Local Food for Local Children

The relationships between household agriculture and the health and nutrition of school-age children

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Declaration

I declare that I am solely the author of this thesis and that all the work herein is my own, apart from what is referenced and the collaborations with others gratefully acknowledged below.

Signed

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September 2014

Abstract

The target groups for many nutrition interventions are mothers and children under the age of two, as evidence has shown significant and substantial benefit for these age groups. Less is known about the potential for school-age children to benefit nutritionally from interventions through a complementary, life-cycle approach. The central hypothesis tested here is that nutrition-sensitive interventions can improve growth at school-age and that schools are an effective platform for children to be able to access these interventions. I address this hypothesis by examining three key research questions: 1) whether and to what extent catch-up growth can occur at school age; 2) how household characteristics (agriculture and dietary quantity and quality in particular) are related to nutrition at school age and what entry points may exist for holistic intervention; and 3) how school feeding programs are related to education participation (and thus access to nutritional inputs through programming) and how programs may be strengthened to improve links with local agriculture.

Examining the first question, in a review of the potential for catch-up growth at school age, a range of intervention studies counter claims of the irreversibility of pre-school growth faltering with evidence that early deficits can, at least to some extent, be made up in childhood and adolescence. For the second question, in analysis of relationships between school-age nutritional status and household agriculture in Mali, associations were observed between household agricultural production variety and measures of dietary diversity and food variety, but no associations between these measures and school-age child nutrition outcomes were found. In making the link to programming through the third question, no significant associations were found between school feeding and the education participation outcomes measured at the school level in Kenya.

I conclude that opportunities for improving the nutrition of school-age children do exist and that understanding the potential for agriculture-nutrition disconnects and the dynamic nature of school feeding programs could help improve the design of multi-sectoral, nutrition-sensitive interventions at school age, including Home Grown School Feeding (HGSF).

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Acronyms and Abbreviations

2SLS	two-stage least squares
ANOVA	analysis of variance
APHLIS	African Postharvest Losses Information System
BAZ	body-mass-index-for-age z-scores
BMI	body mass index
CBA	controlled before and after study
CCT	conditional cash transfer
CFA	West African CFA franc
CGS	Communes and School Management Committees
C.I.	confidence interval
COHORTS	Consortium of Health Oriented Research in Transitioning Societies
CPS/MS	Cellule de Planification et de Statistique du Ministère de la Santé (Mali)
CPS/SSDSPF	Cellule de Planification et de Statistique (Mali)
DCP3	*Disease Control Priorities, Third Edition*
DDS	dietary diversity score
DHS	Demographic and Health Survey
DNSI/MEIC	Direction Nationale de la Statistique et de l'Informatique du Ministère de l'Économie, de l'Industrie et du Commerce (Mali)
ECD	Early Childhood Development
EMIS	Education Management Information System
EPDC	Education Policy and Data Center
ES	effect size
FAO	Food and Agriculture Organization of the United Nations
FEWS NET	Famine Early Warning Systems Network
FMI	fraction of missing information
FO	farmers' organization
FVS	food variety score
HAD	height-for-age difference
HALI project	Health and Literacy Intervention project
HANES	Health and Nutrition Surveys
HAZ	height-for-age z-scores
HES	Health Examination Survey
HGSF	Home Grown School Feeding
HGSM	Home Grown School Meals
IDP	Internally Displaced Persons
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
INSTAT	Institut National de la Statistique (Mali)
INT	intervention group
IPA	Innovations for Poverty Action
IUGR	intrauterine growth restriction
IV	instrumental variable
KCPE	Kenyan Certificate of Primary Education
MAR	mean adequacy ratio
MICE	multiple imputation by chained equations

MoA	Ministry of Agriculture
MoE	Ministry of Education
MoH	Ministry of Health
NAR	nutrient adequacy ratio
NCHS	National Center for Health Statistics
NGO	non-governmental organization
NMK	Njaa Marufuku Kenya
NOAA	National Oceanic and Atmospheric Administration
OC	older cohort
OECD	Organisation for Economic Co-operation and Development
OLS	ordinary least squares
PCD	Partnership for Child Development
PDS	production diversity score
PL	placebo group
PVS	production variety score
RCT	randomized controlled trial
RESET	regression specification error test
RMSE	root mean squared error
RVI	relative variance increase
SACMEQ	Southern and Eastern Africa Consortium for Monitoring Educational Quality
SD	standard deviation
SES	socio-economic status
STH	soil-transmitted helminths
STN	stunted
UNICEF	United Nations Children's Fund
UNW	underweight
USAID	United States Agency for International Development
VIP latrine	ventilated improved pit latrine
WAZ	weight-for-age z-scores
WFP	World Food Programme
WHO	World Health Organization
WHZ	weight-for-height z-scores
WST	wasted
YC	younger cohort

Chapter 1. Introduction and overview

Approximately 1.2 billion people currently live in extreme poverty (Olinto *et al*. 2013).[i] Additionally, over the past decade, food prices as well as price spikes and volatility have all increased (von Braun and Tadesse 2012), further jeopardizing the over 840 million people who are now undernourished (FAO, IFAD, and WFP 2013). The recent food, fuel, and financial crises have focused global attention on the issue of food security, a key component of which is nutrition, with the numerous impacts that malnutrition can have on health, education, and earning potential.

The target groups for many nutrition interventions are mothers and children under the age of two, as evidence has shown significant and substantial benefit for these age groups. Less is known on the potential for school-age children to benefit nutritionally from interventions through a complementary, life-cycle approach. The central hypothesis tested here is that nutrition-sensitive interventions can improve growth at school-age and that schools are an effective platform for children to be able to access these interventions. I address this hypothesis by examining three key research questions: 1) whether and to what extent catch-up in growth can occur at school age; 2) at the household delivery platform level, how household characteristics (agriculture and dietary quantity and quality in particular) are related to nutrition at school age and what entry points may exist for holistic intervention; and 3) at the school delivery platform level, how school feeding programs are related to education participation (and thus access to nutritional inputs through programming) and how programs may be strengthened to improve links with local agriculture.

1.1 Growth at school age: Examining the evidence on catch-up

While evidence has shown substantial benefits of nutrition-specific interventions delivered antenatally and postnatally (Bhutta *et al*. 2013), less is known on the potential for school-age children to benefit nutritionally from interventions that are implemented in a complementary, life-cycle approach, and particularly whether children can recover from early stunting and wasting, and if so, at what ages and to what extent.

The possibility of catch-up growth into childhood and adolescence has been a source of debate in the literature. Golden's (1994) review is often referred to as providing evidence for catch-up growth later in life, while a longitudinal supplementation study in Guatemala of children aged 0–7 years is frequently cited in support of the irreversible effects of early stunting (Martorell, Kettel

[i] Olinto *et al*. (2013) define extreme poverty as those living on incomes of less than $1.25 per day (2005 Purchasing Power Parity dollars).

Khan, and Schroeder 1994). The authors' conclusions that "stunting is a condition resulting from events in early childhood and which, once present, remains for life" are echoed elsewhere, including in *The Lancet* series on maternal and child undernutrition. "Poor fetal growth or stunting in the first 2 years of life leads to irreversible damage, including shorter adult height, lower attained schooling, reduced adult income, and decreased offspring birthweight" (Victora *et al*. 2008).

To examine the evidence to date on growth at school age, the literature review presented in Chapter 2 addresses three key questions: 1) whether height and weight at school age matter; 2) whether height and weight can change at school age; and 3) what is the scale of the effect.

To help frame these questions, it is important to examine standard growth, what happens when the growth curve is displaced by early malnutrition, what trajectories have been observed from this faltering, and results from intervention studies early in life aimed at restoring the growth trajectory, all of which is discussed in the initial parts of the chapter.

The focus of the review then turns to considerations related to growth at school age (including the impact of growth faltering during childhood on education, adult income and productivity), followed by findings from intervention studies aimed at restoring growth trajectories of school-age children. Many claims have been made that growth recovery cannot occur at these times later in life and that early stunting is irreversible, but much of the evidence that is cited in support of this is from studies where no intervention has been undertaken. In the absence of change, early stunting may well persist as decreased height throughout life, but intervention studies reviewed here counter the irreversibility claim with evidence that early deficits can, at least to some extent, be made up in childhood and adolescence.

As to the scale of the effects, findings from changes in environment studies, including immigration, adoption, and moves to institutional settings have included catch-up to within national and international standards following early growth faltering. Additionally, interventions addressing secondary stunting and underweight have resulted in partial as well as complete catch-up growth. Food and micronutrient supplementation at school age have been reported to have more measured impact on height and weight, with small but significant gains over control groups. Recent findings have indicated that school feeding programs could also have important spill-over benefits for younger siblings as well as promoting the health of the next generation of mothers. Furthermore, even as variations in worm species, distribution, treatment, initial health status, and follow-up duration complicate any definitive conclusions about the magnitude of the effects of deworming, studies have shown positive impacts on height and weight, impacts that may be strengthened when interventions are carried out in conjunction with supplementary feeding.

A number of the key considerations reviewed, including regression to the mean, ethnic differences, secular change, the adolescent growth spurt, and possible delays in skeletal maturity, underscore the complexity of assessing catch-up growth in school age and adolescence. Even with these intricacies, the evidence reviewed supports the hypotheses that height and weight at school age matter and that catch-up growth at school age is possible and has been achieved, to varying degrees, through interventions in school age and adolescence.

1.2 Relationships between household agriculture and child nutrition in three regions of Mali

The next set of chapters build upon this discussion on timing and patterns of growth and determinants of nutrition to analyze determinants of school-age nutritional status using child-, household-, and community-level data from a large-scale survey in Mali, with the relationship between child nutrition and household agriculture being of particular interest. As much of what is produced in the sample households appears to be consumed rather than sold, it is hypothesized that households that produce a more diversified range of crops and livestock will also consume a more diversified diet. In turn, as dietary diversity has been associated with improved nutrition outcomes (Arimond and Ruel 2004; Eckhardt *et al*. 2005; Himaz 2009; Menon *et al*. 2013), it is expected that school-age children from households with more diversified production and diets will exhibit better nutritional outcomes, as measured by anthropometrics.

1.2.1 The complex interplay between agriculture and nutrition

In examining the relationship between agriculture and nutrition, reviews of agriculture intervention studies have found little evidence of improved nutritional status for children (Ruel 2001; Berti, Krasevec, and FitzGerald 2004; Leroy and Frongillo 2007; Masset *et al*. 2012). In response to these findings, Headey, Chiu, and Kadiyala (2012) present two hypotheses on why nutrition gains may not always be realized with agricultural growth, the first being that there are many direct linkages between agriculture and nutrition but that there are a variety of possible "leakages" along the pathways. The second is that in addition to improvements in agriculture, strengthening of a number of different sectors may be required to realize nutritional gains, for example in health, in education, in infrastructure.

As Headey, Chiu, and Kadiyala (2012) discuss, a complex interplay between agriculture and nutrition exists, with the two exhibiting a more indirect relationship than many think of. The authors highlight that income from agricultural sales, market prices, and production for own consumption all influence household food availability. Moving from the household- to the individual-level, nutrition outcomes are also influenced by intrahousehold food allocation, parental care, and individual health status. Overarching these more immediate determinants are food, land, education, and health policies as well as disease burdens and cultural practices among other socioeconomic drivers.

Examinations of relationships between agriculture and nutrition in light of the various pathways between them is often hampered by data disconnects, with anthropometric and nutritional status surveys rarely collecting agriculture data and, conversely, agricultural surveys rarely collecting data on anthropometrics or nutritional status, as noted by Bhagowalia, Headey, and Kadiyala (2012). Large-scale data from Mali collected and analyzed here includes observations on the nutrition of school-age children as well as household food consumption and agricultural production, allowing for assessment of agriculture and nutrition relationships that accounts for child-level characteristics (including age, gender, and birth order) as well as household-level characteristics (including household expenditure, parental education, maternal age, and household size and composition).

1.2.2 Overview of the Mali chapters

The first chapter in the set on Mali is Chapter 3, which frames the subsequent three chapters and provides an introduction to the survey, which was undertaken as part of a Home Grown School Feeding (HGSF) study in three regions of Mali. Studies on determinants of child nutritional status in low-income countries (with a particular focus on agriculture and nutrition relationships) are then reviewed, which helped inform the subsequent analyses. Finally, the methodology for the following three chapters is detailed together as the overall study design and data collection are shared and many of the same variables of interest, statistical analyses and estimation techniques are used.

Summary statistics on child nutritional status and considerations related to the anthropometric measures are presented in Chapter 4, with findings on household food consumption, diet quality, and agricultural production in Chapter 5. Building on those results, Chapter 6 tests two main hypotheses: 1) households that produce a more diversified range of crops and livestock will also consume a more diversified diet; and 2) school-age children from households with more diversified agricultural production and diets will exhibit better nutritional outcomes.

1.2.3 Main findings of the analyses

Results from analyses on relationships between agricultural production and food consumption indicate that production variety (but not production diversity) is positively correlated with dietary diversity and food variety in the survey population. Additionally, ownership of milk-producing livestock was associated with higher milk shares of total consumption and that ownership of poultry was associated with higher meat shares, suggesting consumption from own production may be particularly important for these two food groups.

Results from nutrition outcome models found no significant effects of household agriculture or food consumption measures on height-for-age z-scores (HAZ) of children between the ages of 5 and 11, in complete case analyses. Similar no effects were observed with an imputation model and when potential over-reporting of age was taken into consideration.

Agriculture-nutrition frameworks provide a structure for discussing disconnects observed and how "leakages" may occur along various pathways in the framework. Chapter 6 concludes with consideration of these leakages in the context of this study, particularly those related to nutrition education and time allocation, disease burdens, energy expenditures, intrahousehold food allocation, and seasonality and time of data collection.

1.3 School feeding and the school environment: Correlations with education participation outcomes in 101 schools in Kenya

Chapter 7 provides an opportunity to examine programmatic aspects of intervening at school-age through school feeding, including whether school feeding is related to increased education participation (and thus access to nutritional inputs through the programs). School-level data from Kenya is used to analyze the relationship between school feeding and education participation outcomes. The primary research aim is to determine whether the presence of school feeding is associated with increased school participation outcomes including enrollment, attendance, girl-to-boy enrollment ratio, and retention, as has been reported elsewhere (Bundy *et al*. 2009). Additional information on the school feeding programs surveyed is examined to provide further context for the findings, including program status over time, the type of meal/snack/ration provided, the type of transfer (food or cash), the quality of service delivery, the types of foods served, information on food preparation and cooking, and information on linkages with smallholder farmers.

Among the principal findings was that no significant associations were found between school feeding and the education participation outcomes measured, which could be due in part to the dynamic nature of school feeding programs observed in the study area. From the data collected, some opportunities were highlighted for strengthening of cash transfer school feeding programs and sourcing from local producers specifically. These included bio-control advances for aflatoxin (which affects production and marketing of crops for smallholder farmers particularly), revision of procurement procedures to be more smallholder farmer friendly, and utilization of menu planning tools to support food basket flexibility while maintaining nutritional quality.

1.4 Conclusions

Through the analyses in the chapters to follow, my thesis presents important considerations for the perception of school-age and adolescent growth (findings that have already contributed to high-level discussions on catch-up growth and will be published in part in *Disease Control Priorities, Third Edition* [DCP3]), determinants of growth for children of school age (a relatively under-studied population), relationships between child nutrition and household agriculture to contribute to the ongoing development of inter-disciplinary agriculture and nutrition linkages, and programmatic opportunities for strengthening the involvement of local agricultural producers in school feeding programs. I conclude that opportunities for improving the nutrition of school-age children do exist and that understanding the potential for agriculture-nutrition disconnects and the dynamic nature of school feeding programs could help improve the design of multi-sectoral, nutrition-sensitive interventions at school age, including Home Grown School Feeding.

Chapter 2. Literature review. Growth at school age: Examining the evidence on catch-up

The target groups for many nutrition interventions are mothers and children under the age of two, as evidence has shown significant and substantial benefit for these age groups (Bhutta *et al*. 2013). Less is known on the potential for school-age children to benefit nutritionally from interventions through a complementary, life-cycle approach, and particularly whether children can recover from early stunting and wasting, and if so, at what ages and to what extent.

This literature review will examine the evidence on growth at school age, addressing the key questions of whether height and weight at school age matter, whether height and weight can change at school age, and what is the scale of the effect. The standard growth curve is first described, followed by what happens when the growth curve is displaced by early malnutrition and what trajectories have been observed from this faltering. Interventions early in life aimed at restoring the growth trajectory are then discussed (much of which has already been reviewed elsewhere). The focus of the review then turns to growth at school age—including the complexities of assessing catch-up given the variability of adolescent growth, secular change, and regression to the mean—followed by interventions aimed at restoring growth trajectories in these age groups. Many claims have been made that growth recovery cannot occur at these times later in life and that early stunting is irreversible, but much of the evidence that is cited in support of this is from studies where no intervention has been undertaken. Intervention studies at school age along with a sub-set of follow-up studies without a specific intervention demonstrate that catch-up growth is possible at this stage, suggesting that the question moving forward is no longer whether later recovery can be achieved but how and to what effect.

2.1 Methods

In examining the research questions outlined above, a narrative overview literature review approach was employed, as described by Green, Johnson, and Adams (2006). For sources of information, personal contact with experts helped identify authoritative texts. These sources were complemented by electronic database searches of PubMed and Google Scholar using the terms "catch-up," "growth," and "children." The review was not limited in geographic scope or dates of publication, with the most recent searches being conducted in September 2014. Reference lists of retrieved articles were also reviewed, and results of systematic reviews are presented where available. Studies on other facets of developmental catch-up besides physical growth (e.g. cognition) were excluded.

2.2 The human growth curve

In answering this question of catch-up growth in childhood and adolescence, the human growth curve serves as an introduction to the normal timing of height and weight gain. As seen by longitudinal studies of growth throughout childhood and adolescence, infants experience rapid height and weight gain in the first two years of life. Clinical longitudinal standards developed from 1965 data on British children help illustrate these early gains and the subsequent shape of the growth curve for individuals (Tanner and Whitehouse 1976).[i] Height velocity for the 50th centile of boys is approximately 18 cm/year over year one, dropping to around 12 cm/year over year two, and then gradually decelerating further from approximately 8 cm/year at age three to around 5 cm/year at age 12. Boys who mature at the normal age then experience an adolescent growth spurt with height velocity jumping back up to 9 cm/year over a two year period before falling back over the next four or so years until the cessation of growth. The peak height velocity for adolescent girls in the 50th centile is around 8 cm/year in the Tanner-Whitehouse standards (Tanner, Whitehouse, and Takaishi 1966).

Early-maturers may experience their growth spurt two years earlier than normal, and late-maturers two years later than normal, with little effect on the final height achieved. For girls, the shape of the growth curve corresponds to that of boys in childhood, but in adolescence, girls tend to experience their growth spurt about two years earlier than boys. The variability of timing of growth spurts in girls and boys is due to both environmental and genetic factors (Thomis and Towne 2006; Ulijaszek 2006), as described later.

In terms of weight, longitudinal standards on velocity for the 50th centile of boys are approximately 9 kg/year over year one, dropping rapidly to around 2 kg/year for ages two to five, then increasing gradually to 3 kg/year at age 12 (Tanner and Whitehouse 1976). With the growth spurt, weight velocity increases rapidly and peaks around 9 kg/year after two years then decreases again over a time pattern similar to height. Similar early-maturer and late-maturer velocity patterns are seen as well. The weight velocity curve for girls is also similar to their height velocity curve,

[i] This is an early data set but remains one of the best since it is based on longitudinal (i.e. cohort or panel) data. Longitudinal standards provide convincing description of growth during adolescence. Cross-sectional data are more commonly collected, because easier and simpler to measure, but are subject to variability due to, for example, secular trends. The cross-sectional data that the current WHO growth reference for children 5–19 years of age is based on are discussed below.

with an earlier growth spurt than boys and a lower peak velocity, as evidenced in the standards (Tanner, Whitehouse, and Takaishi 1966).

2.2.1 Defining growth faltering

When growth does not proceed as expected, often due to undernutrition, faltering can be characterized by low height or weight when compared to a reference standard for a given age. Stunting, or low length/height-for-age, is usually an indication of long-term undernutrition and is defined as two standard deviations (or z-scores) below the reference standard. Wasting, or low weight-for-length/height, can indicate recent as well as ongoing undernutrition, and is similarly defined as less than -2 SD from the reference mean. Underweight, or low weight-for-age (less than -2 SD), is more difficult to interpret as it can indicate stunting and/or wasting but is often easier to screen for as height is not required (Waterlow 1973; WHO Expert Committee 1995). For children under 5 years in low- and middle-income countries, the prevalence of stunting is usually highest (28.0%), followed by underweight (17.4%) and wasting, which is typically much lower (8.8%), based on an analysis of 639 national surveys from 142 countries (Black *et al*. 2013).

2.2.2 Methodological considerations in constructing international growth standards

To monitor the health and nutrition of children globally, WHO has developed growth standards for boys and girls aged 0–60 months (WHO Multicentre Growth Reference Study Group 2006). These growth standards were aimed at improving upon the previous international growth reference (WHO Expert Committee 1995) by incorporating data on healthy, breastfed children and sampling beyond the United States. It is assumed that all populations in the age range are able to attain similar mean heights given ideal conditions, based on the evidence from birth to 7 years of relatively small variations in growth potential between ethnic groups (Habicht *et al*. 1974; Martorell and Habicht 1986).

Following on from this revision, there was a call to update the international growth reference for children aged 5–19 as well. Some of the key considerations around ethnic differences, secular change, obesity, and variability of timing of the growth spurt highlight the difficulties of monitoring growth during this age range (discussed in further detail in Section 2.5). Similar to the pre-school growth standards, a single reference may also be suitable for pre-adolescents as linear growth up to puberty is similar across populations under favorable conditions, with the possible exception of Asians (Ulijaszek 1994).

However, large differences among populations in achieved height emerge during and after puberty,[i] which may be due to environmental and/or genetic causes (Eveleth and Tanner 1990; Haas and Campriano 2006). This presents a challenge in constructing an international reference that can be used for comparison across countries or a defined, recommended standard that can be a prescriptive measure against which to judge growth (Butte, Garza, and de Onis 2006). Secular change has contributed to this variability as studies have shown populations to increase in mean height and weight and to reach maturity and the adolescent growth spurt sooner (Eveleth and Tanner 1990; Karlberg 2002). As cross-sectional sampling is unable to capture these shifts, a prescriptive international reference would ideally be based on longitudinal data of well-nourished children in a population that is no longer undergoing secular change (Seidell *et al*. 2006). Due to the heterogeneity of existing data on growth during childhood and the timing and resources needed to undertake longitudinal studies, the new WHO reference[ii] for children 5–19 years of age are based on a reconstruction of the previous growth reference[iii] (WHO Expert Committee 1995) with a smoothing to merge with the revised standards for children under the age of 5 (de Onis *et al*. 2007).[iv]

2.3 Growth faltering in early life

With the high rates of growth experienced in the first two years of life under the normal growth curve, the discussion of growth faltering often focuses on this age group. The following section describes what happens when growth falters early in life, including timing, causes, and impact on growth later in life.

