Nutrition, WASH and Child Physical Growth

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PRELIMINARY AND INCOMPLETE, DO NOT CITE

Abstract

In this paper we provide, to the best of our knowledge, the first causal evidence on the relative importance of and interaction between nutrition and water, sanitation and hygiene (WASH) practices in determining child health in the first 24 months of life. We estimate flexible production functions for child physical growth that allow for interactions between WASH and nutrition investments. We allow investments to be endogenous and account for the endogeneity in our estimation. We use rich data from the Cebu Longitudinal Health and Nutritional Survey of Filipino infants born between 1983 - 1984. Our study sample faced similar nutritional and WASH conditions as those faced by poor households living in low-income settings today. Hence our findings are relevant for the present debate on how foster child health and human capital development more generally, in developing countries given that around 25% of infants under 5 years of age are stunted. We find evidence of complimentarity between nutrition, particularly protein intake, and WASH among children aged 6-24 months.

JEL Codes: I12, I15, O15, O18, Q53

Keywords: child health; sanitation; nutrition; complementarities; health production function.

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1 Introduction

There is wide consensus that investment in human capital is an important way to escape poverty and to foster economic growth and development. However, an extensive literature documents that children born in poverty lag behind in both physical and non-physical areas of child development, with gaps emerging at birth and widening with child age (Grantham-McGregor et al., 1991, Case et al., 2002, Fernald et al., 2011 among others). Poor child physical growth and child health in the early years impacts longer-term health, and human capital accumulation more generally (Hoddinott et al., 2008, 2013, Maluccio et al., 2009, Victora et al., 2010, Almond and Currie, 2011).Moreover, these early health disadvantages can persist over generations (Behrman et al., 2009, Bhalotra and Rawlings, 2013), making them difficult to overcome without well designed interventions targeted to break these cycles or poverty traps (Ghatak, 2015).

It is thus of utmost policy importance to identify the factors constraining child growth and development in low-income countries. The medical literature highlights the importance of sufficient nutrition and a healthy environment that limits infections as key factors shaping child physical growth in the early years. Indeed, extensive efforts have been made to improve poor nutritional practices prevalent in these settings: for example, rates of exclusive breastfeeding – giving a child only breastmilk until age 6 months – increased from 34% to 48% in least developed countries between 1995 and 2011. However, an emerging literature suggests that nutritional investments on their own are insufficient in reducing the high levels of poor child physical growth, particularly stunting seen in low-income countries (Humphrey [2009], Mbuya and Humphrey, 2016). In particular, it is conjectured that nutritional investments ought to be complemented with improvements to the disease envrionment within which a child grows up. This is because a poor disease environment increases exposure to fecal matter, which may increase susceptibility to infections such as diarrhoea, and also lead to an inflammation in the gut called environmental or tropical enteropathy, which reduces the ability of the small intestines to effectively absorb nutrients (Lunn et al., 1991, Campbell et al., 2003, Lin et al., 2013, Prendergast et al., 2014, Gough et al., 2016, Mbuya and Humphrey, 2016 and George et al., 2016). As a result, improvements in water, sanitation and hygiene (WASH), which could improve disease environments, have received a lot of attention in policy circles as possible key complements. However, little rigorous causal evidence exists on the nature and magnitude of the relationship between WASH and nutrition in determining child physical growth and the extent to which this relationship varies with the type of nutritional inputs.

This paper aims to provide, to our knowledge, the first causal evidence on this important question. To do so, we estimate production functions for child physical growth in early childhood using rich data from the Cebu Longitudinal Health and Nutrition Survey (CLHNS) in the Philippines. A production function approach is particularly advantageous since it allows us to estimate both the size of the marginal productivities of inputs, as well as the direction and magnitude of interactions between these. The CLHNS follows a cohort of around 2,800 children born between 1983-1984 from the third trimester of pregnancy to age 27 years. It has bi-monthly measurements for each child for the first 24 months of life. Importantly, the dataset also has rich information on child-level nutrition practices and WASH practices at the household level. We consider child physical growth in the first two years of life, as measured by child height and weight, and model it to be a function of nutrition and WASH investments. Our choice of including WASH investments, rather than infections such as diarrhoea is motivated by the fact that a poor disease environment could affect child physical growth through environmental enteropathy, and not just through easily observable infections. Environmental enteropathy is not easy to measure, particularly in large samples of children in low-income settings, since it requires the collection of stool samples, and analysis of these for specific biomarkers which may be possible only within highly specialised laboratories. WASH investments are thus likely to capture effects of environmental enteropathy on child physical growth.

Our estimation uses a flexible functional form for the production function – the semi-translog production function – which does not require us to impose any restrictions on the interactions between the inputs. Moreover, we estimate the production function separately for two stages of life – 0-6 months and 6-24 months – since nutritional inputs and their interactions with WASH practices are likely to be different for these two stages. Specifically, breastmilk forms a key part of the diet of children aged 0-6 months, and less so for children aged 6-24 months, for whom semi-solid and solid food intake is more important. The medical literature has established that breast milk can insulate children from infectious diseases by transmitting maternal antibodies to breastfed children (see, for example Sadeharju et al. [2007] and Victora et al. [1987]). In this case WASH and nutrition (breast milk) could act as substitute inputs, rather than complement inputs, in the production of child health. This mechanism would also mean that breastfed children are more likely to be able to absorb nutrients beyond their breastfeeding period, even in the presence of poor WASH practices, due to increased antibodies. However, breastfeeding can also act as an external barrier to water- and food-borne pathogens, by just preventing these pathogens getting into the body in the first instance. Indeed, there is evidence that children that are breastfed but not exclusively are more likely to develop infections (Popkin et al. [1990]). Thus, breastfeeding and WASH could also be complements in this age group. By contrast, the discussion on environmental enteropathy suggests that WASH and nutrition are likely to be complements in the older age-group.

An important concern is that nutrition and WASH investments are endogenous: parents may choose the levels of these inputs in response to shocks that also affect child physical growth and are unobserved by the econometrician; or they may have unobserved preferences for child health that may affect both the levels of inputs chosen and child health. Our estimation strategy addresses this concern using an instrumental variables strategy. Our instruments consist of variables which, conditional on a rich set of individual, household and community controls, are unlikely to affect child physical growth through channels other than affecting either nutrition or WASH investments. Specifically, our instrument set consists of community-level prices of food and sanitation, community-level geological features, community-level wages, distances to shops selling infant food, and a powerful typhoon that hit the study area. We discuss in detail the issue of instrument validity in this context. The instrument set satisfies the Stock and Yogo [2005] conditions for instrument strength for the 6-24 month sample.

We find that nutrition and WASH investments do interact in the formation of child height, and that this interaction varies with the stage of development. For children aged 6-24 months, our findings indicate that WASH and nutrition inputs are complements, particularly for girls: the coefficient between WASH and nutrition intake is positive and statistically significant. Moreover, we also find that the marginal effect of WASH investments on log height is positive for girls, though it is not statistically significant across all specifications. We do not find evidence of any significant complementarities or substitutabilities between WASH and nutrition intake for weight for this sample, particularly once we correct for endogeneity of WASH and nutrition. For the 0-6 month sample, we find evidence of substitution between breastfeeding and WASH in the OLS estimation. However, our instruments for breastfeeding are weak in the preliminary IV estimation, limiting our ability to provide causal estimates for this age group.

This paper contributes to different strands of the economics and child health literatures. First, it contributes to the established literature on the importance of nutrition for child health, and child physical growth in particular. Adair and Guilkey [1997] look at age-specific determinants of stunting in Filipino children and highlights the importance of breastfeeding, preventive healthcare and maternal height to decrease the likelihood of stunting. Studies that use a production function approach to quantify the marginal contribution of different endogenous inputs are particularly relevant to our study. Some of these studies also use the CLHNS dataset. For instance, Puentes et al. [2016] estimate production functions for height and weight gain among children aged 6-24 months in Guatemala and Philippines focusing on protein and calories as (endogenous) nutritional inputs. They find that protein in particular plays an important role in height and weight gain. However, they do not consider the contributions of WASH indicators and infections, though they include these as controls. Cao [2015] also uses the CLHNS to estimate a production function of child height in the first two years of life, which depends on the following endogenous inputs: breastmilk, calories, and diarrhea. However, she uses a linear production function, which imposes an assumption of perfect substitutability between inputs, which our results show to be a strong assumption. A study by Team et al. [1992] is also closely related. They estimate production functions for child weight, diarrhoea and respiratory illness as a function of parental background, parental investments and community characteristics. Again WASH practices enter as control variables in the production function but are not the focus.

Second, it contributes to the more recent and growing literature that investigates the importance of WASH practices and disease environment for health outcomes, in particular child height, in low-income countries. Many of these studies focus on the negative impact of poor sanitation on child height. For example, Hammer and Spears [2016] provide evidence of the prevalence of poor sanitation and its causal negative impact on child height using data from India. Gertler et al. [2014] shows how substantial reductions in open defection at the village level significantly increases child height. Spears [2012] and Geruso and Spears [2015] investigate the link between sanitation and child mortality.

However, to the best of our knowledge, there is no robust evidence about the relative importance, and interaction of WASH and nutrition in determining child health. Our paper aims to fill in this gap by quantifying the relative importance of different nutritional inputs and WASH as well as their interactions for child physical growth. Our strategy is informed by the growing medical literature that emphasises the importance of the interaction between nutrition and WASH practices. As we discussed earlier, environmental enteropathy, caused by poor WASH practices that facilitate fecal-oral contamination, seems to be crucial in explaining low capacity in infants to absorb nutrients in low-income countries, leading to stunting. As mentioned above, Humphrey [2009] discusses this in detail. There are a range of related studies that have documented the relationship between poor WASH practices, gut infections or environmental enteropathy and impaired child growth suggesting that the returns to WASH investment may be higher than previously thought. These include George et al. [2016], Mbuya and Humphrey [2016], Gough et al. [2016], Prendergast et al. [2014], Lin et al. [2013], Campbell et al. [2003] and Lunn et al. [1991], among others. Our study hence also relates to the literature on the effects of other environmental factors and diseases on child and adult health, in both developed and developing countries. A number of studies look at the negative impact of air pollutants on child health in the US context, for example, Chay and Greenstone [2003], Currie and Neidell [2005] and Currie et al. [2009].

Finally, our paper also relates to the growing literature on the determinants of early child development that uses a production function approach to identify and quantify the contribution of different (endogenous) inputs to child physical growth. Rosenzweig and Schulz [1983] is an early contribution, which treats health inputs as choice variables that are endogenous, and estimates Cobb-Douglas and translog production functions. Related papers include Liu et al. [2009], who use the CLHNS data to estimate child health input demand functions and child health production functions for the first two years of a child's life, with a specific focus on parental compensatory behaviours. However, they consider linear production functions, which ignore complementarities between inputs; and also do not focus on WASH inputs.

The remainder of the paper is structured as follows. Section 2 lays out the theoretical framework of our analysis, section 3 discusses the CHLNS data itself, section 4 discusses our estimations strategy and section 5 we lays out our results.

2 Theoretical framework

To estimate the impact of nutrition, WASH and their interaction on child physical growth we take a production function approach. Our key measures of child physical growth are child height and child weight. The discussion below will focus on child height, though we will formulate similar production functions for child weight. In its most general terms, height in period t can be seen as some function of all previous inputs. In our specification we assume that this function can be written in a value added form, denoted as follows.

$$H_{it} = H_t\Bigg[N_{it-1}, S_{it-1}, H_{t-1}(\{N_{is}\}_{s=1}^{t-2}, \{S_{is}\}_{s=1}^{t-2}), \mu_i; X, \varepsilon_{it}\Bigg] \tag{1}$$

where t denotes the child's age in bi-monthly bins, N_{it-1} is nutrition at age $t-1$, S_{it-1} is WASH at age $t-1$ and $\{N_{is}\}_{s=1}^{t-2}$ and $\{S_{is}\}_{s=1}^{t-2}$ are the set of all nutritional and WASH inputs in all previous ages. Letμ_i be the child's initial health endowment, $\mathbf{X}$ be a vector of individual, household and community controls, and ε_{it} be some time-varying child-level shock. This formulation specifies that only past nutrition and WASH investments can affect today's height, which is reasonable since it takes time for nutritional intake and WASH investments to affect height. The benefit of a value added production function is that it dramatically reduces the number of lagged inputs, which we will treat as endogenous variables, in our estimation equation. However, for this approach to be valid lagged height must entirely capture of the effect of past inputs. As discussed in Todd and Wolpin [2003] this imposes a series of assumptions on the nature of this function; namely that the function does not vary with age and that lagged input coefficients and the health endowment geometrically decline (at the same rate) in importance as time passes. Appendix A specifies the assumptions that are needed to obtain unbiased parameters of the value-added form. Our empirical analysis makes use of bi-monthly data over the age range of 0 - 24 months, making the former assumption reasonable in our case.

To estimate this production function as flexibly as possible we take a semi-translog approach.[1] This approach avoids imposing any assumptions about the functional form of the early childhood height production function. This is often a problem when estimating a linear or CES production function, which both impose assumptions on the substitutability between inputs. Using an estimation which imposes some sort of functional form restriction on the production function seems unlikely to be the optimal approach given the acknowledged unknowns in the medical science literature. Our semi-translog approach thus provides some flexibility on this front. As shown in Boisvert [1982], the translog approximation of any function can be interpreted as the second-order taylor expansion of that function around the geometric mean of its arguments.[2]

[1] Other studies estimating translog production functions for child health or child development include Rosenzweig and Schulz [1983] and Agostinelli and Wiswall [2016].

[2] The Kmenta [1967] approximation of the CES production function takes the same form as the translog

This leaves us with a function of the form

$$H_t = \alpha_0 N_{t-1}^{\alpha_1} S_{t-1}^{\alpha_2} H_{t-1}^{\alpha_3} N_{t-1}^{\frac{1}{2}(\gamma_{NN}\ln N_{t-1}+\gamma_{NS}\ln S_{t-1}+\gamma_{NH}\ln H_{t-1})} S_{t-1}^{\frac{1}{2}(\gamma_{SN}\ln N_{t-1}+\gamma_{SS}\ln S_{t-1}+\gamma_{SH}\ln H_{t-1})} H_{t-1}^{\frac{1}{2}(\gamma_{HN}\ln N_{t-1}+\gamma_{HS}\ln S_{t-1}+\gamma_{HH}\ln H_{t-1})} e^{(\delta_t \mathbf{X}+\varepsilon_{it})} \quad (2)$$

where nutrition, WASH and height are denoted as before, and the vector $\mathbf{X}$ is an additional set of controls.[3] Including these controls within a semi-translog framework means that our estimates should be interpreted as average effect across these characteristics.

Running a semi-translog equation for a value added function has some additional implications. While a translog estimation of the whole production function would include every period's inputs and their interaction, we only implicitly control for interactions between sanitation and nutrition outside of contemporaneous periods. This is achieved by interacting lagged height with lagged nutrition, which captures the effect of all the interactions that nutrition at $t-1$ had with all other inputs and endowments in all prior periods as manifest in lagged height. The same logic is applied to WASH; the interaction between WASH yesterday and nutrition in all prior periods to that is captured in the interaction between WASH at $t-1$ and log height at $t-1$.

Whilst this value added approach deals with the confounding effects of individual health endowments, it is still susceptible to other forms of endogeneity. In particular, parental investments might be chosen in response to unobserved shocks. We will address this issue using instrumental variables. This is discussed in greater detail in Section 4.1.

In our analysis we divide our sample into two separate age ranges – 0 to 6 months and 6 - 24 months – and estimate the production function separately for each of these. The primary reason we do this is due to the changing nature of nutritional intake over the course of the first two years of a childs life. As is shown in table 3, which is discussed in greater detail later, the proportion of children who are no longer predominantly breast fed (i.e. who are no longer given only breastmilk and medicinal/ceremonial liquids, according to the WHO definition) increases dramatically between the ages of 2 and 6 months. By 8 months (where our second sample starts) almost all children are no longer being breastfed as their primary source of nutrition. This means that we ought to allow for different nutritional inputs for the two stages. In particular, our key nutritional input for the 0 - 6 month sample will be breastfeeding, while for the 6-24 month sample, we consider calorie and protein intake as the key nutritional inputs of interest.[4]

production function. Moreover, the translog production function can be considered to be a generalisation of the well-known Cobb-Douglas production function.

