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**MASTERS
MINOR
DISSERTATION**

**THE COMPLEX DETERMINANTS OF
CHILDHOOD NUTRITIONAL STATUS AND
UNDERNUTRITION IN SOUTH AFRICA**

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Introduction

I adopt two approaches in estimating a childhood nutrition model. In the first, child nutrition enters as a continuous dependent variable, allowing me to estimate the average marginal effects on childhood nutrition (proxied by three anthropometric measures). The second approach allows me to estimate how the probability of being undernourished changes with variations in the explanatory variables, making use of a limited dependent variable approach – after converting child anthropometry into a binary variable indicating whether or not the child is undernourished.

The ultimate purpose of this exercise is to inform those involved in the design of nutrition policy in South Africa as in what measures can be expected to be most effective. In addition, I intend to make interested researchers aware of the complexities involved in an attempt to promote more accurate studies that will serve to further refine child nutrition policy.

The rest of this paper is devoted to this dual task. First, I motivate the importance of policy designed specifically to target childhood nutrition. I then proceed to discuss the types of factors that influence childhood nutritional status, which provides the rationale for the structural model, analysed in the following section. I test the relative strength of specific variables on childhood nutrition in an analysis of South African survey data. The final section concludes with some recommendations based on the paper's findings.

The need to thinking critically about child nutrition policy

Apart from social, political and ethical motives for improving child nutrition, there is also a powerful economic rationale behind doing so, with which this section is concerned. There is a large body of evidence in support of the notion that levels of childhood nutrition have significant impact on lifetime human capital accumulation. Studies have shown that, all else equal, undernourished children tend to start school later (Alderman et al. 1995; Glewwe et al. 2001; Yamauchi 2008), attain a lower level of schooling (Maluccio et al. 2009; Victora et al. 2008; Yamauchi 2008; Luzi 2010), are more likely to repeat grades (Yamauchi 2008), and perform worse academically, with inferior levels of cognitive development (Pollitt et al. 1993; J. A. Maluccio et al. 2009; Glewwe et al. 2001; Janet Currie 2008; Laus et al. 2011).

The link between an individual's human capital accumulation and her earning potential is well-documented. Better nourished children tend to earn significantly more than their undernourished peers (Hoddinott et al. 2008). Alderman (1995) estimated that if the median Zimbabwean pre-school child in his sample had the nutritional status of the median child in a developed country, he would

have started school six months earlier and completed, on average, an additional 0.85 grades of schooling. The median Zimbabwean child would earn approximately 14% less as a result of this nutrition gap. Glewwe et al. (2001) estimated that a \$1 investment in the early childhood nutrition of Filipinos would result in at least \$3-worth of academic achievement in terms of additional lifetime earnings.

One's nutritional status during childhood tends to have a powerful impact on one's health in later life (Victora et al. 2008). Subsequently, undernutrition can place long-term indirect strain on the public health system through its tendency to yield a higher proportion of unhealthy adolescents and adults. Unhealthy workers are also likely to be less productive and more likely to take off work due to illness. A popular theory is that there exists a nutrition-based 'poverty-trap' whereby people find it impossible to escape from poverty, unable to earn a sustainable living due to lack of energy. This implies a *catch-22* – the poor may be unable to earn enough unless they can become better nourished. But to be able to afford to consume enough nutrients, they need to first earn more (Sachs 2010).

The economic importance of improving childhood nutrition is widely accepted. This fact on its own motivates why governments should be cognisant of the ways in which their policies subsequently affect it. There are, in addition, powerful reasons for implementing *direct* policy interventions – 'nutrition policy' – aimed at tackling the issue. At first glance, for instance, the solution appears simple: aim at improving average household income (high on the list of developing countries anyway) and the nutrition of children therein will take care of itself. However, there is a tenuous link between incomes, whether measured in household or national terms, and undernutrition. Banerjee and Duflo (2011) point out that, even among the poorest of households, when household incomes increase, spending on food typically does not increase commensurately. Moreover, additional food that *is* purchased is not generally more nutritious but instead tends to be better-tasting. Thus income-calorie elasticities are typically below unity.

The motivation behind this paper is thus comprised of two facets: (1) childhood undernutrition has significant economic ramifications for individuals and society. (2) Undernutrition is not merely a symptom of insufficient income – its causes are more complex – so economic growth alone is realistically not sufficient to solve it. What is more, there might be an income-nutrition cycle that traps people in poverty. Given that developing countries face severe economic constraints, these facts make a strong case for critically analysing what aspects appear *most* effective in reducing undernutrition.

The underlying causes of child undernutrition

Undernutrition is ultimately the result of insufficient nutrients having been processed by the body. According to UNICEF (1990), this has 3 underlying causes:

- (i) Inadequate availability of nutrients from food – either due to too little food or the available food containing insufficient nutrients. Not only the quantity important, but also the quality of the food, and the balance of diet, available to the child (de Pee et al. 2010). A child requires a proper mix of the appropriate nutrients to develop healthily.
- (ii) The health of the child (which is determined by the environment and access to health care). Once nutrients are attained through food consumption, they need to be retained by the body and absorbed. Health status is critical in this regard. Diarrhea and intestinal worms are major culprits in robbing the body of nutrients that might have been consumed (Banerjee & Duflo 2011). There are many other health-related factors that prevent the body from processing available nutrients (Sivakumar et al. 2006; Babu & Sanyal 2009), including respiratory conditions.
- (iii) The quality of care that the child receives. The two abovementioned factors interact with the caregivers' ability to use effectively the available resources (Benson & Shikar 2006). This includes knowledge of appropriate dietary mix, how long a child is breastfed, and hygienic practices.

Empirical analysis for South Africa

I present here an empirical analysis in which I attempt to estimate the importance of the relevant determinants of child undernutrition in the South African context. The study is based on version 3 of the 2008 South African *National Income Dynamics Study* (NIDS) dataset. The dataset combines individual and household level variables in a large, nationally representative cross-section of the population.

Variable descriptions

Anthropometric measures

There are several accepted indicators of nutritional status. Consistent with common econometric practise, I make use of child anthropometry (Trapp & Menken 2005) – specifically, Z-scores of

height¹ for age (HAZ), *weight for age* (WAZ), and *weight for height* (WHZ). These variables can be found in the NIDS dataset, calculated in accordance with the latest WHO international standards and practices for children and adolescents (WHO Multicentre Growth Reference Study Group 2006; WHO Multicentre Growth Reference Study Group 2012). They indicate how far away from the mean an individual's anthropometric measurement lies. A HAZ of -1, for instance, indicates that an individual's height, given his age and gender, is one standard deviation below the population reference mean. Undernutrition is defined as having a HAZ, WAZ or WHZ of -2 or below. This implies that whether one is considered undernourished depends on the population adopted as the reference. The World Health Organisation provides international growth standards for consistent identification of undernutrition. Based on a representative population of children and adolescents of various backgrounds from across the world, they are considered objective references (WHO Multicentre Growth Reference Study Group 2012; Onis et al. 2007). The strength of the internationally representative sample lies in the fact that, contrary to popular belief, healthy humans develop similarly in terms of height and body mass, given their age and gender, despite their ethnic origins (Banerjee & Esther Duflo 2011).

Each indicator tells a different story and is more appropriate in some contexts than others (Cogill 2001). Height for age is persistent and thus an appropriate indication of long-term nutritional status, or past (chronic) undernutrition, and defines 'stunting'. It does not tend to change in the short term in response to changes in food intake or environmental factors and may be irreversible in children over two years of age. It is thus considered a 'stock' variable and not appropriate in assessing the short-term effects of an intervention. Weight for height does tend to vary rapidly in the short-term with nutritional inputs and is thus a useful measure of present nutritional status or acute undernutrition – defined as 'wasting'. Although considered a 'flow' variable, it is not appropriate in dynamic studies because it is highly susceptible to seasonal effects. Weight for age may reflect both acute and chronic undernutrition but cannot distinguish between the two. Defining 'underweight', it is an appropriate measure for changes in nutrition over time.