2.3.1 The timing of growth faltering in early life

Timing of growth faltering has been examined by comparing international growth standards to the global mean z-scores for national, cross-sectional anthropometric surveys of children 0–59 months of age in 54 low- and middle-income countries (Victora *et al*. 2010). The overall pattern is

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[i] As evidence of inter-population attained height differences emerging during and after puberty, Haas and Campriano (2006) present growth data on the tallest children (aged 7 to 18 years) from samples of eight different ethnic and geographic groups. At ages 7 and 13, the mean height difference between the shortest and tallest groups of boys was around 6 cm (1 SD HAZ); by age 17, the difference increased to approximately 10 cm (2 SD HAZ). Generally, the tallest attained heights at age 17 of the overall (nominally healthy) samples were of groups from Europe, followed by Africa, followed by Asia.

[ii] Known as the 2007 WHO reference (de Onis *et al*. 2007).

[iii] Known as the 1977 National Center for Health Statistics (NCHS)/WHO growth reference (de Onis *et al*. 2007).

[iv] As de Onis *et al*. (2007) details, the core sample of the 2007 WHO reference was a pooling of the same three cross-sectional data sets of U.S. populations used in the 1977 NCHS/WHO growth reference. The first dataset was the Health Examination Survey (HES) Cycle II of children 6–11 years of age collected between 1963–5 (Hamill, Johnston, and Grams 1970). The second dataset was the HES Cycle III of children 12–17 years of age collected between 1966–70 (Hamill, Johnston, and Lemeshow 1973). The third dataset was a subset of Health and Nutrition Surveys (HANES) I, which included children 1–17 years of age and was collected between 1971–4 (Hamill *et al*. 1977).

as follows. At birth, the global mean anthropometric z-scores are similar to the standards. Weight-for-age z-scores (WAZ) fall gradually until 24 months, where they level off around -1.0 SD, while height-for-age z-scores (HAZ) decrease more dramatically until 24 months to around -1.75 SD and experience small bumps at 24, 36, and 48 months. Weight-for-height (WHZ) falters slightly to -0.25 SD at 9 months before improving slightly to follow the standard thereafter. As height/length and weight exhibit different faltering patterns and as stunting is associated with poor long-term outcomes (see below), Victora *et al*. (2010) highlighted the importance of monitoring height as well as weight in nutritional assessment.

Findings from five birth cohort studies in Brazil, Guatemala, India, the Philippines, and South Africa exhibit similar HAZ patterns up to 24 months (Stein *et al*. 2010). All but the India cohort experienced moderate recovery through mid-childhood (between 48 and 96 months in the studies), with only the Guatemalan study involving an external nutrition intervention. The growth pattern findings of these studies through school age, adolescence, and adulthood are discussed below.

2.3.2 The causes of early growth faltering in children

While the exact mechanisms of growth faltering are not yet fully understood, some of the basic influences on child undernutrition include the social, economic, and political context, which in turn impacts income as well as household food security, the household environment, and health services, as outlined in an operational framework developed by UNICEF (1990). These factors influence some of the more immediate causes of child growth faltering, including poor maternal nutrition (manifest in low birth weight and intrauterine growth retardation[i]), inadequate breastfeeding, poor complementary feeding, and child illness[ii] (Allen and Gillespie 2001). Other environment factors have also been associated with stunting and underweight, such as exposure to aflatoxin, though the underlying mechanisms are yet unclear (Gong *et al*. 2002; Gong *et al*. 2004; Khlangwiset, Shephard, and Wu 2011).

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[i] As the mean *z*-scores of developing countries are very similar to that of the international growth reference at birth and decreases are then observed over the first few years of life (Shrimpton *et al*. 2001), low birthweight and intrauterine growth restriction (IUGR) would seem to not greatly influence growth faltering. Shrimpton *et al*. (2001) point to the differences in weight-for-age means for Africa, Asia, and the Americas at birth. The means for Africa and the Americas are both above the international standard while the Asian mean is approximately -0.3 SD. The pattern of growth faltering thereafter is similar across the three regions. The authors conclude that, given the different starting points of the regions, preventive interventions for low birthweight and IUGR could result in improvements in weight-for-age means. The impact of IUGR is further underscored by a review of studies indicating that despite some catch-up in *z*-scores over the first two years of life, IUGR infants are still shorter and lighter at adolescence (Martorell *et al*. 1998).

[ii] Recent research of interest related to child illness and stunting include findings that open defecation without use of a latrine may contribute to stunting under the age of 5 (potentially through diarrhea) and the excess stunting observed in India, in particular (Spears 2013). Additionally, the implications of chronic enteropathy for child growth have been garnering increased attention (Scharf, Deboer, and Guerrant 2014).

2.3.3 The impact of early growth faltering on size attained later in life

Undernutrition and fetal growth restriction constitute a significant portion of the deaths of children under the age of five. Approximately 1.0 million deaths yearly are attributable to stunting (14.7% of all deaths in the age group), 1.0 million to underweight (14.4%), 0.9 million to wasting (12.6%), and 0.8 million to fetal growth restriction (11.8%) (Black *et al*. 2013). The effect of early growth faltering on education, income, and labor productivity later in life are discussed below in the section on school age and adolescence, but turning first to the impact of early malnutrition on growth in the short- and long-term, findings from longitudinal and cross-sectional data studies are reviewed in turn in the following sections.

2.3.3.1 Longitudinal data

Two sets of important longitudinal growth studies are the Consortium of Health Oriented Research in Transitioning Societies (COHORTS) and *Young Lives*. The COHORTS collaboration includes five existing birth cohort studies from Brazil, Guatemala, India, the Philippines, and South Africa (Richter *et al*. 2011).[i] *Young Lives* includes four ongoing longitudinal studies from Ethiopia, India (Andhra Pradesh), Peru, and Vietnam (Barnett *et al*. 2013). In each of the four countries, data were collected on a younger cohort (initially 6–18 months of age) of approximately 2,000 children and an older cohort (initially 7–8 years of age) of approximately 1,000 children. Further characteristics of COHORTS, *Young Lives*, and other longitudinal growth studies are summarized in Table 2.1, and findings from each are discussed below.

<u>Consortium of Health Oriented Research in Transitioning Societies (COHORTS) studies</u>

Many papers have pointed to studies tracking lack of later recovery as evidence that catch-up growth does not occur. One study that is part of COHORTS and is often cited as demonstrating the long-term impact of early growth faltering is a longitudinal study of 249 children in rural Guatemala who were measured at age 3 and then again at follow-up when they were 18 years of age or older (Martorell *et al*. 1992). The population was marked by a high degree of early malnutrition; nearly three-quarters of the children were classified as stunted by the age of 3. Because length at age 3 was independent of linear growth from age 3 to adulthood and because length at age 3 was highly related with final adult height, the authors concluded that early growth faltering was not recovered later.

These findings contrast with growth data from a birth cohort, non-intervention study in the Philippines that reported significant increases in height-for-age between 2 and 12 years age

[i] The Guatemala cohort was the only study of the five that was designed as a community trial of an energy and protein supplement; the remaining four were designed as prospective cohorts (Stein *et al*. 2010).

(Adair 1999). At age 2, around 63% of the sample children were classified as stunted. Of these, 30% were no longer stunted by 8.5 years of age and 32.5% by 12 years of age (mean increase of 1.14 HAZ). In examining determinants of the catch-up growth observed, Adair (1999) reported that those who recovered from stunting at age 2 had greater potential for growth at birth, as indicated by taller mothers, higher birth lengths, and relative thinness at birth. A general improvement in growth was also observed with increases in socioeconomic status, measured by household income, household assets, and the introduction of electricity and piped water. Energy intake, the only measure of diet assessed, was found to have a positive correlation with growth between the ages of 2 and 8.5 years but not between the ages of 8.5 and 12 years, which Adair (1999) contends could be attributed to imprecise measurement or to other dietary aspects such as quality not being captured. In subsequent analysis of data from the cohort at ages 15.5 and 18.5 years, Eckhardt, Gordon-Larsen, and Adair (2005) reported mean HAZ from 12 years of age seemed to stabilize for males but slightly decrease for females.

Young Lives studies

Emerging evidence from birth cohorts that are part of the *Young Lives* project have also reported improvements in HAZ between the ages of 1 and 5 and of 5 and 8 in samples of the 7,266 children in the younger cohorts from Ethiopia, India, Peru, and Vietnam (Schott *et al*. 2013). Between the ages of 1 and 5, 42% of the sample experienced increases in HAZ. A much greater percent (73%) experienced increases between the ages of 5 and 8, with 0.34 as the median value of absolute change over the interval.[i] Examining variation over the two intervals, the authors reported that HAZ at age 1 and age in months did not predict 40–71%[ii] of the variation in HAZ at age 5 and that HAZ at age 5 and age in months did not predict 26–47%[iii] of the variation in HAZ at age 8. Between the ages of 1 and 5, key distal household and community variables[iv] were found to predict 9–16% of the variation in the unpredicted change in HAZ,[v] while the same variables predicted 2–7% of the variation in the unpredicted change in HAZ between the ages of 5 and 8. The authors

[i] In a related analysis of the data, Lundeen *et al*. (2014) reported that the incidence of recovery (children who were stunted at the beginning of the time interval but not stunted at the end) ranged from 27–53% between ages 1 and 5 and from 30–47% between ages 5 and 8. Mani, Behrman, and Georgiadis (2012) also reported catch-up in the sample, with different levels observed across the distribution of anthropometric outcomes, which varied by country.
[ii] The range values represent the variation not predicted by HAZ at age 1 and age in years in the four countries (40% in Vietnam, 52% in Peru, 65% in India, and 71% in Ethiopia).
[iii] The range values represent the variation not predicted by HAZ at age 5 and age in years in the four countries (26% in Vietnam, 30% in Peru, 35% in India, and 47% in Ethiopia).
[iv] The household characteristics included were consumption per capita, caregivers' and fathers' schooling, mothers' height, and migration, and the community characteristics were hospital presence, urban or rural, and community wealth.
[v] The unpredicted change in HAZ refers to the HAZ changes over the age intervals that are not predicted by initial HAZ and age in months.

conclude that as associations with the distal factors observed appear to lessen with age, interventions before the age of 5 may have greater impact than those later.

Focusing on the younger cohort in Ethiopia, Outes and Porter (2013) report catch-up differing across socio-economic groups. Between the ages of 1 and 5, average gains in HAZ were nearly perfect in relatively wealthier households while HAZ was more persistent in poorer households. Contrastingly, between the ages of 5 and 8, far greater persistence in HAZ and no heterogeneity by wealth groups were observed. The authors contend that the under 5 age window may thus be more effective for remediation, though, they suggest that adolescence may provide opportunities as well.

Fink and Rockers (2014) have examined growth patterns of the older cohorts in all four countries, with data points at around 8, 12, and 15 years of age. At these times in late childhood and adolescence, the authors contend that there was substantial evidence of both catch-up and further growth faltering. Thirty-six percent of children stunted at age 8 were found to be not stunted at age 15, and around one-third of children reported to be stunted at age 15 had not been stunted at age 8. The changes in HAZ were found to be relatively large in magnitude with approximately two-thirds of children experiencing an increase or decrease of 0.25 SD or more and around 45% of children experiencing an increase or decrease of 0.5 SD or more between any two survey rounds. The magnitudes of movements were fairly similar across the 8–12 years and 12–15 years intervals, even with the pubertal growth spurt more likely to occur during the latter.

Examining the older cohort in India, Himaz (2009) analyzed factors associated with children moving into and out of stunting between 8 years of age and 12 years of age. Similar to the cross-country findings, while the majority of those stunted in the first round of data collection remained stunted in the second round, around one-quarter of those stunted initially moved out of stunting. Additionally, approximately 10% of the total sample moved from not being stunted at the first round to being stunted at the second round. The key factors that were reported to influence a child moving out of stunting were mother's education and coming from a prosperous region in the state. The study also assessed food consumption and observed that children who moved out of stunting seemed to consume a diet higher in protein than children in other groups.

<u>Other studies</u>

Additional longitudinal child growth studies conducted in Senegal and Tanzania have also reported recovery following early faltering. In Senegal, the mean HAZ of a cohort of 2,874 individuals was observed to be -1.30 for girls and -1.40 for boys in early childhood (1–5 years of age) and -0.40 for girls and -0.46 for boys in adulthood (Coly *et al*. 2006).[i] Additionally, around 80% of children who were stunted in childhood had a HAZ greater than -2 in adulthood. Similar changes were reported in a study of 540 children followed from early childhood (12–59 mo) to adulthood in rural Tanzania, with mean HAZ increasing from -1.86 to -1.20 over the time period (Hirvonen 2014).[ii] The author argues that most of the catch-up occurs during puberty and that without catch-up, girls would have been 5 cm shorter and boys 4.5 cm shorter in adulthood. Differences in catch-up by initial nutritional status have also been observed, including in a study of 304 Amazonian Bolivian children (2–7 years of age at baseline) who were measured each year for a period of five years (Godoy *et al*. 2010). For HAZ, girls stunted at baseline gained, on average, 0.49 SD and boys 0.45 SD. However, non-stunted girls and boys lost 0.35 SD and 0.61 SD, respectively.

2.3.3.2 Cross-sectional data

Cross-sectional studies from The Gambia and Kenya have also suggested catch-up in growth. From data collected on 36,828 individuals in rural Gambia between 1951 and 2006, mean HAZ was found to be around -0.75 at birth, dropping to between -2.25 and -2.5 at 24 months, and rising to -1.75 at 5 years (Prentice *et al*. 2013). A period of stability ensued until a drop-off in early adolescence (due to the reference entering puberty sooner than the study population), which was followed by a period of extended catch-up in growth until adulthood (mean HAZ approximately -1.5 in males and -0.75 in females). In Kenya, a cross-sectional study employed local rather than international references, comparing adolescents in urban, privileged schools with those in a rural, impoverished school in an area with high malnourishment (Kulin *et al*. 1982). At age 10, the urban students were more than 12 cm taller than the rural students ($p < 0.01$, 1.7 SD greater for boys and 2.0 SD greater for girls), but by age 18, the rural students were found to have heights similar to those from studies of well-nourished groups in Kenya, suggesting catch-up during adolescence.

Both the longitudinal and cross-sectional studies above suggest that catch-up growth is physiologically possible after early growth faltering, in the great majority of cases without any specific interventions. These findings are further supported by studies at school age and adolescence that do involve interventions, which are explored later in Section 2.6.

[i] Using a method to account for regression to the mean suggested by Cameron, Preece, and Cole (2006) (discussed below), HAZ in adulthood was expected to be -0.78 for girls and -0.87 for boys, which the observed adult HAZ values greatly exceed.
[ii] Nearly 75% of children had a negative HAZ in early childhood followed by a change in HAZ that was greater than 0.

Table 2.1 Characteristics of longitudinal birth cohort studies on child growth

Country	Enrollment	Ages (and/or years) at which data on growth were collected	Number at last data point	Sources
COHORTS studies				
Brazil	Birth (1982)	12, 24, 48 mo; 18, 23 yrs	4,297	Stein *et al.* (2010); Richter *et al.* (2011)
Guatemala	Birth (1969–77)	15 d; 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36, 42, 48, 54, 60, 66, 72 mo; adolescence (1988); adulthood	1,571	
India	Conception (1969–72)	Every 6 mo from birth to 21 yrs; adulthood	1,583	
The Philippines	Pregnancy (1983–4)	Birth; every 2 mo until 24 mo; 102 mo; adolescence; adulthood	2,032	
South Africa	Pregnancy (1990)	6, 12, 24, 60, 132 mo; adolescence	2,225	
Young Lives studies				
Ethiopia	6–18 mo for the YC and 7–8 yrs for the OC (2002)	6–18 mo; 4–5, 7–8, 11–12 yrs (14–15 yrs planned for 2016) for the YC 7–8, 11–12, 14–15, 18–19 yrs (21–13 yrs planned for 2016) for the OC	1,757 YC 974 OC	Barnett *et al.* (2013); Schott *et al.* (2013); Fink and Rockers (2014)
India (Andhra Pradesh)			1,825 YC 976 OC	
Peru			1,847 YC 678 OC	
Vietnam			1,837 YC 976 OC	
Other studies				
Bolivia	2–7 yrs (2002)	2002 (children 2–7 yrs), 2003, 2004, 2005, 2006	304	Godoy *et al.* (2010)
Senegal	1–5 yrs (1983–4)	1–5, 18–23 yrs	2,874	Coly *et al.* (2006)
Tanzania	12–59 mo (1991–4)	1991–4 (children 12–59 mo), 2004, 2010	540	Hirvonen (2014)

Abbreviations: YC = younger cohort; OC = older cohort
Note: For ages (and/or years) at which data on growth were collected for *Young Lives*, information was drawn from www.younglives.org.uk/what-we-do/household-and-child-survey in addition to Barnett *et al.* (2013).

2.3.4 Defining catch-up growth and the variability of growth velocity

Before moving on to discuss the effectiveness of addressing stunting through interventions early in life, it is helpful to outline the various ways in which the potential for recovering from early growth faltering has been discussed and understood in the literature. James Tanner, in his treatise on human growth (1986), defined "catch-up growth" as a phase of recovery following nutritional incident, marked by a much higher growth rate for age than expected. Recovery can also be achieved by a lengthening of the time period of growth, as well as a combination between higher growth rate and a longer growth period (Largo 1993). Catch-up growth can be distinguished from "compensatory growth," which has been defined as the effort of an organ to overcome loss of tissue mass by cell division, cell enlargement, or both (Holder 1981; Williams 1981). Boersma and Wit (1997) further contrast the two concepts by characterizing compensatory growth as a response to an alteration in a spatial variable and catch-up growth as a response to a change in a temporal variable.

One further complexity that arises when comparing heights- and weights-for-age over time is the statistical phenomenon of regression to the mean, or more simply put, the tendency for a variable, if measured to be extreme at one time, to be closer to the mean at another time (Galton 1886; Fitzmaurice 2000). To measure "true" catch-up growth, accounting for regression to the mean, Cameron, Preece, and Cole (2005) suggest that the height z-score scale be used rather than height in longitudinal growth studies. By measuring regression to the mean on the same z-score scale as HAZ, the two can be distinguished and mean catch-up growth can be defined as the mean observed z-score minus the expected z-score due to regression to the mean (Cameron, Preece, and Cole 2005).[i]

Regression to the mean could help explain catch-up growth observed in infancy, as smaller birth babies tend to grow more and larger birth babies tend to grow less. An oft-cited longitudinal study of height and weight to 13 years reported that, during the first year, shorter babies gained more in length than longer babies (Simmons and Todd 1938). A prospective cohort study of low birth weight babies also found that the children who exceeded the 3rd height centile by 4 years experienced a significantly greater growth velocity over the first 12 months than the control group (Fitzhardinge and Steven 1972). Similarly for weight, a partially longitudinal study found that 5-lb birth weight babies had higher weight velocities than 9-lb birth weight babies over the first 20 weeks of life (British Ministry of Health 1959). A study of 90 well-nourished American infants also showed that individuals who moved from approximately the 10th centile for height at birth to the 70th centile at 2 years experienced higher growth velocities for one year (Smith *et al.* 1976).

Just as catch-up growth has been documented, "catch-down" growth, or compensatory deceleration, has also been observed as a naturally occurring phenomenon. In addition to the shifting upward in linear growth by infants, Smith and colleagues (1976) also reported larger babies sinking down in the centiles. The infants who were near the 90th centile at birth and who moved to around the 40th centile at 2 years achieved their new growth trajectory by around 13 months. Catch-down growth following artificial stimulation has also been documented. Children with Silver-Russell syndrome who were treated with human growth hormone for a year experienced catch-up growth velocity followed by a time of catch-down velocity, a velocity lower even than was predicted pre-treatment (Tanner, Lejarraga, and Cameron 1975). Similar patterns were seen following growth hormone treatment in children of short stature who were otherwise normal (Van Vliet *et al.* 1983).

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[i] Cameron, Preece, and Cole (2005) calculate catch-up growth using mean HAZ at first measurement (z_1) and at second measurement (z_2) and their correlation (r). With regression to the mean, HAZ at second measurement is expected to be $E(z_2) = rz_1$. Catch-up is then calculated as the HAZ at second measurement minus the expected HAZ at second measurement, $z_2 - rz_1$.

2.4 Interventions in early life to address growth faltering

Evidence on the ability to prevent or address stunting and by what means has informed the timing of nutrition interventions, whether *in utero*, infancy, early childhood, or school-age. There is clear evidence on the impact of maternal and child health programs on child growth, as detailed below, along with the increasing focus on the benefits of intervening in early childhood.

2.4.1 Evidence on the nutrition benefits of intervening during pregnancy and in infancy

A review of the effect of nutrition-related interventions on stunting found that, of large-scale, high-coverage programs, feeding interventions and zinc supplementation could have the greatest relative reduction in the prevalence of stunting by 36 months (Bhutta *et al*. 2008). Their pooled analysis of seven food supplementation studies in food-insecure populations estimated an increase in height-for-age z-scores of 0.41 (95% C.I.: 0.05, 0.76) compared to the controls. A meta-analysis of zinc supplementation studies also found significant effects on both height and weight growth increments of prepubertal children (Brown *et al*. 2002). The weighted average effect size on weight was 0.31 (0.18, 0.44) and on height was 0.35 (0.19, 0.51), with stunted children over 6 months of age experiencing a significantly greater effect.

Supplementary feeding (Ceesay *et al*. 1997; Kramer and Kakuma 2003), multiple micronutrient supplementation (Bhutta *et al*. 2008), and intermittent preventive treatment during pregnancy (ter Kuile, van Eijk, and Filler 2007) have been shown to affect low birth weight and intrauterine growth restriction, which often leads to stunting.

As an instance of practical delivery, conditional cash transfer (CCT) programs have also been shown to significantly improve child growth and reduce the prevalence of stunting. An evaluation of the PROGRESA program in Mexico reported an additional one centimeter increase in height (about one-sixth of the mean growth) per year in children aged 12–36 months (Behrman and Hoddinott 2001). The *Familias en Acción* program in Colombia was also seen to increase height-for-age z-scores in children under 24 months by 0.161 (Attanasio *et al*. 2005).[i] This effect, which is approximately 0.43 cm at one year of age, was not seen in older children. In Nicaragua, the *Red de Protección Social* program reduced the prevalence of stunting in children by 5.5% (Maluccio and Flores 2005).[ii] Contrastingly, the *Programa de Asignación Familiar* in Honduras reported no effect on anthropometric status of preschoolers (IFPRI 2003), and an evaluation of the Bolsa Alimentação

[i] Statistically significant at the 10% level.
[ii] Statistically significant at the 10% level.

program in Brazil found a small reduction in weight gain in children less than 2 years of age (Morris *et al*. 2004). The null effect in Honduras could potentially be attributed to low coverage and a relatively small transfer, and the adverse effect in Brazil may be due in part to a misconception that children would need to continue to be found malnourished in order to qualify for the program (Hoddinott and Bassett 2008).