[3] We additionally exclude square terms, $\gamma_{NN} = \gamma_{SS} = \gamma_{HH} = 0$ and let $\gamma_{ij} = \gamma_{ji}\ \forall i, j \in \{N, S, H\}$.

[4] In the 6-24 month sample, we continue to control for breastfeeding.

3 Context, Data and Measures

We use data from the Cebu Longitudinal Health and Nutrition Survey (CLHNS), an ongoing study of a cohort of Filipino children born between May 1, 1983 and April 30, 1984. Originally conceptualised to study infant feeding patterns and their role in shaping child health, this data contains exceptionally detailed information on infant feeding, child health indicators, and measures of sanitation, water and hygiene practices, collected regularly over the first two years of the child's life; making it particularly suitable for testing our hypothesis. In addition, the surveys also collected detailed background health and socio-economic information on the mother, index child and the household, as well as a range of community variables, including monthly surveys between 1983 and 1986 to collect prices on key foods. This information which will be particularly useful in dealing with some of the endogeneity issues.

All mothers of children born between May 1, 1983 and April 30, 1984 living in 33 neighbourhoods (*barangays*), 17 urban and 16 rural, around metropolitan Cebu area were surveyed at multiple points in time during pregnancy and during the first two years of the child's life. The first interview took place at the start of the third trimester of pregnancy (March 1983 - April 1984), and was followed by surveys a few days after they gave birth (on average five days) and every two months thereafter until the child turned 24 months. Further follow-up surveys were conducted at older ages. In this paper, however, we will focus on the data relating to the first two years of the child's life.

Participation rates in the survey were high. At baseline, 3277 women were successfully interviewed. Of these, 65% were surveyed in every single follow-up survey in the 2-year study period, and a further 11% completed a number, though not all, of the follow-up surveys. 446 mothers (and children) migrated out of the study area, 155 children died and 66 mothers withdrew from the study.[5] Our analysis includes women with single live births only.

Table 1 provides an overview of the sample. A significant majority – over three quarters – live in urban neighbourhoods. On average, before the birth of the child, household heads are just over 35 years of age, 94% of them were employed, and they have just over 7 years of education. Households live in neighbourhoods with significantly less developed infrastructure. On average, 67% of our sample has a safe toilet (77% urban, 35% rural), 50% have access to electric lighting and less than half of all households have access to water from a pipe or pump. Less than 20% of households live in houses constructed from strong materials (e.g. cement). Asset ownership is low, with fewer than 7% owning a refrigerator, and around 70% owning benches or chairs. 6.3% of household heads are female. Mothers are around 26 years of age, and have just over 7.5 years of education

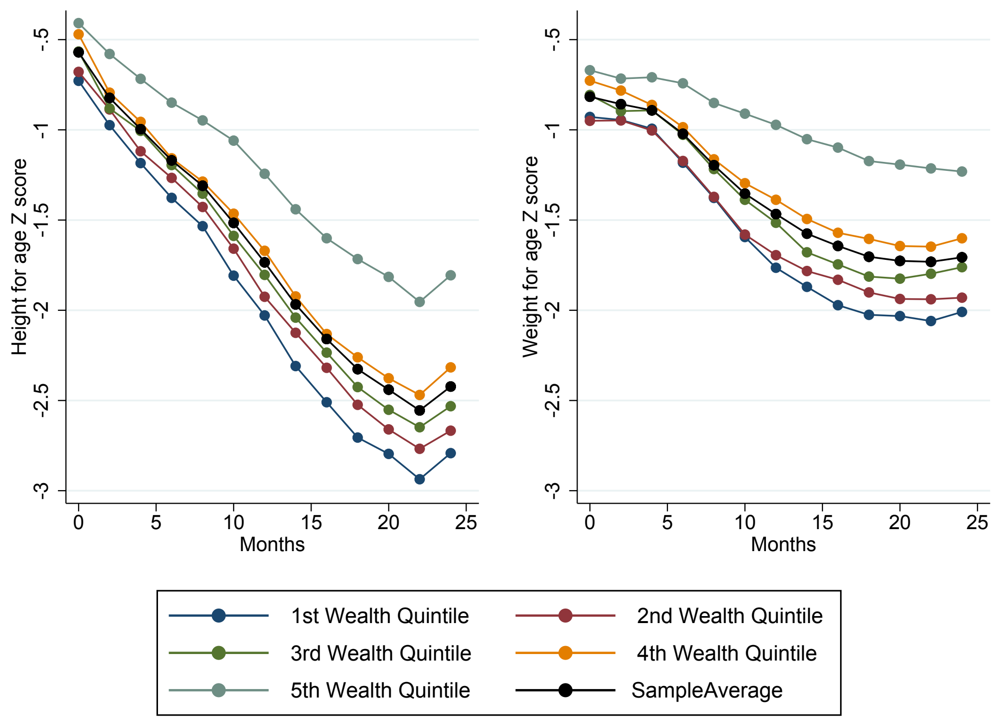
Though this data was collected over 30 years ago, conditions faced by the study sample are similar in many dimensions (e.g. education level, household composition and size, water

[5] Characteristics of the attriting mothers and children are detailed in Appendix B.3.

Table 1: Sample Characteristics

Variable	Mean	Sd	N
Household and Barangay Characteristics			
Percentage in urban barangay	0.765	0.424	2872
Distance to nearest public hospital, km	5.819	4.880	2872
Age of household head	35.38	12.28	2869
Percentage of household heads in employment	0.944	0.231	2870
Household head's years of education	7.395	4.096	2863
Proportion of households with safe toilets	0.670	0.470	2871
Proportion of households with pumped/piped water	0.475	0.499	2872
Home made of concrete, (1=Yes)	0.183	0.387	2872
Household head is female	0.063	0.243	2870
Number of household members	5.586	2.790	2872
Home ownership	0.656	0.475	2872
Households own a refrigerator, (1=Yes)	0.067	0.250	2872
Households ownbenches/chairs, (1=Yes)	0.692	0.462	2872
Percentage of homes with electric lighting	0.505	0.500	2872
Mothers Characteristics			
Years of education	7.594	3.716	2871
Household head/spouse, (1=Yes)	0.774	0.419	2872
Age	26.73	5.92	2871
Number of children under the age of 5	1.208	0.991	2872
Pregnancy at least part covered by insurance, (1=Yes)	0.103	0.303	2798
Percentage working during pregnancy	0.366	0.482	2872
Child Birth Characteristics			
Child Gender, (1=Female)	0.474	0.499	2872
Child Birth Weight, g	3041.3	438.6	2853
Child Birth Height, cm	49.265	2.123	2866

Figure 1: The evolution of HAZ and WAZ scores with child age in months



Notes to Table: This Figure plots the evolution of the height-for-age (left) and weight-for-age (right) z-scores with child age, by wealth quintile. The wealth quintile is calculated using the procedure described in Section B.4.

and sanitation access) to those faced by poor households living in low-income settings today. Thus, it is informative for understanding the process of child health formation in developing countries today.

3.1 Variables of interest

3.1.1 Child health

The CLHNS includes a range of measures of child health, including anthropometric measurements and maternal reports of illnesses including diarrhoea. Anthropometric measurements are collected at birth, and during the bi-monthly follow-ups, while the maternal illness reports are available in the bi-monthly follow-ups only. We calculate height-for-age and weight-for-age z-scores, which compare the child's height (and weight) relative to the median height (weight) for children of the same gender and age (in months) in the WHO reference population. Figure 1 displays the evolution of these scores with the child's age by wealth quintile.[6]

[6]The construction of the wealth index and wealth quintiles is detailed in Section B.4 in the Appendix.

Figure 1 indicates that the average child in our sample is shorter than the WHO reference population at birth, and experiences a growth trajectory that diverges away from the healthy growth trajectory. Moreover, it also indicates substantial differences across wealth quintiles. At birth, the gap between the top and bottom quintiles is around 0.3 standard deviations. This increases with age to around 1 standard deviation by 20 months of age. Remarkably, we observe a significant gap between children in the top quintile and the 4th wealth quintile as well.

Moreover, by age 16 months, the average child in the bottom 4 quintiles is stunted, i.e. has a HAZ score that is 2 standard deviations less than the WHO reference population, which corresponds with being over 6cm shorter than children from the healthy reference population. Stunting rates in this sample are high. At birth, 9.3% of children are stunted, and this increases to 62.4% by age 2 years.

Child weight follows a similar, if less dramatic, pattern. The difference between the top and bottom quintiles at birth is only 0.3 standard deviations, but this gap grows to around 0.7 std deviations by the time the children reach 24 months. The difference between the top and 4th quintile is again surprisingly large, with a 0.4 standard deviation gap opening up by the end of the survey. Relative to the WHO reference population, at birth around 10% of our sample is underweight, increasing to 37% by the age of 2 years.

The poor child growth outcomes are likely to be linked to infections. Table 2 displays illness rates among our sample at different ages. Respiratory illnesses are particularly high among this sample, with over three-fifths of children reported to have suffered a cough at ages between 4 months and 24 months, and a fifth of children reported to have experienced a fever in the 7 days prior to the survey. Diarrhoea rates are also high. At age 4 months, around 12% of children experience diarrhoea. This rate increases sharply to over 20% from 6 months of age, when semi-solid and solid foods, and other liquids are introduced in the child's diets. Diarrhoea rates persist at this higher level until around age 24 months, when they drop to 18%.

Table 2: Illness incidence at different ages

	Child Age, months					
Proportion of children suffering from illness in the past 7 days	4	6	8	12	18	24
Diarhhea	0.12	0.20	0.24	0.23	0.22	0.18
	(0.33)	(0.40)	(0.43)	(0.42)	(0.41)	(0.38)
Cough	0.61	0.66	0.64	0.61	0.61	0.58
	(0.49)	(0.47)	(0.48)	(0.49)	(0.49)	(0.49)
Fever	0.19	0.23	0.24	0.24	0.23	0.22
	(0.39)	(0.42)	(0.43)	(0.42)	(0.42)	(0.41)

3.1.2 Nutrition

The CLHNS data contains exceptionally detailed information on food intake over the first two years of the infant's life. Data was collected on the commencement of breastfeeding, breastfeeding, and the intake of all liquids, solids and semi-solids in the 24 hours prior to the bi-monthly survey by trained survey enumerators. Questions were asked about all the meals consumed by the child, and the quantities consumed. Data was also collected on the frequency of breast-feeding, and the discontinuation of breastfeeding.[7] Particular attention was paid to measuring quantities consumed accurately: the survey enumerators were equipped with measuring aids, which allowed for accurate measurement (in common units) of quantities consumed. Quantities of nutrients were then calculated using food composition tables published by the Filipino Food and Nutrition Research Institute, which were supplemented with nutrient composition information obtained directly from manufacturers for foods such as infant formula (Bisgrove et al. [1989, 1991], Perlas et al. [2004] provide more details).

We use the information on breastfeeding to compute indicators for the proportion of time a child was exclusively breastfed (so given breastmilk only), the proportion of time he/she was predominantly breastfed (given breastmilk and ceremonial liquids and medicines only), when complementary foods are introduced, and breastfeeding duration. Table 3 provides descriptive statistics of these feeding patterns with age.

A number of interesting patterns emerge from table 3. First, a high proportion of mothers breastfeed their children (80% at age 4 months), but this rate drops steadily as the child grows so that by age 24 months, almost no child is still being breastfed. However, despite the high breastfeeding rates, rates of exclusive breastfeeding (as defined by the World Health Organisation) are low. At age 2 months, only 31% of infants are breastfed exclusively. A key reason for such a low rate of exclusive breastfeeding is the provision of sugar water to babies for ceremonial purposes in the first two days of life. Excluding such intake, as well as that of medicines (embodied in the definition of predominant breastfeeding) indicates that around 68% of children are given only breastmilk until age 4 months, after which solid foods and other liquids are introduced.

Semi-solid and solid foods are introduced, for the most part, from the age of around 4 months, and increase in terms of quantity and nutrient intake (excluding breastfeeding) with age. This is apparent from the increased intake of protein, fats and carbohydrates with child age. For instance, sampled children take, on average 6.78 g of protein and 38.7 g of carbohydrates per day at age 6 months, 12.3 g of protein and 73.1 g of carbohydrates per day at age 12 months, and 21.6 g of protein and 129.1 g of carbohydrates per day at age 24 months. These intakes are in line with, or even exceed, WHO recommendations for daily macro-nutrient intake.

Micronutrient intakes also increase, for the most part, with child age. However, they do not increase in line with medical recommendations. For instance, the average retinol intake

[7] Data on the quantities of breastmilk was not collected, though this might be difficult to measure accurately.

is around 147.3mg/day in the sample at age 24 months, which is significantly below the 200mg/day recommended by the WHO and FAO (FAO and WHO [2005]).

Table 3: Nutritional Inputs by Age

	Child Age, months											
	2	4	6	8	10	12	14	16	18	20	22	24
Proportion of time exclusively breastfed since last interview	0.31	0.18	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(0.44)	(0.36)	(0.19)	(0.057)	(0.020)	(0.0027)	(0)	(0)	(0)	(0)	(0)	(0)
Proportion of time predominantly breastfed since last interview	0.88	0.68	0.24	0.026	0.0024	0.00031	0	0	0	0	0	0
	(0.29)	(0.39)	(0.34)	(0.13)	(0.041)	(0.013)	(0)	(0)	(0)	(0)	(0)	(0)
Proportion of children breast feeding in some way	0.86	0.80	0.74	0.69	0.64	0.56	0.45	0.34	0.23	0.14	0.057	0.00037
	(0.34)	(0.40)	(0.44)	(0.46)	(0.48)	(0.50)	(0.50)	(0.47)	(0.42)	(0.34)	(0.23)	(0.021)
Grams/day of protein consumed	2.77	4.45	6.78	8.76	10.2	12.3	14.8	16.0	17.6	19.2	20.2	21.6
	(5.26)	(7.45)	(9.05)	(11.0)	(11.4)	(12.1)	(13.6)	(13.9)	(14.3)	(14.6)	(14.5)	(15.6)
Grams/day of fat consumed	4.33	5.56	6.47	6.93	7.71	8.79	9.04	9.44	9.92	11.0	11.2	12.4
	(8.42)	(10.2)	(11.3)	(11.7)	(12.4)	(13.1)	(12.8)	(13.1)	(13.5)	(15.0)	(15.6)	(18.3
Grams/day of carbohydrates consumed	13.1	21.7	38.7	53.8	64.4	73.1	91.3	100.6	110.7	120.2	126.0	129.1
	(24.0)	(34.0)	(40.9)	(47.9)	(50.3)	(53.8)	(57.5)	(58.9)	(63.0)	(64.0)	(64.2)	(60.8
Milligrams/day of thiamin consumed	0.11	0.15	0.20	0.21	0.22	0.23	0.24	0.25	0.25	0.26	0.26	0.26
	(0.23)	(0.31)	(0.34)	(0.38)	(0.36)	(0.33)	(0.33)	(0.32)	(0.30)	(0.31)	(0.28)	(0.26)
Milligrams/day of iron consumed	1.38	1.81	2.42	2.92	3.09	3.33	3.80	4.35	4.75	5.28	5.51	5.87
	(3.05)	(3.73)	(4.20)	(4.39)	(4.00)	(3.88)	(4.03)	(4.41)	(4.72)	(4.74)	(4.75)	(4.98)
Milligrams/day of retinol consumed	20.2	33.7	54.2	89.8	103.7	177.4	146.2	135.7	144.7	146.2	139.2	147.3
	(85.0)	(114.6)	(173.6)	(1026.6)	(1039.5)	(801.1)	(943.1)	(474.3)	(694.7)	(598.4)	(485.1)	(420.4)

Notes to Table: Nutrient calculations exclude nutrients in breastmilk.