Variables at the cluster level

Dummy variables are included to control for province (with Western Cape the base) and geographical type (Tribal Authority Area, formal urban area, and informal urban area) compared to the base category (formal rural area).

¹ Technically speaking, the term 'length' is used for infants aged 0-24 months

Variables at the household level

Total per member household expenditure is used to proxy income (John Strauss & Duncan Thomas 1995). Expenditure is less prone to random measurement errors, which tend to result in a downward bias in the estimates (Bouis & Haddad 1992). In addition, it is expected to be less volatile than income and thus likely to provide a better representation of long-term household wealth or 'permanent income' (Bassolé 2007). Such a measure is more appropriate since the complex nature of nutrition suggests that it is a function of household income since the child's birth – even when measuring short-term nutritional outcomes. This variable is included in logarithmic form because I assume that the marginal effect of an income change on child nutrition is non-linear, probably decreasing with rising income.

Babu and Sanyal (2009) show that food security, or access to adequate food, can be a significant determinant of child nutrition. To capture this effect, I include a dummy variable that takes the value 1 for households that indicated experiencing 'less than adequate' food consumption. I include a variable which represents the number of children in the household. Additional children increase pressure on household resources (Horton 1986) and there might consequently be a trade-off between family size and health quality of each child (Åslund & Grönqvist 2010).

I include a set of dummy variables for infrastructure that may impact child nutrition – indicating whether the household has access to a flush or chemical toilet; whether rubbish or refuse is removed; whether households reported available healthcare to meet sufficiently household needs; and whether the household's main source of drinking water is 'protected' (coming either directly from a tap or from a rain water tank, well or spring). These variables are of interest because of the strong relationship between malnutrition and illnesses, such as diarrhea, that can be contracted from unsanitary conditions and poor health care.

Variables at the level of the child

Dummies are included to account for different patterns of nutrition by age – something that the literature consistently finds (Babu & Sanyal 2009). This may be the result of time-varying factors, not captured by the model, that have wide-ranging impacts on the determinants of nutrition, since the development of young children is extremely sensitive to environmental factors and early-life nutritional status tends to be persistent over the child's life. Similarly, there tends to be differences by child gender (Sakisaka et al. 2006), for which a dummy is also included. These may be explained in part by biological factors but might also reflect gender bias on the part of their care-givers. Duflo (2000) found this to be the case in South Africa. Only female grandchildren benefitted when female

household members became pension-eligible (an instrument for pension receipt). This result was subsequently confirmed by Ambler (2010) using more recent data for the same country.

The child's mother's highest level of education is captured by a set of dummies for having attended primary school, secondary school, or a tertiary institution. Parental, and specifically maternal, education continually crops up in the literature as an important determinant of child nutrition (Luzi 2010). In most cases, it is difficult to say whether education *causes* parents' behaviour to change in such a way that their children become better nourished or whether there is something about people, unobserved or unobservable, who tend to be better educated that also makes them better at providing their children with nutrition. In theory, there are channels through which education could be driving the outcome. Education might give parents the cognitive tools to care more effectively for their children, given the level and quality of health goods available, and to make more efficient use of their economic resources (Schultz 1984). There is conceivably a more direct and obvious role for education to the extent that the syllabus includes education on nutrition or encourages healthy practices, such as hand-washing, that are also associated with better nutrition. Not much research appears to exist on the subject of causality, but a study comparing biological and adopted children in China found post-natal effects – education was associated with something that mothers did *after* children were born (Chen & Li 2009). Using college availability as an instrumental variable, Currie and Moretti (2003) found education to have a significant causal effect on child nutritional status. Barrera (1990) found that children of less educated mothers benefitted more from a cleaner environment and protected water than those of educated mothers. The opposite trend was found in the case of access to health care and toilet facilities. This suggests that maternal education effects health by increasing the productivity of health inputs and lowering the cost of information (Babu & Sanyal 2009). Education probably does not have a linear influence, however, with its marginal importance dissipating as household education increases (Webb & Block 2004).

On the other hand, education might also be a proxy for parents' ability to make use of information regarding caring practices and health services for the child (Haddad et al. 2003) or for some unobserved characteristic, such as 'propensity for responsibility'. In other words, parents who are better at assimilating information and are more responsible might, on average, attain a higher level of schooling. If these factors drive child nutritional outcomes then education might be a 'mediating variable' (Lockwood et al. 2010). There is also an intra-household bargaining interpretation of education, in which it serves to enhance one parent's bargaining power relative to the other (Sahn & Stifel 2002). This is important to the extent that gender differences influence child nutrition.

I also include a variable that indicates whether the child was born in a hospital and a continuous variable of mothers' height. The 'Barker Hypothesis' (De Boo & Harding 2006; Barker 1997) states that factors affecting a child in utero can impact on its later-life development. This is generally captured in the literature by birth-weight (Bomela 2009), a measure not available in the NIDS 2008 dataset. I follow Alderman and Garcia (1994) in employing whether a child was born in a hospital as a crude proxy for health at birth and a correlate of prenatal care. Mother's height is also used as an indicator of development in the womb and genetic endowment, an approach followed by Haddad et al. (2003). There is also a technical reason necessitating the inclusion of this variable. A mother's nutritional status, which is reflected in her height, is likely correlated with both income and the nutritional status of her child (Banerjee & Esther Duflo 2011). Thus leaving this term out would lead to omitted variable bias (Wooldridge 2001).

Empirical specification

I estimate the structural model by OLS, making use of two different empirical specifications. The first adopts the dependent variable as a continuous measure of child nutritional status (anthropometric Z-score). The second is adapted for a limited dependent variable specification in which nutritional status is coded as a binary variable – indicating whether the child is undernourished or not. I estimate how the probability of being undernourished varies with changes in the explanatory variables, *ceteris paribus*, using a linear probability model (LPM) and a logit model, respectively. The continuous variable approach tells us how child nutritional status changes with the independent variables, regardless of whether the child is undernourished. The second tells us what factors contribute to the probability of being undernourished specifically. I regress each of these 3 models on the 3 respective nutritional indicators – HAZ, WAZ, and WHZ.

In each case, I use sampling weights recommended by NIDS and cluster by primary sampling unit. Failure to do so can result in misleadingly small standard errors and thus falsely precise estimates (Bertrand et al. 2002). This is due to the assumed high correlation between residuals of observations drawn from households in the same primary sampling unit (Bassolé 2007). My estimation method takes account of the two-stage design of the sampling process and should yield robust standard errors.

Descriptive statistics

HAZ is available for children and adolescents aged 0-15 years, WAZ for children 0-10 years, and WHZ for those aged 5 years and younger. As a result, the number of observations in each model is

dependent on which is used. Valid Z-scores and non-missing dependant variables exist for 4272 children in the first cohort, 2876 in the second, and 1234 in the third. Approximately 19% of children are stunted, 10% underweight, and 5% wasted. Looking at the histograms for each, broken down by age-group, we can see that in most cases the Z-scores are approximately normally distributed (Appendix A). Notable exceptions are the 15 year age-group for HAZ and the 5 year age-group for WHZ. This is not surprising, given the small number of observations in each of these categories (10 in the former and 1 in the latter). Over all age groups, the average height for age is 0.93 standard deviations below the mean; the average weight for age is 0.31 standard deviations below; and weight for height 0.49 standard deviations above.