Breastfeeding promotion and Vitamin A supplementation in children have not been shown to greatly influence growth. A meta-analysis of breastfeeding promotion interventions reported a positive but non-significant impact on height or weight gain for infants (Giugliani and Victora 2008). Similarly, a meta-analysis of 19 datasets found a small but non-significant effect of Vitamin A supplementation on height gain in children under 5 years of age, and no overall effect on change in weight-for-age or weight-for-height z-scores (Ramakrishnan, Nguyen, and Martorell 2009).

2.4.1.1 Early hospital treatment for severe malnutrition and assessment of catch-up growth

Complementing the well-reviewed literature on early interventions above are studies of hospital treatment for severe malnutrition early in life. Subsequent follow-up from these interventions have indicated more mixed effects on height and weight in the short- and long-term, with some studies suggesting progressive improvement into school age and adolescence.

<u>Short-term assessment of growth following early hospitalization</u>

Some studies involving early hospitalization for treatment of severe malnutrition have found limited improvements in short-term growth. In Jamaica, 17 severely malnourished children between the ages of 6 and 24 months were admitted to a hospital for treatment and then followed for 36 months after discharge (Grantham-McGregor *et al*. 1982). Their growth was compared with 14 well-nourished children in the hospital for other reasons. The malnourished children failed to make up any of their deficits while in the hospital, and while there was some improvement in height and head circumference over the next three years, they were still significantly behind the controls at the time that observation ended. A study that compared the growth of 369 severely malnourished children at admission to a hospital in the West Indies to that at discharge did not find any overall change in height-for-age (mean of -3.4 SD at both time points) (Walker and Golden 1988). However, of these children who were under the age of 3 and spent more than 3 weeks in hospital, a sub-group of 108 demonstrated catch-up growth in height. These children, who did not differ in age or sex from the overall sample, were significantly more stunted at admission.

Long-term assessment of growth following early hospitalization

Studies that have followed up growth longer term after early hospitalization have also found some catching up in height but falling short of local comparison groups. One example is from Uganda, where 152 children, who had been treated in hospital for severe protein deficiency between 1–5 years of age and released, were examined six to eleven years later (Krueger 1969). The height and weight centiles were unchanged between admission and follow-up, but as only two of the girls had reached puberty, Krueger suggests that further growth may have been observed had follow-up occurred post-puberty.

Another study in Uganda compared age during treatment for protein energy malnutrition with growth at 11–17 years of age (Briers, Hoorweg, and Stanfield 1975). The retrospective analysis, which divided the children into three groups according to the age they had been treated (8–15 months, 16–21 months, and 22–27 months), found no later differences in height or bone age[i] between the groups. These malnourished children were however significantly shorter than a local comparison group.

Similarly, in Chile, children who had also been admitted to a hospital during infancy for treatment of protein energy malnutrition were subsequently followed for a period of 4–6 years (Alvear *et al*. 1986). Though they showed some evidence of catching up in height-for-age, they were still shorter than local controls at the end of follow-up, potentially also associated with their significantly lower birth weight and the shorter stature of their mothers.

While the long-term studies above have been cited as suggesting that early malnutrition results in permanent height stunting, other studies have reported subsequent catch-up to local and international standards. For instance, no differences between malnourished children and controls were seen in a long-term follow-up study in Jamaica (Garrow and Pike 1967). Sixty-five children who were treated in hospital an average of 8 weeks for severe malnutrition were followed up 2–8 years after discharge and compared with siblings or close relatives. The height-for-age and weight-for-age of the two groups did not significantly differ, a finding that was further confirmed by follow-up at 6–11 years (Richardson 1975). After the age of 7, the height-for-age and weight-for-age of the treated group also did not differ significantly from Jamaican standards.

In South Africa, a longitudinal study of 123 kwashiorkor[ii] patients under the age of five who were treated in hospital found that ten years later, nearly half the children had reached international

[i] See discussion of bone age below.
[ii] Kwashiorkor is a clinical form of severe protein-energy malnutrition, resulting from protein deficiency (while marasmus, another form of protein-energy malnutrition, reflects energy deficiency) (Waterlow 1997). Williams (1935) introduced the name kwashiorkor, which comes from the Ga language of Ghana and means "the disease of the displaced

standards for both height and weight (Keet *et al*. 1971). Growth of the ex-patients and matched sibling controls also was not significantly different. At admission, 8.6% of the ex-patients were above the 3^{rd} centile of the international height standard. Five years later, 22.1% were above the 3^{rd} centile, and ten years later, 42.3% exceeded this cut-off point. Follow up after 15 years indicates that the mean weight-for-age of boys (both ex-patients and their sibling controls) crossed above the 3^{rd} centile around 12 years of age, and for mean height-for-age, cross-over occurred at 15 years (Bowie *et al*. 1980). For girls, growth appeared to be less slowed as mean weight-for-age crossed above the 3^{rd} centile at 9–10 years, and at 16–17 years, mean weight-for-age was closer to the 50^{th} centile of the standard than the 3^{rd} centile. The mean height-for-age of girls crossed above the 3^{rd} centile around 14 years.

The studies above suggest that further improvements in growth status can occur during school age and adolescence following early intervention, and complement findings from studies of nutrition interventions at later ages discussed in Section 2.6.

2.4.2 Evidence on the nutrition benefits of intervening in early childhood

Between interventions before the age of two and interventions at school-age, there has historically been a gap in programmatic responses, one that early childhood development programs are increasingly looking to fill (OECD 2006). A meta-analysis of 30 early childhood interventions targeted to infants/toddlers and/or preschoolers in low-, middle-, and high-income countries assessed effect sizes on health, including motor skills as well as height-for-age, weight-for-age, and other anthropometric outcomes (Nores and Barnett 2010). These interventions were found to have substantial and sustained benefits for health, with a mean Cohen effect size (ES) of 0.38 (SD 0.60) for cash transfers, ES 0.38 (SD 0.23) for nutrition interventions, and ES 0.23 (SD 0.29) for nutrition and education or stimulation.

2.5 School-age and adolescent growth

Having explored growth faltering in early life and interventions before school above, the following section details key considerations when discussing growth in school age and adolescents. The impacts throughout life of growth faltering are discussed, particularly as regards education, adult income, and productivity. Undernutrition also delays the adolescent growth spurt and puberty, which along with related issues of skeletal maturity, present challenges when assessing catch-up growth later in life.

child" (Waterlow 1997), indicating how, in at-risk populations, older children may suffer from weaning to a protein-deficient diet when a new child is born.

2.5.1 The impact of growth faltering on education, adult income, and productivity

Growth faltering during childhood has also been shown to have far-reaching implications throughout life. A number of cross-sectional studies have shown that stunted children enroll later in school (Moock and Leslie 1986; Glewwe and Jacoby 1995; PCD 1999; Glewwe, Jacoby, and King 2001), lag behind in school (Jamison 1986), and score lower on cognitive tests (Johnston *et al*. 1987; Sigman *et al*. 1989). In longitudinal studies as well, stunting early in life has been associated with outcomes later on. Analysis of data from the *Young Lives* studies found that HAZs at 1 year were positively associated with math, reading, and vocabulary scores at 8 years (Crookston *et al*. 2013). Similarly, in Jamaica, children under two who were stunted scored lower on cognitive tests at 17–18 years and were more likely to drop out of school (Walker *et al*. 2005). In addition to poorer cognitive ability and increased dropout, children with stunting at age 2 in the Philippines were also more likely to have enrolled later and repeated grades in follow-up at ages 8 and 11 (Mendez and Adair 1999). A pooled analysis of five birth cohorts also found that one standard deviation increases in birthweight and in weight gain from 0 to 2 years were associated with increased years of schooling and reduced likelihood of grade failure (Martorell *et al*. 2010).

Though causality is not yet fully understood, non-stunted children may perform better scholastically at least in part because they enter school earlier and enjoy greater learning productivity per school year, rather than because of inputs such as hours of homework, help with homework, and absenteeism that have been found to be uncorrelated (Glewwe, Jacoby, and King 2001). Based on the effect of stunting and poverty on years of schooling attained and learning per year in school, as well as the effect of each year of schooling attained on adult yearly income (Duflo 2001; Psacharopoulos and Patrinos 2004), Grantham-McGregor *et al*. (2007) estimated the effect of stunting and poverty on adult income. According to their calculations, children who are stunted but not living in poverty lose an estimated 22.2% in adult yearly income and children who are both stunted and living in poverty lose 30.1%.

Additionally, in Guatemala higher HAZs at 24 months have been associated at adulthood with different characteristics of marriage partners (older, more educated, taller) (Hoddinott *et al*. 2013). For women, the same study found associations between higher HAZs at 24 months with being older at first birth as well as with fewer pregnancies and children.

Relationships between stature and fitness have also been established. In the same Guatemala cohort, severely stunted pre-school children had significantly lower oxygen uptake at maximum exertion during adolescence (Haas *et al*. 1996), and in adulthood, shorter sugarcane laborers in Brazil were found to have lower productivity (Florêncio *et al*. 2008).

2.5.2 Undernutrition delays the adolescent growth spurt and the onset of puberty

In addition to health, education, and economic impacts later in life, early undernutrition can affect growth at adolescence. Stunted children reach peak height and weight velocity later, as seen in a cross-sectional survey in Kenya comparing the growth of poor, rural children who were malnourished with well-off children living in urban areas. The rural boys experienced a 3 year delay in the onset of sexual maturity, and in the rural girls, the beginning of menarche also lagged by 2.1 years (Kulin *et al*. 1982). Similarly, in India the age of peak height and weight velocity was delayed by 2 years in severely stunted boys (Satyanarayana, Nadamuni Naidu, and Narasinga Rao 1980), and the age of menarche was delayed by 1.5 years in severely stunted girls (Satyanarayana and Nadamuni Naidu 1979). In the United States, it was found that undernourished girls also reached menarche 2 years later than well-nourished girls, but as their time of increased growth velocity lasted longer, there was no significant difference in the final heights of the two groups at skeletal maturity (Dreizen, Spirakis, and Stone 1967). In the height growth study throughout the life cycle in the Gambia mentioned above, catch-up was observed both at the delayed onset of puberty and through a prolonged period of growth (Prentice *et al*. 2013a).

2.5.3 Challenges in assessing catch-up growth at school age

In addition to the issues around regression to the mean, ethnic differences, and secular change discussed earlier, complexities that the growth spurt, skeletal maturity, and standard deviations raise all present challenges when assessing catch-up growth at school age.

2.5.3.1 Conflation between the pubertal growth spurt and catch-up growth

The growth spurt at puberty also presents difficulties in assessing catch-up in adolescence, as demonstrated by the frequent conflation between the pubertal growth spurt and catch-up growth throughout the history of the study of human growth. As Tanner (1979) relates, during the 18th century, catch-up growth was being confused for the adolescent growth spurt, while during the 19th century, the opposite confusion was happening. The normal adolescent growth spurt was cited as evidence of catch-up following illness. Now, even though greater understanding of catch-up growth and the growth spurt at puberty exists, any clear distinctions between the two along an individual's growth curve are often impossible to draw.

2.5.3.2 The difference between bone age and height age

The issue of bone age versus height age has also been subject to much discussion when examining catch-up growth and the maturation process. Early in life, a greater part of the skeleton is made of cartilage, which progressively becomes ossified and grows in length and shape until full ossification, resulting in the adult skeleton. When examining the relationship between delays in this maturation process and delays in height, if the bone maturation of undernourished children is not slowed to the same extent as growth in body size, any potential later catch-up may be restricted by earlier ossification, as some have concluded based on z-score comparisons of the two (Martorell *et al*. 1979). On the other hand, Golden (1994) contends that as bone age and height curves have very different shapes and as the standard deviations for bone age are much greater than those for height, z-scores may not be able to provide an adequate comparison. When bone maturity scores of stunted children are plotted against standards for bone age, Golden concludes that both bone maturation and height gain are decidedly delayed and that the potential for catch-up growth is retained. Further studies report mixed results for the relative timing of delays in bone maturation and height (Dreizen, Spirakis, and Stone 1967; Reichman and Stein 1968; Adams and Berridge 1969; Keet *et al*. 1971; Graham 1972; Briers, Hoorweg, and Stanfield 1975; Alvear *et al*. 1986). The variability in the skeletal ages derived from the main methods used to assess bone maturation further highlights the difficulty of drawing conclusions between the relationship between bone age and height age (Roemmich *et al*. 1997).

2.5.3.3 The increase in age- and sex-specific SDs from childhood to adolescence

Age- and sex-specific SDs are used to calculate HAZs (i.e. HAZ = [individual's height – average height of the reference population by age and sex]/standard deviation of reference the population by age and sex). These SDs are not constant but rather increase from childhood to adolescence. As Leroy, Ruel, and Habicht (2013) contend, if an individual's height deficit stays the same over time, his/her HAZ will increase. They suggest that catch-up growth then should not be defined as improvements in z-scores over time but rather as a reduction in the absolute deficit in height. Prentice *et al*. (2013b) respond by arguing that even if increases in absolute deficits in height occur in the COHORTS data (Stein *et al*. 2010), the proportional deficit from the 50th centile reference decreases.[i] They also use centile equivalents of z-scores to provide examples of how increases in z-scores can dramatically improve an individual's centile placement between early childhood and adulthood.

[i] It could also be argued that examining catch-up growth using height deficits is unable to account for regression to the mean in longitudinal studies, as discussed earlier (Cameron, Preece, and Cole 2006).

All of the intricacies above may underlie some of the variability that has been seen in the growth outcomes of interventions at school age, discussed below.

2.5.4 Is catch-up growth at school age always beneficial?

Even if catch-up growth is possible, the case may be that it is not always beneficial later in life. A systematic review of 23 studies reported positive associations between rapid postnatal growth and blood pressure in adulthood; however, the association could not be determined independently of prenatal growth (Huxley, Shiell, and Law 2000). A study in India also found associations between impaired glucose tolerance and diabetes and increases in body mass index (BMI) between 2 and 12 years of age (Bhargava *et al*. 2004). However, the study also reported that the higher the age at which adiposity rebound occurred, the lower the prevalence of impaired glucose tolerance and diabetes, similar to findings from a longitudinal study in Helsinki (Eriksson *et al*. 2003). In India, greater BMI gain in childhood and adolescence (but not in infancy) was also associated with increased adult adiposity (Sachdev *et al*. 2005). Similar findings were reported in Brazil, though the authors concluded that no clear critical age period of tissue mass programming could be discerned (Victora *et al*. 2007). Additionally, the Cochrane review of school feeding programs found that gains in weight were moving children not from normal to overweight but from underweight to normal (Kristjansson *et al*. 2007).

In the discussion of catch-up at school-age, it is important to distinguish between linear growth and weight gain, as highlighted by a recent analysis of five birth cohorts, which suggested that after the age of 2, rapid weight gain that is not accompanied by gains in linear growth can do more harm than good (Adair *et al*. 2013). The authors recommend the development and promotion of interventions that improve linear growth rather than just weight gain.

2.6 Interventions at school age

Interventions at school-age have been shown to be an important part of a life-cycle approach to nutrition. In terms of impact on anthropometric outcomes, evidence related to changes in environment, interventions addressing secondary stunting and underweight, food and micronutrient supplementation, and deworming is presented below.

2.6.1 Changes in environment

A number of studies following the growth of children who immigrated, were adopted, or moved to institutional settings indicate the impact that changes in environment can have on height and weight gain later in life.

2.6.1.1 Immigration studies

One study on immigration compared the growth of Turkish children born in Turkey and Sweden (Mjönes 1987). In the cross-sectional part of the study that analyzed data from 7–9 year olds, Turkish children born in Sweden were found to have significantly lower height-for-age and weight-for-age than Swedish standards. In the retrospective analysis component, children who were born in Turkey but then immigrated to Sweden were found to be short at first measurement but soon caught up and were not short at subsequent measurements, with heights similar to those of Turkish children born in Sweden. Likewise, a cross-sectional immigration study in Glasgow assessed the growth of 196 Asian, 89 African, 96 Chinese, and 98 Scottish children according to their country of origin (Goel *et al*. 1981). For all the ethnic groups, children who were born in Scotland had higher mean heights and more advanced bone age than those born overseas. The Asian, African, and Chinese children were all found to be taller than their Scottish counterparts as well.

A semi-longitudinal study of immigrant children to San Francisco assessed anthropometric measures of 5–12 year olds of Hispanic, Chinese, Filipino, and Southeast Asian descent shortly after arrival and followed up at three-month intervals for one year thereafter (Schumacher, Pawson, and Kretchmer 1987). Upon arrival, most of the mean heights and weights of the four ethnic groups were between the 5^{th} and 25^{th} centiles of the U.S. population. Upon follow-up, most cohorts featured a median growth rate that exceeded that of the U.S. reference, with no differences noted between younger and older children. Had the smaller size of the immigrant children also been corrected for, an even greater growth rate would have been observed. These results suggest that catch-up was occurring rapidly across ethnic groups over the first year following immigration. Another cross-sectional study compared the height and sitting height of Maya children 5–12 years of age living in the U.S. (n = 431), the offspring of Maya adults who immigrated, to that of Maya children living in Guatemala (n = 1,347) (Bogin *et al*. 2002). Maya children living in the U.S. were found to be 11.5 cm taller and 6.8 cm longer-legged than their counterparts in Guatemala, further supporting the hypothesis that both height and body proportions are sensitive to changes in environment.

2.6.1.2 Adoption studies

As Golden (1994) highlights, these immigration studies show the effect of changes in the physical rather than the familial environment. Adoption and institutional studies address this latter case, further supporting the evidence that a change in the quality of an environment can improve growth later in life. In Peru, a unique study was conducted (Graham and Adrianzen 1971), wherein severely malnourished children from very poor families were admitted to a convalescent unit shortly after birth and kept in this protected environment on an ideal diet until an average age of 17.6

months. The growth of these children (n = 26) was followed up to age 8 (Baertl, Adrianzen, and Graham 1976) and compared with siblings as controls (n = 444) (Adrianzen, Baertl, and Graham 1973). At six months, the mean heights for girls for both groups were around the 10th centile of the U.S. reference. By 18 months, the mean height for the malnourished group in hospital had risen to nearly the 50th centile, while the mean height of the siblings at home had dropped to just below the 3rd centile, with a similar pattern seen in both groups of boys. Within a year of returning home, the mean height of the malnourished group dropped back down to that of the siblings who had remained at home, and up through the last measurements at 8 years, there was no significant difference in the heights of the two groups. These findings suggest that environments promoting growth later in life are needed to consolidate early gains.

Another study in Peru examined the converse, children moving from a poor to a privileged environment (Graham and Adrianzen 1972). Sixteen severely malnourished children were admitted to the convalescent unit, eight of whom were adopted to a more privileged home environment after discharge and eight of whom, who had been selected to "match" as controls, returned to their low-income home environments after discharge. The later adopted children had a mean age of 9 months at admission and a mean height nearly identical to that of the matched controls (mean age 8 months at admission). The control children were discharged around a mean age of 16 months whereupon they returned to their homes, while the adopted children stayed in the hospital until a mean age of 26 months and were adopted around 48 months. Throughout the first 48 months of life, both groups were found to have similar heights-for-age, gaining at a comparable and slow pace. However, the last reported measurement at age 9, the children who were adopted were found to be significantly taller than the controls. The children back at home grew beneath the 3rd centile of the U.S. reference whereas the adopted children by age 9 were at the 25th centile, further underscoring the significance of later environment for growth.

The growth of 240 female Korean orphans has also been studied following their adoption between the age of 2 and 5 years by American families (Lien, Meyer, and Winick 1977). In the retrospective analysis, at the time of admission to the adoption agency, the children were divided into three groups according to their height centile in reference to normal growth of Korean children: the first group being malnourished (below the 3rd centile), the second group being moderately malnourished (between the 3rd and 24th centiles), and the third group being well-nourished (above the 25th centile). When the children were measured 4–15 years later, all three groups were found to be above the 50th centile of the Korean reference for both height and weight, though there were still statistically significant differences in the mean height and weight centiles between all the three groups. In a similar study following growth of female Korean orphans who were adopted before the age of 2, all groups also surpassed the 50th centile for height and weight, with the only statistically significant difference remaining between groups one and three for height (Winick, Meyer, and Harris 1975).

A further study followed growth through adulthood of 107 Indian girls adopted into Swedish families and found rapid catch-up following adoption (Proos, Hofvander, and Tuvemo 1991a). At arrival in Sweden, the majority of the girls were between 3 and 6 years old, and two years after arrival, it was possible to calculate catch-up in height for 60 of the girls and in weight for 63 of the girls. Over these two years, the mean height-for-age z-score increased from -2.3 to -0.8, with weight-for-age also improving from -2.0 to -0.8 (U.S. reference population). Analysis also showed that the children with lower heights and weights at arrival subsequently experienced more pronounced catch-up growth. The girls with the fastest catch-up growth and later arrival ages (after the age of 3) also had significantly early ages at menarche (Proos, Hofvander, and Tuvemo 1991b). On the whole, at puberty the height-for-age of the children was -0.3 z-score, far exceeding local Indian standards, but at the final adult stature was found to be -1.4 z-score, suggesting that the very early puberty may have led to a lower final height.

In England, the growth of previously abused children was followed up after they were either discharged home (n = 64), placed in long-term foster care or adopted (n = 20), or placed in short-term foster care and then returned home (n = 11) (King and Taitz 1985). At referral, the ages of the children ranged from 8 weeks to 12 years, and at follow-up, the ages ranged from 9 months to 14 years. Overall, the children experienced significant improvements in both height-for-age and weight-for-age z-scores, with the long-term foster care group showing the greatest improvement.

2.6.1.3 Other changes in environment studies

Studies of other instances of changes in environment have reported remarkable catch-up in growth, including among slaves and boys in military schools. Data from the coastal slave trade in the United States from 1820 to 1860 include the names, age, sex, and height of 50,606 individuals, the growth of whom has been analyzed by Steckel (1987). Throughout childhood, both males and females were at about the 1st centile of modern standards for height. During adolescence, however, a rapid rise through the centiles was observed. The peak height increase for girls and boys was reported at 13 and 15 years of age, respectively, with later maturation but a longer period of growth than modern standards. By adulthood, females were found to be around the 32nd centile of the reference population and males were around the 24th centile. Steckel suggests that poor pre-natal care and early weaning along with poor nutrition and a heavy disease burden contributed to poor growth in childhood and that the improved food rations given to adolescents as they became laborers may be the only change that could account for the catch-up growth observed.[i]

In comparison to data from other populations in the 18th and 19th centuries, including German peasants, Creole slaves, English laborers and non-laborers, Irish and Americans in Boston, lower and upper classes in Italy, and Russian factory workers, the catch-up growth reported among American slaves is unique (Steckel 1987). One other study of students at Hapsburg military schools is more similar to the Steckel findings (Komlos 1986). The height of the boys, who were sons of ordinary soldiers and who were stunted at admission, increased significantly in adolescence following the Napoleonic Wars.

