0.02)
Urban	0.008	0.008	-0.02***	-0.02***	-0.006**	-0.006**
	(0.005)	(0.005)	(0.006)	(0.006)	(0.003)	(0.003)
Mat. Age	-0.0007***	-0.0007***	0.0005***	0.0005***	-0.001***	-0.001***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Female	-0.007***	-0.007***	-0.009***	-0.009***	-0.01***	-0.01***
	(0.002)	(0.002)	(0.0010)	(0.0010)	(0.001)	(0.001)
Sample Mean	.28		.28		.15	
Country FE	✓		✓		✓	
Country-Age		✓		✓		✓
Lifespan	✓	✓	✓	✓	✓	✓
r2	0.026	0.020	0.024	0.011	0.032	0.006
Obs	673599	673599	658003	658003	680641	680641

Ordinary Least Squares, All Controls Included, Regressions clustered by country, controls also include dummies for maternal education

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A Representation of Identifying Variation

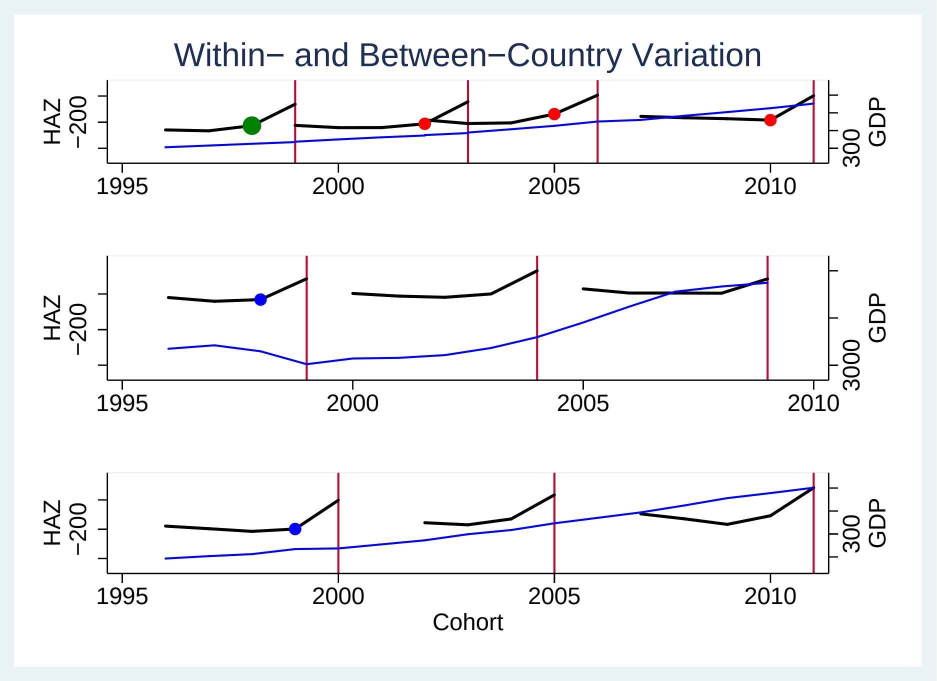

Figure A1: Identifying Variation

B Summary Statistics by Country

Table A1: Summary Statistics: Asia

Country Name	**Survey Years**	**BirthYears**	**N**	**HAZ**	**Birth Year GDP pc (USD 2005)**
1. Armenia	3	1996-2010	4,074	-73.08	1356.94
2. Bangladesh	5	1992-2011	22,391	-190.37	391.141
3. Cambodia	3	1995-2010	10,803	-181.53	420.29
4. Jordan	5	1986-2012	27,806	-67.39	2183.46
5. Pakistan	2	1986-2012	7,114	-202.13	611.84
6. Turkey	3	1989-2003	9,943	-81.47	5605.791

Table A2: Summary Statistics: South America

Country Name	**Survey Years**	**BirthYears**	**N**	**HAZ**	**Birth Year GDP pc (USD 2005)**
7. Bolivia	3	1993-2007	23,032	-135.51	971.06
8. Brazil	2	1982-1995	5234	-80.06	4035.81
9. Colombia	5	1984-2009	38,430	-91.91	3321.21
10. DominicanRepublic	3	1987-2013	10,109	-75.47	3081.81
11. Guatemala	2	1991-1998	12,420	-232.49	3081.80
12. Haiti	3	1997-2011	9,217	-111.84	472.59
13. Peru	4	1987-2000	34,168	-148.99	2183.584