Where mothers are absent, I use fathers' data as a proxy. For the total sample with non-missing data (for children up to 15), this is the case for 75 observations. There is a higher proportion of absent mothers in the total sample but those with non-missing data necessarily have resident mothers or fathers. Turning to the dummy variables, about 80% of children were born in hospitals, although only 55% were from households that reported having sufficient health care. Rubbish removal and access to a water or chemical toilet are available for only 40% of children. Most of the children (87%) in the sample have access to a protected source for their main supply of drinking water. This appears high but is confirmed by a recent Statistics South Africa (Statistics South Africa 2011) household survey, which states that 89.3% of households have access to piped water. Households reported not having adequate food for the members' needs for 44% of the children in the sample.

Results

The regression output is reproduced in Table 1. Since each anthropometric indicator measures different aspects of nutrition, I present the results and my interpretations accordingly. Regarding the limited dependent variables model, I estimate both by logit and LPM to allow for comparison and robustness checks.

Long-term indicator: HAZ and chronic undernutrition (stunting)

Income per household member (proxied here by expenditure) does not appear to significantly affect either HAZ or the probability of stunting *when the other factors in the model are controlled for*. This is not to say that wealthier people will not tend to have better-nourished children. However, when controlling for other factors that are associated with both HAZ and income, it does not appear to matter. Children of mothers who have attended tertiary education are on average 0.95 ($p < 0.01$) standard deviations taller than their peers. The existence of a flush or chemical toilet significantly increases HAZ by an average of 0.3 standard deviations ($p < 0.01$) and decreases the chance of child

stunting by approximately 5 percentage points ($p < 0.1$). Children born in a hospital are about 0.18 ($p < 0.05$) standard deviations taller for their age on average than those who were not but do not appear to be less likely to suffer from chronic undernutrition.

Female children are on average 0.11 ($p < 0.1$) points better off than male children but are no more likely to be stunted. Compared to children less than 1 year of age, those aged 1-4 are more likely to suffer from chronic undernutrition and have lower average HAZ measures. Some of the provincial dummies are significant. For instance, compared to children living in the Western Cape, those living in the Eastern Cape and the Free State have heights 0.67 standard deviations lower for their age ($p < 0.01$). Compared to living in a formal rural area, living in a Tribal Authority Area (TAA) is associated with an approximate 6.5 percentage point decrease in the chance of wasting ($p < 0.1$) according to the logit model (although the LPM finds this statistically insignificant), with a HAZ 0.34 points higher on average ($p < 0.05$).

The signs on the abovementioned variables are as we would expect. However, puzzlingly, food insecurity is significantly, but negatively, associated with stunting ($p < 0.05$) – children from households reporting insufficient food availability are approximately 3.5 percentage points *less* likely to suffer from chronic undernutrition. Also confusing is the finding that mothers who have at least some level of primary school education are significantly *more likely* ($p < 0.05$) to have stunted children compared to those who have no education.

Short-term indicator: WHZ and acute undernutrition (wasting)

An additional R1% of per-household member income is associated with a 0.00227 standard deviation increase in WHZ. Although this result is *statistically* significant ($p < 0.05$), it is probably not economically so – doubling income would result in a 0.227 standard deviation increase in WHZ. A child's mother having attended primary education is associated with a 4.4 percentage point ($p < 0.1$) reduction in the chance of wasting but only in the logit model. Secondary education is significant across all models. Mothers who attend secondary school have children who have WHZ measures on average 0.5 points higher than their peers who do not. The LPM and logit models both report significant marginal effects ($p < 0.05$) but while the LPM estimates a 12.5 percentage point average decrease in the chance of wasting, the logit reports 7.6 percentage points. Households complaining of inadequate healthcare have children who are on average 0.28 standard deviations lighter for their age and about 3 percentage points more likely to be underweight ($p < 0.1$ according to the logit and $p = 0.107$ in the LPM case).

Table 1: Regression output

VARIABLES	HAZ			WHZ			WAZ		
	OLS	LPM	Logit	OLS	LPM	Logit	OLS	LPM	Logit
Household expenditure per capita (log)	-0.0301	-0.00212	-0.00401	0.227**	-0.0137	-0.0148	0.116*	-0.00125	-0.00143
	[0.0565]	[0.0105]	[0.0108]	[0.103]	[0.0173]	[0.0141]	[0.0667]	[0.0116]	[0.0125]
Inadequate food	0.0623	-0.0356**	-0.0368**	0.0186	0.0224	0.0226	0.108	-0.0272	-0.0264
	[0.0819]	[0.0161]	[0.0164]	[0.132]	[0.0182]	[0.0171]	[0.0828]	[0.0179]	[0.0173]
Mother's height	0.0263***	-0.00521***	-0.00453***	0.00681	0.000210	7.20e-05	0.0140***	-0.00121	-0.000937
	[0.00569]	[0.00133]	[0.00142]	[0.00597]	[0.000792]	[0.000995]	[0.00500]	[0.000959]	[0.000710]
Flush or chemical toilet	0.296***	-0.0533*	-0.0494*	-0.0455	0.0208	0.0147	0.235	-0.0610**	-0.0519**
	[0.0988]	[0.0281]	[0.0261]	[0.199]	[0.0232]	[0.0223]	[0.144]	[0.0296]	[0.0263]
Child born in hospital	0.178**	-0.0102	-0.0110	-0.131	0.0194	0.0201	0.0250	0.00673	0.00456
	[0.0731]	[0.0171]	[0.0157]	[0.134]	[0.0193]	[0.0209]	[0.0835]	[0.0212]	[0.0195]
Unprotected water source	0.0344	-0.0429	-0.0419	-0.0131	-0.0241	-0.0287	-0.145	-0.0269	-0.0229
	[0.111]	[0.0307]	[0.0274]	[0.205]	[0.0202]	[0.0277]	[0.125]	[0.0255]	[0.0254]
Inadequate health care	-0.0160	0.0302*	0.0282	-0.282**	0.0308	0.0323*	-0.315***	0.0481**	0.0445**
	[0.0835]	[0.0179]	[0.0175]	[0.134]	[0.0190]	[0.0188]	[0.105]	[0.0203]	[0.0187]
Rubbish is removed	0.165	-0.0415	-0.0402	0.0770	-0.0211	-0.0276	0.290	-0.0503	-0.0486
	[0.123]	[0.0332]	[0.0308]	[0.237]	[0.0368]	[0.0270]	[0.178]	[0.0398]	[0.0348]
Child is male	-0.106*	0.0167	0.0155	0.234**	-0.0128	-0.0157	-0.104	0.00653	0.00742
	[0.0581]	[0.0144]	[0.0144]	[0.105]	[0.0168]	[0.0180]	[0.0678]	[0.0154]	[0.0155]
Maternal education									
Primary education	-0.101	0.0651**	0.0583**	0.335	-0.0820	-0.0441*	0.00771	0.0172	0.0135
	[0.113]	[0.0314]	[0.0284]	[0.286]	[0.0562]	[0.0251]	[0.147]	[0.0344]	[0.0264]
Secondary education	0.0253	0.0277	0.0251	0.498**	-0.125**	-0.0764***	0.0708	-0.0282	-0.0250
	[0.0917]	[0.0257]	[0.0252]	[0.228]	[0.0490]	[0.0231]	[0.126]	[0.0299]	[0.0245]
Tertiary education	0.940***	-0.0737	-0.147	-0.202	-0.133**		0.462	-0.0810**	
	[0.353]	[0.0475]	[0.0971]	[0.392]	[0.0550]		[0.331]	[0.0355]	
Child age (years)									
1	-0.728**	0.156***	0.149***	0.167	-0.0173	-0.0146	-0.280	-0.0212	-0.0254
	[0.352]	[0.0491]	[0.0482]	[0.227]	[0.0402]	[0.0414]	[0.228]	[0.0398]	[0.0437]
2	-1.275***	0.132**	0.130**	0.198	-0.0711**	-0.0671*	-0.550**	-0.0160	-0.0165
	[0.292]	[0.0535]	[0.0523]	[0.194]	[0.0349]	[0.0344]	[0.229]	[0.0417]	[0.0450]
3	-1.106***	0.153***	0.149***	0.0684	-0.0349	-0.0274	-0.522**	0.00765	0.00591
	[0.308]	[0.0515]	[0.0508]	[0.202]	[0.0363]	[0.0408]	[0.244]	[0.0439]	[0.0468]
4	-0.940***	0.0431	0.0345	-0.126	-0.0477	-0.0422	-0.585**	-0.00767	-0.00798
	[0.308]	[0.0456]	[0.0444]	[0.196]	[0.0350]	[0.0364]	[0.244]	[0.0409]	[0.0432]
5	-0.745**	-0.0244	-0.0292	0.0264	-0.0697		-0.533**	-0.0260	-0.0289
	[0.315]	[0.0452]	[0.0446]	[0.252]	[0.0463]		[0.253]	[0.0387]	[0.0419]
6	-0.685**	-0.00621	-0.00890				-0.682***	0.0264	0.0253
	[0.307]	[0.0508]	[0.0501]				[0.235]	[0.0477]	[0.0505]
7	-0.571*	0.0217	0.0159				-0.705***	0.0340	0.0332
	[0.296]	[0.0473]	[0.0473]				[0.203]	[0.0299]	[0.0327]
8	-0.624**	-0.0203	-0.0291				-0.583***	-0.00198	-0.00163
	[0.297]	[0.0417]	[0.0415]				[0.207]	[0.0384]	[0.0419]
9	-0.689**	-0.0562	-0.0521				-0.872***	0.0256	0.0244
	[0.292]	[0.0392]	[0.0387]				[0.227]	[0.0441]	[0.0470]
10	-0.810**	-0.0146	-0.0202				-0.643**	0.0308	0.0222
	[0.321]	[0.0508]	[0.0496]				[0.263]	[0.0582]	[0.0645]