2.6.2 Interventions addressing secondary stunting and underweight

The effect of treating illnesses that lead to stunting, including both chronic and acute conditions, has also been explored. Conditions that have been found to limit linear growth include celiac disease (Young and Pringle 1971; Exner *et al.* 1978), growth hormone deficiency (Rimoin *et al.* 1968), hypothyroidism (Rivkees, Bode, and Crawford 1988), and corticosteroid excess (Hyams and Carey 1988).

2.6.2.1 Treatment of celiac disease

In a study of 60 children with celiac disease, who were diagnosed before the age of nine and whose growth was analyzed up to puberty, increasing growth retardation was observed for both height-for-age and weight-for-height in the year before diagnosis (Damen *et al.* 1994). After initiation of a gluten-free diet, the children experienced a rapid catch-up in height over the first year, with complete catch-up in 2–3 years, irrespective of age. Complete catch-up growth in the mean weight-for-height was achieved in 15 months. These findings support previous results from a study of 13 children 9–15 months of age who completely caught up in height, weight, and bone age following a gluten-free diet for 3 years (Barr, Schmerling, and Prader 1972). In adulthood, the final heights of celiac patients on a gluten-free diet for at least 18 months were found to be no different to the adult heights of a matched reference population (Bodé *et al.* 1991). While some smaller studies have suggested that the higher the age at diagnosis the lower the chance of catch-up (De Luca *et*

[i] Findings from recent studies on economic growth and civil conflict further support the importance of adolescence for growth. Moradi (2010) analyzed Demographic and Health Survey (DHS) data on heights of approximately 200,000 women from 28 countries in sub-Saharan Africa and reported significant positive effects of economic growth on adult height not only during infancy but also during puberty. Interestingly, a study of Nigeria DHS data on over 13,000 women who were children during the civil war that ran from 1967–70 found that adult height was more sensitive to war exposure during adolescence (13–16 years of age) than during younger ages (Akresh *et al.* 2012).

al. 1988; Bosio *et al*. 1990), a study of 136 adults with celiac disease found no great effect of early treatment on final height (Cacciari *et al*. 1991).

2.6.2.2 Treatment of growth hormone deficiency

Studies of growth hormone replacement therapy for children with growth hormone deficiency have shown significant increases in height velocity over the first years of therapy. However, with early methods, final height remained below the population means. For example, in an oft-cited study, the final height of 55 patients treated for various hormone deficiencies for 2 to 15 years was found to be an average of 2.3 SD below the population mean (Burns *et al*. 1981), compared to approximately 6 SD below that has been found in untreated patients (Rimoin *et al*. 1968). As growth at puberty appeared normal in the treated patients (the majority of whom were 9–14 years of age), Burns *et al*. suggest early diagnosis and treatment may be important in the prevention of such significant growth faltering. A more recent analysis of data from growth hormone treatment of idiopathic short stature in 3,743 patients included cohorts of children under 5 (n = 283) and children who were pubertal at the start of treatment (mean age 13.8 years; n = 940) (Kemp *et al*. 2005). Though the younger cohort experienced greater improvements in height-for-age z-scores, the pubertal children also showed significant increases in growth rate and height-for-age z-scores, even while limited to the length of time they are able to respond to the treatment. Optimal growth hormone regimens continue to be investigated, particularly treatment during puberty (Wit *et al*. 2008).

2.6.2.3 Treatment of hypothyroidism

The efficacy of hypothyroidism treatment has also been mixed. A study of 103 children with congenital hypothyroidism found that, in the oldest group (children older than 1 year; n = 26), mean height was still significantly below normal after 8 years of treatment (Bucher, Prader, and Illig 1985). Complete catch-up in height, bone age, and weight was reported for children who started treatment under the age of 1. A 9 year follow-up study of 28 children also found marked catch-up from below the 3rd centile for height to above the 50th centile after 2 to 4 years of hypothyroidism treatment begun before the age of 2 (Von Harnack *et al*. 1972). In juvenile acquired hypothyroidism, a study of 24 adolescents found that at diagnosis, height-for-age of the girls was approximately 4 SD below the mean and of the boys approximately 3 SD below (Rivkees, Bode, and Crawford 1988). Following treatment, adult height was reported as 2 SD below the mean. Other studies of longstanding untreated hypothyroidism have also shown considerable if incomplete catch-up in growth following diagnosis (Pantsiotou *et al*. 1991; Boersma *et al*. 1996).

2.6.2.4 Treatment of corticosteroid excess

Cushing's syndrome is a rare condition that provides an opportunity to examine growth following a transient period of corticosteroid excess. In an early study, following the removal of an adrenal tumor from a girl with Cushing's syndrome, rate of growth reached 3.5 times the average eight months after the operation and was still twice the average two years later (Prader, Tanner, and Von Harnack 1963). On the other hand, a similar study did not find such catch-up growth (Mosier, Smith, and Schultz 1972). In a cohort study, 14 pediatric patients (aged 6.4–16.6 years) were cured of Cushing's syndrome and then treated for growth hormone deficiency (Davies *et al*. 2005). At diagnosis, mean height-for-age z-scores were -2.5 SD while at final adult height or latest assessment, height-for-age had significantly improved to -1.3 SD, within the target height range.

2.6.3 Food supplementation

Food supplementation studies at school-age have reported small but significant gains in growth, as highlighted by the recent Cochrane systematic review of the effect of school feeding programs on both the physical and psychosocial health of students (Kristjansson *et al*. 2007). The review included 18 studies (nine from lower income countries), with both randomized controlled trials (RCTs) and controlled before and after studies (CBAs), of schoolchildren from 5 to 19 years of age. Seven of these studies were from lower income countries and included outcomes related to height and weight. These are described below and detailed in Table 2.2, along with three more recent impact evaluations in Burkina Faso, Lao PDR, and Uganda.

2.6.3.1 Randomized controlled trials

A meta-analysis of three RCTs in lower income countries (Powell *et al*. 1998; Grillenberger *et al*. 2003; Du *et al*. 2004) in the Cochrane review reported a small, significant effect of supplementation on weight gain (0.39 kg, 95% C.I.: 0.11, 0.67), approximately 0.25 kg per year factoring in study duration (Kristjansson *et al*. 2007). The review also found a small, non-significant effect from the three RCTs on height gain (0.38 cm, 95% C.I.: -0.32, 1.08).

In one of the studies, 395 children in grades 2–5 in rural Jamaican schools were given breakfast each day for one school year (Powell *et al*. 1998). A RCT compared their height, weight, height-for-age, and weight-for-age gains (among other outcomes) to 396 controls. With the additional gain of 0.25 cm in height ($p < 0.05$) over the eight months, the authors suggest that the breakfast program could result in a 2.4 cm gain in height over the primary school years, an additional one-third SD in height by age 11. As the weight gain reported in the breakfast group was relatively greater than the height gain, a small increase in BMI was observed (0.16 kg/m^2). Small, significant increases were also reported for both height-for-age and weight-for-age z-scores.

Improvements in height-for-age z-scores among the most stunted as well as weight gain were also seen in a supplementation study of 544 Kenyan schoolchildren in class 1 (Grillenberger *et al*. 2003). Children were given a meat, milk, or energy supplement during the first school break of the day for a total of 18 months, and the changes in height, weight, height-for-age, and weight-for-age for each of the three groups were compared to that of a control group. In each of the supplementation groups, children gained approximately 10% more weight than those in the control group. Decreases in average weight-for-height z-scores were reported in all the groups, though the declines for the meat and energy groups were approximately 50% less than for the milk and control groups. The results indicated no overall effect on height gain or height-for-age, though children with baseline height-for-age z-scores below the median (-1.4), in the milk group, a 1.3 cm (15%) height gain over the control group ($p = 0.05$) was observed. The authors suggest a lack of rainfall as well as periods of severe food shortage during the time of the study, along with potential substitution at home, may have contributed to the negligible effects on nutrition status observed.

Another school milk intervention trail of 757 girls (average age of 10 years) in nine primary schools in Beijing reported statistically significant increases in both height and weight (Du *et al*. 2004). The two-year intervention followed the growth of three groups: group 1 receiving milk fortified with calcium, group 2 receiving milk fortified with both calcium and vitamin D, and group 3 serving as a control group receiving no supplementation. The milk supplementation groups experienced increases of ≥0.6% in height and ≥2.9% in weight more than the control group ($p < 0.0005$). Results from other outcomes of bone mineral content and bone mineral density suggest that increasing bone mineralization may have contributed to the increases in height.

More recently, three impact evaluations in Burkina Faso, Lao PDR, and Uganda by the World Food Programme and the World Bank have also assessed the impact of school feeding on anthropometric outcomes, including those of younger siblings of beneficiaries. The impact of both school feeding and take-home rations were examined in Internally Displaced Persons (IDP) camps in northern Uganda (Adelman et al. 2008). No significant effects were found on body-mass-index-for-age z-scores (BAZ) or height-for-age z-scores in 6–13 year old children, but preschooler siblings in the school feeding group experienced significant HAZ gains of 0.363 relative to the control group, suggesting intrahousehold redistribution.

Similarly, in Burkina Faso, no significant effects of school feeding and take-home rations on BMI or weight-for-age in schoolchildren 6–15 years of age were found, though marginal gains were observed in weight-for-age for 6–10 year olds (Kazianga, de Walque, and Alderman 2010). For preschooler siblings, the reverse of the Ugandan results were found; significant gains in WAZ (0.38) were reported for take-home rations but not school meals.

Table 2.2 Studies of the effect of food supplementation on height and weight in school-age children

Reference	Country	Intervention (if relevant, quality in terms of protein/fat/carbs)	Study type	Sample characteristics (size, features)	Age at intervention	Length of intervention	Effect size for height and weight
Bailey 1962	Indonesia	*group I*: iron (control, 100 mg) *group II*: palm-sugar (180 kcal, 1.5 g protein) *group III*: green gram and palm-sugar (195 kcal, 12 g protein, 3.1 mg iron) *group IV*: skimmed milk (powder, 90 kcal, 10 g protein, 0.3 mg iron) *group V*: Saridele (powder, 170 kcal, 10 g protein, 1.3 g iron) *group VI*: tempeh (soya, 80 kcal, 12.5 g protein, 5.0 mg iron) *group VII*: tempeh (velvet bean, 50 kcal, 10 g protein) All supplements served as a mid-morning snack, except for the tempeh which was given before school.	CBA	504 boys from relatively wealthy backgrounds Mean values for height and weight at baseline slightly greater than those of boys in more remote villages	Range: 7–13 yrs	12 mo (average of 201 days of supplementat ion per group)	*height*: 0.63 cm for group II; 0.60 cm for group V; no significant effect in other groups *weight*: no significant effect in any groups
Devadas *et al*. 1979	India	*supplement group*: vegetable protein mixture (395 kcal and 14 g protein) *control group*: no supplement Supplement of local, low cost food made up for caloric deficit (20%) and micronutrient deficits of home diet.	CBA	400 children (214 boys and 186 girls) Caloric and micronutrient intake without the supplement was less than recommended	Range: 5–8 yrs	10 mo	*height*: 2.62 [2.22, 3.02] cm, 5–6 yrs; 2.75 [2.24, 3.26] cm, 6–7 yrs; 2.55 [2.24, 2.86] cm, 7–8 yrs *weight*: 0.95 [0.70, 1.20] kg, 5–6 yrs; 0.33 [0.08, 0.58] kg, 6–7 yrs; 0.90 [0.68, 1.12] kg, 7–8 yrs †
Powell, Grantham-McGregor, and Elston 1983	Jamaica	*breakfast group*: half pint milk (130 kcal and 8 g protein) and banana cake (250 kcal and 5 g protein) or patty (meat and vegetable pastry, 600 kcal and 16.5 g protein) *control group*: no supplement *control syrup group*: syrup drink (33 kcal) Breakfast served daily at 9:00 a.m. Patties served 35% of the time.	CBA	106 children, majority from poor farming families *weight-for-age*: 82.7% of standard for breakfast, 87.6% for control, 82.3% for control syrup *height-for-age*: 94.3% of standard for breakfast, 95.3% for control, 93.5% for control syrup	Mean: 12.6 ± 0.4 yrs for breakfast group; 12.5 ± 0.3 yrs for control group; 12.6 ± 0.3 yrs for syrup group Range: 11–17 yrs	3 mo	*height-for-age, percentage of standard*: -0.75 [-1.11, -0.39] *weight-for-age, percentage of standard*: 0.90 [-0.40, 2.20] †

Reference	Country	Intervention (if relevant, quality in terms of protein/fat/carbs)	Study type	Sample characteristics (size, features)	Age at intervention	Length of intervention	Effect size for height and weight
Agarwal, Agarwal, and Upadhyay 1989	India	*supplement group*: mid-day meal (450–500 kcal and 10–12 g protein) *control group*: no supplement All meals served during the recess on all school days.	CBA	450 children (331 boys and 115 girls)	Range: 7–11 yrs	2 yrs (175 days in first year and 181 days in second year)	*height*: boys -0.30 [-0.95, 0.35] cm; girls 0.20 [-0.74, 1.14] cm *weight*: boys 0.70 [0.39, 1.01] kg; girls 0.80 [0.35, 1.25] kg †
Powell *et al*. 1998	Jamaica	*breakfast group*: cheese sandwich or spiced bun and cheese and flavored milk (576–703 kcal and 27.1 g protein) *control group*: one-quarter of an orange (18 kcal and 0.4 g protein) All meals served before start of classes on all school days.	RCT	407 *undernourished* children (≤-1 WAZ) 407 *adequately-nourished* children (>-1 WAZ)	Mean: 9.0 ± 1.2 yrs	8 mo †	*height*: 0.25 [0.06, 0.44] cm *weight*: 0.37 [0.19, 0.55] kg *HAZ*: 0.04 [0.02, 0.06] *WAZ*: 0.07 [0.04, 0.10] †
Grillenberger *et al*. 2003	Kenya	*meat supplement*: githeri and minced beef (~250–300 kcal, >50% RDI vitamin A, >75% RDI vitamin B-12, ~33% RDI iron, >50% RDI zinc) *milk supplement*: githeri and cow's milk (~250–300 kcal, >50% RDI vitamin A, >75% RDI vitamin B-12, >75% RDI riboflavin) *energy supplement*: githeri and extra oil (~250–300 kcal) *control group*: no supplement All supplements served at 9:30 a.m. on school days.	RCT	544 children *stunting* (<-2 HAZ): 19.4% *severe stunting* (<-3 HAZ): 4.6% *underweight* (<-2 WAZ): ~30% of boys and 30% of girls *mild underweight* (-1 to -2 WAZ): 42.1% of boys and 31.1% of girls ‡	Mean: 7.4 yrs Range: 6–14 yrs ‡	23 mo (18 mo of which schools were in session)	*height*: no significant overall effect (but for milk group, 1.3 cm (15%) gain in children with HAZ <-1.4, p = 0.05) *weight*: ~0.39 kg for each group (p < 0.02) *HAZ*: no overall effect *WHZ*: declines in each group

Reference	Country	Intervention (if relevant, quality in terms of protein/fat/carbs)	Study type	Sample characteristics (size, features)	Age at intervention	Length of intervention	Effect size for height and weight
Du *et al*. 2004	China	*group 1*: 330 ml milk fortified to contain 560 mg Ca (~10 g protein and ~10 g fat) *group 2*: 330 ml milk fortified to contain 560 mg Ca and vitamin D (~10 g protein and ~10 g fat) *group 3*: no supplementary milk Milk served in the morning before classes or during the first break on every school day over the two-year period (average daily intake of 144 ml milk). Daily increase of energy about 5%, protein about 8%, and calcium about 50%.	RCT	757 girls low calcium intake (43.1% RDI) low vitamin D intake (9.0% RDI)	Mean: 10.1 ± 0.4 yrs for group 1; 10.1 ± 0.3 yrs for group 2; 10.1 ± 0.3 yrs for group 3	24 mo	*height*: for group 1, 1.20 [0.46, 1.94] cm *weight*: for group 1, 1.50 [0.25, 2.75] kg †
Adelman *et al*. 2008	Uganda	*school feeding program (SFP)*: mid-morning snack of corn-soya-blend and lunch of beans and rice or posho (maize-meal), oil, and salt (combined, ~1049 kcal, 32.6 g protein, 24.9 g fat; 99% RDI iron, and >two-thirds of other vitamin and mineral requirements) *take-home rations (THR)*: equivalent amount of food to school feeding program *control group*: no treatment Children in school feeding program received daily in-school meals while take-home rations (21 days worth) were distributed once a month conditioned on 85% attendance rate.	RCT	2,159 children living in IDP camps *stunted*: >20% *HAZ*: -0.87 for SFP; -0.83 for THR; -0.95 for control *WAZ*: -0.74 for SFP; -0.73 for THR; -0.88 for control *BAZ*: -0.60 for SFP; -0.59 for THR; -0.63 for control	Mean: 9.59 yrs for SFP; 9.61 yrs for THR; 9.42 for control Range: 6–13 yrs	*SFP*: average of 145.7 school feeding days per child *THR*: average of 4.2 mo of rations per child	*HAZ*: no significant effect *BAZ*: no significant effect
Kazianga, de Walque, and Alderman 2010	Burkina Faso	*school canteens*: daily in school lunch meal, boys and girls *take-home rations*: 10 kg of cereal flour per month, girls only, conditioned on 90% attendance rate *control group*: no treatment	RCT	4,140 children in the Sahel region *HAZ (6–60 mo)*: -2.35 for school meals; -2.09 for THR; -2.32 for control *WAZ (6–60 mo)*: -2.20 for school meals; -2.52 for THR; -2.39 for control	Mean: 9.78 yrs for school meals; 9.79 yrs for THR; 9.84 for control Range: 6–15 yrs	1 school yr	*WAZ*: no significant effect *BAZ*: no significant effect

Reference	Country	Intervention (if relevant, quality in terms of protein/fat/carbs)	Study type	Sample characteristics (size, features)	Age at intervention	Length of intervention	Effect size for height and weight
Buttenheim, Alderman, and Friedman 2011	Lao PDR	*on-site feeding (OSF)*: 100 g corn-soya blend and 12.5 g sugar each school day, with a target of 83 feedings per term *on-site feeding and take-home rations*: see above and below *take-home rations*: 15 kg rice upon enrollment, 30 kg rice at end of school year if attendance was 80%; one can of fish per month if attendance was 80% *control group*: no treatment	quasi-experimental longitudinal comparison	9,810 children aged 3–14 surveyed *HAZ*: -2.34 for OSF; -2.31 for OSF & THR; -2.47 for THR; -2.23 for control *WAZ*: -1.91 for OSF; -1.94 for OSF & THR; -2.18 for THR; -1.82 for control	Mean: 7.86 yrs for OSF; 7.97 yrs for OSF & THR; 7.87 yrs for THR; 7.97 yrs for control Range: 6–14 yrs	Considerable variation in start-up among villages (most fall 2006–fall 2007); follow-up fall 2008 Median 280 days OSF; 235 days OSF & THR	*HAZ (3–10 yrs)*: 0.29 SD ($p < 0.01$) for THR; no significant effect for other groups *WAZ (3–10 yrs)*: 0.22 SD ($p < 0.05$) for THR; no significant effect for other groups
Singh, Park, and Dercon 2014	India	*treatment group*: children attending public school, all assumed to be receiving mid-day meal (at least 300 kcal and 8–12 g protein; in the study year, the standards were revised up to at least 450 kcal and 12 g of protein; thus children may have been receiving this larger ration) *comparison group*: children not currently attending public school	CBA	1,231 children *HAZ*: -1.35 for treatment; -1.60 for comparison (2002) *WAZ*: -1.62 for treatment; -1.65 for comparison (2002)	Mean: 57 mo Range: 48–65 mo	Mean: 9 mo Range: 7–11 mo	*HAZ*: no significant effect for preferred IV specification; 0.22 SD ($p < 0.01$) for OLS *WAZ*: 0.60 SD ($p < 0.01$) for IV; 0.25 SD ($p < 0.01$) for OLS

† Kristjansson *et al*. 2007
‡ Neumann *et al*. 2003

Buttenheim, Alderman, and Friedman (2011) evaluated the impact of on-site feeding, take-home rations, and a combination of both in schools in remote mountainous areas of Lao PDR. Significant improvements in both height-for-age (0.29 SD) and weight-for-age (0.22 SD) among children 3–10 years of age were reported for take-home rations, though the authors suggest that the nutritional findings are inconclusive because of the complications that arise in stratified analyses. As for spillover effects in younger siblings, significant increases in height-for-age were observed in children 3–5 years of age, but the differences seemed to be driven more by declines in the controls.

2.6.3.2 Controlled before and after studies

Among CBAs, a meta-analysis of three studies in lower income countries (Bailey 1962; Devadas *et al*. 1979; Agarwal, Agarwal, and Upadhyay 1989) found greater weight gains than those in the RCTs (0.71 kg, 95% C.I.: 0.48, 0.95), approximately 0.75 kg per year given study duration (Kristjansson *et al*. 2007). In contrast to the RCT findings, meta-analysis of the three CBAs found a significant effect on height gain (1.43 cm, 95% C.I.: 0.46, 2.41), approximately one-third more than rates of gain in the control groups.

In one of the studies, a 12-month supplementation trial of 504 Indonesian schoolboys 7–13 years of age assessed the impact of six different supplements of varying caloric, protein, and iron content on gains in height and weight (Bailey 1962). No significant difference was seen in weight increment between an expected value predicted by a regression equation and any of the groups. However, the height increment for all of the groups was greater than the expected value, with a significant difference observed for both the sugar and Saridele (soya bean milk) supplements. A tendency for the height and weight gains to be correlated with the caloric value of the supplement was observed, though fluid retention that is associated with higher caloric content unaccompanied by higher protein content as well may have also contributed to the lack of effect reported for weight gains.

Conversely, large and significant effects on both height and weight were reported in a supplementation study of 400 schoolchildren in six villages in India (Devadas *et al*. 1979). Two hundred children aged 5–8 years were provided with a daily supplement of local, low cost food for ten months, and their height and weight increments over the time were compared to those of un-supplemented children serving as a control. Each of the three age sub-groups were reported to have significant height gains of >2.5 cm over the control as well as significant weight gains between 0.33–0.95 kg more than the control.

A controlled before and after study was also undertaken in Jamaica, assessing the impact of school breakfast on the percent of standard height-for-age and weight-for-age in 106 children with a mean age around 12.5 years (Powell, Grantham-McGregor, and Elston 1983). After three months, no significant effect was observed for either height or weight, but a reanalysis by Kristjansson *et al*. (2007) reported a small but significant effect for height in favor of control children. Like in Kenya, the authors suggest that the apparent lack of gains may be due in part to substitution at home.

A study of the India mid-day meal program assessed the effect of two years of food supplementation on 146 rural primary schoolchildren compared to 304 controls (84–132 months) (Agarwal, Agarwal, and Upadhyay 1989). No significant effect on height gain was observed, though weight gain was 0.63 and 0.79 kg higher for boys and girls respectively in the supplemented group. This minimal influence could be due in part to substitution at home as a dietary survey of a sub-sample of the children found an average increase of 200 kcal rather than the 450–500 kcal of the mid-day meal supplement.