3.1.3 Water, Sanitation and Hygiene

The data contain a number of measures of water, sanitation and hygiene practices related to child and his/her home environment. These include indicators for the type of toilet facility owned by the household (collected at baseline), how mothers dispose of their child's feces (collected when the child was around 18 months old), the household's main source of drinking water, and whether drinking water given to the child was treated or not (collected in the longitudinal survey rounds), and soap expenditures (collected at baseline).[8]

For the sanitation variables, we construct indicators for whether or not a household owns a safe toilet – defined as either a flush, water sealed or antipolo toilet – and whether a child's feces are safely disposed of – defined as disposal, either of wash water or directly, into a toilet.[9] For water, we construct indicators for whether a child was given no water, or if he/she was given water and whether it was treated or not. The former is relatively common before age 4 months. We also construct indicators for whether a household's main water source is through a water pump or a pipe, which are safer sources than open wells or springs, rivers and lakes. Finally, we take community level averages of each of these variables, excluding the household itself.

Table 4 provides some descriptive statistics of these variables for our sample. We see that around 67% of households own a safe toilet, but only 16% use that toilet to safely dispose of child excreta. Moreover, households spend 203 pesos on average on soap, and 38% percent of 0-6 month olds were given untreated water compared to 98% of 6-24 month olds.

Table 4: Water, Sanitation and Hygiene Variables

	mean	sd	N
Safe toilet in household (dummy)	0.67	0.47	3006
Child's feces is disposed of safely (i.e. toilet)	0.17	0.37	2502
Weekly household soap expenditure (Pesos)	203.81	164.38	3001
Was untreated water fed to child			
0-6 months	0.38	0.49	5154
6-24 months	0.98	0.13	13055

For our analysis, we combine all parental investments in WASH into a single variable. In doing so, we assume that all variables that directly affect the disease environment faced by the child

[8]The surveys also collect information on whether children are given leftovers, and if so, how food given to the child is stored, and interviewer observations of the cleanliness of the cooking area, and of the general area around the household. Unfortunately, the factor loadings associated with these variables were very low in the factor analysis described below, indicating that they did not provide much more information or variation beyond that captured by other variables included in the factor analysis.

[9]A significant proportion of households (27%) report disposing feces in the garbage. This need not correspond to safe disposal of feces, according to the UNICEF-WHO joint monitoring program.

are to some extent driven by a common factor – parental investment in WASH. We do this for two reasons: first, including all the different inputs will complicate the interpretation of the interaction effects of interest; and second, to make it easier to solve the endogeneity issue. Including all the different WASH variables would require a sufficiently strong instrument for each variable, which can be challenging to find. By using this one variable instead of the full collection of hygiene- and sanitation-related variables, we can use only one instrument and include WASH as a single term in a production function, allowing us to more easily interpret its relationship with nutrition.

We construct the WASH score using polychoric factor analysis both for our primary analysis sample of 6-24 months and for children aged 0-6 months.[10] We include the following variables: (i) an indicator for whether the household has a safe toilet, (ii) household soap expenditures (in logs), (iii) an indicator for whether the child's excreta is safely disposed of, and (iv) whether the child is given no, or treated water. We drop variables with factor loadings < 0.3, which offer little additional explanatory power. As a result, the last variable is dropped from the construction of the WASH score for the 0-6 month group. A second WASH score includes, in addition to these child- and household-level variables, a community-level average of these variables. We retain the first factor as the WASH score. In all cases, the eigenvalue associated with the first factor was always greater than 1.

Table 5 provides the factor loadings for the 4 different WASH scores constructed. Columns 1 and 2 displays those for the 0-6 months sample, while columns 3 and 4 displays those from the 6 - 24 month sample. In addition, columns 1 and 3 display the factor loadings for scores constructed from child- and household-level variables only, while those in columns 2 and 4 include barangay-level averages of these variables as well. Table 5 indicates that safe toilet ownership has the highest factor loading among the household-level variables across all constructed scores. The barangay-level averages also have relatively high loadings, while those on soap expenditures and the provision of no or treated water have lower loadings than the sanitation-related variables.

[10] Polychoric factor analysis allows us to combine binary, categorical and continuous variables.

Table 5: Factor loadings on WASH score

	Factor Loadings			
	0-6 months		6-24 months	
	[1]	[2]	[3]	[4]
Household Level Variables				
Safe toilet ownership	0.716	0.791	0.875	0.793
Safe disposal of child excreta	0.623	0.568	0.632	0.545
Log household soap expenditures	0.405	0.328	0.412	0.376
Child was given no or treated water			0.455	0.371
Barangay Averages				
Safe toilet ownership		0.911		0.919
Safe disposal of child excreta		0.878		0.851
Log household soap expenditures				0.784
Child given no or treated water				0.755
N	7947	7947	21756	21756

We assess how the resulting WASH scores correlate with various child-, household- and community-level variables. Tables 6 and 7 summarize these findings for the 0-6 month and 6-24 month samples respectively. For the 0-6 month sample, there is no correlation between either WASH score and the child's age, while an increasing and concave relationship is detected for the 6-24 month sample. We also detect no systematic correlation with the child's gender, as indicated by the small and usually statistically insignificant coefficient on the female dummy. We detect an important positive wealth gradient in the all the WASH scores, with children in wealthier households having a significantly larger WASH score. Interestingly, WASH scores are also larger in households with female heads, and where the household head has more education, particularly high school or greater. Wealthier households should be better able to afford to make (costly) water, sanitation and hygiene investments, while those with more educated heads might also be better informed about the benefits of these investments. Households in larger, urban barangays also have larger WASH scores. This is not surprising since safe water and sanitation facilities are much more widely available in urban barangays than in rural ones.

Table 6: Correlations between WASH score and Observed Variables, 0-6 months

	(1)	(2)	(3)	(4)	(5)	(6)
	WASH score, HH variables			WASH score, HH + Barangay Means		
Child age (months)	0.0000	-0.0016	-0.0019	-0.0015	-0.0020	-0.0026
	[0.0038]	[0.0033]	[0.0030]	[0.0034]	[0.0032]	[0.0020]
Child age sq (months)	-0.0001	0.0001	0.0002	0.0000	0.0001	0.0003
	[0.0005]	[0.0004]	[0.0004]	[0.0004]	[0.0004]	[0.0003]
Female	-0.0070	0.0002	0.0072	-0.0264**	-0.0216**	-0.0055
	[0.0078]	[0.0084]	[0.0076]	[0.0105]	[0.0104]	[0.0048]
2nd wealth quintile		0.0445**	0.0497***		0.0133	0.0209***
		[0.0163]	[0.0144]		[0.0204]	[0.0067]
3rd wealth quintile		0.1127***	0.0960***		0.0639**	0.0245***
		[0.0171]	[0.0135]		[0.0241]	[0.0061]
4th wealth quintile		0.1936***	0.1665***		0.0934***	0.0314***
		[0.0166]	[0.0138]		[0.0290]	[0.0075]
5th wealth quintile		0.2584***	0.2232***		0.1090***	0.0305***
		[0.0219]	[0.0192]		[0.0306]	[0.0093]
Head's age		0.0006	0.0004		0.0003	0.0001
		[0.0027]	[0.0022]		[0.0024]	[0.0012]
Head's age-sq		0.0000	0.0000		0.0000	0.0000
		[0.0000]	[0.0000]		[0.0000]	[0.0000]
Head is female		0.0416*	0.0213		0.0612***	0.0182*
		[0.0207]	[0.0180]		[0.0193]	[0.0105]
Head has no schooling		-0.2979***	-0.1892***		-0.3291***	-0.1001***
		[0.0225]	[0.0269]		[0.0529]	[0.0256]
Head has some elementary schooling		-0.1855***	-0.1150***		-0.2172***	-0.0684***
		[0.0266]	[0.0229]		[0.0373]	[0.0208]
Head has elementary schooling		-0.1105***	-0.0756***		-0.1159***	-0.0414**
		[0.0245]	[0.0210]		[0.0275]	[0.0179]
Head has some high school		-0.0330**	-0.0218*		-0.0399*	-0.0173*
		[0.0157]	[0.0118]		[0.0218]	[0.0102]
Head has completed high school		-0.0038	-0.0044		0.0048	0.0027
		[0.0126]	[0.0133]		[0.0113]	[0.0095]
Barangay popn (logs)			0.0753***			0.1501***
			[0.0204]			[0.0420]
Urban			0.1233**			0.2651**
			[0.0567]			[0.1090]
Observations	8,405	8,381	8,381	8,405	8,381	8,381
R-squared	0.0002	0.3104	0.4520	0.0021	0.2030	0.7730

Robust standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1

4 Estimation Strategy

In this section, we formulate our estimation strategy, and discuss how we identify the key parameters of interest – the marginal productivities of nutritional and WASH investments, and the complementarity/substitution parameter between the two inputs.

Table 7: Correlation between WASH scores and observed variables

	(1)	(2)	(3)	(4)	(5)	(6)
	WASH score, HH variables			WASH score, HH + Barangay Means		
Child age (months)	0.0025**	0.0018**	0.0015*	0.0020*	0.0014	0.0009
	[0.0010]	[0.0008]	[0.0007]	[0.0010]	[0.0009]	[0.0008]
Child age sq (months)	-0.0001***	-0.0001***	-0.0001***	-0.0001**	-0.0001**	-0.0001**
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Female	-0.0046	0.0031	0.0114	-0.0156*	-0.0115	-0.0013
	[0.0107]	[0.0106]	[0.0101]	[0.0084]	[0.0079]	[0.0054]
2nd wealth quintile		0.0692**	0.0780***		0.0354*	0.0412***
		[0.0271]	[0.0230]		[0.0207]	[0.0081]
3rd wealth quintile		0.1603***	0.1340***		0.1048***	0.0652***
		[0.0249]	[0.0202]		[0.0229]	[0.0073]
4th wealth quintile		0.2938***	0.2517***		0.1686***	0.1072***
		[0.0262]	[0.0206]		[0.0275]	[0.0084]
5th wealth quintile		0.3985***	0.3411***		0.2211***	0.1410***
		[0.0350]	[0.0301]		[0.0306]	[0.0118]
Head's age		-0.0002	-0.0008		-0.0002	-0.0006
		[0.0039]	[0.0030]		[0.0028]	[0.0013]
Head's age-sq		0.0000	0.0000		0.0000	0.0000
		[0.0000]	[0.0000]		[0.0000]	[0.0000]
Head is female		0.0588**	0.0296		0.0609***	0.0234*
		[0.0277]	[0.0243]		[0.0201]	[0.0122]
Head has no schooling		-0.3988***	-0.2501***		-0.3297***	-0.1442***
		[0.0326]	[0.0358]		[0.0436]	[0.0232]
Head has some elementary schooling		-0.2653***	-0.1626***		-0.2200***	-0.0937***
		[0.0404]	[0.0342]		[0.0326]	[0.0203]
Head has elementary schooling		-0.1536***	-0.1070***		-0.1163***	-0.0602***
		[0.0362]	[0.0304]		[0.0247]	[0.0174]
Head has some high school		-0.0506**	-0.0347*		-0.0383**	-0.0200*
		[0.0245]	[0.0188]		[0.0186]	[0.0098]
Head has completed high school		-0.0116	-0.0141		0.0017	-0.0026
		[0.0182]	[0.0196]		[0.0100]	[0.0088]
Barangay popn (logs)			0.1062***			0.1138***
			[0.0268]			[0.0343]
Urban			0.1810**			0.2605***
			[0.0715]			[0.0835]
Observations	22,104	22,056	22,056	22,104	22,056	22,056
R-squared	0.0001	0.3350	0.4765	0.0012	0.3359	0.7504

Robust standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1

To obtain our estimation equation, we take logs of Equation (2), which yields the following linear-in-logs equation:

$$\ln H_{it} = \alpha_0 + \alpha_1 \ln N_{it-1} + \alpha_2 \ln S_{it-1} + \alpha_3 \ln H_{it-1} + \gamma_{SN} \ln S_{it-1} \ln N_{it-1} + \gamma_{SH} \ln S_{it-1} \ln H_{it-1} + \gamma_{NH} \ln H_{it-1} \ln N_{it-1} + \delta_t \mathbf{X} + \varepsilon_{it} \quad (3)$$

Where $S_{it-1}, N_{it-1}$and H_{it-1} are as defined in Section 2, and the vector $\mathbf{X}$ is a set of controls including child gender, household wealth quintile, birthweight, child's age (quadratically), child illnesses, the education of the mother and the household head, the age distribution of the household, regional and interview month fixed effects, as well as logged barangay population and an indicator for whether the household lives in an urban barangay. This specification can be easily estimated using OLS, which is a further advantage of the semi-translog production function. We cluster standard errors at the barangay level. We obtain a similar estimation equation for child weight.

From this specification, we can obtain the marginal effects of nutrition and WASH investments on child height as follows:

$$\frac{\partial \ln H_{it}}{\partial \ln N_{it-1}} = \alpha_1 + \gamma_{SN} \ln S_{it-1} + \gamma_{NH} \ln H_{it-1} \quad (4)$$

$$\frac{\partial \ln H_{it}}{\partial \ln S_{it-1}} = \alpha_2 + \gamma_{SN} \ln N_{it-1} + \gamma_{SH} \ln H_{it-1} \quad (5)$$

where α_1 captures the direct effect of nutritional investments, γ_{SN} captures the complementarity/substitution parameter between nutrition and WASH, and γ_{NH} the interaction effect between nutrition and log height at age $t-1$. α_2 captures the direct effect of WASH, and γ_{SH} the interaction effect between log height at age $t-1$ and WASH investments. A positive value of γ_{SN} indicates that WASH and nutrition are complements, while a negative value indicates that they are substitutes.

We estimate the production function pooling data for all children aged 6-24 months, and 0-6 months respectively. Thereafter, since boys and girls face different growth patterns, we split the sample by gender, and estimate the production functions separately for males and females.

4.1 Endogeneity

Although our estimation approach deals with the confounding influence of individual health endowments, it leaves several other forms of endogeneity. In particular, unobserved parental preferences, or parental reactions to unobserved past shocks would create correlations between our variables of interest – nutrition, WASH and the interaction term – and the error term.

Our estimates for the effect of nutrition on child height for example would be biased if parents changed their investment behaviour in response to unobserved child health shocks in previous periods. To address this we take an instrumental variable approach, dividing our instruments into two sets, one for children aged 0-6 months, and the second for children aged 6-24 months.

Nutritional Intake

6-24 months For nutritional intake for children between 6 and 24 months we use the natural log of food prices at the time of the interview and those from the interview immediately prior. Using food prices as an instrument is a common approach when estimating health production functions (Todd and Wolpin [2003], Attanasio et al. [2015]Liu et al. [2009]). Given the small proportion of the community which was sampled for the CHLNS dataset, as well as considering that we control for regional fixed effects and have extensive barangay level controls, it is likely that the remaining price variation is (exogenously) driven by supply side factors. One source of variation in prices is a large inflationary spike partway during the sample period, which was caused by political turmoil and the consequent large devaluations of the peso. The spike affected prices of tradeable goods such as evaporated milk more than those of nontraded goods such as tomatoes. Moreover, it affected children in our sample differently depending on their age: children born in May 1983 were older than those born in April 1984 when the spike hit, and their families experienced higher prices of foods for a shorter fraction of the first 2 years of the child's life, thereby suggesting that at least part of the variation in prices we rely on is from sources that could not be influenced by the household itself. The set of prices we use includes the price of rice, corn, cooking oil, dried fish, various milks, eggs, tomatoes and kerosene (which is used for cooking). These prices vary by both barangay and time, and are deflated using the Filipino consumer price index as provided by the World Bank.