11	-0.700**	-0.0141	-0.0186						
	[0.283]	[0.0420]	[0.0425]						
12	-0.922***	0.0808	0.0742						
	[0.333]	[0.0507]	[0.0500]						
13	-0.775**	0.00805	0.00484						
	[0.308]	[0.0471]	[0.0462]						
14	-1.040***	0.0398	0.0377						
	[0.258]	[0.0540]	[0.0533]						
15	-1.548***	0.0507	0.0480						
	[0.385]	[0.136]	[0.116]						
Race									
African	-0.430*	-0.0339	-0.00622	0.147	0.00663	-0.0113	-0.236	0.0475	0.158*
	[0.244]	[0.0406]	[0.0713]	[0.493]	[0.0512]	[0.0697]	[0.194]	[0.0331]	[0.0948]
Coloured	-0.858***	0.0564	0.0841	-0.0871	-0.0457	-0.0825	-0.0702	0.0637	0.168*
	[0.205]	[0.0552]	[0.0782]	[0.430]	[0.0341]	[0.0640]	[0.284]	[0.0410]	[0.0936]
Asian or Indian	-0.0974	-0.120***	-0.128	-0.898*	0.000431		-0.854***	0.111**	0.214**
	[0.263]	[0.0455]	[0.0856]	[0.515]	[0.0544]		[0.225]	[0.0516]	[0.101]
Geographical type									
Tribal	0.342**	-0.0628	-0.0645*	0.0739	-0.00829	-0.0158	0.332**	-0.0561*	-0.0435*
	[0.174]	[0.0386]	[0.0332]	[0.207]	[0.0331]	[0.0290]	[0.142]	[0.0315]	[0.0231]
Urban Formal	0.0708	-0.0460	-0.0511	-0.278	0.0340	0.0333	-0.0114	0.0131	0.0153
	[0.171]	[0.0396]	[0.0382]	[0.262]	[0.0445]	[0.0411]	[0.183]	[0.0398]	[0.0334]
Urban Informal	0.254	-0.0648	-0.0673	-0.427	0.0336	0.0251	-0.128	-0.0234	-0.0225
	[0.209]	[0.0501]	[0.0458]	[0.314]	[0.0482]	[0.0382]	[0.260]	[0.0576]	[0.0541]
Number of children	-0.0333	0.00393	0.00386	-0.0269	-0.00108	-0.00202	-0.0663***	0.00552	0.00466
	[0.0230]	[0.00520]	[0.00483]	[0.0330]	[0.00556]	[0.00398]	[0.0237]	[0.00550]	[0.00521]
Province									
Eastern Cape	-0.674***	0.154***	0.141***	0.0895	-0.0152	0.00206	0.547**	0.00374	-0.00834
	[0.219]	[0.0490]	[0.0424]	[0.382]	[0.0336]	[0.0305]	[0.263]	[0.0436]	[0.0675]
Northern Cape	-0.283	0.0873**	0.0667**	-0.830***	0.0384	0.0823	-0.308	-0.00372	-0.0134
	[0.181]	[0.0392]	[0.0335]	[0.274]	[0.0339]	[0.0504]	[0.252]	[0.0370]	[0.0454]
Free State	-0.673***	0.121**	0.120**	-0.462	-0.0197	0.00587	0.132	-0.0151	-0.0268
	[0.212]	[0.0536]	[0.0527]	[0.400]	[0.0325]	[0.0291]	[0.262]	[0.0588]	[0.0802]
Kwazulu-Natal	-0.485**	0.0713	0.0622	-0.394	-0.00875	0.0179	0.683***	-0.0731	-0.0777
	[0.206]	[0.0481]	[0.0406]	[0.313]	[0.0347]	[0.0298]	[0.263]	[0.0444]	[0.0659]
North West	-0.279	0.0462	0.0364	-0.838**	0.0334	0.0531	0.139	0.00178	-0.0118
	[0.194]	[0.0473]	[0.0422]	[0.333]	[0.0376]	[0.0365]	[0.269]	[0.0438]	[0.0688]
Gauteng	-0.455*	0.114**	0.108**	-0.719**	0.0135	0.0356	0.0847	0.00315	-0.00563
	[0.264]	[0.0515]	[0.0488]	[0.321]	[0.0282]	[0.0297]	[0.249]	[0.0433]	[0.0675]
Mpumalanga	-0.260	0.0376	0.0257	-1.134***	0.0185	0.0366	0.154	-0.0615	-0.0722
	[0.209]	[0.0540]	[0.0474]	[0.369]	[0.0485]	[0.0459]	[0.263]	[0.0433]	[0.0665]
Limpopo	-0.437*	0.0661	0.0558	-0.946***	0.0208	0.0410	0.128	-0.0141	-0.0274
	[0.225]	[0.0554]	[0.0467]	[0.337]	[0.0387]	[0.0388]	[0.267]	[0.0519]	[0.0718]
Constant	-3.638***	0.988***		-1.739	0.205		-2.807***	0.335*	
	[1.038]	[0.231]		[1.248]	[0.176]		[1.083]	[0.199]	
Observations	4,272	4,272	4,272	1,234	1,234	1,213	2,876	2,876	2,844
R-squared	0.116	0.073		0.108	0.054		0.119	0.041	
Standard errors in brackets									
*** p<0.01, ** p<0.05, * p<0.1									

Male children have a 0.23 point advantage in terms of WHZ compared to females. Once again, children in some provinces have significantly better nutritional status, although there is no evidence that living in another province, *ceteris paribus*, predicts a different chance of wasting.