Another study in India not included in the Cochrane review examined *Young Lives* data from Andhra Pradesh to assess whether the mid-day meal program ameliorated the effects of a severe drought in 2002–3 (when sample children were around 1 year of age) and a less severe drought in 2004–5 (when sample children were around 3 years of age) (Singh, Park, and Dercon 2014). The sample included over 1,000 children just entering school in the 2006–7 school year. The authors estimated that drought led to a height loss of around 0.77 SD and a weight loss of around 0.44 SD for boys 65 months of age (the mean sample age). In presenting findings on effects of the mid-day meal program that correct for self-selection, a closing of the entire gap by the feeding intervention was reported.[i] The relative high performance of service delivery of Andhra Pradesh in relation to other states was highlighted in the discussion of broader applicability of the results.

2.6.4 Micronutrient supplementation

Micronutrient supplementation and fortification have also been found to increase growth at school age. As mentioned above, a meta-analysis of 33 zinc supplementation studies in prepubertal children reported significant effects for both weight (0.31 kg, 95% C.I.: 0.18, 0.44) and height (0.35 cm, 95% C.I.: 0.19, 0.51) (Brown *et al*. 2002). In seven of the studies, the mean initial age of the children was greater than 5 years of age. A meta-analysis of the effects of vitamin A, iron, and multiple micronutrient interventions on the growth of children <18 years of age found significant improvements in height and weight with multiple micronutrient interventions but not with vitamin A or iron alone (Ramakrishnan *et al*. 2004). Of the 14 vitamin A intervention studies, only one was in children of school age, which did report significant improvements in growth (Mwanri *et al*. 2000). Anemic schoolchildren 9–12 years of age receiving vitamin A supplementation gained 0.4 kg

[i] The mid-day meal intervention had a mean duration of 9 months for the treatment children.

(95% C.I.: 0.19, 0.65) and 0.2 cm (95% C.I.: 0.08, 0.42) more over the three-month study period than those receiving the placebo.[i] Of the 21 iron interventions studies in the meta-analysis, seven were in children of school age (Chwang, Soemantri, and Pollitt 1988; Latham *et al.* 1990; Lawless *et al.* 1994; Aguayo 2000; Beasley *et al.* 2000; Mwanri *et al.* 2000; Sungthong *et al.* 2002). Stratifying all 21 studies by age at baseline did not result in any significant weighted mean effect sizes (Ramakrishnan *et al.* 2004). Five multiple micronutrient interventions were included in the meta-analysis, two of which were in school-age children and reported significant effects for height and weight (Abrams *et al.* 2003; Ash *et al.* 2003).

A more recent systematic review focusing on multiple micronutrient fortification in school-age children reported mixed effects for height and weight gain (Best *et al.* 2011). Significant improvements in weight gain were found in four studies (Abrams *et al.* 2003; Ash *et al.* 2003; Sarma *et al.* 2006; Hyder *et al.* 2007), averaging between 0.47 and 0.56 kg more than the control groups (Best *et al.* 2011). Ash *et al.* (2003) and Sarma *et al.* (2006) also reported significant height gains over the control groups of 0.6 cm after 6 months and 1.2 cm after 14 months, respectively. However, three studies fortification studies included in the systematic review did not find any significant effects for height or weight (van Stuijvenberg *et al.* 1999; Solon *et al.* 2003; Manger *et al.* 2008).

2.6.5 Deworming

Another intervention that has been shown to improve growth at school age is deworming. A recent Cochrane review of the effect of soil-transmitted helminths (STH) on growth in children 16 years of age or younger analyzed the findings of studies grouped together by screening and then treating those infected versus treating all children and by single versus multiple rounds of deworming as well as stratified by worm prevalence and intensity (Taylor-Robinson *et al.* 2012). For the three studies that screened for infection, a significant mean increase for weight (0.58 kg [0.40, 0.76]) was found, with no significant difference in the two studies on height. Two of nine studies on the entire target population being treated found significant increases in mean weight while the remaining studies reported no effects. Both of the studies were in very high prevalence settings, and one also reported a significant increase in mean height (the remaining six studies that measured height found no effect). For multiple doses of deworming, outcomes from within a year in the same high prevalence setting also indicated a significant increase in mean weight, but no effects were reported in the remaining seven multiple dose, outcomes within a year studies that measured weight or in any

[i] While the causal relationship between vitamin A and growth is not clear, there is some evidence that vitamin A may play a protective role against morbidity and mortality of infectious diseases that may in turn affect growth (Villamor *et al.* 2002).

of the seven studies that measured height. For outcomes beyond the first year with multiple dose deworming, one of five studies found a significant mean weight increase while none of the three studies that measured height found any effect.

2.6.5.1 Considering the Cochrane review findings and examining age and health status of the child as well as follow-up duration

Many variables complicate the interpretation of the Cochrane findings, including the treatment type, worm prevalence and intensity (which the authors attempted to address in response to feedback on the previous review [Taylor-Robinson, Jones, and Garner 2007]), the age and health status of the child, and the follow-up duration. To provide a more comprehensive picture of the studies on height and weight included in the Cochrane review, Table 2.3 presents the mean differences for height and weight reported in the review alongside information from the individual studies on the age range of the children, their nutritional status at baseline, and the time from baseline to follow up measurements.

For the studies which involved screening, it is noteworthy that the two that measured height were both marked by relatively moderate levels of stunting at baseline,[i] which may be why, at least in part, a more pronounced height change was not observed. In a study not included in the Cochrane review, which involved 63 children screened for treatment of *Trichuris* in Jamaica, at baseline the children exhibited height-age a year and half behind their mean age of 4.5 years (Cooper *et al.* 1995). At six months following deworming, the children were reported to have a mean height velocity of 10.9 cm per year and a mean weight velocity of 4.0 kg per year, both 2 SD above British children at that age. Another study included in the Cochrane review suggests Vitamin A status at baseline may also influence anthropometric outcomes (Donnen *et al.* 1998). However, Dossa *et al.* (2001) found no effect of multiple deworming doses on height or weight of pre-school children, even when a sub-sample of stunted and anemic children was analyzed. This could be attributable to a rapid rate of re-infection in the population as well as poor dietary intakes as reported in the study's food consumption survey.

Additionally, none of the screening studies with targeted treatment involved follow-up beyond 16 weeks, which may preclude both accurate measurements of anthropometric change (Nokes *et al.* 1992) and capturing of potential longer term gains (Bundy and Peto 2000), which has been argued in response to a previous version of the review (Dickson *et al.* 2000). Even for the five

[i] In the Adams *et al.* (1994) study, HAZ at baseline was -1.35 ± 0.18 in the placebo group and -1.48 ± 0.15 in the intervention group. Similarly moderate levels of stunting were observed by Sarkar *et al.* (2002), with 91.4% ± 5.9 of median height for age for the placebo group and 93.0% ± 8.8 for the intervention group.

studies in which the entire target population was treated with multiple deworming doses and outcomes were measured beyond the first year, no follow-up exceeded three years. In addressing Bundy and Peto (2000), Taylor-Robinson *et al*. (2012) state, "...this analysis clearly examines long-term outcomes from trials conducted over the last 10 years," but this seems to speak to when the studies were conducted rather than the follow-up time of each of them.

For the studies in which the entire target population was treated with a single deworming dose, all of the studies in high prevalence areas were of school-age children while all of the studies in moderate and low prevalence areas were of pre-school children. When just the four high prevalence studies are examined, Taylor-Robinson *et al*. (2012) report a mean weight difference approaching significance (0.73 kg [-0.12, 1.57]), and the two studies that found no effect had shorter follow-up periods (7 weeks and 14.2 weeks) compared to the 6 months and 8.2 months follow-ups in the two studies that reported significant increases.

2.6.5.2 Comparing the Cochrane review with other review findings

Another meta-analysis of 19 randomized controlled trials that treated children 1–19 years of age for intestinal worm infections found significant improvements in height (9 studies, 0.11 cm [0.03, 0.19]), weight (11 studies, 0.21 kg [0.17, 0.26]), HAZ (6 studies, 0.09 [0.06, 0.11]), WAZ (5 studies, 0.06 [0.03, 0.08]), and WHZ (4 studies, 0.38 [0.30, 0.46]) (Hall *et al*. 2008). Taylor-Robinson *et al*. (2012) contend that differences in the findings of the two reviews could be due to different review protocols and to Hall *et al*. (2008) excluding low prevalence studies, not differentiating between trials with and without screenings, not adjusting for clustering, and including data from sub-groups.

For growth effects to be realized, Hall *et al*. (2008) suggest that deworming may need to be complemented by supplementary feeding. Few deworming studies have also supplied food supplements, but one study of Kenyan school boys that included a porridge supplement before treatment and at the four-month follow-up found that appetite as well as growth improved with deworming (Stephenson *et al*. 1993a).

Table 2.3 Studies of the effects of deworming on height and weight in children

Grouped analysis or study/sub-group	Number of participants	Age range in years	Nutritional status at baseline	Time to follow-up	Mean difference (95% C.I.) Height (cm)	Weight (kg)
Grouped analysis: Screened for infection, single dose					0.10 (-0.15, 0.35) (N = 136)	0.58 (0.40, 0.76) (N = 149)
Adams *et al*. 1994	55	5–10	WAZ: PL -1.10 ± 0.15; INT -1.45 ± 0.12 HAZ: PL -1.35 ± 0.18; INT -1.48 ± 0.15 WHZ: PL -0.27 ± 0.15; INT -0.66 ± 0.12	9 weeks	0.10 (-0.19, 0.39)	0.70 (0.47, 0.93)
Freij *et al*. 1979	13	1.5–5	moderate malnutrition in about half of the children	4 weeks	not measured	0.20 (-2.68, 3.08)
Sarkar *et al*. 2002	81	2–12	% of median weight for age: PL 79.4 ± 14.7; INT 75.4 ± 15.1 % of median height for age: PL 91.4 ± 5.9; INT 93.0 ± 8.8	16 weeks	0.10 (-0.41, 0.61)	0.38 (0.09, 0.67)
Grouped analysis: Target population treated, single dose					not reported	not reported
High prevalence					0.25 (-0.10, 0.60) (N = 566)	0.73 (-0.12, 1.57) (N = 629)
Hadju *et al*. 1996	64	6–10	% of median weight for age: PL 76.0 ± 10.1; INT 73.1 ± 12.4	7 weeks	not measured	0.40 (-0.93, 1.73)
Stephenson *et al*. 1989	150	6–16	% of median weight for age: PL 74.2 ± 1.2; INT 72.1 ± 1.3 % of median height for age: PL 91.5 ± 0.5; INT 92.1 ± 0.5	6 months	0.60 (0.34, 0.86)	1.30 (1.04, 1.56)
Stephenson *et al*. 1993b	189	6–15	% of median weight for age: PL 80.7 ± 1.12; INT 80.5 ± 1.11	8.2 months	0.10 (-0.23, 0.43)	1.10 (0.68, 1.52)
Watkins and Pollitt 1996	226	7–12	WAZ: PL -1.57 ± 0.05; INT -1.66 ± 0.06 HAZ: PL -2.62 ± 0.08; INT -2.71 ± 0.09 WHZ: PL 0.56 ± 0.08; INT 0.39 ± 0.07	14.2 weeks	0.06 (-0.08, 0.20)	0.01 (-0.16, 0.18)
Moderate prevalence					-0.20 (-0.47, 0.07) (N = 191)	0.11 (-0.16, 0.38) (N = 873)
Palupi *et al*. 1997	191	2–5	all children: 40.1% STN, 39.4% UNW, 6.9% WST	9 weeks	-0.20 (-0.47, 0.07)	0.06 (-0.13, 0.25)
Sur *et al*. 2005	682	2–5	—	6 months	not measured	0.50 (--0.28, 1.28)
Low prevalence					-0.26 (-0.74, 0.21) (N = 1,556)	-0.09 (-0.22, 0.03) (N = 1,556)
Awasthi, Pande, and Fletcher 2000	987	1.5–3.5	PL: 54.8% STN, 66.4% UNW, 18.0% WST INT: 59.7% STN, 68.5% UNW, 18.7% WST	6 months	-0.40 (-1.06, 0.26)	-0.17 (-0.33, -0.01)
Donnen *et al*. 1998	222	0–6	PL: 65.0% STN, 50.4% UNW, 5.3% WST INT: 65.0% STN, 56.9% UNW, 8.9% WST	3 months	-0.62 (-1.15, -0.09)	-0.15 (-0.34, 0.04)
Garg *et al*. 2002	347	2–4	all children: 39% STN, 28% UNW	6 months	0.08 (-0.21, 0.37)	0.02 (-0.13, 0.17)

Grouped analysis or study/sub-group	Number of participants	Age range in years	Nutritional status at baseline	Time to follow-up	Mean difference (95% C.I.) Height (cm)	Weight (kg)
Grouped analysis: Target population treated, multiple dose, outcomes within first year					-0.02 (-0.17, 0.12) (N = 1,779)	0.06 (-0.17, 0.30) (N = 2,460)
High prevalence					0.02 (-0.15, 0.18) (N = 415)	0.50 (-0.25, 1.25) (N = 414)
Stephenson *et al*. 1993b	188	6–15	% of median weight for age: PL 80.7 ± 1.12; INT 81.3 ± 1.22	8.2 months	-0.10 (-0.42, 0.22)	0.90 (0.54, 1.26)
Watkins and Pollitt 1996	227 for height 226 for weight	7–12	WAZ: PL -1.57 ± 0.05; INT -1.66 ± 0.06 HAZ: PL -2.62 ± 0.08; INT -2.71 ± 0.09 WHZ: PL 0.56 ± 0.08; INT 0.39 ± 0.07	25.0 weeks	-0.10 (-0.42, 0.22)	0.13 (-0.08, 0.34)
Moderate prevalence					0.10 (-0.46, 0.66) (N = 129)	0.03 (-0.20, 0.26) (N = 811)
Dossa *et al*. 2001	64	3–5	all children: 58% STN	10 months	0.00 (-0.62, 0.62)	0.00 (-0.27, 0.27)
Dossa *et al*. 2001	65	3–5	all children: 58% STN	10 months	0.50 (-0.75, 1.75)	0.00 (-0.52, 0.52)
Sur *et al*. 2005	682	2–5	not available	12 months	not measured	0.50 (-0.42, 1.42)
Low prevalence					-0.17 (-0.59, 0.25) (N = 1,235)	-0.23 (-0.60, 0.14) (N = 1,235)
Awasthi, Pande, and Fletcher 2000	963	1.5–3.5	PL: 54.8% STN, 66.4% UNW, 18.0% WST INT: 59.7% STN, 68.5% UNW, 18.7% WST	1 year	-0.11 (-0.39, 0.17)	0.04 (-0.06, 0.14)
Donnen *et al*. 1998	198	0–6	PL: 65.0% STN, 50.4% UNW, 5.3% WST INT: 65.0% STN, 56.9% UNW, 8.9% WST	1 year	-1.19 (-2.27, -0.11)	-0.45 (-0.77, -0.13)
Kruger *et al*. 1996	74	6–8	all children: 17.9% STN, 14.0% UNW	11 months	0.08 (-0.33, 0.49)	-0.38 (-0.82, 0.06)
Grouped analysis: Target population treated, multiple dose, outcomes after first year					not reported	not reported
High prevalence					not measured	0.00 (-0.14, 0.14) (N = 80)
Hall *et al*. 2006 (unpublished)	80 (clusters)	mean: 8.7	not available	2 years	not measured	0.00 (-0.14, 0.14)
Moderate prevalence					not measured	0.15 (-0.02, 0.33) (N = 48)
Alderman *et al*. 2006	48 (clusters)	1–7	all children: 26% UNW	3 years	not measured	0.15 (-0.02, 0.33)
Low prevalence					-0.26 (-0.84, 0.31) (N = 1,219)	0.37 (-0.40, 1.15) (N = 1,219)
Awasthi, Pande, and Fletcher 2000	1,045	1.5–3.5	PL: 54.8% STN, 66.4% UNW, 18.0% WST INT: 59.7% STN, 68.5% UNW, 18.7% WST	2 years	-0.41 (-1.03, 0.21)	-0.05 (-0.20, 0.10)
Awasthi and Pande 2001	124 (clusters)	0.5–1	all children: 61% STN, 47% UNW, 17% WST	1.5 years	0.40 (-1.89, 2.69)	0.17 (-0.50, 0.84)
Awasthi *et al*. 2008	50 (clusters)	1–5	all children: 63% STN, 49% UNW, 18% WST	2 years	1.19 (-1.17, 3.55)	0.98 (0.69, 1.27)

Abbreviations: PL = placebo group; INT = intervention group; STN = stunted; UNW = underweight; WST = wasted

Note: Source for the number of participants, mean differences, and information on the Hall et al. (2006) study is Taylor-Robinson et al. (2012). The authors used definitions from WHO (2002) technical guidelines to classify high, moderate, and low prevalence.

2.7 Conclusions

The possibility of catch-up growth into childhood and adolescence has been discussed varyingly in the literature. Golden (1994) is illustrative of the studies cited as demonstrating catch-up growth later in life, while findings from a longitudinal supplementation study in Guatemala of children aged 0–7 years are often cited in support of the irreversible effects of early stunting (Martorell, Kettel Khan, and Schroeder 1994). The authors' conclusions that "stunting is a condition resulting from events in early childhood and which, once present, remains for life" are echoed in *The Lancet* series on maternal and child undernutrition. "Poor fetal growth or stunting in the first 2 years of life leads to irreversible damage, including shorter adult height, lower attained schooling, reduced adult income, and decreased offspring birthweight" (Victora *et al*. 2008).

In the absence of change, early stunting may well persist as decreased height throughout life, but intervention studies reviewed here counter the irreversibility claim with evidence that early deficits can, at least to some extent, be made up in childhood and adolescence. Findings from changes in environment studies, including immigration, adoption, and moves to institutional settings have included catch-up to within national and international standards following early growth faltering. Additionally, interventions addressing secondary stunting and underweight have resulted in partial as well as complete catch-up growth. Food and micronutrient supplementation at school age have been reported to have more measured impact on height and weight, with small but significant gains over control groups. Recent findings have indicated that school feeding programs could also have important spill-over benefits for younger siblings as well as promoting the health of the next generation of mothers. Furthermore, even as variations in worm species, distribution, treatment, initial health status, and follow-up duration complicate any definitive conclusions about the magnitude of the effects of deworming, studies have shown positive impacts on height and weight, impacts that may be strengthened when interventions are carried out in conjunction with supplementary feeding.

While the heterogeneity of the types of intervention studies reviewed here may preclude a meta-analysis of their findings, Table 2.4 aims to summarize the findings that support the possibility of catch-up growth across the different interventions. To address quality of evidence, the table details whether the studies were cross-sectional or longitudinal, the sample size, and follow-up duration, where applicable, and whether there have been any meta-analyses or systematic reviews in the area.

As catch-up to national and international standards has been reported by changes in environment studies as well as interventions addressing secondary stunting and underweight, greater understanding of how this catch-up growth is achieved may be able to strengthen the design of food and micronutrient interventions.

A number of the key considerations reviewed, including regression to the mean, ethnic differences, secular change, the adolescent growth spurt, and possible delays in skeletal maturity, underscore the methodological limitations and the complexity of assessing catch-up growth in school age and adolescence. Even with these intricacies, the evidence above supports the hypothesis that catch-up growth is possible and has been achieved, to varying degrees, through interventions in school age and adolescence.

Table 2.4 Summary of conclusions regarding catch-up growth findings from interventions at school age

Type of intervention	Types of evidence	Overview of findings
Changes in environment		
Immigration studies	1 semi-longitudinal and 3 cross-sectional studies with medium to large sample sizes	catch-up to national standards rapid increase in growth rate
Adoption studies	5 longitudinal studies with small to medium sample sizes	catch-up to national and international standards significant improvements in HAZ and WAZ
Other changes in environment studies	2 retrospective analyses of large-scale cross-sectional data sets	catch-up to international standards
Interventions addressing secondary stunting and underweight		
Treatment of celiac disease	6 longitudinal studies with small sample sizes	complete catch-up in height and weight 2–3 years after start of gluten-free diet
Treatment of growth hormone deficiency	2 longitudinal studies with small to medium sample sizes	significant increases in growth rate and HAZ
Treatment of hypothyroidism	5 longitudinal studies with small to medium sample sizes	partial catch-up in height and weight
Treatment of corticosteroid excess	3 longitudinal studies with small sample sizes	significant increases in growth rate and HAZ
Food supplementation		
Randomized controlled trials	6 interventions with medium to large sample sizes, ranging between 8 and 24 months in duration	small, significant effect on weight gain small, non-significant effect on height gain spill-over effects on growth of younger siblings
Controlled before and after studies	4 interventions with medium sample sizes, ranging between 3 and 24 months in duration	significant effects on height and weight gain
Micronutrient supplementation	2 meta-analyses and 1 systematic review of zinc, iron, vitamin A, and multiple micronutrient interventions	significant effects on height and weight gain with zinc and multiple micronutrient interventions
Deworming	2 meta-analyses of deworming interventions	significant effects on height and weight gain

As is the case in many related fields of study, the quality of the available evidence could be said to be limited. A proposal for the ideal study on the magnitude of catch-up growth at school-age could involve removing a cohort of severely undernourished pre-school children from their surroundings and administering nutritional remediation in an advantaged setting through to adulthood. While ethics, costs, and a host of other considerations may preclude any such study, analysis of existing (Richter *et al*. 2011) and upcoming (Barnett *et al*. 2013) data sets from a number of large-scale birth cohort studies could provide valuable insight into growth and catch-up throughout school age and adolescence. In addition to their longitudinal nature, these studies are capturing a greater number of covariates, potentially contributing increased understanding of complexity and range of growth inputs (further research implications of these studies are detailed in Section 8.1.2).

Chapter 3. Framing of analysis on relationships between household agriculture and child nutrition in three regions of Mali

Building from the discussion on timing and patterns of growth and determinants of nutrition from the catch-up growth review, this next set of chapters analyzes relationships between school-age nutritional status and household agriculture using data from a large-scale survey in Mali. As much of what is produced in the sample households appears to be consumed rather than sold, it is hypothesized that households that produce a more diversified range of crops and livestock will also consume a more diversified diet. In turn, it is expected that school-age children from households with more diversified production and diets will exhibit better nutritional outcomes, as measured by anthropometrics.

This first framing chapter provides an introduction to the survey, which was undertaken as part of a Home Grown School Feeding (HGSF) study in three regions of Mali. To provide context for subsequent analyses, findings from other studies in Mali on child nutrition status (including anthropometric and micronutrient indicators) as well as household food intake are presented. Studies on determinants of child nutritional status in low-income countries are then reviewed to help inform the analyses, with a particular focus on agriculture and nutrition relationships. Finally, the methodology for the subsequent three chapters is detailed together as the overall study design and data collection are shared and many of the same variables of interest, statistical analyses and estimation techniques are used.

Summary statistics on child nutritional status and considerations related to the anthropometric measures are presented in the next chapter, with findings on household food consumption, diet quality, and agricultural production in the chapter after that. Building on these results, the final Mali chapter tests two main hypotheses: 1) households that produce a more diversified range of crops and livestock will also consume a more diversified diet; and 2) school-age children from households with more diversified agricultural production and diets will exhibit better nutritional outcomes.