In addition, we also use log average male wages for the two largest employers in each barangay, collected in the baseline community survey, as another instrument. This captures labour market conditions in each barangay, and affects household investments in nutrition, and potentially also WASH, through the budget constraint. For it to be a valid instrument, it ought to capture factors associated with labour demand, which the household itself may be unable to influence. This is likely to hold in our context.

0-6 months In our younger sample we use as instruments a set of variables that are likely to influence mothers' breastfeeding decisions. In particular, we use community-level milk prices (evaporated milk, condensed milk and formula milk) and their lags, the community-level median walking time in minutes to the nearest infant formula store, an indicator for whether the mother was working during the final trimester of pregnancy (as captured in the baseline survey), and an indicator for whether the mother had emotional or health problems when she started to breastfeed. set of prices as instruments that better reflect a mothers decision on breastfeeding. Milk prices, and the distance to the nearest infant formula store to capture available substitutes to breastmilk: mothers in communities with high milk prices would be more likely to continue breastfeeding, and similarly those with distant stores selling infant formula would have fewer alternatives and hence be more likely to breastfeed their child. Those mothers working late into their pregnancy are more attached to the labour market than their non-working peers and thus are more likely to return after the child has been born, inhibiting their ability to breastfeed. Additionally, there is evidence that if a mother struggles to start breastfeeding soon after birth she is much less likely to do so in future. Along this vein we create a dummy for if the mother had emotional or health problems when she first started to breastfeed. Given the nature of the problems listed in the survey it is unlikely that these are correlated with the underlying health of the mother (and therefore do not contribute to the child's initial health endowment). Another instrument we use for breastfeeding is a dummy for whether the mother herself has been ill in the past 24 hours at the time of interview. Short term illnesses like this will drive a mothers decision to breastfeed but may not necessarily reflect underlying maternal health.

We further instrument nutritional intake for all ages with the occurrence of Typhoon Nitang, which killed over 1400 people when it hit the island in September 2nd 1984. The estimated cost of Nitang was large, with an estimated $76.5 million worth of crop damage in the Philippines alone. This along with documented evidence on the effect of extreme weather conditions on malnutrition and disease (Ugaz and Zanolini [2011]) makes it likely that Nitang had an impact on households ability to invest in nutritional intake, without affecting child height directly. Furthermore there is evidence to suggest that the impact of natural disasters on early childhood development is larger the younger a child is when it occurs (Rosales-Rueda [2014]). Along these lines we follow Cao [2015] and create a dummy variable equal to one if the child was under the age of 1 when the hurricane hit. Natural disasters can also be expected to impact WASH practices (it is difficult for example to give your child treated water if you've just been flooded), and as such typhoon Nitang can also be used as an instrument for WASH.

WASH In both child age categories, we instrument for WASH score using the cost of installing an antipolo toilet. Antipolo toilets are a type of sealed toilet introduced to the Philippines by the American colonial government in the early 20th century, and were designed as a cheap and easy alternative to traditional flushing toilets. They are still popular in poorer parts of the Philippines to this day, and are often seen as the easiest way for households without a toilet to construct a safe formal one. We observe the estimated price of such toilets, inside and outside the household, across barangays only in the baseline survey, but despite the lack of time variation they prove to be a strong predictor of WASH investments.

A further instrument used is the average soil depth in the barangay. This feature influences the type of toilet that can be built in the area. In areas with low soil depth, the water table may be relatively shallow, and soils wet so that relatively cheap pit toilets cannot be built.

Interestingly, areas with low soil depth may be well suited for agriculture, so that soil depth could affect nutritional investments as well.

5 Results

We report the results for two measures of nutrition – calorie intake and protein intake – for the pooled 6-24 month sample, and then separately for males and females. In what follows, we display results for the WASH score constructed using child- and household-level variables only. This will capture primarily household-level WASH investments. Thereafter, we report preliminary results for children aged 0-6 months, where the key nutrition indicator is breastfeeding. We start by reporting the results for height, before displaying those for child weight.

5.1 Child Height

6-24 months Our empirical results for the pooled 6-24 month sample are shown in Tables 8 and 9, before estimating separately the production functions for males and females.

We run a semi-translog specification both with and without the interaction between our primary inputs and lagged height. Columns 1 and 3 display the coefficients from an OLS estimation of the production functions, while Columns 2 and 4 display the IV estimates. The OLS coefficients indicate a positive and statistically significant interaction term between log WASH and calories and log WASH and protein intake, suggesting that linear production functions may not sufficiently capture the process of child height formation. Interestingly, the coefficient on the log WASH term becomes significant on the addition of the interaction terms between the inputs and log lagged height, underscoring the importance of including these controls.

When we correct for endogeneity of inputs, we obtain more nuanced results. The diagnostics for all of our instruments are shown in appendix B.2. In most cases, the F-test values exceed a value of 10, indicating that the instruments are sufficiently strong. The IV coefficient on calorie intake displays a negative sign in the augmented translog specification, while that on log WASH is also negative but statistically insignificant from 0. We also obtain a positive interaction coefficient between log WASH and log calories, though this is statistically insignificant from 0, given the large standard errors. For protein intake, the coefficients on log protein intake and log WASH are both positive, but statistically insignificant from 0. We also obtain a positive, but statistically insignificant interaction term between protein intake and log WASH.

We obtain more meaningful, and interesting results when we estimate the production functions separately for boys and girls. These results are displayed in Tables 10 and 11 for boys,

Table 8: Calories 6 - 24 Months

	Translog		Augmented Translog	
	(1)	(2)	(3)	(4)
	OLS	IV	OLS	IV
Log of previous height	0.8118***	0.8111***	0.8083***	0.8018***
	(0.0066)	(0.0082)	(0.0070)	(0.0596)
Log of previous calorie intake	0.0003	-0.0061	-0.0007**	-0.0317***
	(0.0002)	(0.0042)	(0.0003)	(0.0082)
lWASH_6_24HH	0.0012*	0.0072	0.0237	-0.0630
	(0.0006)	(0.0112)	(0.0232)	(0.4991)
WASH-Nutrition interaction term	0.0000	-0.0033	0.0007*	0.0024
	(0.0003)	(0.0042)	(0.0003)	(0.0093)
Birthweight (kg)	-0.0003	-0.0003	-0.0002	-0.0002
	(0.0002)	(0.0004)	(0.0002)	(0.0005)
Child gender (1=female)	0.0006**	0.0004	0.0006**	-0.0000
	(0.0002)	(0.0004)	(0.0002)	(0.0005)
Child age (months)	-0.0022***	-0.0014**	-0.0022***	-0.0023***
	(0.0002)	(0.0007)	(0.0002)	(0.0007)
Child age squared	0.0001***	0.0001***	0.0001***	0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Child still breastfed in some way	0.0020***	-0.0002	0.0020***	0.0009
	(0.0003)	(0.0017)	(0.0003)	(0.0017)
Fever Dummy	0.0005*	0.0005*	0.0005**	0.0008**
	(0.0002)	(0.0003)	(0.0002)	(0.0003)
L.Fever Dummy	-0.0002	-0.0005	-0.0001	0.0003
	(0.0002)	(0.0004)	(0.0002)	(0.0005)
Diarrhoea dummy	-0.0005**	-0.0005**	-0.0005**	-0.0003
	(0.0002)	(0.0002)	(0.0002)	(0.0003)
L.Diarrhoea dummy	-0.0004	-0.0006	-0.0004	0.0004
	(0.0004)	(0.0004)	(0.0004)	(0.0006)
Previous Log Weight	0.0520***	0.0539***	0.0518***	0.0505***
	(0.0016)	(0.0024)	(0.0016)	(0.0032)
Nutrition and lagged log height interaction			0.0003***	0.0069***
			(0.0001)	(0.0020)
WASH and lagged log height interaction			-0.0055	0.0118
			(0.0055)	(0.1198)
Constant	0.7323***	0.7609***	0.7507***	0.8947***
	(0.0231)	(0.0442)	(0.0252)	(0.2420)
Community Controls	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes
Observations	18667	18665	18667	18665
Adjusted R^2	0.941	0.938	0.941	0.911

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Community controls include municipality dummies, interview month dummies, census population and an urban/rural dummy. Household controls include wealth quintile, age of household head and their education, mother age and education as well controls for the distribution of ages within the household

Table 9: Protein 6 - 24 Months

	Translog		Augmented Translog	
	(1)	(2)	(3)	(4)
	OLS	IV	OLS	IV
Log of previous height	0.8114***	0.8125***	0.7946***	0.8205***
	(0.0065)	(0.0075)	(0.0098)	(0.1682)
Log of previous protein intake	0.0007***	-0.0000	-0.0210**	0.0798
	(0.0002)	(0.0038)	(0.0088)	(0.2299)
lWASH_6_24HH	0.0002	-0.0057	0.0475*	0.2575
	(0.0007)	(0.0121)	(0.0280)	(0.5860)
WASH-Nutrition interaction term	0.0005*	0.0012	0.0007**	0.0080
	(0.0003)	(0.0044)	(0.0003)	(0.0093)
Birthweight (kg)	-0.0002	-0.0003	-0.0002	-0.0001
	(0.0002)	(0.0003)	(0.0003)	(0.0005)
Child gender (1=female)	0.0006**	0.0006*	0.0006**	0.0005
	(0.0002)	(0.0003)	(0.0002)	(0.0004)
Child age (months)	-0.0022***	-0.0020***	-0.0021***	-0.0023
	(0.0002)	(0.0007)	(0.0003)	(0.0021)
Child age squared	0.0001***	0.0001***	0.0001***	0.0001
	(0.0000)	(0.0000)	(0.0000)	(0.0001)
Child still breastfed in some way	0.0021***	0.0012	0.0021***	0.0011
	(0.0003)	(0.0015)	(0.0003)	(0.0016)
Fever Dummy	0.0005**	0.0005**	0.0005**	0.0007**
	(0.0002)	(0.0003)	(0.0002)	(0.0003)
Lag Fever Dummy	-0.0002	-0.0002	-0.0002	-0.0002
	(0.0003)	(0.0004)	(0.0003)	(0.0004)
Diarrhoea dummy	-0.0005**	-0.0005*	-0.0005**	-0.0004
	(0.0002)	(0.0003)	(0.0002)	(0.0003)
Lag Diarrhoea dummy	-0.0004	-0.0005	-0.0004	-0.0006
	(0.0004)	(0.0004)	(0.0004)	(0.0005)
Previous Log Weight	0.0519***	0.0520***	0.0517***	0.0514***
	(0.0016)	(0.0025)	(0.0016)	(0.0034)
Nutrition and lagged log height interaction			0.0051**	-0.0181
			(0.0021)	(0.0538)
WASH and lagged log height interaction			-0.0111	-0.0642
			(0.0066)	(0.1398)
Constant	0.7343***	0.7220***	0.8046***	0.6837
	(0.0226)	(0.0289)	(0.0369)	(0.7012)
Community Controls	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes
Observations	18753	18751	18753	18751
Adjusted R^2	0.941	0.941	0.941	0.938

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Community controls include municipality dummies, interview month dummies, census population and an urban/rural dummy. Household controls include wealth quintile, age of household head and their education, mother age and education as well controls for the distribution of ages within the household

and Tables 12 and 13 for girls. For boys, we find very small and statistically insignificant interaction terms between log WASH and the two nutrition indicators. Moreover, the IV coefficients in Table 11 indicate a large positive impact of protein intake for height for boys, though we also estimate a surprisingly negative effect of log WASH.

For girls, by contrast, we obtain positive and statistically significant interactions between log WASH and nutrition intake (calories and protein) in both OLS and IV specifications. The direct effects of the nutrition input are often small and statistically insignificant, though with negative coefficients. Indeed, the estimates for calorie intake indicate that all effects of calorie intake on child height go through the interaction term, suggesting that calories are unlikely to be effective in improving height without related WASH investments. Log WASH has a positive impact on height for girls, particularly in the augmented translog specifications.

A further point of interest is the importance of the interaction between current inputs and lagged height endowment. As has already been discussed, these terms catch the interaction between nutrition or sanitation and all previous inputs. Our results suggest that this dynamic interaction between sanitation and nutrition in periods far removed from each other also has an influence on child height. From an economic point of view our results could be read as showing diminishing returns to sanitation where there is a significant negative value, as seen in table 9. Further to this, the fact that these seem to be statistically significant effects lends weight to the argument that it is not sufficient to run linear production functions when estimating a height production function.

Other general coefficients of interest continue to take the expected sign as we change our specification. A prominent example of this is our illness dummies, with both fever and diarrhea having significant negative impacts on child height. The negative coefficient on age should be interpreted in the context of how fully we control for prior height. Here we see that the change in height is decreasing in percentage terms as the child grows older, a result in line with expectations.

0-6 Months We additionally estimate the production function under the age of 6 months using breastfeeding variables as our key nutritional inputs. However both our nutritional intakes under the age of 6 months the instrumental variable regressions are under identified, with robust F-stats under 10. This is still a work in progress, and there are sets of instruments which have been relevant under different specifications in previous versions of our estimations which have produced significant results, so we remain hopeful that future versions of this paper will include more robust findings for children under the age of 6 months. Despite this we still observe some promising results, displayed in full in appendix B.1. In tables 20 and 21 we see hints of subsitutability between nutrition and sanitation in the interaction term. This switch between complementarity and subsitutability is exactly what we would expect to see given the established role breastfeeding has on insulating children from diseases (Sadeharju et al. [2007] and Victora et al. [1987]), as well as the growing literature on how WASH investment can

Table 10: Effects of calories and WASH on height, males

	Translog		Augmented Translog	
	(1)	(2)	(3)	(4)
	OLS	IV	OLS	IV
Log of previous height	0.8150***	0.8150***	0.8127***	0.8408***
	(0.0101)	(0.0119)	(0.0106)	(0.0359)
Log of previous calorie intake	0.0001	-0.0101*	-0.0009**	-0.0315***
	(0.0003)	(0.0060)	(0.0004)	(0.0105)
lWASH_6_24HH	0.0017**	0.0226	0.0117	-0.3350
	(0.0007)	(0.0173)	(0.0284)	(0.3231)
WASH-Nutrition interaction term	-0.0002	-0.0101	0.0003	-0.0125
	(0.0003)	(0.0067)	(0.0004)	(0.0085)
Birthweight (kg)	-0.0007**	-0.0012**	-0.0006**	-0.0010
	(0.0003)	(0.0006)	(0.0003)	(0.0007)
Child age (months)	-0.0018***	-0.0012	-0.0018***	-0.0021***
	(0.0003)	(0.0008)	(0.0003)	(0.0006)
Child age squared	0.0001***	0.0000***	0.0001***	0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Child still breastfed in some way	0.0021***	-0.0001	0.0021***	0.0002
	(0.0004)	(0.0018)	(0.0004)	(0.0017)
Fever Dummy	0.0004	0.0003	0.0005	0.0005
	(0.0003)	(0.0004)	(0.0003)	(0.0004)
Lag Fever Dummy	-0.0006**	-0.0010**	-0.0005*	-0.0006
	(0.0003)	(0.0005)	(0.0003)	(0.0006)
Diarrhoea dummy	0.0001	0.0002	0.0001	0.0004
	(0.0003)	(0.0003)	(0.0003)	(0.0005)
Lag Diarrhoea dummy	-0.0002	-0.0002	-0.0002	0.0004
	(0.0005)	(0.0005)	(0.0005)	(0.0006)
Previous Log Weight	0.0510***	0.0546***	0.0509***	0.0541***
	(0.0025)	(0.0036)	(0.0025)	(0.0045)
Nutrition and lagged log height interaction			0.0003**	0.0047***
			(0.0001)	(0.0016)
WASH and lagged log height interaction			-0.0026	0.0831
			(0.0067)	(0.0778)
Constant	0.7197***	0.7714***	0.7330***	0.7498***
	(0.0370)	(0.0603)	(0.0390)	(0.1590)
Community Controls	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes
Observations	9837	9837	9837	9837
Adjusted R^2	0.941	0.934	0.941	0.909

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11: Effects of protein intake and WASH on height, males