The inconsistencies between the LPM and logit models suggest that we should be careful about how we interpreting these results. Indeed, a goodness-of-fit test for the WHZ logit model rejects the null hypothesis that the model fits the data (see Appendix B).

Long-term and short-term indicator: WAZ and underweight

Income has a slight significant effect on weight for age, with WAZ increasing by an average 0.00116 points for every 1% increase in income ($p < 0.1$). Education does not appear to be important, except in the LPM model where maternal tertiary education is associated with an 8 percentage point reduction in the chance of having a child that is wasted ($p < 0.05$). The missing value in the logit model results from the variable perfectly predicting undernourishment. Access to a flush or chemical toilet decreases the probability of child wasting by 5-6 percentage points ($p < 0.05$) and self-reported inadequate health-care by 4-5 percentage points, also associated with a 0.32 standard deviation drop in WAZ.

Living in a TAA is associated with better child nutrition, with WHZ measures about 0.33 ($p < 0.05$) points higher on average compared to children living in a formal rural area. They are between 4 and 6 percentage points less likely to be wasted ($p < 0.1$). There appear not to be many provincial effects on WAZ, although living in the Eastern Cape and KwaZulu-Natal does predict a higher nutritional status on average. WAZ decreases on average with fertility. Having one more child predicts a 0.07 ($p < 0.01$) standard deviation decrease in weight for age.

Interpretations in the context of existing literature

In general, where the continuous and limited dependent variable models are at odds (where one yields significant results while the other does not), I believe that it points to non-linearities in the model. Consider, for example, if the presence of X significantly reduces the chance of the 'average child' being undernourished but does not appear to significantly increase his related Z-score. This appears to be a contradiction – if X does not lead to a significantly higher Z-score, how can it predict a lower chance of undernutrition? I believe that the answer lies in the structural model's linear form. It might be that, *on average*, looking at both healthy and unhealthy children, X does not tend to increase Z-scores. However, this might overlook the effects that X has on the Z-scores of children who have specific characteristics (such as for those with Z-scores close to the undernutrition cut-off of -2). This issue, as well as several other important considerations, are covered in more detail in the following section.

Income

My results suggest that household income does not play an important role in child nutrition, once other factors have been taken into account – at least in the South African context. Much of the empirical literature seems to confirm this finding. In a large cross-sectional dataset covering 62 countries, Haddad et al. (2003) estimated that a 1% increase in GDP would result in the average prevalence of child undernutrition decreasing by 7.44%. Based on these findings, the authors estimated that between 2004 and 2015, undernutrition would decline by 27% if per capita *real* growth rates were maintained at 2.5% per year. Estimates calculated from a panel study spanning 5 continents suggest that halving stunting from a level of 30% would require a 3.7% *real* per capita growth rate for 25 years (Heltberg 2009). Glewwe et al. (2003) found that income growth accounted for only half of the 16 percentage point decrease in the incidence of undernutrition for children younger than 5 in Vietnam during the 1990s, despite a 6% per capita growth rate over that period.

A different picture is suggested by a cross-sectional study of South African data, in which Duflo (2000) estimated that pension receipts were responsible for increasing WHZ by 1.19 and HAZ by 1.16 on average for children under 5 (but only for *granddaughters* and when the pensioner was female). A similar approach using more recent South African data produced strikingly similar results (Ambler 2010), although the effect appeared to decrease with the child's age. Agüero (2007) estimated that receipt of the South African Child Support Grant (CSG) resulted in a large and significant increase in child HAZ. These results appear to contradict my finding. I believe that this can be explained mainly by the nature of these studies, which are experimental in nature and analyse the effects of exogenous changes in income. For instance, we should expect that as incomes increase, people will move to areas with better infrastructure or upgrade their dwellings to include such things as toilets and piped water. If this is indeed the case then my results would underestimate the impact of income – part of the effect would be captured by whether a household has a flush or chemical toilet, for example – by disregarding the importance of income in accessing infrastructure. The strength of the experimental approach is that one does not need to control for such variables because they are exogenous. Because they are endogenous in my model, not including them would result in omitted variable bias. In addition, my model does not control for the gender of the caregiver and does not allow gender to interact with the other explanatory variables. It might be that under certain conditions, income becomes more important.

Education

I reserve my discussion of the education variables from the HAZ regressions for a separate section because they are potentially problematic. Apart from that, levels of maternal schooling appear to be important short-run determinants of nutrition. It is unclear whether primary schooling is relevant in the short-run (the logit and LPM models are at odds here) but secondary education is both statistically and economically significant (whichever model you look at). Tertiary education is also important for predicting a decrease in nutrition in the short-run, although we should be cautious of this result, given that only 9 children have mothers with tertiary education in the WHZ sample.

Looking at the empirical literature, education of adult household members has consistently been shown to vary positively with the nutritional status of children. In Pakistan, it was estimated that if all mothers were educated to at least the primary-school level, wasting would be reduced by almost half its 1994 level, or six times the impact of a 10% increase in per capita income. In some cases, only *maternal* education was found to be significant. Such has been found to be the case in the Cameroon (Pongou et al. 2006), Central Asia (Bomela 2009), Mozambique (where level of schooling was found to have a positive but decreasing marginal effect on child nutrition so that primary schooling had the strongest impact) (Burchi 2010), Senegal (Linnemayr et al. 2008), and in Smith and Haddad's (2001) panel study of 63 developing countries between 1970 and 1996. In other studies, male education was also found to be important – in Sahn and Stifel's (2002) study spanning 14 African countries, in Ethiopia (Kiros & Hogan 2001), Pakistan (Alderman & Garcia 1994), and India (V. Borooah 2009), among others. Even when male education is found to be significant, female education is generally found to be far more important. This evidence provides some support for my findings.

Infrastructure and health inputs

There is some evidence for the importance of health care and infrastructure. That being born in hospital is significant only for long-run nutrition makes sense. As a proxy for prenatal care, it should not be expected to make much of a difference in the short-run (Alderman & Garcia 1994, p.497). Access to a flush or chemical toilet appears to be significant in the long-run, which also makes intuitive sense, since access to such infrastructure does not change in the short-term.

Inadequate healthcare is important both for short-term and the long-term nutritional status. Although the LPM and logit models are in disagreement, and we should be careful in interpreting these results, the WAZ regressions show it to be important across all three models. This is a very crude proxy and is based on a simple question so it probably fails to capture the real significance of

health care. To illustrate the point, Glewwe et al. (Glewwe et al. 2003) found distance to the nearest hospital or pharmacy to have a very weak effect but that availability of oral rehydration salts increased HAZ by an average of 0.44 points. If a caregiver in this sample were asked to rate the adequacy of her health care, on which metric would she base her answer?

The removal of rubbish, a rough proxy for sanitation, is not important. It may be that this is actually a poor proxy as it is unlikely that the environment does not play a part. It is surprising that the absence of access to a safe source of drinking water is consistently unimportant for all measures of child nutrition. Bomela (2009) found that children who did not have access to piped water were 1.41 times more likely to be underweight in Central Asia and Pongou (2006) found a strong positive association between water quality and HAZ in the Cameroon. A Senegalese study estimated significant effects of access to safe water only for those in the lower 10th percentile of Z-scores. It became unimportant when including the entire nutritional range. Thus my results might be a product of non-linearity, a possibility that I expand upon in the following section.