3.1 Introduction

This section includes an introduction to the concept of Home Grown School Feeding, the national Home Grown School Feeding program in Mali, and the design of a study on that program, which forms the basis for the analyses undertaken in this set of chapters.

3.1.1 Home Grown School Feeding globally

An increasing number of countries in sub-Saharan Africa are looking to link school feeding with local agricultural production—known as Home Grown School Feeding—as a means of providing a stable, structured market for smallholder farmers while supplying schoolchildren with fresh, nutritious food (Gelli, Neeser, and Drake 2010). The advantages of linking local agriculture and school feeding are many, and the potential outcomes are substantial: more prosperous smallholder farmers, with a more secure future (Sumberg and Sabates-Wheeler 2011); stronger rural communities, with more stable economies (Devereux, Sabates-Wheeler, and Martínez 2010); increased demand for local, fresh food; and healthier, better-educated children (Bundy *et al.* 2009, Galloway 2010).

Despite recent efforts, there are several important gaps in the knowledge on optimal implementation and measures of effectiveness of HGSF, especially given the potential multiple impacts. Many of the education benefits of school feeding have already been established, but less is known on areas such as the nutrition impact of using local foods, entrepreneurial opportunities across the supply chain, and income gain for smallholder farmers. Currently, country-level impact evaluations are being undertaken, aimed at bridging these knowledge gaps and supporting governments in evidence-based decisions about program design and implementation. The focus here is on such a study on HGSF in Mali, which is described below.

3.1.2 Home Grown School Feeding in Mali

The national HGSF program in Mali was launched in 2009 and currently targets 651 schools in vulnerable communes. Communes and School Management Committees (CGS) coordinate the decentralized implementation of the program, receiving funds from the central government (via the Ministry of Finance's Regional Offices) for food staples (cereals, pulses, and oil), cooking equipment, and infrastructure. Food is procured on local markets, with no fixed ration specified as yet. Parents and the community provide fresh vegetables to complement the purchased staples, along with labor for cooking the meals.[i]

[i] Further information can be found at www.hgsf-global.org.

3.1.3 The design of an impact evaluation of Home Grown School Feeding in Mali

In Mali, the Government is seeking to scale up its national HGSF program and study the impact of different designs using a cluster randomized trial involving three treatment groups in the regions of Kayes, Koulikoro, and Mopti (Masset and Gelli 2013). The first group is the Government's standard HGSF program, the second group is the standard HGSF program plus training on social accountability for the community and local government (referred to as HGSF+), and the third group is a control group that will be phased in after two years.

A baseline survey was undertaken in January 2012 at the household, school, and village level. The main outcomes measured were farm income, smallholder farmer participation, schooling, attention, learning achievement, physical growth, diet diversity, and social accountability.

The analysis I focus on is of the nutritional status of school-age children at baseline, including weight-for-age, height-for-age, weight-for-height, and BMI-for-age z-scores. As much of what is produced in the sample households appears to be consumed rather than sold, I hypothesize that households that produce a more diversified range of crops and livestock will also consume a more diversified diet. I also hypothesize that, as dietary diversity has been associated with improved nutrition outcomes (Arimond and Ruel 2004; Eckhardt *et al*. 2005; Himaz 2009; Menon *et al*. 2013), school-age children from households with more diversified production and diets will exhibit better nutritional outcomes, as measured by anthropometrics.

These agriculture and nutrition linkages are seldom examined, which Headey, Chiu, and Kadiyala (2012) partially attribute to the analytical divide between those interested in agriculture and economics and those focused on public health and nutrition. An attempt to bridge this disconnect using agriculture and child nutrition data from Mali is undertaken here. First, the available literature on the determinants of child nutritional status is reviewed, with a focus on agricultural influences and results from agriculture intervention studies. Then, the methodology used here is presented, which was informed by techniques used in the studies reviewed. Analysis of child nutritional status and household food consumption, diet quality, and agricultural production along with findings and discussion of the analysis on the determinants of child nutrition status are presented in the subsequent three chapters.

3.2 Literature review

The literature review below begins with findings from other studies in Mali on child nutrition status and on household food intake. The review then turns to studies on determinants of child nutritional status in low-income countries, with a particular focus on agriculture and nutrition relationships, all of which helps inform the methodology of these sets of chapters as well as discussion of the results.

3.2.1 The nutritional status of children in Mali

Findings from studies on the nutrition status of children in Mali are reviewed below, including both anthropometric and micronutrient indicators. The focus is on school-age children, with findings on other age groups presented where information on school-age children is limited.

3.2.1.1 Anthropometric indicators

As in many other countries, there is a relative dearth of data on the nutritional status of school-age children compared with those under the age of 5. Data from the latest Mali Demographic and Health Survey (DHS), presented in Table 3.1, indicate that, nationally, 28.3% of 0–5 year olds observed had low height-for-age, 12.7% had low weight-for-height, and 25.5% had low weight-for-age (CPS/SSDSPF *et al.* 2014).[i] In the three study regions, under 5 nutrition status was generally poorer than the national average, while among the oldest age group surveyed (48–59 months of age), height-for-age indicators were poorer but weight-for-height and weight-for-age better than among all of the under 5s.

Table 3.1 DHS data on nutritional status of children under the age of 5 in Mali

	Height-for-age			Weight-for-height			Weight-for-age			Number of children
	% < -3SD	% < -2SD	Mean SD score	% < -3SD	% < -2SD	Mean SD score	% < -3SD	% < -2SD	Mean SD score	
Region										
Kayes	18.4	34.3	-1.3	6.5	12.2	-0.5	7.4	21.4	-1.1	617
Koulikoro	20.1	39.5	-1.5	4.3	11.1	-0.5	6.9	24.4	-1.2	1,078
Mopti	26.0	46.5	-1.8	6.6	14.7	-0.6	14.6	32.1	-1.5	623
Age group in months										
48–59	19.2	38.8	-1.6	3.7	8.8	-0.5	7.5	25.1	-1.3	1,021
Total	19.3	28.3	-1.5	5.1	12.7	-0.5	9.1	25.5	-1.2	4,857

Source: CPS/SSDSPF *et al.* (2014)

In one of the few studies on the nutritional status of school-age children in the country, Pawloski (2002) reports findings from a cross-sectional survey of over 1,000 females between the ages of 10 and 17 in the city of Ségou and in five rural villages nearby, with the WHO-recommended United States data as the reference population. Overall prevalence of stunting in the sample was found to be 14.7%, with higher prevalences observed in the rural areas than in the urban. Across the age groups, mean HAZ was -0.60 ± 1.13 at 10 years, dipping down to its lowest mean value of -1.17 ± 1.28 at 13 years, before improving to its peak of -0.42 ± 1.19 at 17 years. WAZ was relatively steadier, with only a gradual increase from a mean of around -1.2 at 10 years of age to around -0.8 at 17 years of age. Pawloski (2002) also assessed age at menarche, reporting a mean of 14.4 ± 0.42 years compared to that of 11.4 ± 1.3 years observed in African-American girls

[i] The three northern regions of Gao, Kidal, and Tombouctou were not surveyed due to the security situation at the time.

and 11.5 ± 1.3 in Caucasian-American girls (Wattigney *et al.* 1999), in line with the dip and recovery pattern observed in HAZ scores across age groups.[i]

3.2.1.2 Micronutrient deficiencies

Studies on iron, iodine, vitamin A, and zinc deficiencies in Mali are reviewed below.

<u>Iron deficiency</u>

For pre-school children, data from the latest Mali DHS provide some indications of the prevalence of anemia across the country (CPS/SSDSPF *et al.* 2014).[ii] In the five regions surveyed, around 82% of children aged 6–59 months were found to be anemic, with 21% exhibiting mild anemia, 52% moderate anemia, and 9% severe anemia. Those in rural areas were found to be more frequently anemic than those in urban areas, 85% and 68% respectively. Of the regions, Mopti had the highest prevalence of severe anemia, at 15%.

A couple of studies have examined rates of anemia among schoolchildren in Mali, reporting high prevalences in the respective study areas. In a trial of weekly iron supplementation in rural schools in the Sikasso region of southern Mali, involving over 1,000 schoolchildren between the ages of 6 and 19 years, 56% were found to be anemic at baseline (Hall *et al.* 2002). In an urban neighborhood of Bamako with high prevalences of malaria and urinary schistosomiasis, a cross-sectional study of 34 schoolchildren 7–14 years of age reported 68% to be anemic and 24% having iron deficiency anemia (Ayoya *et al.* 2009).

<u>Iodine deficiency</u>

The latest available data from the WHO Global Database on Iodine Deficiency for Mali (WHO 2007b) reports urinary iodine results from a nationally-representative survey of children aged 6–13 years.[iii] Five percent of children were found to be severely iodine-deficient, and 27% were found to be at least moderately deficient.

Other studies provide indication of deficiencies in particular geographic areas as well as challenges faced by iodization initiatives.[iv] One of these studies assessed iodine status in women of reproductive age in a rural area of Bafoulabé district in Kayes Region in western Mali (Torheim *et al.* 2005). Thirty-five percent of women were severely iodine-deficient, 75% were at least moderately deficient, 60% had visible goiter, and only 6% had an adequate iodine status. In comparison to other iodine deficiency studies in Mali that have found lower prevalences of

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[i] These findings are also similar to the delay in menarche observed in other low-income countries, discussed in Section 2.5.2.

[ii] The three northern regions of Gao, Kidal, and Tombouctou were not surveyed due to the security situation at the time.

[iii] The reference given for the survey is: Ntambwe, T. K.. 2005. "Enquete nationale sur la lutte contre les troubles dus a la carence en iode au Mali." Bamako, Mali, Ministere de la Santé, Direction Nationale de la Santé.

[iv] In 1995, Mali adopted salt iodization as a method for preventing iodine deficiency, passing legislation on it the same year (WHO 1998).

deficiency, the authors suggest that the remoteness and relative inaccessibility of the study area could contribute to the higher prevalences observed, as may the salt reaching the area potentially not being iodized at all or losing iodization during long transport and storage.

One of the studies that reported lower prevalences assessed iodine deficiency among 89 adolescent girls aged 10–15 years in an urban area and a rural area of Ségou Region in central Mali (Pawloski *et al*. 2003). Five percent were found to be severely iodine-deficient, and 32% were at least moderately deficient. No difference in deficiency prevalences was observed between urban and rural girls. The authors argued that addressing iodine deficiencies is important in the adolescent girl population as they enter child-bearing age, with deficiency potentially leading to congenital hypothyroidism in future children. They also cited reasons why many people preferred not to buy iodized salt, including its higher cost relative to uniodized salt (US$4.00/kg compared with US$0.50/kg, respectively) and the view that it is unnecessary "western" food, even though iodized salt in the country is imported from neighboring Senegal[i]. Gewa, Leslie, and Pawloski (2013) suggest that public-private partnerships should be engaged to explore the feasibility of iodizing locally-produced salt as a means of increasing acceptability.

Vitamin A deficiency

For vitamin A deficiency, a national survey to map xerophthalmia[ii] in children under the age of 10 reported that prevalence rates exceeded the WHO-defined thresholds for a serious public health problem in the regions of Gao, Kidal, Mopti, Ségou, and Timbuktu, with the highest prevalences in the latter three (Schémann *et al*. 2007). In their risk factors analysis, the authors cite the finding that villages producing millet having higher prevalences of xerophthalmia as surprising and unexpected, with rice seeming to have a protective effect. As rice has been introduced more recently and is becoming increasingly important in the Malian diet compared to traditional staples such as millet, they suggest the finding may be an indication of the importance of dietary diversity and of foods that facilitate inclusion of beta-carotene rich vegetables in diets (rice is often served with various condiments, including bean-leaf and groundnut sauces).

While the national survey was unable to undertake serum testing for vitamin A deficiency as well, one study administered serum testing in 1,510 pre-school children in the Bandiagara Cercle in Mopti Region (Schémann *et al*. 2002). Forty-four percent of children were reported to have serum retinol lower than 0.35 µmol/L (the threshold for severe deficiency), with 93% having serum retinol lower than 0.70 µmol/L (the threshold for low status). A dietary survey of the previous week was

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[i] As reported by the Global Micronutrient Project, Tulane University, "Iodine in Mali," http://www.tulane.edu/~internut/Countries/Mali/maliiodine.html.

[ii] Schémann *et al*. (2007) define xerophthalmia as a term covering all eye symptoms brought about by vitamin A deficiency, including night blindness, abnormal dryness, and build up of keratin in the conjunctiva and cornea, which can ultimately lead to corneal necrosis and eyeball perforation.

also conducted to examine the frequency that foods rich in vitamin A were eaten. Over three-quarters of children had not consumed any vitamin A rich animal-based foods during the week, and while some green-leaf vegetables are consumed in sauces, the authors highlight that the long cooking times partially destroy the carotenoids.

Zinc deficiency

While there are no known studies that have assessed serum zinc concentration in Mali, a recent study on the global prevalence of zinc deficiency employed a method of comparing country-level theoretical physiological zinc requirements with estimations on amounts of absorbable zinc from national food supplies (Wessells and Brown 2012). The prevalence of inadequate zinc intake in Mali was estimated to be between 15% and 25%.

Another study examined zinc content in soil, crops, and meals at selected sites in the Niger inland delta in Mali (Gårdestedt *et al*. 2009). Zinc content in soil and in crops was found to be low (similar to results from similar studies in the country), as was human intake in the simplified assessment undertaken. As the diet in Mali is dominated by cereals (which are generally low in zinc compared to animal-based foods), the authors suggest that interventions to assess deficiencies should be focused on improving uptake of zinc from the soil by cereals and on improving availability of zinc in meals for human uptake. They cite the success of foliar application of zinc for cereal grains elsewhere (Cakmak 2008) as well as the potential to increase the availability of zinc in food through different preparation methods, including fermentation, malting, and soaking (Marfo *et al*. 1990).

3.2.2 Food intake in Mali

No nationally representative surveys of food intake in Mali have been undertaken, which Kennedy *et al*. (2010) attributes to the cost and time required to collect accurate quantitative dietary intake information, illiteracy levels restricting which survey tools can be used (Solomons and Valdés-Ramos 2002), and the need to adapt instruments in areas where shared-plate eating is practiced. The few studies that have assessed food intake in Mali provide indications of dietary quality in particular geographic areas as well as comparisons between rural and urban populations.

One study examined dietary diversity as well as nutrient adequacy among 502 men and women aged 15–45 years in 319 households in the Bafoulabé district in Kayes Region in western Mali, a rural area marked by seasonal food insecurity (Torheim *et al*. 2004).[i] All respondents

[i] Ninety-four percent of respondents practiced agriculture and 55% animal husbandry. As regards survey timing, the questionnaire was conducted between October and December 1997, when sorghum and groundnuts are harvested in the area.

reported eating cereals (including maize, sorghum, rice, and wheat), legumes (including groundnuts[i] and cowpeas), vegetables (including onions, okra, pumpkin, hot peppers, and tomatoes), and green leaves (including onion and pumpkin leaves). Over 90% of subjects reported consuming fish, but the amounts were often small, with smoked and dried fish being used as a spice. Fruit (including lemon, red sorrel, and baobab pulp), meat (including beef and mutton), and egg intake was low. For micronutrients, 80% of respondents were below the recommended daily nutrient intake for calcium, 70% for vitamin A, 49% for iron, and 48% for vitamin C. Only 10% of the sample had a mean adequacy ratio (MAR) of 1, the value that indicates a diet reaches all of the recommended intakes of the nutrients surveyed.

Another study assessed food variety and dietary diversity of 817 households in one rural area and one urban area in Koutiala Cercle in the Sikasso region of southern Mali (Hatløy *et al.* 2000).[ii] Households were asked what foods they had used on the previous day. Data were collected at two different time points as well, the first during the rainy season and second during the post-harvest season. Nearly all households, in both the urban and the rural areas, reported consuming staple foods (including sorghum, millet, maize, and rice), vegetables (including onions, peppers, okra, tomatoes), and energy-dense foods (sugar, shea butter, and vegetable oil). Urban/rural differences were observed in the types of foods consumed within these food groups and in other food groups. Intake of fruit, meat, and milk was more frequently reported in the urban area than the rural, while rural households more frequently reported use of leaves/gathered foods. Rural households also used more locally-produced shea butter while urban households used more oils that were available on the market. Additionally, for most of the food groups, urban households reported higher numbers of different food items eaten. For example, urban households used a mean of 4.7 different vegetables and 1.8 different fruits, significantly higher than the 3.3 vegetables and 0.8 fruits of rural households. The study assessed socio-economic status (SES) of the households as well and reported a correlation with SES of around 0.3 for both food variety and dietary diversity in the urban area and a correlation of around 0.1 for both dietary quality indicators in the rural area. No seasonal variations in the measures of food variety or dietary diversity were found.

3.2.3 Evidence on determinants of child nutritional status

As mentioned in Section 2.3.2, undernutrition is the manifestation of an interplay among basic, underlying, and immediate causes, which is summarized in the UNICEF (1990) operational framework. In studies of determinants of child nutritional status, the determinants are often classified as child-, household-, or community-level characteristics. Findings from nutrition

[i] All subjects reported consuming groundnuts in considerable amounts, with a median intake per day of 140 g.
[ii] Households in the rural area were predominantly subsistence farmers, with cotton, millet, sorghum, and maize as the primary crops. The main economic activity in the urban area was generated by a cotton factory.

determinants studies are presented below, with school-age results included where available. The majority of the literature uses anthropometric measures of nutritional status, with the longer-term height-for-age measure as the most frequently examined and discussed outcome. Shorter-term weight-for-height is also often assessed, with the composite weight-for-age occasionally included as well.

3.2.3.1 Child-level characteristics

Child-level characteristics that have been found to be determinants of nutrition status include age, gender, and birth order, which are reviewed in turn below.

<u>Age</u>

In many nutrition determinants studies in developing countries, age coefficients for pre-school children reveal a pattern of growth faltering similar to that discussed in Section 2.3.1, with weight-for-height usually bottoming out before height-for-age (see Strauss 1990). For school-age children, the delay in the adolescent growth spurt and the onset of puberty often observed in low-income settings (see Section 2.5.2) also can contribute to diverging z-score patterns in adolescence.

<u>Gender</u>

Meta-analyses of populations in sub-Saharan Africa have found boys to be more likely to experience linear growth faltering than girls at both pre-school age (Svedberg 1990; Sahn and Stifel 2002; Wamani *et al*. 2007) and school-age (Svedberg 1990). Though there is no conclusive evidence on why this may be, several authors have offered hypotheses, one being that there may be issues with the separate reference standards for girls and boys (Sahn and Stifel 2002). Wamani *et al*. (2007) counter that if this were true, it would be difficult to explain why in many studies the gender differences disappear in sub-groups that are better off socio-economically. In another hypothesis, Svedberg (1990) suggests that the gender bias in nutritional status in sub-Saharan Africa may exist because females may be given preferential treatment due to their relative importance for agricultural labor. Alternatively, citing epidemiological studies, Wamani *et al*. (2007) propose that part of the explanation could be that males are more vulnerable than females in early life, both in terms of mortality and morbidity. Sahn and Stifel (2002) have also suggested caution is needed when interpreting gender differences in height-for-age and weight-for-age indicators, as the age of boys may be overstated to gain earlier admission to school and the age of girls may be understated to improve marriage prospects.

<u>Birth order</u>

Studies in low-income settings have also found birth order to have an effect on child nutritional status, favoring older siblings over younger. In an oft-cited study of birth order and nutrition status of children under the age of 15 in the Philippines, Horton (1988) found that children from earlier birth orders were better nourished than children from later birth orders (depending on the estimates used, the youngest child in a family of seven was estimated to have a 0.5 to 2.5 SD lower HAZ than the oldest). The author suggests that this effect is due to constrained per capita resources (including parental time and attention as well as financial resources) with increasing family size. Additional birth order and child nutrition hypotheses that Horton (1988) discusses include increased exposure to infection with larger numbers of children per household, maternal depletion (children born to older mothers having lower birth weights), and socioeconomic considerations (e.g. if children conventionally support parents in old age, elder children being favored as the first to reach economic independence). Also, as some studies have suggested that middle children may be worse off nutritionally than older or younger children, the relationship between birth order and nutritional status may not be linear (Horton 1988).[i]

3.2.3.2 Household-level characteristics

At the household level, parental education, parental height, maternal age, gender of the household head, household size and composition, household income, household nutrient intake, and household agriculture have all been found to be determinants of child nutrition. Findings on each of these characteristics are reviewed below.

Parental education

A number of studies have reported an effect of parental education on child nutrition. In rural Côte d'Ivoire, paternal and maternal education was found to have a positive effect on pre-school child weight-for-height, with maternal education exhibiting a positive effect on pre-school child height as well (Strauss 1990). In Brazil, parental education was found to have a strong positive effect on nutritional status of children under the age of 8, even when parental height was included in the model as a partial proxy for unobserved familial background (Thomas, Strauss, and Henriques 1990). Maternal education was also found to have a positive effect on nutritional status of children under the age of 5 in Nicaragua (Blau 1986). In Jamaica, where child care is often shared by females in the household, an increase in education for any household female was associated with a positive effect on pre-school child health (Handa 1999). An analysis examining the determinants of nutrition of children under the age of 13 in Vietnam reported a strong effect of parental education even when income was controlled for, suggesting a direct effect of parental education on child nutrition as opposed to through income alone (Haughton and Haughton 1997).

In line with these findings, two ways through which maternal education has been reported to have an effect on child nutritional status include cognitive ability in managing available resources

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[i] Thus, introduction of a quadratic formulation of birth order may be warranted in analysis.

(Rubalcava and Teruel 2004), as well as maternal nutritional knowledge (Christiaensen and Alderman 2004).

Parental height

As Mueller (1986) summarized, studies have often found infant length to be more associated with the mother's height than the fathers, while the height of older children tends to be associated with the heights of both parents. In analyses of child nutrition determinants, maternal (and sometimes paternal) height has been used to capture genetic effects as well as unobserved familial background characteristics, including any ethnic variation (see Strauss 1990; Thomas, Strauss, and Henriques 1990). In Vietnam, Haughton and Haughton (1997) also found parental height to be highly important contributors to the fit of their model.[i]

Maternal age

Studies have found very young mothers to have a negative effect on child nutritional status. Strauss (1990) reported lower weight-for-height outcomes for children with a mother under the age of 18, with no effect thereafter.[ii] The study also examined the difference between including mother's age at survey and mother's age at birth, with the expectation that the former might be more closely related to weight-for-height and the latter to attained height. However, the author found roughly similar results using the two specifications.[iii] The two mechanisms proposed include: 1) a quality-quantity trade-off in beginning child-bearing early to produce more children; and 2) constrained resources for households with very young mothers.

In a study on the determinants of stunting in children under the age of 5 in rural households in India, Gaiha and Kulkarni (2005) reported the opposite effect of mother's age. Increased stunting was associated with older mothers, with the effect weakening with advancing maternal age. The study also examined the effect of mother's age at marriage, finding that early marriages (women under the age of 20) were also associated with increased stunting.