	Translog		Augmented Translog	
	(1) OLS	(2) IV	(3) OLS	(4) IV
Log of previous height	0.8141***	0.8174***	0.8084***	1.3797***
	(0.0100)	(0.0111)	(0.0142)	(0.1913)
Log of previous protein intake	0.0006*	-0.0015	-0.0058	0.7450***
	(0.0003)	(0.0038)	(0.0110)	(0.2355)
lWASH_6_24HH	0.0006	0.0032	0.0219	-1.4415**
	(0.0009)	(0.0130)	(0.0317)	(0.6927)
WASH-Nutrition interaction term	0.0003	-0.0031	0.0004	-0.0096
	(0.0004)	(0.0048)	(0.0004)	(0.0085)
Birthweight (kg)	-0.0006**	-0.0009**	-0.0006**	-0.0023**
	(0.0003)	(0.0004)	(0.0003)	(0.0010)
Child age (months)	-0.0019***	-0.0019**	-0.0018***	-0.0081***
	(0.0003)	(0.0007)	(0.0003)	(0.0018)
Child age squared	0.0001***	0.0001***	0.0001***	0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0001)
Child still breastfed in some way	0.0022***	0.0018	0.0022***	0.0026
	(0.0004)	(0.0014)	(0.0004)	(0.0019)
Fever Dummy	0.0005	0.0004	0.0005	0.0001
	(0.0003)	(0.0004)	(0.0003)	(0.0004)
Lag Fever Dummy	-0.0006*	-0.0007	-0.0005*	-0.0012*
	(0.0003)	(0.0004)	(0.0003)	(0.0007)
Diarrhoea dummy	0.0000	0.0000	0.0000	0.0001
	(0.0003)	(0.0003)	(0.0003)	(0.0004)
Lag Diarrhoea dummy	-0.0002	-0.0002	-0.0002	-0.0005
	(0.0005)	(0.0005)	(0.0005)	(0.0006)
Previous Log Weight	0.0511***	0.0519***	0.0510***	0.0595***
	(0.0025)	(0.0031)	(0.0025)	(0.0052)
Nutrition and lagged log height interaction			0.0015	-0.1749***
			(0.0025)	(0.0557)
WASH and lagged log height interaction			-0.0050	0.3394**
			(0.0074)	(0.1636)
Constant	0.7227***	0.7084***	0.7470***	-1.6480**
	(0.0363)	(0.0404)	(0.0546)	(0.8052)
Community Controls	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes
Observations	9895	9895	9895	9895
Adjusted R^2	0.941	0.941	0.941	0.908

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 12: Effects of calorie intake and WASH on height, females

	Translog		Augmented Translog	
	(1)	(2)	(3)	(4)
	OLS	IV	OLS	IV
Log of previous height	0.8033***	0.8012***	0.7977***	0.7020***
	(0.0079)	(0.0092)	(0.0085)	(0.0747)
Log of previous calorie intake	0.0005	-0.0009	-0.0005	-0.0131
	(0.0003)	(0.0037)	(0.0005)	(0.0103)
lWASH_6_24HH	0.0006	-0.0111	0.0417	0.7177
	(0.0009)	(0.0093)	(0.0301)	(0.5881)
WASH-Nutrition interaction term	0.0004	0.0054*	0.0012**	0.0212***
	(0.0004)	(0.0032)	(0.0005)	(0.0082)
Birthweight (kg)	0.0004	0.0005	0.0004	0.0003
	(0.0005)	(0.0005)	(0.0005)	(0.0007)
Child age (months)	-0.0025***	-0.0017***	-0.0025***	-0.0020***
	(0.0003)	(0.0006)	(0.0003)	(0.0007)
Child age squared	0.0001***	0.0001***	0.0001***	0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Child still breastfed in some way	0.0019***	-0.0002	0.0019***	0.0014
	(0.0004)	(0.0017)	(0.0004)	(0.0017)
Fever Dummy	0.0005	0.0007**	0.0006	0.0009**
	(0.0004)	(0.0003)	(0.0004)	(0.0004)
Lag Fever Dummy	0.0003	0.0002	0.0003	0.0008*
	(0.0004)	(0.0004)	(0.0004)	(0.0005)
Diarrhoea dummy	-0.0012***	-0.0012***	-0.0012***	-0.0011**
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Lag Diarrhoea dummy	-0.0007*	-0.0011**	-0.0007*	-0.0007
	(0.0004)	(0.0005)	(0.0004)	(0.0008)
Previous Log Weight	0.0540***	0.0543***	0.0538***	0.0503***
	(0.0021)	(0.0027)	(0.0021)	(0.0033)
Nutrition and lagged log height interaction			0.0003***	0.0049**
			(0.0001)	(0.0022)
WASH and lagged log height interaction			-0.0100	-0.1790
			(0.0071)	(0.1401)
Constant	0.7640***	0.7638***	0.7910***	1.2119***
	(0.0276)	(0.0412)	(0.0311)	(0.2942)
Community Controls	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes
Observations	8830	8828	8830	8828
Adjusted R^2	0.938	0.935	0.938	0.920

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 13: Effects of protein intake and WASH on height, females

	Translog		Augmented Translog	
	(1)	(2)	(3)	(4)
	OLS	IV	OLS	IV
Log of previous height	0.8035***	0.8024***	0.7774***	0.5749***
	(0.0079)	(0.0088)	(0.0128)	(0.1735)
Log of previous protein intake	0.0008**	0.0034	-0.0327**	-0.1643
	(0.0003)	(0.0037)	(0.0138)	(0.2859)
lWASH_6_24HH	-0.0004	-0.0199*	0.0742**	1.1116**
	(0.0009)	(0.0106)	(0.0346)	(0.5405)
WASH-Nutrition interaction term	0.0009*	0.0084**	0.0011**	0.0226***
	(0.0005)	(0.0037)	(0.0005)	(0.0086)
Birthweight (kg)	0.0003	0.0003	0.0004	0.0008
	(0.0005)	(0.0005)	(0.0005)	(0.0008)
Child age (months)	-0.0026***	-0.0023***	-0.0023***	-0.0005
	(0.0003)	(0.0006)	(0.0003)	(0.0023)
Child age squared	0.0001***	0.0001***	0.0001***	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0001)
Child still breastfed in some way	0.0019***	0.0010	0.0020***	0.0011
	(0.0004)	(0.0017)	(0.0004)	(0.0018)
Fever Dummy	0.0005	0.0007**	0.0005	0.0009**
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Lag Fever Dummy	0.0003	0.0004	0.0003	0.0006
	(0.0004)	(0.0004)	(0.0004)	(0.0005)
Diarrhoea dummy	-0.0012***	-0.0011***	-0.0012***	-0.0010**
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Lag Diarrhoea dummy	-0.0006	-0.0008	-0.0006	-0.0011
	(0.0004)	(0.0006)	(0.0004)	(0.0007)
Previous Log Weight	0.0538***	0.0528***	0.0536***	0.0499***
	(0.0021)	(0.0028)	(0.0022)	(0.0045)
Nutrition and lagged log height interaction			0.0079**	0.0407
			(0.0032)	(0.0668)
WASH and lagged log height interaction			-0.0176**	-0.2717**
			(0.0081)	(0.1296)
Constant	0.7648***	0.7507***	0.8736***	1.6852**
	(0.0271)	(0.0330)	(0.0491)	(0.7185)
Community Controls	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes
Observations	8858	8856	8858	8856
Adjusted R^2	0.938	0.935	0.938	0.920

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

affect the efficacy of childhood nutritional intake (George et al. [2016], Mbuya and Humphrey [2016]).

5.2 Child Weight

Tables 14 and 15 display the findings for child weight for the pooled 6-24 month sample, while Tables 16 - 19 display those for boys and girls separately. As before, Columns 1 and 3 display the OLS results for the semi-translog production function, and the augmented translog production function, while Columns 2 and 4 display coefficients from the IV estimation.

In the pooled sample, the OLS estimates indicate a positive, though small, effect of calories and protein on weight, a very small and statistically insignificant effect of log WASH, and a positive and usually statistically significant interaction term. When we correct for endogeneity, we obtain a larger and statistically significant effect of protein intake on weight, and a surprisingly negative effect of calories on weight. The IV coefficients also indicate no statistically significant effect of log WASH or the interaction between log WASH and nutrition on weight.

When we estimate the production functions separately by child gender, we see that calorie intake has a statistically significant and large effect on weight for boys, but not for girls when we correct for endogeneity of inputs. Moreover, the OLS estimation indicates positive and statistically significant interaction between log WASH and nutrition for both girls and boys, particularly with the augmented translog production function. However, when we correct for endogeneity of inputs, we fail to obtain a statistically significant interaction term for any of the specifications. Interestingly, the magnitude of the interaction term increases for the female sample in the IV estimation. However, the standard errors also increase, yielding statistically insignificant results.

Throughout, the magnitude of the interaction term remains small, compared to the magnitude of the coefficients on nutrition intake or log WASH.

6 Conclusion

Nutrition and WASH investments play an important and nuanced role in early childhood development. Whilst much evidence exists that both are separately important, our results show that the interaction between them plays an equally important role. Our results, although still preliminary, provide clear evidence that there exists an interaction between environmental levels of sanitation and nutritional intake on child health.

When the primary source of nutrition is breastmilk, environmental factors and nutrition are (in a correlational way) substitutes for each other. This fits with to the findings of Sadeharju et al. [2007] and Victora et al. [1987] who argue that breastfeeding insulates children from disease and infection in early life, which in turn drives our own finding of subsitutability.

Table 14: Effects of calorie intake and WASH on weight, pooled sample

	Translog		Augmented Translog	
	(1) OLS	(2) IV	(3) OLS	(4) IV
Log of previous height	0.2131***	0.2125***	0.2119***	0.2082***
	(0.0174)	(0.0197)	(0.0171)	(0.0222)
Log of previous calorie intake	0.0021***	-0.0119*	0.0007	-0.0359**
	(0.0007)	(0.0062)	(0.0011)	(0.0164)
lWASH_6_24HH	-0.0005	0.0090	0.0251	0.0329
	(0.0023)	(0.0261)	(0.0161)	(0.2103)
WASH-Nutrition interaction term	0.0014	-0.0057	0.0026**	0.0020
	(0.0009)	(0.0104)	(0.0010)	(0.0164)
Birthweight (kg)	0.0035***	0.0033***	0.0036***	0.0036***
	(0.0007)	(0.0009)	(0.0007)	(0.0010)
Child gender (1=female)	-0.0043***	-0.0049***	-0.0044***	-0.0053***
	(0.0006)	(0.0006)	(0.0006)	(0.0008)
Child age (months)	-0.0067***	-0.0050***	-0.0066***	-0.0052***
	(0.0006)	(0.0012)	(0.0006)	(0.0015)
Child age squared	0.0002***	0.0002***	0.0002***	0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Child still breastfed in some way	0.0019*	-0.0031	0.0020**	-0.0020
	(0.0010)	(0.0021)	(0.0010)	(0.0027)
Fever Dummy	-0.0097***	-0.0096***	-0.0096***	-0.0093***
	(0.0009)	(0.0009)	(0.0009)	(0.0008)
Lag Fever Dummy	0.0032***	0.0025***	0.0032***	0.0033***
	(0.0007)	(0.0009)	(0.0007)	(0.0012)
Diarrhoea dummy	-0.0124***	-0.0123***	-0.0124***	-0.0121***
	(0.0008)	(0.0008)	(0.0008)	(0.0009)
Lag Diarrhoea dummy	0.0054***	0.0050***	0.0055***	0.0059***
	(0.0009)	(0.0010)	(0.0009)	(0.0010)
Previous Log Weight	0.8575***	0.8616***	0.8490***	0.8175***
	(0.0087)	(0.0090)	(0.0115)	(0.0523)
Nutrition and lagged log height interaction			0.0009	0.0137*
			(0.0006)	(0.0077)
WASH and lagged log height interaction			-0.0134*	-0.0223
			(0.0077)	(0.1065)
Constant	-0.5032***	-0.4488***	-0.4773***	-0.2669**
	(0.0587)	(0.0871)	(0.0535)	(0.1319)
Community Controls	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes
Observations	18680	18678	18680	18678
Adjusted R^2	0.917	0.915	0.917	0.911

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 15: Effects of protein intake and WASH on weight, pooled sample

	Translog		Augmented Translog	
	(1) OLS	(2) IV	(3) OLS	(4) IV
Log of previous height	0.2103***	0.2123***	0.2097***	0.2398***
	(0.0171)	(0.0192)	(0.0168)	(0.0309)
Log of previous protein intake	0.0022***	-0.0046	0.0028	0.2695**
	(0.0008)	(0.0074)	(0.0063)	(0.1293)
lWASH_6_24HH	-0.0018	-0.0054	0.0243	-0.2079
	(0.0023)	(0.0307)	(0.0179)	(0.2691)
WASH-Nutrition interaction term	0.0020*	-0.0006	0.0027**	0.0075
	(0.0010)	(0.0116)	(0.0011)	(0.0184)
Birthweight (kg)	0.0035***	0.0033***	0.0036***	0.0024
	(0.0007)	(0.0008)	(0.0007)	(0.0014)
Child gender (1=female)	-0.0044***	-0.0044***	-0.0044***	-0.0043***
	(0.0006)	(0.0006)	(0.0006)	(0.0009)
Child age (months)	-0.0067***	-0.0056***	-0.0066***	-0.0116***
	(0.0006)	(0.0013)	(0.0007)	(0.0038)
Child age squared	0.0002***	0.0002***	0.0002***	0.0004***
	(0.0000)	(0.0000)	(0.0000)	(0.0001)
Child still breastfed in some way	0.0019*	-0.0015	0.0019*	-0.0024
	(0.0010)	(0.0025)	(0.0010)	(0.0026)
Fever Dummy	-0.0096***	-0.0096***	-0.0096***	-0.0093***
	(0.0009)	(0.0009)	(0.0009)	(0.0009)
Lag Fever Dummy	0.0032***	0.0028***	0.0033***	0.0021**
	(0.0007)	(0.0010)	(0.0007)	(0.0011)
Diarrhoea dummy	-0.0122***	-0.0122***	-0.0122***	-0.0121***
	(0.0008)	(0.0008)	(0.0008)	(0.0009)
Lag Diarrhoea dummy	0.0054***	0.0049***	0.0054***	0.0049***
	(0.0009)	(0.0009)	(0.0009)	(0.0009)
Previous Log Weight	0.8578***	0.8600***	0.8520***	1.1924***
	(0.0087)	(0.0093)	(0.0153)	(0.1962)
Nutrition and lagged log height interaction			-0.0001	-0.1308**
			(0.0030)	(0.0633)
WASH and lagged log height interaction			-0.0130	0.0929
			(0.0085)	(0.1371)
Constant	-0.4842***	-0.5067***	-0.4705***	-1.2568***
	(0.0570)	(0.0727)	(0.0530)	(0.4664)
Community Controls	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes
Observations	18766	18764	18766	18764
Adjusted R^2	0.917	0.916	0.917	0.901

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 16: Effects of calorie intake and WASH on weight, males