Child characteristics

Gender does appear to predict variations in nutritional status but not the probability of undernutrition. Females have better nutrition in the short-run and males in the long-run. There are a number of reasons why this could be the case. One explanation is that caregivers favour female children in general and thus feed them better when they are young. This could be for cultural reasons, such as the expectation of lobola once she is married. In the long-term however, males may make up the difference by finding employment. The data does not allow me to make any reliable deductions. Age appears to have a non-linear relationship to long-term nutrition as the marginal effect of age is neither constant nor does it appear to change systematically. Compared to children less than 12 months, older children tend to have a lower nutritional status. It does make intuitive sense that the effects of long-term nutrition would play a greater role as children get older.

Household and community characteristics and geography

Long-term nutrition is generally better for those living in a TAA than those living in formal rural areas. This is an interesting result. Fotso (2007) found no significant differences between urban and rural populations after controlling for other determinants. This seems to support my findings, which do not show differences between rural and urban areas in general. TAAs are areas that fall 'under traditional authority' (Khumalo 2009, p.2). Although each TAA might differ, it is conceivable that there are social, economic, and governance structures in place that support child health and access to nutrients. Interestingly, TAA residence has no significant effect on short-term nutritional status,

which suggests that the advantage of living in such areas lies in better access to health care, even if not formal, sanitation and information. This is an intuitively appealing result, suggesting that access to formal infrastructure is not important as long as the underlying effects of infrastructure (sanitation for example) are felt in other ways. In addition, my model fails to account for other important determinants of nutrition due to limitations of the data and these may be picked up by the TAA dummy. An example is how long a child is breastfed. It might be that children are more likely to be breastfed if they are brought up in a traditional environment, in which case the TAA dummy might proxy such positive health-care practices. Another interpretation is that this reflects how poor conditions are in farming areas that lie outside of a TAA. However, the details of this result are beyond the scope of this paper.

Number of children does not appear to make much of a difference to child nutrition. Even where it is statistically significant, it is not economically so. Household size has been found to strongly and negatively influence the probability of wasting and stunting in Pakistan (Alderman & Garcia 1994) and having fewer children was associated with a lower chance of being underweight and stunted in Central Asia (Bomela 2009). However, other studies suggest that no such relationship exists (Banerjee & Esther Duflo 2011).

Africans and coloureds are significantly worse-off in terms of long-term nutrition compared to whites. That it is not important in the short-run gives support to the idea that ethnic background captures access to infrastructure, as suggested by Haddad et al. (2003). There is some evidence that it also increases the chance of undernutrition (both long-term and short-term) and the coefficients are very large. The province in which a child lives has a significant impact on his nutritional status and the probability of his being undernourished. This is most strongly with respect to long-term nutrition. This probably reflects differences in such things as infrastructure, environmental factors, and access to information.

Limitations and suggestions for future research

Variables with unexpected signs

The signs on the primary education and food security dummies in the HAZ binary dependent variable models are the opposite of what theory and empirical evidence suggest. This is worrying as it indicates that there may be very serious problems with the model. Kennedy (2005) suggests some possibilities that may apply here, although his list is not exhaustive. The problems could be a result of high variances, perhaps as a result of multicollinearity. The VIF on the OLS regression is approximately 2.5, which is far from the 10 that would suggest a problem. The continuous

dependent variable model reports the correct signs (although they are not statistically significant). The problem could therefore be heteroskedasticity, which affects latent dependent variable models differently to usual OLS (Kennedy 2005). Wooldridge (2001, p.479) shows that in the context of such models, heteroskedasticity can lead to incorrect signs.

Endogeneity

My model does not properly control for the possible endogeneity of income. As in my analysis, income is often proxied by expenditure, for reasons that I have already mentioned. However, it is still sensitive to measurement error and may not truly represent permanent income (J.R. Behrman & Deolalikar 1990). More problematic is that expenditure and child nutrition are probably jointly determined by time-allocation decisions. It would be best to use a two-stage least squares approach, instrumenting for expenditure. The literature suggests using wealth indices constructed from asset ownership, such as land, cattle and vehicles (Bassolé 2007; Linnemayr et al. 2008; Christiaensen & Alderman 2004; Smith & Haddad 2001). These should be correlated with income but not time-allocation decisions. I did not use this approach because in my opinion the data does not appear to be able to support it and having a badly specified first-stage equation can lead to more problems (Wooldridge 2001). However, it is possible that I have overlooked something and perhaps others can take up the challenge. An alternate approach is to use fixed effects or random effects estimators when the second wave of NIDS data is released. Assuming that the time-allocation decisions are constant, this should sterilise the unobservable factors that lead to endogeneity.

Simultaneity bias might also result from endogeneity between income and nutrition (Bouis 1994). Better nutrition leads to higher income on average, while higher income generally results in better nutrition. This probably is not so much of an issue in my WHZ and WAZ regressions, which include very young children. However, the HAZ regression includes children up to the age of 15. It is conceivable that a 13 year-old, say, might be able to find a job before his undernourished peers. This would raise the household expenditure value and result in bias.

Model misspecification and omitted variables

Elasticities are likely to differ between income groups. Meng et al. (2004) found that income-calorie elasticities were greater for lower-income groups. Systematic differences were also found between countries with different average levels of income (Salois et al. 2011). Bassolé (2007) suggests using quantile regression to account for the non-linearities that appear to exist between individuals of different nutritional status. For example, he found that access to health facilities was important only up to the 90th percentile and that the marginal effect decreased by percentile until the 75th. Borooah

(2005) found that improving parental education would be more useful for Indian children with relatively high levels of HAZ while those at the lower end would benefit more from better access to safe drinking water. Different results by quantile were also found by Aturupane et al. (2006), implying that appropriateness of policies should be assessed by population segment. It would thus be interesting to repeat my analysis using quantile regression approaches.

More relevant and accurate results might be obtained by including interaction terms. For instance, the interaction between male and female education and the different impacts that they have on different *types* of undernutrition could reveal more than simply looking at parental education in isolation. In Central Java, Webb and Block (2004) found that mothers' and fathers' education tended to complement each other. Fathers' education was found to be significant for reducing long-run (chronic) undernutrition, even when women in the household had high levels of formal education. But paternal education had no effect on undernutrition as measured by WAZ. Similar results were found for Indonesia (Wasito et al. 2002). In India, literate fathers tended to have better nourished children, but only when the mother was also literate (V. Borooah 2009). Gender, province and geographical location may reveal additional insights in interaction with other dependent variables.

The issue of causality is complicated and is not limited to nutrition studies. It is important to be aware that without appropriate methods and controls, it might be inappropriate to infer causal relationships. For example, it might be misguided to prioritise education in increasing nutritional status because of the positive association between higher levels of education and Z-scores. It is terribly important to clarify the extent to which parental education *causes* children to be healthier. It might be more appropriate to target mothers directly with nutritional education outside of the formal schooling system. Studies that have attempted to separate out the effects of formal schooling from nutrition-specific knowledge learned outside of the classroom have found the latter to be important in its own right (Bomela 2009; Burchi 2010; Webb & Block 2004; D. Thomas et al. 1990; Lamontagne et al. 1998; Glewwe 1999). These findings suggest that formal schooling and nutritional education are complementary and independent determinants of childhood nutrition.