Gender of the household head

There is also evidence that suggests that income controlled by women has a greater positive effect on child health than income controlled by men. Thomas (1990) reported in an analysis of Brazilian survey data that unearned income controlled by the mother had a greater positive effect on the nutritional status of children 8 years old and younger than that controlled by the father.

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[i] They also reported that the tall children of tall parents were more likely to be wasted, suggesting that in areas of food insecurity, increased height may not be an advantage.

[ii] To allow for different effects before and after a specified cut-off point, Strauss (1990) created a linear spline for mother's age, with the cut-off point at 18 years.

[iii] Excluding mother's age altogether resulted in a 40% reduction in the coefficient for mother's education, with young mothers more likely to have had some education in the study setting.

However, as data on intrahousehold resource allocation are rarely routinely collected, the gender of the household head is often used as a proxy (with the assumption that the head has the greatest control of allocation) (Charmarbagwala *et al*. 2004).

In terms of mechanisms, Charmarbagwala *et al*. (2004) point out that female headship has contradictory means of impacting child nutrition. While households where women have greater decision-making powers exhibit better child well-being, female-headed households also tend to earn less, thus worsening child nutritional status. All of child nutrition studies in the meta-analysis Charmarbagwala *et al*. (2004) conducted that included female headship found that it had either positive or insignificant effects. In regional analysis, all of the West African studies reported no effect of female headship, which is in line with the greater financial and decision-making powers of women typical in the region.[i]

Household size and composition

While larger household sizes are often associated with negative effects on household welfare, for child nutrition Charmarbagwala *et al*. (2004) found studies that reported negative effects as well as studies that reported positive effects, though the majority of studies reviewed (two-thirds) reported insignificant effects. In discussing possible mechanisms for positive effects, the authors suggest that the increased earning potential for larger households as well as the availability of additional care givers may contribute to the impact.

An analysis of the determinants of pre-school age child nutrition in Mozambique reported no effect of household size on children under the age of 2 but did find that larger percentages of children in the household who were under the age of 5 negatively impacted height-for-age of children under 2 (Garrett and Ruel 1999). In explaining the positive effect observed of household size on the nutrition of children between 2 and 5 years of age, the authors suggested it may be related to economies of scale in providing food and other needs for older children.

For Mali, results from analyses of DHS data on children under the age of 3 imply that the impact of household size has changed over time, going from no effect in 1987 to a negative effect in 1995 (Stifel, Sahn, and Younger 1999). The authors caution however that the overall worsening in child nutritional status between the two time points may reflect some sample selection problems, particularly for the 1987 survey. Additionally, no effect of the number of household members under the age of 5 was observed.[ii]

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[i] Another important consideration that Charmarbagwala *et al*. (2004) highlight is the need to account for household size when assessing the impact of the gender of the household head on child nutrition as female-headed households tend to be smaller. Without addressing household size, there may be omitted variable bias and the coefficient of female headship may not be found to be significant.

[ii] On presenting findings on the effect of having other siblings by age categories on nutrition of children between 3 and 36 months of age, Sahn and Stifel (2002) highlight that while some contend there may be endogeneity with fertility decisions, their study (as well as others) lack plausible instruments to address the potential issue. However, when they

Polygamy is another household composition variable that may affect child nutrition outcomes. As Desai (1992) outlines, polygamy could constrain household resources and negatively affect nutrition outcomes with a greater number of household members sharing the husband's contribution to household income. She also presents a counter argument that research of family structure in West Africa has suggested that females bear higher burdens of family support than males. If women are providing the majority of food and subsistence needs for themselves and their children (while men may bear more of the education and non-food expenditure costs), children in polygamous households may not necessarily be worse off nutritionally than children in monogamous households. Consistent with the latter argument, Desai (1992) reported no significant effect of the nature of maternal marital status (in a monogamous or polygamous union) on child nutrition outcomes in data from Ghana, Mali, and Senegal.[i]

Household income

How to account for income in child nutrition determinants analyses is a matter of some debate as inclusion of total household income directly as an independent variable in an ordinary least squares (OLS) regression of a model that implies the endogeneity of income may produce biased estimates (Charmarbagwala *et al.* 2004). However, as income is often included in practice, Behrman and Deolalikar (1988) suggest that it be instrumented, with either one (e.g. unearned income) or multiple variables. Following this approach, income was found to have a positive effect on child nutrition in Côte d'Ivoire (Sahn 1990; Strauss 1990) and in Brazil (Thomas, Strauss, and Henriques 1990).

Charmarbagwala *et al.* (2004) counter the instrumental variables method by arguing that the fit of the instrumenting regression is often poor and that issues of co-linearity may arise. They contend that as severe malnutrition is an extreme condition, the endogeneity issue may not be a concern in practice. For the bias to be introduced, household earners would need to wait until children are stunted before seeking to increase income, which is an unlikely scenario both in the factors leading to stunting and the ability to then respond to it. The authors also argue it is improbable that current income is endogenous with height-for-age, an indicator of long-term nutritional status.

estimated the models with the household composition variables and without, the results between the two were not qualitatively different.

[i] Desai (1992) also notes that polygamy can change over the life cycle. Polygamous households may once have been monogamous, and following death or divorce, polygamous households may become monogamous households. These temporal variations suggest any effects of polygamy may be overestimated in the former instance and underestimated in the latter.

Household nutrient intake

Child's food intake, despite its explanatory potential for nutritional status, is seldom directly observed. Among the few child nutritional determinants studies that have tried to proxy for it, Alderman and Garcia (1994) used household calories, protein, and vitamin A per capita as measures of family nutrient availability. While some positive effects of protein and vitamin A were observed, no effect of calories was found, which the authors suggest could be due to unobserved intra-family distribution as well as the potential for smaller effects as caloric intake rises.

Alderman (1990), in his study of nutrition determinants of pre-school age children in Ghana, suggests that food expenditures should be disaggregated as much as possible when using per capita household food expenditures as a proxy for food inputs. In support of this, he argues that quality differences within commodity groups are relatively small, but that as incomes rise, food expenditures vary with shifts in preference for different commodity groups. The results of the analysis reported no significant effect of total food expenditures or of individual cereals, root crop, meat, or other food expenditures. As this is in line with findings from other studies of limited effects of increased food consumption, Alderman (1990) contends that this should challenge conceptions of nutrition and the measurement thereof.

Household agriculture

A few studies that have examined the effect of unfavorable household agriculture factors (like crop failures and drought) have reported negative impacts on child nutritional status. A nationally-representative survey of children under the age of 5 in Rwanda examined the impact of crop failure experienced at the time of their birth on their HAZ several years later (Akresh, Verwimp, and Bundervoet 2011). Girls born during crop failure were significantly negatively affected (0.86 SD lower HAZ), with girls from poor households particularly impacted (1.33 SD lower HAZ). No nutritional status effect was observed for boys, which the authors argue suggests that parents were able to shield boys but not girls from the crop failure shock. In the aftermath of drought in rural Zimbabwe, Hoddinott and Kinsey (2001) reported a 1.5–2 cm loss in growth among children aged 12–24 months. The authors also suggest a permanent effect as catch-up growth was limited. No effect was observed among children aged 24–60 months.

Findings on relationships between agriculture and nutrition are reviewed in greater detail in Section 3.2.4.

3.2.3.3 Community-level characteristics

Community-level characteristics have also been found to be determinants of child nutritional status. Review findings are divided between observed community variables and urban, rural, and geographic effects below.

Community variables

Studies measuring community-level characteristics have found water and sanitation and health care to affect child nutritional status. Analyzing DHS data on nutrition of children between 3 and 36 months of age from 25 surveys in 14 countries in Africa, Sahn and Stifel (2002) reported that community-level water and sanitation conditions (including piped drinking water and flush toilets) and availability of prenatal care were important determinants of child nutritional status. The study of determinants of pre-school child nutritional status in rural Côte d'Ivoire also reported strong effects of community characteristics, with local wages, health infrastructure quality (including accessibility of medicines, water and sanitation, and hospital congestion), and public health issues (including malaria) among the most important (Strauss 1990). The study also assessed an interaction between maternal education and distance to health and educational facilities. The interaction was found not to be significant, which the author attributed to the unimportance in these distance variables in explaining the outcome and to the low education levels observed in rural areas.

Market prices at the community level have also been assessed in child nutrition determinants studies. In their analysis of child nutrition determinants in rural India, Gaiha and Kulkarni (2005) constructed seven village-level price indices[i]. Increased prices of milk and milk products; of edible oils; and of meat, fish, and eggs were reported to have an association with increased stunting while higher prices of pulses and of cereals were found to be associated with decreased stunting. With the available data, the authors were unable to account for the increased prices with decreased stunting finding but suggest that substitution for cheaper nutrient sources may occur with higher prices of some food items. In a similar study on changes over time in nutritional status of children under the age of 3 in India, Imai *et al.* (2014) also found inconsistencies in price effects across three rounds of data collection in 1992–93, 1998–99, and 2005–06.[ii] In addition to suggesting the need to capture cross-price effects of substitutions, the authors also proposed disaggregating commodity groups as much as possible (as discussed in the nutrient intake section). Importantly, any discussion of price effects should also include consideration of whether the households surveyed are net food producers or net food consumers (see Ivanic and Martin [2008], which examined the differential impacts of the recent global food price crises on low-income countries).

[i] The seven price indices were constructed from household data and included indices of cereals; of pulses; of *gur* and sugar; of milk and milk products; of edible oils; of meat, fish, and eggs; and of vegetables.

[ii] Concern about the 1992–93 data collection round has been raised as a variety of partners implemented the survey (Headey, Chiu, and Kadiyala 2012), which could be a source of some of the inconsistencies observed.

Urban, rural, and geographic effects

When community-level data on characteristics such as food prices and access to health services are unavailable, geographic dummy variables[i] are often used to determine community-level effects (Charmarbagwala *et al*. 2004). While these dummies are frequently found to have a significant effect, their interpretation is limited as which aspects of the areas are causing different nutrition outcomes is unknown. Additionally, as Charmarbagwala *et al*. (2004) point out, some argue that the use of these dummy variables is inappropriate as household location may be endogenous with child nutrition (e.g. families with ill children may choose to relocate closer to health facilities). They counter by stating that this argument may overstate the ability of the majority of families to relocate, but that the statistical significance of community-level dummy variables may be reduced by multicollinearity with income and education, factors that may have more influence on where a family chooses to live.

3.2.4 Evidence on the relationships between agriculture and child nutrition

In examining the relationship between agriculture and nutrition (of particular interest for the chapters to follow), reviews of agriculture intervention studies have found little evidence of improved nutritional status for children (Ruel 2001; Berti, Krasevec, and FitzGerald 2004; Leroy and Frongillo 2007; Masset *et al*. 2012; Webb and Kennedy 2014). For instance, the review by Masset *et al*. (2012) included 23 studies from developing countries, eight of which reported prevalences of stunting, underweight, and wasting. There was little evidence of improvements in these measures of undernutrition for children under the age of 5, but the authors argue that methodological weaknesses (including lack of statistical power) of many of the studies limit the conclusiveness of the findings.

In another measure of the relationship between agriculture and nutrition, Headey, Chiu, and Kadiyala (2011) assessed relationships between agricultural growth and nutrition improvements at the state level in India. Examining changes between 1992 and 2005, the authors grouped states by the strength of their agricultural growth in relation to improvement in nutritional indicators (stunting and underweight for children under the age of 3 and BMI in women). While a number of states exhibited no obvious disconnect between agricultural and nutritional improvements, agricultural growth was a weak predictor of nutritional gains overall.

[i] Such as urban versus rural, geographic administrative units, or each survey cluster. For urban versus rural in particular, Smith, Ruel, and Ndiaye (2005) analyzed data on malnutrition from 36 developing countries and found little evidence of differences between urban and rural areas in the nature of socioeconomic determinants or strengths of association. However, the authors did find differences in the levels of the determinants, the cumulative effects of which may drive the urban/rural differences in malnutrition observed. Examining biophysical and geographic correlates of child malnutrition in 367 sub-national areas of Africa, de Sherbinin (2011) found that only drought, piped water, and diarrheal disease had significant associations with malnutrition when spatial autocorrelation was addressed.

In response to the studies above and other similar findings reported in the literature, Headey, Chiu, and Kadiyala (2012) present two hypotheses on why nutrition gains may not always be realized with agricultural growth, the first being that there are many direct linkages between agriculture and nutrition but that there are a variety of possible "leakages" along the pathways. The second is that in addition to improvements in agriculture, strengthening of a number of different sectors may be required to realize nutritional gains, for example in health, in education, in infrastructure.

As Headey, Chiu, and Kadiyala (2012) discuss, a complex interplay between agriculture and nutrition exists, with the two exhibiting a more indirect relationship than is generally thought. The authors highlight that income from agricultural sales, market prices, and production for own consumption all influence household food availability. Moving from the household- to the individual-level, nutrition outcomes are also influenced by intrahousehold food allocation, parental care, and individual health status. Overarching these more immediate determinants are food, land, education, and health policies as well as disease burdens and cultural practices among other socioeconomic drivers.

Headey, Chiu, and Kadiyala (2011) and Gillespie and Kadiyala (2012) present an agriculture-nutrition framework that further delineates these pathways, in the Indian context; similar frameworks have been proposed recently by the World Bank (2007), Arimond *et al*. (2011), and Hoddinott (2012). Important pathways that are consistent across all of the frameworks include production for own consumption, food availability, incomes, prices, household behavior, and time allocation (Pinstrup-Andersen 2012). Evidence related to each of these pathways is discussed in turn below, followed by mention of additional considerations not discussed in detail here but elaborated elsewhere.

3.2.4.1 Production for own consumption and food availability

Because of their interrelation, the pathways of production for own consumption and food availability are discussed together, first with respect to dietary diversity and meat and dairy production and second with respect to food losses and food waste.

<u>Dietary diversity and meat and dairy production</u>

Headey, Chiu, and Kadiyala (2012) suggest that improving dietary diversity may be one element of strengthening nutritional outcomes. Evidence on the importance of dietary diversity for nutrition include a study on children 6–23 months of age using data from 11 DHS surveys, which found dietary diversity to be significantly associated with HAZ, even when socioeconomic characteristics were adjusted for (Arimond and Ruel 2004). Similar findings were reported in a recent study of infant and young child feeding practices in India (Menon *et al*. 2013). At school-age, in a longitudinal study of children in a southeastern state of India, stunted children were found to eat a less diversified diet than non-stunted children (Himaz 2009). Additionally, a significantly higher percentage of children who moved from being stunted to not being stunted reported eating legumes (including protein-rich lentils and beans) and fish and seafood.[i] Moreover, in a longitudinal study of height across the post-infancy period (from 2 to 18.5 years of age) in the Philippines, each additional unit of diet diversity (measured on a scale from 0 to 8) was associated with a 0.33 cm increase in height for boys[ii] and each additional 100 kilocalories per day was associated with a 0.05 cm increase in height for boys and 0.02 cm for girls (Eckhardt *et al*. 2005).

In making the link from household agriculture to household food consumption and dietary diversity, ownership of livestock that produced milk was found to be strongly associated with own consumption of dairy products in an analysis of agricultural households in India (Bhagowalia, Headey, and Kadiyala 2012). A similar positive association was observed for ownership of poultry and consumption of meat. Additionally, both irrigation and the number of crops grown by the household were found to be positively associated with dietary diversity scores. Citing the livestock and poultry findings, Headey, Chiu, and Kadiyala (2012) propose that, especially for small farms, engaging in higher value agricultural activities could benefit both return to household capital as well as improve nutrition.

Historical data has also suggested that proximity to dairy production can play an important role in explaining differences in height. A study that examined height data on United States Army recruits in the antebellum period assessed the influence of county-level agricultural-output variables, including milk cows, pigs, and wheat per capita (Zehetmayer 2011). Milk cows and pigs per capita both exhibited a significant, positive effect on recruit height,[iii] while wheat had no effect. Baten (2009) reported similar findings in a study of the influence of local supplies of different food items on heights in the Bavarian population in the nineteenth century. Inhabitants of areas that specialized in milk production were found to be taller than those living in grain-producing or other areas, and similar relationships were reported in analyses of regional data from France and Prussia.[iv] Zehetmayer (2011) cites the importance of calcium and protein for growth, which grain provides much less of in comparison to meat and dairy products.[v]

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[i] However, dietary diversity was not included in analyses that adjusted for other observed characteristics.

[ii] No significant effect of diet diversity was observed for girls.

[iii] Central to the proximity argument is the fact that, at the time, spoilage prevented dairy products from being transported over long distances (Baten 2009).

[iv] Baten (2009) also reports that inhabitants of areas near towns had lower nutritional status, which he suggests may be attributable to proximity to the urban disease pool or because high shares of food may be sold to satisfy the urban market.

[v] However, there is no conclusive evidence to date on which particular components of milk may contribute to growth stimulation; the candidates include bioactive peptides, amino acids, growth factors, and milk minerals (such as zinc and calcium).

To assess findings from dairy and height studies that involved experimental controlled designs, de Beer (2012) conducted a meta-analysis of data from 12 trials,[i] reporting an approximate 0.4 cm of additional growth per year per 245 ml of milk daily. The author also found that milk may be more important for growth than other dairy products and that greater effects were observed with lower height-for age and with teenagers. Thus, children who are less well-nourished and children who are near their pubertal growth spurt may benefit more from dairy supplementation.

<u>Food losses and food waste</u>

Another factor that has a significant impact on food availability is food losses and waste. FAO (2011) recently estimated global food losses and waste to be approximately one-third of the food produced for human consumption. Regional estimations were also made, with sub-Saharan Africa and south and southeast Asia generally experiencing less food lost and wasted during consumption at the household level than other regions. However, estimations of food lost or wasted during agricultural production, post-harvest handling and storage, processing, and distribution were often higher for sub-Saharan Africa and south and southeast Asia compared with other regions, which the authors, for perishable crops, attribute in part to the warm and humid conditions experienced in many developing countries. High losses in meat and meat products during production in sub-Saharan Africa are ascribed to high animal mortality as a result of frequent diseases (including pneumonia, parasites, and digestive diseases).

3.2.4.2 Income and commercialization

One issue regarding household agriculture and child nutrition that has been the matter of some debate and that helps frame a discussion of income is the effects of the commercialization of agriculture. Pinstrup-Andersen (1985) and von Braun and Kennedy (1986) argue that commercialization may potentially have a negative impact on child nutrition outcomes of poor households. With income being an important determinant of nutritional status, they contend that income of poor households may not increase with commercialization as experience from Africa and Asia indicates that marketed surplus is produced mainly by larger, wealthier landowners rather than poorer smallholder farmers (who primarily produce for own consumption and are net buyers of food). Additionally, they reason that real income of poor households may even decrease if policies directly increase the price of commercial food crops or indirectly result in higher food prices if production of export crops is incentivized. Another argument is that even if household incomes do increase with commercialization, there may be a decrease in nutrition due to changes in the source

[i] Seven were conducted since the 1990s, and five were from between 1926 and 1980. The geographic locations included were China, Europe, India, Indonesia, Kenya, the United States, and Vietnam. The author categorized most studies as having design and execution limitations.

of the income. One example of this is that households may be more likely to consume food from own production than through income from marketed cash crops (Alderman 1994). Another example is that the shift from subsistence to cash crops may result in a shift of income control from women to men, with women more likely to spend incremental income on food than men (Kennedy and Cogill 1987).

An oft-cited study on the nutrition status of pre-school children in Côte d'Ivoire examined the impact of commercialization, particularly through the increased production of export crops (Sahn 1990). The findings suggest that poorer as well as wealthier households would experience increased income from higher prices of the export crops of coffee and cocoa and that a farm household deciding to allocate land to export crops rather than food crops does not pose a risk for short-term child nutritional status. The author further argues that income growth brought about by production of export crops may even improve nutritional status. In similar findings, modest improvements in pre-school child nutrition were observed with an export crop study in Guatemala (von Braun, Hotchkiss, and Immink 1989).

Another explanation proffered for small or no nutritional improvements observed with commercialization is the constraints of existing health and sanitation conditions, such as high levels of sickness among pre-school children in a study of shifting from corn to sugarcane production in the Philippines (Bouis and Haddad 1990) and lack of drinking water in a rice irrigation and commercialization study in The Gambia (von Braun, Puetz, and Webb 1989). Pinstrup-Andersen (2012) also suggests that the lack of effect may be expected when low diet quality is more constraining for child nutrition than low food quantity.

Among school-age children, in a comparative analysis on the effects of cash crop production on nutrition in six countries,[i] Kennedy, Bouis, and von Braun (1992) were able to obtain data for children between the ages of 6 and 10 for The Gambia and Guatemala. They report increases in household caloric intake positively impacting growth of these children. As the effect of cash crop production in pre-school children was found to be weak, the authors argue that older children may be better able to achieve food needs themselves as compared to younger children, who are more likely to suffer illnesses and may feel satiated before their actual caloric needs are met.

3.2.4.3 Food prices and price shocks

Research on recent food price shocks provides insight into price effects on nutrition. In addition to increases in poverty that have been documented with the global food price crises (Ivanic, Martin, and Zaman 2012), a few studies have reported negative effects on caloric and micronutrient intake as well as diet diversity with rising food prices. In an analysis of the nutritional impacts of

[i] The Gambia, Guatemala, Kenya, Malawi, the Philippines, and Rwanda.

the 2006–08 food price crisis in Latin America, there was an 8.0% median reduction in calories consumed in the seven countries studied (Iannotti and Robles 2011).[i]

The impact of food price shocks on micronutrient intake has also been explored. Iannotti *et al*. (2012) used data from the 2006 Guatemala National Living Conditions Survey to determine energy and nutrient intakes along with adequacy levels. After determining income-nutrient and price-nutrient elasticities, nutrient intake was modeled by reductions in income and by increases in food prices. As income decreased, zinc exhibited the greatest increase in likelihood of inadequacy, with folate and vitamin A following. Similarly, as food prices increased, the intake of zinc was the most acutely affected micronutrient. The authors suggest that the micronutrient intake changes were attributable to changes in consumption of legumes rather than the animal-source foods hypothesized.

Another study of urban households in Burkina Faso reported negative effects on food security and dietary diversity as well following considerable food price increases at local markets between 2007 and 2008 (Martin-Prevel *et al*. 2012). Significantly fewer households were found to be food secure in 2008 compared to 2007 (22% and 33%, respectively). Additionally, in 2008, individuals were found to have consumed less meat, poultry, and dairy and fewer fruits and vegetables. These decreases were particularly important for medium socio-economic status households, which the authors argue is due to the richest households being better able to absorb food price shocks and the poorest households having low dietary diversity to begin with.

3.2.4.4 Household behavior change and nutrition education

Even if access to nutrition foods is not limited, knowledge on the importance of consuming these foods or on methods of preparation to maximize nutritional gain may be lacking. A review often cited in discussions of the importance of nutrition education for achieving nutrition gains from agriculture interventions is Ruel (2001), which assessed a number of studies from developing countries that employed food-based approaches aimed at reducing iron and vitamin A deficiencies. Interventions that did not involve a nutrition education component did not have a significant effect on nutrition outcomes, while studies that included education, marketing, and/or media campaigns along with homestead gardening interventions did observe significant impacts.