	Translog		Augmented Translog	
	(1)	(2)	(3)	(4)
	OLS	IV	OLS	IV
Log of previous height	0.2153***	0.2216***	0.2139***	0.2053***
	(0.0175)	(0.0224)	(0.0170)	(0.0255)
Log of previous calorie intake	0.0017*	-0.0148	0.0006	-0.0211
	(0.0009)	(0.0124)	(0.0012)	(0.0151)
lWASH_6_24HH	0.0006	0.0398	0.0390*	0.2973*
	(0.0026)	(0.0447)	(0.0205)	(0.1747)
WASH-Nutrition interaction term	0.0011	-0.0201	0.0024*	-0.0066
	(0.0010)	(0.0178)	(0.0013)	(0.0225)
Birthweight (kg)	0.0025**	0.0013	0.0026**	0.0022*
	(0.0010)	(0.0013)	(0.0009)	(0.0013)
Child age (months)	-0.0057***	-0.0055***	-0.0056***	-0.0039*
	(0.0008)	(0.0019)	(0.0008)	(0.0022)
Child age squared	0.0002***	0.0002***	0.0002***	0.0001**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Child still breastfed in some way	0.0023**	0.0001	0.0024**	-0.0011
	(0.0011)	(0.0034)	(0.0011)	(0.0035)
Fever Dummy	-0.0091***	-0.0095***	-0.0090***	-0.0088***
	(0.0011)	(0.0012)	(0.0011)	(0.0013)
Lag Fever Dummy	0.0029***	0.0023**	0.0030***	0.0026**
	(0.0009)	(0.0011)	(0.0009)	(0.0013)
Diarrhoea dummy	-0.0136***	-0.0134***	-0.0135***	-0.0133***
	(0.0011)	(0.0012)	(0.0011)	(0.0012)
Lag Diarrhoea dummy	0.0061***	0.0063***	0.0062***	0.0063***
	(0.0012)	(0.0015)	(0.0012)	(0.0015)
Previous Log Weight	0.8568***	0.8624***	0.8457***	0.7916***
	(0.0094)	(0.0117)	(0.0134)	(0.0510)
Nutrition and lagged log height interaction			0.0009	0.0044
			(0.0006)	(0.0087)
WASH and lagged log height interaction			-0.0192*	-0.1297
			(0.0099)	(0.0863)
Constant	-0.5251***	-0.4614***	-0.4947***	-0.2413
	(0.0564)	(0.1199)	(0.0499)	(0.1548)
Community Controls	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes
Observations	9843	9843	9843	9843
Adjusted R^2	0.911	0.907	0.911	0.906

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 17: Effects of protein intake and WASH on weight, males

	Translog		Augmented Translog	
	(1) OLS	(2) IV	(3) OLS	(4) IV
Log of previous height	0.2103***	0.2201***	0.2090***	0.2193***
	(0.0174)	(0.0214)	(0.0166)	(0.0385)
Log of previous protein intake	0.0017*	-0.0096	-0.0026	0.0793
	(0.0009)	(0.0120)	(0.0131)	(0.1244)
lWASH_6_24HH	-0.0003	0.0295	0.0444*	0.1571
	(0.0030)	(0.0480)	(0.0255)	(0.2815)
WASH-Nutrition interaction term	0.0015	-0.0160	0.0024*	-0.0061
	(0.0012)	(0.0184)	(0.0013)	(0.0214)
Birthweight (kg)	0.0026***	0.0014	0.0027***	0.0013
	(0.0009)	(0.0012)	(0.0009)	(0.0017)
Child age (months)	-0.0057***	-0.0056***	-0.0055***	-0.0063
	(0.0008)	(0.0019)	(0.0008)	(0.0047)
Child age squared	0.0002***	0.0002***	0.0002***	0.0002
	(0.0000)	(0.0000)	(0.0000)	(0.0001)
Child still breastfed in some way	0.0021*	0.0008	0.0022*	-0.0005
	(0.0012)	(0.0033)	(0.0011)	(0.0036)
Fever Dummy	-0.0091***	-0.0096***	-0.0091***	-0.0093***
	(0.0010)	(0.0012)	(0.0010)	(0.0013)
Lag Fever Dummy	0.0030***	0.0024**	0.0031***	0.0022*
	(0.0009)	(0.0012)	(0.0008)	(0.0012)
Diarrhoea dummy	-0.0133***	-0.0134***	-0.0133***	-0.0133***
	(0.0011)	(0.0012)	(0.0011)	(0.0012)
Lag Diarrhoea dummy	0.0061***	0.0059***	0.0061***	0.0059***
	(0.0012)	(0.0015)	(0.0012)	(0.0015)
Previous Log Weight	0.8574***	0.8619***	0.8421***	0.9259***
	(0.0095)	(0.0120)	(0.0241)	(0.1811)
Nutrition and lagged log height interaction			0.0023	-0.0413
			(0.0061)	(0.0579)
WASH and lagged log height interaction			-0.0218*	-0.0648
			(0.0120)	(0.1329)
Constant	-0.4986***	-0.5244***	-0.4642***	-0.6505
	(0.0562)	(0.0804)	(0.0557)	(0.4831)
Community Controls	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes
Observations	9901	9901	9901	9901
Adjusted R^2	0.911	0.909	0.911	0.907

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 18: Effects of calorie intake and WASH on weight, females

	Translog		Augmented Translog	
	(1) OLS	(2) IV	(3) OLS	(4) IV
Log of previous height	0.2140***	0.2131***	0.2131***	0.2168***
	(0.0245)	(0.0261)	(0.0245)	(0.0307)
Log of previous calorie intake	0.0024**	-0.0083	0.0008	-0.0354**
	(0.0010)	(0.0056)	(0.0020)	(0.0177)
lWASH_6_24HH	-0.0010	-0.0190	0.0153	-0.0520
	(0.0026)	(0.0211)	(0.0218)	(0.1613)
WASH-Nutrition interaction term	0.0016	0.0054	0.0027**	0.0109
	(0.0012)	(0.0087)	(0.0013)	(0.0101)
Birthweight (kg)	0.0049***	0.0053***	0.0049***	0.0042***
	(0.0011)	(0.0013)	(0.0011)	(0.0016)
Child age (months)	-0.0077***	-0.0055***	-0.0077***	-0.0061***
	(0.0008)	(0.0013)	(0.0008)	(0.0013)
Child age squared	0.0002***	0.0002***	0.0002***	0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Child still breastfed in some way	0.0017	-0.0049**	0.0018	-0.0029
	(0.0013)	(0.0025)	(0.0013)	(0.0031)
Fever Dummy	-0.0104***	-0.0099***	-0.0103***	-0.0100***
	(0.0014)	(0.0013)	(0.0014)	(0.0012)
Lag Fever Dummy	0.0033***	0.0029**	0.0034***	0.0038***
	(0.0011)	(0.0011)	(0.0011)	(0.0014)
Diarrhoea dummy	-0.0111***	-0.0112***	-0.0111***	-0.0112***
	(0.0014)	(0.0013)	(0.0014)	(0.0015)
Lag Diarrhoea dummy	0.0045***	0.0035***	0.0046***	0.0048***
	(0.0011)	(0.0012)	(0.0011)	(0.0012)
Previous Log Weight	0.8556***	0.8576***	0.8489***	0.8218***
	(0.0122)	(0.0120)	(0.0146)	(0.0428)
Nutrition and lagged log height interaction			0.0010	0.0158*
			(0.0009)	(0.0084)
WASH and lagged log height interaction			-0.0090	0.0045
			(0.0106)	(0.0800)
Constant	-0.4928***	-0.4771***	-0.4712***	-0.3358**
	(0.0835)	(0.1027)	(0.0811)	(0.1620)
Community Controls	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes
Observations	8837	8835	8837	8835
Adjusted R^2	0.913	0.909	0.913	0.904

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 19: Effects of protein intake and WASH on weight, females

	Translog		Augmented Translog	
	(1) OLS	(2) IV	(3) OLS	(4) IV
Log of previous height	0.2138***	0.2136***	0.2137***	0.2148***
	(0.0247)	(0.0264)	(0.0245)	(0.0323)
Log of previous protein intake	0.0026***	0.0002	0.0058	0.0545
	(0.0009)	(0.0058)	(0.0066)	(0.1341)
lWASH_6_24HH	-0.0027	-0.0326	0.0101	0.0331
	(0.0027)	(0.0221)	(0.0227)	(0.1894)
WASH-Nutrition interaction term	0.0025*	0.0099	0.0028**	0.0166
	(0.0013)	(0.0088)	(0.0013)	(0.0110)
Birthweight (kg)	0.0048***	0.0049***	0.0048***	0.0051***
	(0.0011)	(0.0013)	(0.0011)	(0.0014)
Child age (months)	-0.0077***	-0.0065***	-0.0078***	-0.0076**
	(0.0008)	(0.0014)	(0.0009)	(0.0037)
Child age squared	0.0002***	0.0002***	0.0002***	0.0002**
	(0.0000)	(0.0000)	(0.0000)	(0.0001)
Child still breastfed in some way	0.0018	-0.0025	0.0018	-0.0019
	(0.0013)	(0.0028)	(0.0013)	(0.0032)
Fever Dummy	-0.0103***	-0.0099***	-0.0103***	-0.0097***
	(0.0013)	(0.0013)	(0.0013)	(0.0013)
Lag Fever Dummy	0.0034***	0.0033***	0.0034***	0.0034***
	(0.0011)	(0.0012)	(0.0011)	(0.0012)
Diarrhoea dummy	-0.0110***	-0.0110***	-0.0110***	-0.0110***
	(0.0014)	(0.0013)	(0.0014)	(0.0013)
Lag Diarrhoea dummy	0.0045***	0.0037***	0.0045***	0.0036***
	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Previous Log Weight	0.8557***	0.8557***	0.8557***	0.8911***
	(0.0122)	(0.0124)	(0.0172)	(0.1771)
Nutrition and lagged log height interaction			-0.0015	-0.0250
			(0.0032)	(0.0654)
WASH and lagged log height interaction			-0.0065	-0.0362
			(0.0110)	(0.0939)
Constant	-0.4831***	-0.5208***	-0.4825***	-0.5925
	(0.0829)	(0.0949)	(0.0824)	(0.4134)
Community Controls	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes
Observations	8865	8863	8865	8863
Adjusted R^2	0.913	0.911	0.913	0.910

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

However, our more substantial and policy relevant result is that the nature of this interaction changes as the child grows older. After the age of 6 months we find a statistically significant positive coefficient on the interaction between WASH investments and protein, particularly for girls.

This finding suggests that contamination of solid foodstuffs plays a major role in transmitting illnesses in the home; once children are weaned they are more exposed to the consequences of poor sanitary conditions in their environment. When this happens WASH investment stops being a substitute to nutrition and becomes a compliment to it. This story fits with the existing medical literature on the value of nutrition in child development, which places increasing emphasis on the impact of poor sanitary conditions on stunting and other poor health outcomes. This result goes some way to explaining the puzzle of stubbornly high stunting rates in some countries, even in the face of significant income growth.

References

Linda S Adair and David K Guilkey. Age-specific determinants of stunting in filipino children. *The Journal of nutrition*, 127(2):314–320, 1997. 1

Francesco Agostinelli and Matthew Wiswall. Estimating the technology of children's skill formation. Technical report, National Bureau of Economic Research, 2016. 1

D. Almond and J. Currie. *Human Capital Development Before Age 5*, volume pp.1315-1486. Elsevier, 2011. 1

O. Attanasio, S. Cattan, Fitzsimons, C. Meghir, and M. Rubio-Codina. Estimating the production function for human capital: Results from a randomized control trial in colombia. NBER Working Paper No. 20965, February 2015. 4.1

J. Behrman, M. Calderon, S.H. Preston, J.F. Hoddinott, R. Martorell, and A.D. Stein. Nutritional supplementation of girls influences the growth of their children: Prospective study in guatemala. *American Journal of Clinical Nutrition*, 90(5):1372–9, 2009. 1

Sonia Bhalotra and Samantha Rawlings. Gradients of the intergenerational transmission of health in developing countries. *The Review of Economics and Statistics*, 95(2):660–672, 2013. doi: 10.1162/REST_a_00263. URL http://dx.doi.org/10.1162/REST_a_00263. 1

Eilene Bisgrove, Barry M Popkin, and Corazon Barba. Profiling infant feeding patterns in cebu, philippines. *Ecology of food and nutrition*, 26(4):291–302, 1991. 3.1.2

Eilene Z Bisgrove, Barry M Popkin, and Corazon Barba. Infant feeding in the philippines: a cluster analysis approach. *Ecology of food and nutrition*, 23(2):75–90, 1989. 3.1.2

Richard N Boisvert. *The Translog Production Function: Its Properties, Its Several Interpretations and Estimation Problems.* 1982. 2

DI Campbell, M Elia, and PG Lunn. Growth faltering in rural gambian infants is associated with impaired small intestinal barrier function, leading to endotoxemia and systemic inflammation. *The Journal of nutrition*, 133(5):1332–1338, 2003. 1

Elisabetta De Cao. The height production function from birth to age two. *Journal of Human Capital*, 9(3):329–363, 2015. doi: 10.1086/682356. URL https://doi.org/10.1086/682356. 1, 4.1

Anne Case, Darren Lubotsky, and Christina Paxson. Economic status and health in childhood: The origins of the gradient. *American Economic Review*, 92(5):1308–1334, December 2002. doi: 10.1257/000282802762024520. URL http://www.aeaweb.org/articles?id=10.1257/000282802762024520. 1

Kenneth Y Chay and Michael Greenstone. Air quality, infant mortality, and the clean air act of 1970. Technical report, National Bureau of Economic Research, 2003. 1

Janet Currie and Matthew Neidell. Air pollution and infant health: what can we learn from california's recent experience? *The Quarterly Journal of Economics*, 120(3):1003–1030, 2005. 1

Janet Currie, Matthew Neidell, and Johannes F Schmieder. Air pollution and infant health: Lessons from new jersey. *Journal of health economics*, 28(3):688–703, 2009. 1

FAO and WHO. Vitamin and mineral requirements in human nutrition. 2005. 3.1.2

Lia C.H. Fernald, Ann Weber, Emanuela Galasso, and Lisy Ratsifandrihamanana. Socioeconomic gradients and child development in a very low income population: evidence from madagascar. *Developmental Science*, 14(4):832–847, 2011. ISSN 1467-7687. doi: 10.1111/j.1467-7687.2010.01032.x. URL http://dx.doi.org/10.1111/j.1467-7687.2010.01032.x. 1

Christine Marie George, Lauren Oldja, Shwapon Biswas, Jamie Perin, R Bradley Sack, Shahnawaz Ahmed, Mohammad Shahnaij, Rashidul Haque, Tahmina Parvin, Ishrat J Azmi, et al. Unsafe child feces disposal is associated with environmental enteropathy and impaired growth. *The Journal of pediatrics*, 176:43–49, 2016. 1, 5.1

P. Gertler, M. Shah, L. Cameron, S. Martinez, and S. Patil. How does health promotion work? evidence from the dirty business of eliminatingopen defecation. December 2014. 1

Michael Geruso and Dean Spears. Neighborhood sanitation and infant mortality. Technical report, National bureau of economic research, 2015. 1

Maitreesh Ghatak. Theories of Poverty Traps and Anti-Poverty Policies. *World Bank Economic Review*, 29(suppl$_1$) $: 77 - -105, 2015. URL$. 1

EK Gough, DA Stephens, EE Moodie, AJ Prendergast, RJ Stoltzfus, Jean Hawes Humphrey, and AR Manges. Linear growth faltering in infants is associated with acidaminococcus sp. and community-level changes in gut microbiota. *World review of nutrition and dietetics*, 114: 125–126, 2016. 1

S.M Grantham-McGregor, C.A Powell, S.P Walker, and J.H Himes. Nutritional supplementation, psychosocial stimulation, and mental development of stunted children: the jamaican study. *The Lancet*, 338(8758):1 – 5, 1991. ISSN 0140-6736. http://dx.doi.org/10.1016/0140-6736(91)90001-6. URL http://www.sciencedirect.com/science/article/pii/0140673691900016. Originally published as Volume 2, Issue 8758. 1

Jeffrey Hammer and Dean Spears. Village sanitation and child health: Effects and external validity in a randomized field experiment in rural India. *Journal of Health Economics*, 48(C):

135–148, 2016. 10.1016/j.jhealeco.2016.0. URL https://ideas.repec.org/a/eee/jhecon/v48y2016icp135-148.html. 1

J. Hoddinott, J. Behrman, J.A. Maluccio, P. Melgar, A.R. Quisumbing, M. Ramirez-Zea, A.D. Stein, K.M. Yount, and R. Martorell. Adult consequences of growth failure in early childhood. *The American Journal of Clinical Nutrition*, 98(5):1170–78, 2013. 1