Practical considerations

It might be important to control for the timing of the study, sources of income, and price levels. In rural areas, measurements are subject to seasonality effects. For instance, in Pakistan the income-calorie elasticity was found to be 0.61 during planting season while becoming negligible in the harvest stage in households with below-average wealth (Jere R. Behrman et al. 1997). Moreover, Villa et al. (2011) suggest that total household income might obscure the results – they find that

calorie-income elasticities differ for various *sources* of income. They propose that 'mental accounting' might be responsible, with people allocating incomes from different sources to particular uses. It is possible that income-nutrient elasticities are sensitive to food prices. Although intuitively appealing, evidence appears to contradict this theory. Despite strong income growth and substantial reduction in food prices in India since 1983, the country has seen a 10% average reduction in calorie consumption since then (A. Deaton & Drèze 2008). Two separate analyses of Indonesian data found the total calorie-income elasticity to be insensitive to food prices, with people substituting towards relatively cheaper sources – elasticities increased for some foods and decreased for others but remained little unchanged on *average* – when food prices increased (Skoufias 2003; Skoufias et al. 2011). They demonstrate that, during the economic crisis that hit the country over 1997-1998, income elasticities of some nutrients (including iron, calcium and vitamin B1) were higher than usual while others (including vitamin C) were close to zero. Calorie-income elasticities remained stable throughout the study. It would be interesting to conduct similar studies in South Africa to test this theory.

Income-calorie elasticities appear to vary across populations, even after controlling for different characteristics. For example, income-calorie elasticities have been estimated at 0.4 in Tanzania (Abdulai & Aubert 2004), 0.6 in Urban Papua New Guinea (Gibson & Rozelle 2002), about 0.19 in Nigeria (Babatunde et al. 2010; Aromolaran 2004) and Pakistan (Dawson 1997), between 0.3 and 0.5 in India (Subramanian & Angus Deaton 1996; Dawson & Tiffin 1998), and between 0.1 and 0.25 in a cross-country analysis of 171 countries (Salois et al. 2011). In apparent contradiction of these results, others have found very low elasticities of between 0.08 and 0.14 in the Philippines (Bouis & Haddad 1992) and close to zero in India (J. Behrman & A. Deolalikar 1987). In general, there is little consensus and income-calorie estimates swing extravagantly, between 0.01 and 1.18 (John Strauss & Duncan Thomas 1995). Estimates for income elasticities of other nutrients are sparser but similarly diverse. A study using Indonesian household data revealed elasticities of less than 0.03 for various nutrients, including proteins, fats, carbohydrates, calcium, calories, phosphorous, iron, and vitamins A and C (Pitt & M.R. Rosenzweig 1985). Another found elasticities of between 0.7 and 1.2 for the poorest 40% sampled in Java. A study from Nicaragua estimated elasticities that range between 0.04 and 0.11 for calories, proteins, iron, and vitamin A while Bouis (1991) estimated a figure of 0.16 for calories and insignificant elasticities for vitamins A and C in the Philippines. In a recent cross-country analysis, income-nutrient elasticities of protein were estimated at 0.14-0.15, fat at 0.23-0.24, and carbohydrates at f 0.02-0.025. Elasticities clearly differ by nutrient (J. Behrman & A. Deolalikar 1987). Even for the same income group in the same country (China), using the same estimation strategies,

different estimates was calculated for 1987 and 2000 respectively, suggesting that there might be some unobserved or unobservable factor driving these results.

Race

Race is included in the model out of necessity. It is likely that it is correlated to characteristics such as income and access to infrastructure and also child nutrition. Omitting race would then lead to omitted variable bias. However, what we really want to capture are the underlying differences that exist. Indeed, the complex nature of racial differences might mean that there are aspects correlated with belonging to a certain race group that are also correlated to nutrition that are not included in the model. If this is the case then omitted variable bias remains. It might be useful to instrument for race then, using variables in the two stage equation that predict racial membership but not nutrition. This would also allow us to move away from talking about race and towards an analysis based on the underlying characteristics of people regardless of their backgrounds.

Concluding discussion

One must be very careful in drawing conclusions from non-experimental studies such as the one presented in this paper. I have highlighted the many problems that plague this type of research and, despite my best efforts, some have inevitably cropped up in my own. A clear lesson from the literature is that the impacts of relevant interventions are very sensitive to context-specific factors, some of which are likely unobservable. The large discrepancies in estimates from different countries, and between different segments of the population, reveal the need for analysis focused on potential target groups.

More research is needed to infer which types of interventions would be most appropriate for people with different characteristics and levels of access to state infrastructure. Future studies should explore the complex interactions between these variables. They need to account for the likely non-linear nature of the relationships, using quantile regression techniques, as well as accounting for likely heterogeneity. A good way to sidestep this second problem is by experimental studies that evaluate the impacts of exogenous shocks. How these exogenous events affect individuals with different characteristics, and access to different levels of infrastructure and health care, are important questions that have not been adequately answered in the literature. Thus, even when targeting policy at particular determinants of childhood nutrition, government should avoid blanket roll-out in favour of context-specific interventions.

Another important aspect to this problem that is often overlooked is that of efficiency. Where income is found to be important, for example, it is unclear why. If the additional resources allow households to upgrade their toilet facilities, for instance, so that children are less prone to diarrhea, it may be that a government rollout of oral rehydration therapy could be more cost-effective or it might be more efficient for the government to build public sanitation facilities. The government should conduct cost-benefit analyses to estimate where funds will be best spent.

The balance of evidence seems to suggest that income and availability of food are far less important than other factors in effecting childhood nutrition. Interestingly, the number of children within a household does not appear to have a strong impact on child nutritional status. Specifically, health care and sanitation appear very important, as does the level of education achieved by parents. One can make logical sense of these results. In order for economic resources to have an impact, they must be used to purchase goods or services that serve to improve the nutritional status of one's child. This is less likely to be the case when one is uneducated and lacks the required information to make use of available resources. And even when the nutrients are there, if children are unhealthy, their bodies will be unable to retain them.

The significance of living in a Tribal Authority Area on child nutrition is an interesting and unexpected result that might deserve further exploration in future studies. One should attempt to tease out the underlying effects that make living in such areas so beneficial to a child's nutritional outcome. Possible culprits could be obvious variables that were not included in the model because of gaps in the data, such as details on breast-feeding. However, a further analysis of the characteristics unique to these areas could offer government further insights into problems unique to South Africans.