Table A3: Summary Statistics: Africa

Country Name	**Survey Years**	**BirthYears**	**N**	**HAZ**	**Birth Year GDP pc (USD 2005)**
14. Benin	3	1997-2011	23,748	-167.17	535.46
15. BurkinaFaso	4	1988-2010	22,319	-149.18	358.81
16. Cameroon	3	1986-2010	10,548	-127.84	963.09
17. Congo	2	2001-2011	8,368	-109.47	1746.24
18. CoteDIvoire	2	1994-2011	4,689	-123.17	1013.27
19. Egypt	5	1988-2013	53,200	-96.21	1195.76
20. Ethiopia	3	1988-2002	22,035	-181.96	138.30
21. Ghana	3	1994-2008	8,099	-130.72	463.35
22. Guinea	3	1995-2012	8,645	-121.63	292.66
23. Kenya	3	1988-2008	14,647	-141.86	529.37
24. Liberia	2	1981-2013	7,495	-140.04	207.41
25. Madagascar	3	1988-2008	13,277	-196.03	289.29
26. Malawi	4	1988-2009	25,037	-194.54	215.22
27. Mali	3	1996-2012	24,450	-150.38	420.92
28. Morocco	3	1982-2003	14,203	-111.99	1458.99
29. Mozambique	2	1999-2011	17,372	-170.48	317.04
30. Namibia	4	1988-2012	10,675	-122.68	3317.52
31. Niger	3	1987-2011	12,579	-173.03	280.13
32. Nigeria	4	1986-2012	53,293	-148.08	855.14
33. Rwanda	4	1988-2010	18,045	-184.38	254.15
34. Senegal	3	1988-2010	10,271	-114.48	731.27
35. Tanzania	5	1987-2009	27,852	-181.88	329.15
36. Uganda	5	1984-2011	17,784	-167.55	251.265
37. Zambia	4	1987-2006	20,978	-189.17	647.78
38. Zimbabwe	4	1984-2010	13,302	-134.20	539.93

C Aggregate Regressions

This table provides the results from the aggregate regressions for 2 outcomes HAZ and stunted growth[15]. Column 3 and 6 are the preferred specifications and include both country-age and cohort-age fixed effects. Here we see that a 10% increase in GDP increases aggregate HAZ by 0.025 SD and decreases stunting by 0.005% (not statistically significant). The estimates on the aggregate HAZ outcome lies within the range of the individual age wise regressions in Table A4. This reiterates our argument that other studies that estimate changes at the aggregate level will tend to underestimate the effect of GDP on HAZ.

Table A4: Results: Aggregate Impacts of GDP on HAZ

	(1) HAZ b/se	(2) HAZ b/se	(3) HAZ b/se	(4) Stunted b/se	(5) Stunted b/se	(6) Stunted b/se
GDP at Birth	22.6	26.6*	25.4*	-0.04	-0.06	-0.05
	(11.7)	(10.9)	(11.1)	(0.03)	(0.03)	(0.03)
Urban	32.6***	32.6***	32.6***	-0.09***	-0.09***	-0.09***
	(2.3)	(2.3)	(2.3)	(0.008)	(0.008)	(0.008)
Mat. Age	0.8***	0.8***	0.8***	-0.002***	-0.002***	-0.002***
	(0.1)	(0.1)	(0.1)	(0.0003)	(0.0003)	(0.0003)
Female	14.3***	14.3***	14.3***	-0.04***	-0.04***	-0.04***
	(1.2)	(1.2)	(1.2)	(0.003)	(0.003)	(0.003)
Mean	-144			.36		
Age	X			X		
Survey	X			X		
Country	X	X		X	X	
Country_Age			X			X
Lifespan		X	X		X	X
r2	0.16	0.16	0.05	0.13	0.13	0.04
N	685075	685075	685075	685075	685075	685075

In Table A5 we see how the effects on stunting play out by age. Column 4 is our preferred specification that includes both country-age and lifespan fixed effects. In line with Figure 2 we see that, current GDP has no impact on children who are age 0 at the time of the survey. By age 1, a 10% increase in GDP decreases stunting by 0.006%. By age 3, GDP has decreased incidence by 0.008%. This effects then wears out by age 4.

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[15] Stunting is defined as a condition in which a child's HAZ score is 2 SD below the reference group's mean.

Table A5: Age Specific Outcomes on Stunting

	(1) Stunted b/se	(2) Stunted b/se	(3) Stunted b/se	(4) Stunted b/se
Age 0	0.005	0.06^{*}	-0.008	-0.008
	(0.03)	(0.03)	(0.03)	(0.02)
Age 1	-0.06^{*}	-0.06^{*}	-0.07^{**}	-0.06^{**}
	(0.03)	(0.03)	(0.03)	(0.03)
Age 2	-0.08^{**}	-0.10^{***}	-0.09^{***}	-0.09^{**}
	(0.03)	(0.03)	(0.03)	(0.04)
Age 3	-0.07^{**}	-0.10^{***}	-0.08^{***}	-0.08^{**}
	(0.03)	(0.03)	(0.03)	(0.04)
Age 4	-0.06^{*}	-0.06	-0.07^{***}	-0.05
	(0.03)	(0.04)	(0.03)	(0.04)
Urban	-0.09^{***}	-0.09^{***}	-0.09^{***}	-0.09^{***}
	(0.007)	(0.007)	(0.007)	(0.007)
Mat. Age	-0.002^{***}	-0.002^{***}	-0.002^{***}	-0.002^{***}
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Female	-0.04^{***}	-0.04^{***}	-0.04^{***}	-0.04^{***}
	(0.003)	(0.003)	(0.003)	(0.003)
Sample Mean	.36			
Survey FE	✓	✓		
Country FE	✓		✓	
Country-Age		✓		✓
Lifespan			✓	✓
r2	0.081	0.040	0.082	0.041
Obs	685075	685075	685075	685075

Ordinary Least Squares, All Controls Included