J. F. Hoddinott, J. A. Maluccio, J. R. Behrman, R. Flores, and R. Martorell. Effect of a nutrition intervention during early childhood on economic productivity in guatemalan adults. *The Lancet*, 371(9610):411–6, 2008. 1

Jean H Humphrey. Child undernutrition, tropical enteropathy, toilets, and handwashing. *The Lancet*, 374(9694):1032–1035, 2009. 1

J. Kmenta. On estimation of the ces production function. 8(2):180–189, 1967. 2

Stanislav Kolenikov and Gustavo Angeles. Socioeconomic status measurement with discrete proxy variables: Is principal component analysis a reliable answer? *Review of Income and Wealth*, 55(1):128–165, 2009. B.4

Audrie Lin, Benjamin F Arnold, Sadia Afreen, Rie Goto, Tarique Mohammad Nurul Huda, Rashidul Haque, Rubhana Raqib, Leanne Unicomb, Tahmeed Ahmed, John M Colford Jr, et al. Household environmental conditions are associated with enteropathy and impaired growth in rural bangladesh. *The American journal of tropical medicine and hygiene*, 89(1):130–137, 2013. 1

Haiyong Liu, Thomas Mroz, and Linda Adair. Parental compensatory behaviors and early child health outcomes in cebu, philippines. *Journal of development economics*, 90(2):209–230, 2009. 1, 4.1

PG Lunn, CA Northrop-Clewes, and RM Downes. Intestinal permeability, mucosal injury, and growth faltering in gambian infants. *The Lancet*, 338(8772):907–910, 1991. 1

J. A. Maluccio, J. F. Hoddinott, J. R. Behrman, A. R. Quisumbing, R. Martorell, and A. D. Stein. The impact of nutrition during early childhood on education among guatemalan adults. *Economic Journal*, 119(537):734–63, 2009. 1

Mduduzi NN Mbuya and Jean H Humphrey. Preventing environmental enteric dysfunction through improved water, sanitation and hygiene: an opportunity for stunting reduction in developing countries. *Maternal & child nutrition*, 12(S1):106–120, 2016. 1, 5.1

Leah A Perlas, Rosalind S Gibson, and Linda S Adair. Macronutrient and selected vitamin intakes from complementary foods of infants and toddlers from cebu, philippines. *International journal of food sciences and nutrition*, 55(1):1–15, 2004. 3.1.2

Barry M Popkin, Linda Adair, John S Akin, Robert Black, John Briscoe, and Wilhelm Flieger. Breast-feeding and diarrheal morbidity. *Pediatrics*, 86(6):874–882, 1990. 1

Andrew Prendergast, Sandro Rukobo, Bernard Chasekwa, Kuda Mutasa, Robert Ntozini, Mduduzi Mbuya, Andrew Jones, Lawrence Moulton, Rebecca Stoltzfus, and Jean Humphrey. Stunting is characterized by chronic inflammation in zimbabwean infants (620.4). *The FASEB Journal*, 28(1 Supplement):620–4, 2014. 1

Esteban Puentes, Fan Wang, Jere R Behrman, Flavio Cunha, John Hoddinott, John A Maluccio, Linda S Adair, Judith B Borja, Reynaldo Martorell, and Aryeh D Stein. Early life height and weight production functions with endogenous energy and protein inputs. *Economics & Human Biology*, 22:65–81, 2016. 1

Maria Rosales-Rueda. Impact of early life shocks on human capital formation: Evidence from el nino floods in ecuador. *University of California Irvine working paper*, 2014. 4.1

M.R. Rosenzweig and T.P. Schulz. Estimating a household production function: Heterogeneity, the demand for health input, and their effects on birthweight. *Journal of Political Economy*, 92:723–746, 1983. 1, 1

Karita Sadeharju, Mikael Knip, Suvi M Virtanen, Erkki Savilahti, Sisko Tauriainen, Pentti Koskela, Hans K Åkerblom, Heikki Hyöty, Finnish TRIGR Study Group, et al. Maternal antibodies in breast milk protect the child from enterovirus infections. *Pediatrics*, 119(5): 941–946, 2007. 1, 5.1, 6

Dean Spears. Effects of rural sanitation on infant mortality and human capital: Evidence from india's total sanitation campaign, 2012. Princeton. 1

J.H. Stock and M. Yogo. *Testing for weak instruments in linear IV regression*, chapter 5, pages 80–108. Cambridge University Press, 2005. 1

Cebu Study Team et al. A child health production function estimated from longitudinal data. *Journal of development Economics*, 38(2):323–351, 1992. 1

P.E. Todd and K.I. Wolpin. On the specification and estimation of the production function for cognitive achievement. *The Economic Journal*, 113(485):F3–F33, 2003. 2, 4.1

Jorge Ugaz and Arianna Zanolini. Effects of extreme weather shocks during pregnancy and early life on later health outcomes: the case of philippines? typhoons, 2011. 4.1

CesarG Victora, J Patrick Vaughan, Cintia Lombardi, SandraM C Fuchs, LucianaP Gigante, PeterG Smith, LeticiaC Nobre, AnaMariaB Teixeira, LeilaB Moreira, and FernandoC Barros. Evidence for protection by breast-feeding against infant deaths from infectious diseases in brazil. *The Lancet*, 330(8554):319–322, 1987. 1, 5.1, 6

C.G. Victora, M. de Onis, P.C. Hallal, M. Bloessner, and R. Shrimpton. Worldwide timing of growth faltering: Revisiting implications for interventions. *Pediatrics*, 125(3):e473–e480, 2010. 1

A Proofs

A.1 Translog with full history of Endowments

Consider production functions for height and weight at date t[11]

$$H_{it} = H_t\left[\{N_s\}_{s=1}^{t-1}, \{S_s\}_{s=1}^{t-1}, \mu_{i0}, \varepsilon_{it}\right] \tag{6}$$

$$W_{it} = W_t\left[\{N_s\}_{s=1}^{t-1}, \{S_s\}_{s=1}^{t-1}, \mu_{i0}, \varepsilon_{it}\right] \tag{7}$$

where $\{N\}_{t-1}$ is the set of all lagged nutritional inputs, $\{S\}_{t-1}$ all lagged sanitation inputs, μ is the child's initial height endowment and ε is some time varying shock. To estimate this most general form of the height and weight production functions we are going to adapt an approximation of it using a translog estimation. To do this we are assuming that this function is separable in its arguments, smooth, doubly differentiable and continuous. To illustrate the assumptions made to get from (6) and (7) to something estimatable we consider first the translog estimation of the entire function in its exponential form.

$$H_{it} = \left[\alpha_0^h \prod_s^{t-1} N_{is}^{\alpha_{is}^h} \prod_s^{t-1} S_{is}^{\beta_{is}^h} \prod_s^{t-1} N_{is}^{\frac{1}{2}(\sum_j^{t-1} \gamma_{Nsj}^{'} \ln N_{is} + \sum_j^{t-1} \gamma_{Nsj}^h \ln S_{is})} \prod_s^{t-1} S_{is}^{\frac{1}{2}(\sum_j^{t-1} \gamma_{Ssj}^h \ln N_{is} + \sum_j^{t-1} \gamma_{Ssj}^{h'} \ln S_{is})}\right] e^{(\delta_t^h \mathbf{X} + \sigma_t^h \mu_{i0} + \varepsilon_{it})} \tag{8}$$

Taking logs and letting $\alpha_{it}^h = \alpha_t^h \ \forall i$

$$\ln H_t = \alpha_0^h + \sigma_t^h \mu_{i0} + \varepsilon_t + \delta_t^h \mathbf{X} + \alpha_1^h \ln N_1 + ... + \alpha_{t-1}^h \ln N_{t-1} + \beta_1^h \ln S_1 + ... + \beta_{t-1}^h \ln S_{t-1}$$
$$+ \frac{1}{2}(\sum_j^{t-1} \gamma_{Nj1}^{h'} \ln N_j + \sum_j^{t-1} \gamma_{Nj1}^h \ln S_j) \ln N_1 + ... + \frac{1}{2}(\sum_j^{t-1} \gamma_{Njt-1}^{h'} \ln N_j + \sum_s^{t-1} \gamma_{Njt-1}^h \ln S_j) \ln N_{t-1}$$
$$+ \frac{1}{2}(\sum_j^{t-1} \gamma_{Sj1}^h \ln N_j + \sum_j^{t-1} \gamma_{Sj1}^{h'} \ln S_j) \ln S_1 + ... + \frac{1}{2}(\sum_s^{t-1} \gamma_{Sjt-1}^h \ln N_j + \sum_j^{t-1} \gamma_{Sjt-1}^{h'} \ln S_j) \ln S_{t-1}$$

Let $\gamma_{Njs}^{h'} = \gamma_{Sjs}^{h'} = 0$ and $\gamma_{Njs}^h = \gamma_{Sjs}^h = \gamma_{js}^h$ for all s. In practical terms this means we are assuming the effect of the squared logarithmic in each period for each input is zero. The second statement clears up the nomenclature.

[11] This current draft has left out parental preferences and the endogeneity that creates.

$$\ln H_t = \alpha_0^h + \sum_s^{t-1} \alpha_s^h \ln N_s + \sum_s^{t-1} \beta_s^h \ln S_s + \sum_s^{t-1}\sum_j^{t-1} \gamma_{sj}^h \ln N_s \ln S_j + \sigma_t^h \mu_0 + \delta_t^h \mathbf{X} + \varepsilon_t \tag{9}$$

The translog parts of this equation are the same as the taylor series expansion of the underlying production function around its geometric mean. We can follow the exact same procedure for the weight equation to get to the following

$$\ln W_t = \alpha_0^w + \sum_s^{t-1} \alpha_s^w \ln N_s + \sum_s^{t-1} \beta_s^w \ln S_s + \sum_s^{t-1}\sum_j^{t-1} \gamma_{sj}^w \ln N_s \ln S_j + \sigma_t^w \mu_0 + \delta_t^w \mathbf{X} + \varepsilon_t \tag{10}$$

To reduce the number of endogenous variables we make a few further assumptions.
Only contemporaneous interactions between sanitation and nutrition matter. That is: $\gamma_{sj}^i = 0 \; \forall s, j$ where $s \neq j$
For $i \in \{h, w\}$: $\alpha_s^i = \lambda \alpha_{s-1}^i$, $\beta_s^i = \lambda \beta_{s-1}^i$, $\gamma_s^i = \lambda \gamma_{s-1}^i, \sigma_s = \lambda \sigma_{s-1}$. The impact of past inputs follow a monotonic rate of change, λ, which is common across both weight and height. Using assumption 1 and taking the first differences in height and weight to get to the following

$$\Delta \ln H_t = \alpha_{t-1}^h \ln N_{t-1} + \beta_{t-1}^h \ln S_{t-1} + \gamma_{t-1}^h \ln N_{t-1} \ln S_{t-1} + \sum_s^{t-2} (\alpha_s^h - \alpha_{s-1}^h) \ln N_s$$
$$+ \sum_s^{t-2} (\beta_s^h - \beta_{s-1}^h) \ln S_s + \sum_s^{t-2} (\gamma_s^h - \gamma_{s-1}^h) \ln N_s \ln S_s + (\sigma_t^h - \sigma_{t-1}^h)\mu_0 + (\delta_t^h - \delta_{t-1}^h)\mathbf{X} + \varepsilon_t - \varepsilon_{t-1}$$

We can then apply assumption 2 to get to

$$\Delta \ln H_t = \alpha_{t-1}^h \ln N_{t-1} + \beta_{t-1}^h \ln S_{t-1} + \gamma_{t-1}^h \ln N_{t-1} \ln S_{t-1} + (\lambda - 1) \sum_s^{t-2} \alpha_{s-1} \ln N_s$$
$$+ (\lambda - 1) \sum_s^{t-2} \beta_{s-1} \ln S_s + (\lambda - 1) \sum_s^{t-2} \gamma_{s-1} \ln N_s \ln S_s + (\lambda - 1)\sigma_{t-1}^h \mu_0 + (\delta_t^h - \delta_{t-1}^h)\mathbf{X} + \varepsilon_t^h - \varepsilon_{t-1}^h \tag{11}$$

We then make a further assumption about the crossover between the coefficients of inputs on weight and height.

The coefficients of inputs on height are the same as those on weight up to a constant, which is true for all inputs. $\alpha_s^h = a\alpha_s^w$,$\beta_s^h = a\beta_s^w$,$\gamma_s^h = a\gamma_s^w$, $\sigma_s^h = a\sigma_s^w$ where a is some scalar constant.

Taking the difference between (9) and (10) gives us

$$\ln H_{t-1} - \ln W_{t-1} = \alpha^h - \alpha^w + \sum_{s}^{t-2} (\alpha_s^h - \alpha_s^w) \ln N_s + \sum_{s}^{t-2} (\beta_s^h - \beta_s^w) \ln S_s$$
$$+ \sum_{s}^{t-2} (\gamma_s^h - \gamma_s^w) \ln N_s \ln S_s + (\sigma_{t-1}^h - \sigma_{t-1}^w)\mu + (\delta_{t-1}^h - \delta_{t-1}^w)\mathbf{X} + \varepsilon_{t-1}^h - \varepsilon_{t-1}^w$$

Applying assumption 3 to this expression simplifies it to

$$\ln H_{t-1} - \ln W_{t-1} - \alpha^h + \alpha^w - \varepsilon_{t-1}^h + \varepsilon_{t-1}^w - (\delta_{t-1}^h - \delta_{t-1}^w)\mathbf{X} =$$
$$(a-1)\Big[\sum_{s}^{t-2} \alpha_{s-1} \ln N_s + \sum_{s}^{t-2} \beta_{s-1} \ln S_s + \sum_{s}^{t-2} \gamma_{s-1} \ln N_s \ln S_s + \sigma_{t-1}^h \mu_0 \Big]$$

We can then put this back into (11) to get to

$$\Delta \ln H_t = k^h + \alpha_{t-1}^h \ln N_{t-1} + \beta_{t-1}^h \ln S_{t-1} + \gamma_{t-1}^h \ln N_{t-1} \ln S_{t-1} + \frac{\lambda - 1}{a-1} \ln H_{t-1} - \frac{\lambda - 1}{a-1} \ln W_{t-1} + b^h \mathbf{X} + \pi_t^{\Delta h} \tag{12}$$

where
$k^h = \frac{\alpha_h - \alpha_w}{1-a}$
$b^h = \delta_t^h - \delta_{t-1}^h \frac{a}{a-1} + \frac{\delta_{t-1}^w}{a-1}$
$\pi_t^{\Delta h} = \varepsilon_t^h - \varepsilon_{t-1}^h + \frac{\varepsilon_{t-1}^h - \varepsilon_{t-1}^w}{1-a}$

The exact same logic can be applied to the change in weight estimation.