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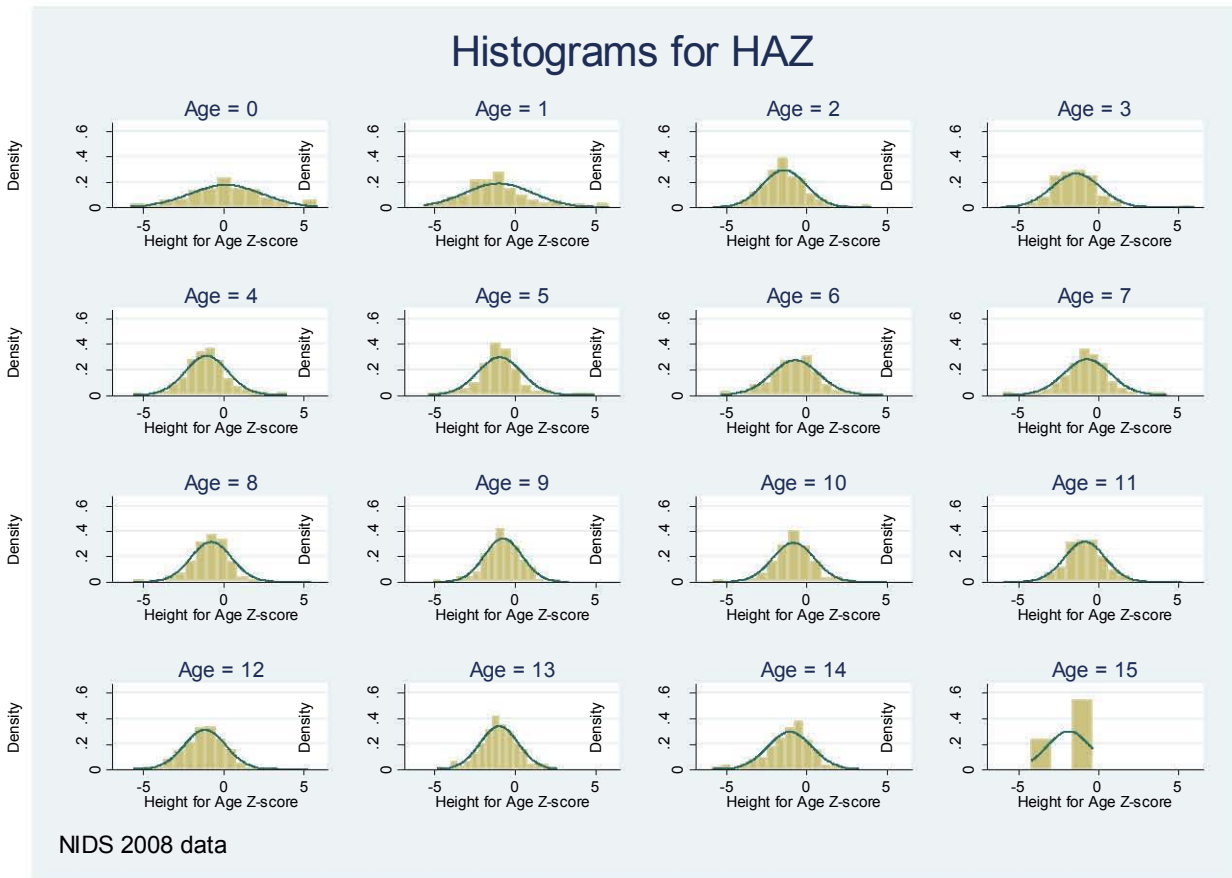
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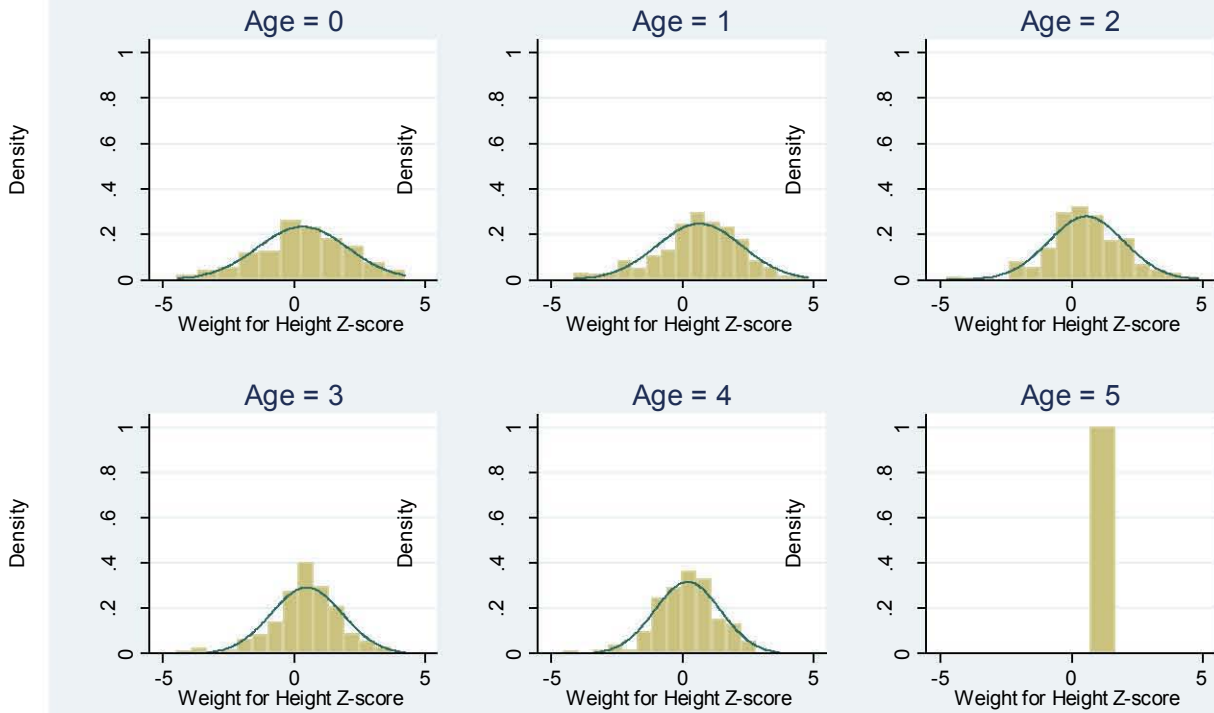
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Appendix A

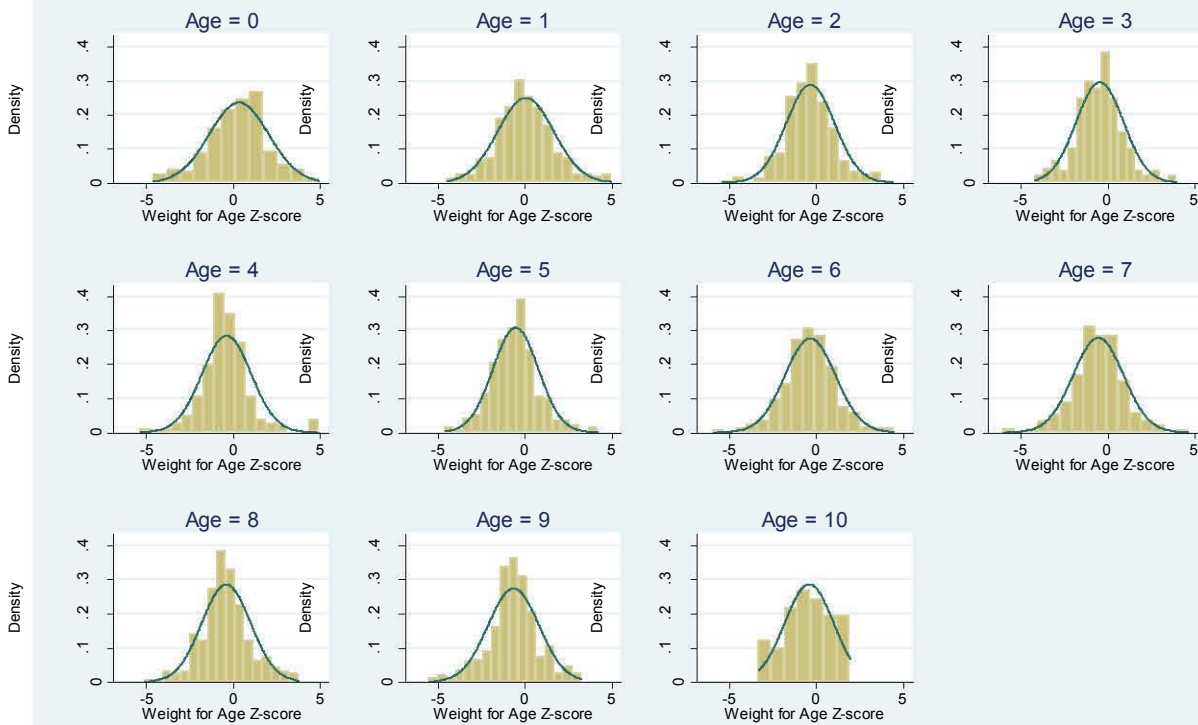


Histograms for WHZ



NIDS 2008 data

Histograms for WAZ



NIDS 2008 data

Appendix B

Goodness-of-fit test for logit regression of WHZ

```
. svylogitgof
      Number of observations =          1213
F-adjusted test statistic = F(9,306) =    17.679
      Prob > F =                   0.000
```