B Additional Tables

B.1 0-6 Month Estimations

Table 20: Breast Feeding dummy

	Translog		Augmented Translog	
	(1) OLS	(2) IV	(3) OLS	(4) IV
Log of previous height	0.5245***	0.5220***	0.5475***	-1.2632
	(0.0148)	(0.0152)	(0.0278)	(1.5526)
Previous Log Weight	0.0720***	0.0710***	0.0716***	0.0952***
	(0.0043)	(0.0080)	(0.0042)	(0.0210)
Was the baby breast fed this period (Dummy)	0.0081**	0.0537	0.1683*	-0.4953
	(0.0035)	(0.0633)	(0.0864)	(3.0518)
WASH score for 0-6 months old using HH characteristics only	0.0130***	0.0747	-0.0595	-10.5285
	(0.0039)	(0.0842)	(0.1004)	(6.9306)
WASH-Nutrition interaction term	-0.0089**	-0.0785	-0.0078*	0.0113
	(0.0041)	(0.0860)	(0.0038)	(0.1310)
Birthweight (kg)	0.0017*	0.0025*	0.0016*	-0.0019
	(0.0009)	(0.0014)	(0.0009)	(0.0033)
Childs gender (1=female)	-0.0063***	-0.0064***	-0.0064***	-0.0023
	(0.0009)	(0.0010)	(0.0009)	(0.0032)
Childs age (months)	-0.0068	-0.0006	-0.0053	-0.0090
	(0.0126)	(0.0162)	(0.0129)	(0.0379)
Childs age squared	0.0004	-0.0003	0.0002	0.0001
	(0.0012)	(0.0016)	(0.0013)	(0.0037)
Fever Dummy	0.0016**	0.0021**	0.0016**	0.0023
	(0.0007)	(0.0009)	(0.0007)	(0.0014)
L.Fever Dummy	0.0002	0.0002	0.0002	-0.0001
	(0.0009)	(0.0011)	(0.0009)	(0.0015)
Diarrhoea dummy	-0.0001	-0.0006	-0.0001	0.0002
	(0.0009)	(0.0010)	(0.0009)	(0.0019)
L.Diarrhoea dummy	-0.0012	-0.0008	-0.0012	-0.0014
	(0.0012)	(0.0012)	(0.0012)	(0.0026)
Nutrition and lagged log height interaction			-0.0395*	0.1157
			(0.0209)	(0.7542)
WASH and lagged log height interaction			0.0176	2.5837
			(0.0244)	(1.6904)
Constant	1.8958***	1.8433***	1.8001***	9.1746
	(0.0581)	(0.1106)	(0.1249)	(6.3836)
Community Controls	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes
Observations	5370	5323	5370	5323
Adjusted R^2	0.743	0.725	0.743	.

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Community controls include municipality dummies, interview month dummies, census population and an urban/rural dummy. Household controls include wealth quintile, age of household head and their education, mother age and education as well controls for the distribution of ages within the household

Table 21: Predominant Breast Feeding

	Translog		Augmented Translog	
	(1)	(2)	(3)	(4)
	OLS	IV	OLS	IV
Log of previous height	0.5245***	0.5224***	0.5430***	-1.3169
	(0.0148)	(0.0161)	(0.0227)	(1.6990)
Previous Log Weight	0.0726***	0.0652***	0.0719***	0.0928***
	(0.0043)	(0.0069)	(0.0041)	(0.0281)
Proportion of time predominantly breastfed since last interview	0.0036**	0.0608*	0.1991**	0.2066
	(0.0016)	(0.0327)	(0.0853)	(3.8409)
WASH score for 0-6 months old using HH characteristics only	0.0067***	0.0349	-0.0245	-11.5564
	(0.0017)	(0.0241)	(0.1035)	(11.0791)
WASH-Nutrition interaction term	-0.0031	-0.0719	-0.0025	-0.0579
	(0.0029)	(0.0447)	(0.0031)	(0.0836)
Birthweight (kg)	0.0016*	0.0023**	0.0016*	-0.0022
	(0.0009)	(0.0010)	(0.0009)	(0.0046)
Childs gender (1=female)	-0.0063***	-0.0072***	-0.0063***	-0.0026
	(0.0009)	(0.0010)	(0.0009)	(0.0048)
Childs age (months)	-0.0064	0.0054	-0.0042	-0.0151
	(0.0121)	(0.0154)	(0.0121)	(0.0538)
Childs age squared	0.0003	-0.0005	0.0001	0.0003
	(0.0012)	(0.0014)	(0.0012)	(0.0052)
Fever Dummy	0.0016**	0.0022***	0.0016**	0.0028
	(0.0007)	(0.0008)	(0.0007)	(0.0020)
L.Fever Dummy	0.0002	0.0004	0.0001	-0.0003
	(0.0010)	(0.0011)	(0.0010)	(0.0026)
Diarrhoea dummy	-0.0001	0.0004	-0.0000	0.0002
	(0.0009)	(0.0010)	(0.0009)	(0.0026)
L.Diarrhoea dummy	-0.0012	-0.0000	-0.0013	-0.0017
	(0.0012)	(0.0013)	(0.0012)	(0.0038)
Nutrition and lagged log height interaction			-0.0482**	-0.0468
			(0.0211)	(0.9464)
WASH and lagged log height interaction			0.0076	2.8475
			(0.0252)	(2.7223)
Constant	1.8999***	1.8496***	1.8203***	9.3877
	(0.0568)	(0.0705)	(0.0942)	(6.9837)
Community Controls	Yes	Yes	Yes	Yes
Household Controls	Yes	Yes	Yes	Yes
Observations	5370	5323	5370	5323
Adjusted R^2	0.743	0.704	0.743	.

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Community controls include municipality dummies, interview month dummies, census population and an urban/rural dummy. Household controls include wealth quintile, age of household head and their education, mother age and education as well controls for the distribution of ages within the household

B.2 Instrument Relevance Tests

B.2.1 6 - 24 months

Pooled Sample

Table 22: F-tests for calorie intake regression, pooled sample

	R sq	Adj R sq	Part R sq	Robust F
prevlogweight_logprevpro	0.50	0.49	0.01	24.29
prevlogweight_lWASH_6_24HH	0.52	0.52	0.03	37.11
logprevpro_lWASH_6_24HH	0.30	0.30	0.02	15.31
lWASH_6_24HH	0.52	0.52	0.03	33.52
logprevcal	0.45	0.45	0.01	37.61

Table 23: F-tests for protein intake regression, pooled sample

	R sq	Adj R sq	Part R sq	Robust F
prevlogweight_logprevpro	0.50	0.49	0.01	25.40
prevlogweight_lWASH_6_24HH	0.52	0.52	0.03	42.59
logprevpro_lWASH_6_24HH	0.30	0.30	0.02	17.07
lWASH_6_24HH	0.52	0.52	0.03	37.15
logprevpro	0.43	0.42	0.01	29.05

Boys

Table 24: F-tests for calorie intake regression, males

	R sq	Adj R sq	Part R sq	Robust F
prevlogweight_logprevpro	0.50	0.50	0.01	46.35
prevlogweight_lWASH_6_24HH	0.53	0.52	0.04	12.89
logprevpro_lWASH_6_24HH	0.32	0.32	0.02	12.35
lWASH_6_24HH	0.53	0.53	0.03	10.53
logprevcal	0.46	0.46	0.01	28.05

Table 25: F-tests for protein intake regression, males

	R sq	Adj R sq	Part R sq	Robust F
prevlogweight_logprevpro	0.50	0.50	0.01	52.20
prevlogweight_lWASH_6_24HH	0.53	0.52	0.04	13.75
logprevpro_lWASH_6_24HH	0.32	0.32	0.02	12.36
lWASH_6_24HH	0.53	0.53	0.03	10.48
logprevpro	0.43	0.43	0.01	64.76

Girls

Table 26: F-tests for calorie intake regression, females

	R sq	Adj R sq	Part R sq	Robust F
prevlogweight_logprevpro	0.49	0.48	0.01	18.59
prevlogweight_lWASH_6_24HH	0.52	0.52	0.02	9.38
logprevpro_lWASH_6_24HH	0.30	0.29	0.02	11.74
lWASH_6_24HH	0.52	0.52	0.02	11.25
logprevcal	0.44	0.44	0.01	32.24

Table 27: F-tests for protein intake regression, females

	R sq	Adj R sq	Part R sq	Robust F
prevlogweight_logprevpro	0.49	0.48	0.01	20.30
prevlogweight_lWASH_6_24HH	0.52	0.52	0.02	8.38
logprevpro_lWASH_6_24HH	0.30	0.29	0.02	12.79
lWASH_6_24HH	0.52	0.52	0.02	10.31
logprevpro	0.42	0.42	0.01	18.65

B.2.2 0 - 6 months

Table 28: Breast Feeding Dummy

	R sq	Adj R sq	Part R sq	Robust F
Previous height - Nutriton Interaction	0.12	0.11	0.02	9.24
Previous height - Sanitation Interaction	0.50	0.49	0.05	10.47
Nutrition - Sanitation Interaction	0.18	0.17	0.03	18.46
Sanitation	0.49	0.49	0.05	10.50
Breast Feeding Dummy	0.12	0.11	0.02	9.11

Table 29: Proportion of time predominantly breastfed

	R sq	Adj R sq	Part R sq	Robust F
Previous height - Nutriton Interaction	0.33	0.32	0.01	6.48
Previous height - Sanitation Interaction	0.49	0.49	0.05	12.18
Nutrition - Sanitation Interaction	0.28	0.27	0.02	9.63
Sanitation	0.49	0.48	0.05	12.24
Proportion of time predominantly breastfed	0.33	0.33	0.01	6.57

B.3 Attrition

We document the extent of attrition over the sample period. The table shows the causes of sample loss over the panel rounds, by urban and rural barangays.

The table below displays the characteristics of those who attrited and those who stayed in the sample. Across almost all of the baseline characteristics described, attributed and non-attrited children are not statistically significantly different. There are however some notable exclusions to this rule, the most obvious being home ownership. That attrited mothers are significantly less likely to own the home they lived in during the baseline survey is hardly a surprise; home ownership is likely to make mothers less mobile and therefore more likely to stay in the survey. That attrited mothers are also significantly younger is again possibly a function of younger mothers being more able or willing to move out of the survey area.

Table 30: Attrited vs Non-Attrited Samples

	Mean		
Variable	Not Attrited	Attrited	p value
Household and Barangay Characteristics			
Percentage of Households in Urban Barangay	0.754	0.813	0.809
	(.113)	(.214)	
Distance to nearest public hospital, km	5.92	5.392	0.849
	(1.29)	(2.44)	
Age of household head	35.519	34.738	0.427
	(.456)	(.863)	
Percentage of household heads in employment	0.947	0.933	0.509
	(.009)	(.018)	
Heads years of education	7.268	7.71	0.662
	(.469)	(.889)	
Proportion of households with safe toilets	0.65	0.752	0.517
	(.073)	(.139)	
Proportion of households with pumped/piped water	0.48	0.462	0.911
	(.074)	(.14)	
Home made of concrete, (1=Yes)	0.18	0.18	0.996
	(.025)	(.047)	
Household head is female	0.063	0.07	0.662
	(.008)	(.016)	
Number of household members	5.64	5.321	0.136
	(.099)	(.187)	
Home ownership	0.691	0.486	0.074
	(.053)	(.1)	

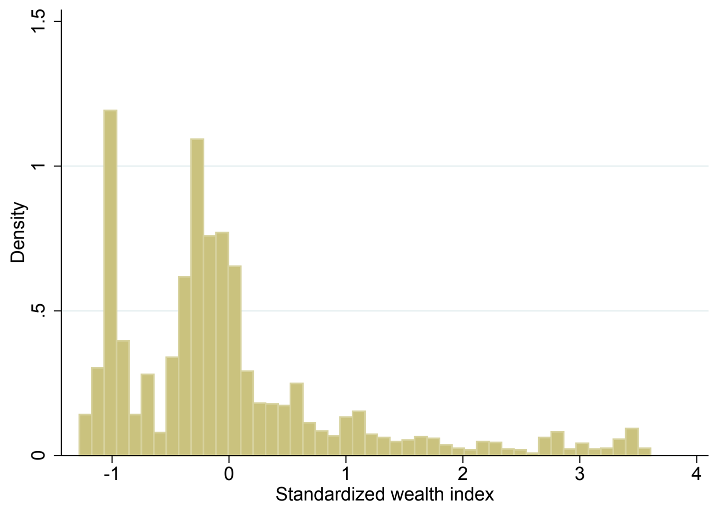
Continued from previous page

Variable	Not Attrited	Attrited	p value
Households own a refrigerator, (1=Yes)	0.067	0.07	0.892
	(.011)	(.022)	
Household owns benches/chairs, (1=Yes)	0.704	0.652	0.202
	(.023)	(.033)	
Household has electric lighting (1=Yes)	0.484	0.528	0.7
	(.065)	(.094)	
Mothers Characteristics			
Years of education	7.484	7.868	0.65
	(.394)	(.745)	
Head/Spouse of head	0.777	0.764	0.72
	(.017)	(.032)	
Age	26.827	26.503	0.509
	(.201)	(.445)	
Number of children under 5	1.233	1.074	0.08
	(.042)	(.079)	
Pregnancy at least part covered by insurance, (1=Yes)	0.101	0.102	0.99
	(.012)	(.024)	
Percentage of mothers working during pregnancy	0.376	0.325	0.337
	(.025)	(.046)	
Child Birth Characteristics			
Child Gender, (1=Female)	0.473	0.449	0.54
	(.016)	(.036)	
Child Birth Weight, g	3045.19	2957.08	0.237
	(29.221)	(-67.713)	
Child Birth Height, cm	49.252	49.218	0.881
	(.093)	(.205)	

B.4 Wealth Index

Like most other surveys in developing countries the CHLNS provides very detailed information on household assets, and it is necessary to reduce the dimensionality of the wealth information provided to create a wealth index which captures the underlying socio-economic status of the household. To do this we use a polychoric principle component analysis, following the approach laid out in Kolenikov and Angeles [2009]. This allowed us to construct a wealth index combining continuous, categorical and discrete variables to estimate the underlying wealth factor for each household without violating any assumptions of normality or the loss of information associated with a standard PCA approach.

Figure 2: Wealth Distribution



Discrete variables on furniture ownership (cupboards, benches, tables etc), electrical appliances (electric fans, refrigerators, televisions, radios) and home ownership are used with categorical variables such as light source and cooking fuel type to construct the wealth index score, the standardized distribution of which is shown below. The first principle component in this analysis explains around 73% of the variation in these variables. The scree plot for this analysis is shown below. This standardized wealth score is then broken into 5 evenly populated quintiles for use in later stages of the analysis.

B.5 Determinants of Breastfeeding

Table 31: Linear Probability model for if the child is breastfed

	(1)	(2)	(3)	(4)
Mother is ill at time of survey	-0.0082	-0.011	-0.0092	-0.010
	(0.0062)	(0.0062)	(0.0061)	(0.0063)
Mother is employed	0.015	0.0037	0.0018	-0.0015
	(0.011)	(0.010)	(0.0099)	(0.010)
Mother is pregnant again	-0.26***	-0.26***	-0.26***	-0.26***
	(0.0091)	(0.0095)	(0.0096)	(0.0095)
Gender, 1=Female	0.020	0.024*	0.023	0.023
	(0.011)	(0.011)	(0.012)	(0.012)
Child Age, months	-0.18***	-0.19***	-0.19***	-0.19***
	(0.041)	(0.042)	(0.042)	(0.041)
Child Age squared	0.0039**	0.0042**	0.0041**	0.0041**
	(0.0012)	(0.0012)	(0.0012)	(0.0012)
Diarrhea dummy	-0.031**	-0.031**	-0.029**	-0.029**
	(0.0089)	(0.0091)	(0.0090)	(0.0093)
Child born prematurely	0.0017	-0.00045	0.0026	0.00085
	(0.016)	(0.016)	(0.016)	(0.016)
Mothers first child	-0.087***	-0.080*	-0.085**	-0.093**
	(0.016)	(0.030)	(0.031)	(0.030)
Hours mother worked in the last week	-0.0021***	-0.0019***	-0.0018***	-0.0017***
	(0.00024)	(0.00023)	(0.00024)	(0.00024)
1980 census population of barangay			-0.0050	
			(0.013)	
Urban/Rural Barangay (Urban=1)			-0.037	
			(0.035)	
Average wealth score in barangay			-0.22*	
			(0.096)	
Distance to store which sells formula milk, km			-0.00065	
			(0.00041)	
Munincipality Fixed Effect	No	No	Yes	No
Household Controls	No	Yes	Yes	Yes
Individual Controls	Yes	Yes	Yes	Yes
Barangay fixed effects	No	No	No	Yes
Observations	21168	21128	21128	21128
R^2	0.4463	0.4585	0.4610	0.4636
Adjusted R^2	0.445	0.457	0.459	0.462

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Household controls include wealth quintile, age of household head and their education, mother age and education, controls for the distribution of ages within the household as well as the number of existing children the mother has. Individual controls include birth-weight, child height, mothers age and education.