Another study that reported a nutrition knowledge link examined the relationship between maternal nutrition knowledge and household food budgets in rural Indonesia (Block 2003). Households with and without nutrition knowledge allocated similar budget shares to food, but households with nutrition knowledge allocated significantly more of the food budget to items rich in micronutrients. These households were also less willing to compromise micronutrient-rich food

[i] The authors note that some households may have benefitted from increased income if they were net sellers of food.

consumption as staple food prices increased. The differences observed were not attributable to maternal formal education.

3.2.4.5 Time allocation of caregivers

Pinstrup-Andersen (2012) highlights that even with the right nutrition knowledge, time or income constraints may limit the ability of households to implement change. A recent study examined barriers to improving child feeding practices among caregivers in a rural farming region in the Bolivian Andes (Jones *et al*. 2012). The barriers that caregivers most frequently reported were women's time spent in agricultural labor, household agricultural production being low in diversity, and spouses and mothers-in-law not showing support for child feeding. These barriers were found to be negatively associated with child meal frequency, child caloric intake, and changes to child diet diversity. While child caregiving knowledge and other individual-level characteristics were also found to affect child feeding practices, the influences of physical and social caregiving environments in the study area were found to be more important. The authors argue that behavior change communication alone may not be able to address these latter barriers and that agriculture, particularly in rural areas, may have a strong effect on child feeding, not only through household food security, but also through women's capacities to provide caregiving.

3.2.4.6 Other factors

Additional considerations in the relationship between agriculture and nutrition include: 1) drivers of human behavior, which can involve environmental cues and stimuli (Marteau, Hollands, and Fletcher 2012) rather than the pure utilitarianism on which many agriculture and nutrition studies are based; 2) the interaction between food systems (supply factors) and consumption by individuals (demand factors)[i] (Pinstrup-Andersen 2012); 3) food-borne pathogens,[ii] which can be introduced during production, processing, storage, and transportation (Nakimbugwe and Boor 2010); 4) water-associated pathogens and diseases, which can be spread by contaminated irrigation water[iii] as well as breed in water storage and irrigation systems[iv] (McDermott and Grace 2012); 5) zoonoses,[v] which make up around 60% of all human diseases (Taylor, Latham, and Woolhouse 2001); 6) HIV and AIDS, which can reduce agricultural labor productivity and increase

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[i] For example, rapid increases in demand for particular agricultural items (food or non-food) changing what farmers produce, or marketing by food processors driving what households purchase and consume (Pinstrup-Andersen 2012).
[ii] Including bacteria, viruses, parasites, and fungi, which can cause short-term diarrhea, vomiting, and fever as well as long-term complications that can result in death (Nakimbugwe and Boor 2010).
[iii] Including cholera, cryptosporidiosis, and chemical intoxication caused by poisonous metals such arsenic and cadmium (McDermott and Grace 2012; Pinstrup-Andersen 2012).
[iv] Including malaria and schistosomiasis (McDermott and Grace 2012).
[v] Including endemic zoonoses (e.g. brucellosis, leptospirosis, and salmonellosis), outbreak or epidemic zoonoses (e.g. leishmaniasis, anthrax, rabies, and Rift Valley fever), and emerging zoonoses (e.g. HIV and AIDS) (Grace *et al.* 2012).

malnutrition and immune system vulnerability (Gillespie and Kadiyala 2005); 7) the production of drugs and medicinal plants, which can generate income as well as have both positive and negative effects on health (Pinstrup-Andersen 2012); 8) agricultural pests and pest management, which can have direct effects on human health through toxins and allergens[i] as well as indirect effects through changes in production and income (Nelson 2010); and 9) the occupational hazards of agricultural labor, with agriculture being classified as one of the three most dangerous sectors to work in (Pinstrup-Andersen 2012). These considerations are further elaborated by Pinstrup-Andersen (2010) and Pinstrup-Andersen (2012).

3.2.5 Seasonal food insecurity considerations

Consideration of seasonality involves a range of factors (many of which have relevance for agriculture and nutrition relationships and have been mentioned above) and how they change and interact over different seasons and years. As an example that delineates some of the diverse aspects of seasonality, Chambers, Longhurst, and Pacey (1981) characterize hungry seasons as involving limited food stores; high prices; limited time for cooking, child care, and hygiene; peak energy needs for agricultural labor; and high prevalence of tropical diseases. While these various facets of seasonal food insecurity have been examined by a number of studies in different developing country settings (findings from which were most notably compiled by Sahn [1989]), a detailed, interdisciplinary analysis conducted in Mali (Adams 1992; Adams 1995) provides helpful insight into the interaction of many aspects of seasonal food insecurity in an area near the regions surveyed in this study and sharing in many characteristics. Findings from Adams (1992) and Adams (1995) are the focus of the discussion below, with reference made to additional studies where they augment discussion.

Examining studies of seasonal food insecurity in Mali, no variations in food variety or dietary diversity scores were observed between rainy and post-harvest seasons in the Sikasso region of southern Mali in a study mentioned above (Hatløy *et al*. 2000). However, the more detailed analysis of seasonal food insecurity in an agriculturalist area in Koulikoro Region also mentioned above did report seasonal variation (Adams 1992; Adams 1995).[ii] The study included longitudinal data collection on 33 households over a 14 month period, from the harvest of one year to the harvest of the next.[iii] Data were collected on a range of factors potentially related to seasonality, including

[i] Examples include aflatoxin, which is a naturally occurring mycotoxin, and arsenic, which is a carcinogen that both occurs naturally in soil and water and may be added to both through use as an insecticide, in animal feed, and in animal manure used as fertilizer (Nelson 2010; Pinstrup-Andersen 2012).

[ii] Adams (1992) argues that lack of understanding of the interaction of the range of seasonal food insecurity factors and lack of interdisciplinary analysis may result in mistaken dismissal of seasonality effects.

[iii] Cross-sectional data were also collected in 148 households in surrounding villages to provide a broader, regional overview of seasonal food insecurity and to help indicate to what extent the longitudinal study was representative of the wider area.

adult time allocation (measured six times a month); household morbidity, food stocks, expenditure, and labor exchange (twice a month); whole household anthropometry (once a month); and household food consumption (twice a season over three seasons [harvest, dry, and rainy]), among other data. The findings on nutrition status, food consumption, adult energy expenditure, morbidity, and their interactions are discussed in turn below, followed by a summary on seasonality effects from more recent studies in sub-Saharan Africa.

3.2.5.1 Nutrition status

In all age groups examined, children under five, school-age children and adolescents, and adults, seasonal fluctuations in anthropometric measures of nutritional status were observed. Adams (1992) suggests that some of the growth faltering observed among children under five during the rainy season could be attributable to the combination of morbidity, food scarcity, and maternal time constraints limiting child feeding. Among school-age children and adolescents, height and weight velocities slowed during the rainy season and accelerated during the harvest and dry seasons.[i] For some age and gender sub-groups, growth velocities equaled or exceeded the reference values, during the dry season in particular.[ii] Among adults, significant depletion of body fat was observed during the rainy seasons, with regaining of these stores occurring during the harvest and dry seasons.

3.2.5.2 Food consumption

While overall energy intake appeared to be maintained (or increased) in the rainy season relative to the other two, variation was observed in the food sources of energy. Net energy intake was found to be less in the dry than in the harvest and rainy seasons (largely explained by seasonality of groundnuts[iii]), energy provided by vegetables less in the rainy season than in the harvest and dry seasons, energy provided by fruit less in the harvest season than in the dry and rainy seasons, and energy provided by milk, roots/tubers, and sugars less in the dry and rainy seasons than in the harvest season. No significant seasonal difference was observed for energy from meat/fish. Protein intake was also observed to be significantly higher in the harvest season than in the dry, but in all seasons the risk of protein inadequacy is reported to be low, when compared with safe level recommendations. Micronutrient intake was also assessed,[iv] and while seasonality was

[i] Adams (1992) highlights that longer-term temporal effects cannot be ruled out, which could potentially be disentangled from seasonal effects if a longitudinal study over a number of years were conducted.
[ii] Other studies that have reported similar catch-up growth at school-age and adolescence are discussed in Section 2.6.
[iii] Adams (1992) also reported how crop income (particularly for groundnuts) affected other food intake and how availability of sauce ingredients varied by season. For instance, during harvest, groundnuts were used as the base of most sauces, and groundnut income allowed purchase of a range of other condiments, including dried fish, sour milk, tomato, and dried okra. Dried leaves and seeds became the important sauce ingredients during the dry season and wild leaves and shea butter during the rainy season.
[iv] Including for calcium, iron, thiamine, riboflavin, niacin, vitamin C, and vitamin A.

observed, adequate intake was reported for most nutrients during most seasons, with the exception of deficiencies of riboflavin overall and vitamins A and C during the rainy season. When considering interpretation of the results, Adams (1992) highlights that the method of measurement did not permit observation of intrahousehold intake and that the seasonal hunger that year was considered to be relatively mild.

3.2.5.3 Energy expenditure by active adults

To examine whether energy balance was influenced by the intensity of agricultural labor by season, Adams (1992) observed time allocation of active adults over 15-hour waking days[i] and calculated energy expenditure. Male energy expenditure was found to be constant in the harvest and dry seasons but significantly greater in the rainy season, with agricultural labor intensifying. Female energy expenditure was relatively constant across all seasons, with agricultural energy expenditure slightly higher in the harvest season. Adams (1992) comments that the lighter activity of males in the harvest and dry season may provide them opportunities to recover fitness after the agricultural demands of the rainy season while females may have less opportunity to recover from higher demands of the rainy season as they maintain moderate levels of activity during the harvest and dry seasons as well.

3.2.5.4 Morbidity

Adams (1992) also assessed seasonal morbidity as it may affect appetite and activity, finding frequency of morbidity episodes to be four to five times greater in the rainy season than in the harvest or dry seasons. Incidence of fever episodes (most related to malaria) was particularly high among children during the rainy season. In making the link with dietary intake, another seasonality study in rural Bangladesh among children 5–30 months of age found that the intake of most nutrients decreased by around 10% during febrile illness (Brown *et al*. 1985). As regards activity and productive work, around 30% of the active population were unable to work due to illness during the rainy season compared to around 7% during the harvest and dry seasons. Adams (1992) argues that the adverse effects on productivity increases vulnerability particularly for smaller households.

3.2.5.5 Interaction of seasonal variables

In discussing interaction between the variables observed above, Adams (1992) comments on the decline in nutrition status during the rainy season occurring simultaneously with the increase in morbidity. Significant associations between nutrition status and morbidity during the rainy season

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[i] Time was categorized into eight activities: agricultural, food preparation, gathering, general, household, manufacture and crafts, resting, and social.

are confined to children under the age of 5, and while the causal direction cannot be established, the results suggest strong influence of environmental factors on the causes of seasonal nutritional risk for the pre-school population studied. Additionally, Adams (1992) argues that the decline in body fat among adults during the rainy season may be more attributable to an increase in agricultural labor intensity than a decline in food intake.

3.2.5.6 Perceptions of seasonality over time

Some consider the topic of seasonal food insecurity to have been generally neglected over the past 20 years (Devereux, Sabates-Wheeler, and Longhurst 2011), potentially motivated by the perception that local markets are increasingly integrated (Kaminski, Christiaensen, and Gilbert 2014). Adoption of advances in communication technology may increase some of this integration, but effects may differ by type of crop. For instance, in a study of mobile phone coverage in West Africa, Aker and Fafchamps (2013) reported improved market efficiency for cowpeas (a semi-perishable crop) but no effect on millet or sorghum (storable crops). Additionally, for Mali in particular, recent research has found poor market integration within the country as well as with other countries in the area (Araujo-Bonjean, Aubert, and Egg 2008).[i] As regards magnitude of seasonal food insecurity effects, a recent analysis of monthly data from Malawi, Tanzania, and Uganda reported intra-annual variations in food consumption to be substantial, with gaps between the highest and lowest months ranging from 31% in rural southern Malawi to 82% in urban Tanzania (Kaminski, Christiaensen, and Gilbert 2014). The authors argue the findings highlight how seasonality continues to permeate sub-Saharan Africa food markets.

3.3 Methodology

The data analyzed here were collected as part of a baseline survey for the cluster randomized trial mentioned above, conducted by the Partnership for Child Development (PCD), Imperial College London, funded by a grant on Home Grown School Feeding from the Bill & Melinda Gates Foundation. With supervision by PCD, Innovations for Poverty Action (IPA) collected and entered the data and performed the initial cleaning.

3.3.1 Characteristics of the study area

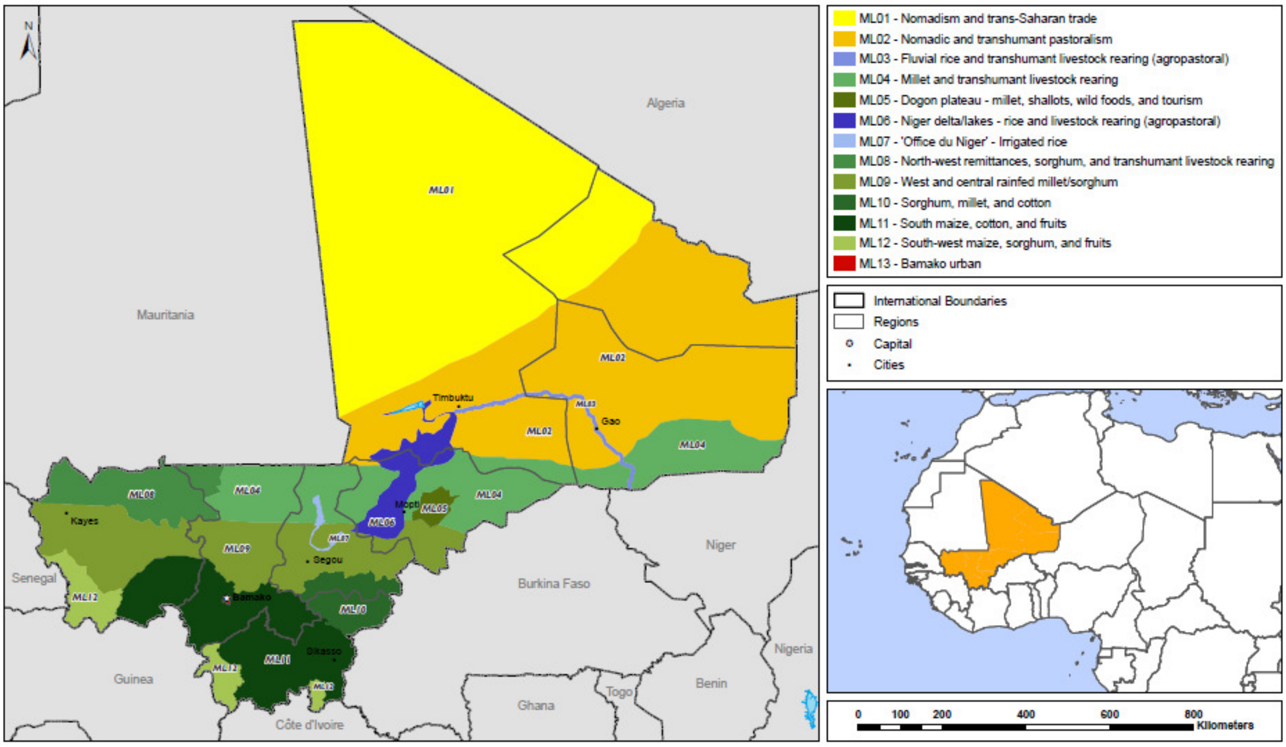
Data were collected from 111 villages selected at random in three regions (Kayes, Koulikoro, and Mopti) of Mali's eight.[ii] The outlines of all the country's regions are shown in the

[i] Araujo-Bonjean, Aubert, and Egg (2008) assessed market integration by analyzing the propagation and persistence of price shocks.
[ii] Mali is divided administratively into regions, which are sub-divided into cercles, which are sub-divided into communes. The 111 study villages were located in 56 communes across 8 cercles of the three regions of Kayes, Koulikoro, and Mopti.

Famine Early Warning Systems Network (FEWS NET) map in Figure 3.1, with the study regions marked by the cities of Kayes, Bamako, and Mopti, respectively. Together, the three regions comprise an area nearly the size of Italy, and their collective population exceeds 6.4 million,[i] around 45% of the national population (INSTAT 2009).

The study villages were located in the north of the regions of Kayes and Koulikoro and in the west of Mopti. The FEWS NET map depicts the range of livelihood zones that characterize these areas, influenced by factors including latitude, elevation, and waterways. While the rainy season in the study area generally occurs from June to September, the livelihood zones vary by amount of annual precipitation (ranging from 300 to 800mm), main crops (principally millet and sorghum), the time of the major harvest (ranging from October to January), the importance of livestock (greater importance toward the north), and ease of market access (difficulties often experienced in the rainy season), among other factors. Table 3.2 presents a summary of these variations in the FEWS NET livelihood zones 4, 5, 8, and 9 in which the study villages were located using information from the "Livelihood Zoning and Profiling Report" for Mali (USAID 2010a).

Figure 3.1 FEWS NET Mali Livelihood Zones Map



Source: USAID (2010a)

[i] Excluding the capital district of Bamako, which is located within the region of Koulikoro.

Table 3.2 Variations in the livelihood zones that characterize the study area

FEWS NET Livelihood Zone	Annual precipitation	Rainy season	Main crops	Major harvests	Livestock rearing	Market access	Staple food purchase	Hunger period	Other notes
ML04: Millet and transhumant livestock rearing	300–500mm	Jun–Sep	millet, sorghum, cowpeas, onions, garlic, tobacco	Oct–Dec (millet, sorghum)	mainly cattle, goats, sheep, camels; important source of cash income for the better off	more difficult in the rainy season than in the dry	Jan–Sep	Jul–Sep	aid relatively common
ML05: Dogon plateau – millet, shallots, wild foods, and tourism	400–600mm	Jun–Sep	millet, cowpeas, groundnuts, shallots, tomatoes, wild foods	Oct–Dec (millet, cowpeas)	cattle, goats, sheep; livestock less important than in neighboring zones	relatively good	not reported	Aug–Sep	a main tourist area; aid relatively common
ML08: North-west remittances, sorghum, and transhumant livestock rearing	400–500mm	Jun–Sep	sorghum, millet, calabash, okra, shallots, lettuce	Oct–Nov (sorghum)	cattle, sheep, goats; important economic activity	relatively poor	Nov–Dec	Jul–Sep	remittances define livelihoods; low population density; very hot
ML09: West and central rainfed millet/sorghum	600–800mm	Jun–Sep	sorghum, millet, cowpeas, maize, groundnuts, watermelon, cotton, sesame	Oct–Jan (sorghum, millet, cowpeas)	cattle, sheep, goats; less important than in zones further north	generally good, some difficulty in rainy season	Jan–Oct	Jul–Sep	moderate population density, important in north-south trade

Note: The source for the data summarized in this table is USAID (2010a). The ML04, ML05, ML08, and ML09 livelihood zone codes correspond to those in Figure 3.1.

3.3.2 Study design

The trial was designed in conjunction with the government as it expanded the national school feeding program in areas of Kayes, Koulikoro, and Mopti. In line with the government's vulnerability targeting aim, the Ministry of Education (MoE) specified that in selecting intervention areas priority be given to those that experienced food insecurity, low enrollment (especially for girls), and limited external aid but that had strong community involvement. In the selection of schools, criteria included schools with low retention and completion (especially for girls), schools that served nomadic populations, schools that served children with special needs, schools that served rural populations, and schools that needed canteens (Masset and Gelli 2013).

Out of the 170 most vulnerable communes in the country, the MoE selected 58 that the school feeding program would be expanded into.[i] In line with the eligibility criteria, two schools in different villages that shared similar qualities were selected by mayors in each of the 58 communes, for a total of 116 schools in 116 villages.[ii] In each commune, one school was then randomly selected to receive the school feeding intervention and the other to serve as the control. A second level of randomization was then undertaken to allocate half of the intervention schools to regular HGSF and the other half to HGSF+ (see discussion of the treatment groups above and see Masset and Gelli [2013] for further details on the randomization). However, the intended school feeding implementation did not take place due to the deteriorating security situation following the administering of the baseline survey, described below.

3.3.3 Survey implementation

The survey was completed in one round in the post-harvest season between January and February 2012; instruments included village, mayor, school, and household questionnaires. In each village, 25 households were randomly selected using household listings compiled through interviews with village chiefs.[iii] Of the 2,900 households in 116 villages targeted for inclusion in the sample, 2,719 households in 111 villages were surveyed, due in part to the increasing security threats at the time.[iv] The household survey included twelve modules designed to collect information on the socio-demographic characteristics of the household members; educational attainment, participation, and constraints; economic activities; food and non-food consumption/expenditure; agricultural land, production, marketing, and tools; livestock; businesses; and income transfers. Additionally, cognitive tests were administered for children between 5–15

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[i] Areas that posed significant accessibility issues or security threats were excluded.
[ii] A protocol was used to avoid contamination between the two schools.
[iii] The full sampling procedure is detailed in Masset and Gelli (2013), with additional information provided in Gelli *et al*. (2014). The household was defined as those who normally live and eat together (Masset and Gelli 2013).
[iv] The number of household members surveyed in each village is reported in Appendix A.

years of age, and anthropometric measurements were taken for children between 2–15 years of age (the focus of this analysis, further description of the methodology below).

Quality control involved supervisors who oversaw each enumeration team and central coordinators who oversaw the supervisors. The supervisors undertook regular field monitoring of completed questionnaires, including nightly meetings to review results and make any necessary adjustments. Difficulties encountered in administering the household questionnaire included unavailability of respondents due to agricultural work, travel to markets, and transhumance; unavailability of children for anthropometric measurements and cognitive tests; language barriers; problems in accessing households located on inclines; the wide dispersion of households in some villages; distances between villages; and the deteriorating security situation.

3.3.4 Description of the data

How variables used in subsequent analyses were measured and calculated is described below, including child anthropometry, household socioeconomic status, household food consumption, household agriculture, school feeding information, and regional dummies. Considerations related to their construction are also discussed.

3.3.4.1 Child anthropometry

The weight and height of each child between 2–15 years of age were collected, along with sex, age, date of birth,[i] and whether the child had fallen ill within the last 7 days. Weight was measured to the nearest 0.1 kg using the Terraillon Mira Electronic Bathroom Scale (Croissy-sur-Seine, France), and height was measured to the nearest 0.1 cm using the Leicester Height Measure (Chasmors, UK).

The weight-for-age, height-for-age, and BMI-for-age z-scores of school-age children (those with reported ages of 5–15 years) were calculated using the WHO AnthroPlus software (WHO, Geneva, Switzerland) Stata macro.[ii] Weight-for-age was only calculated for children 61–120 months of age, because into adolescence, the measure is unable to distinguish between relative height and body mass (de Onis *et al.* 2007). Additionally, the software flags extreme, potentially incorrect z-scores using lower and upper standard deviation limits (-6 and +5 for WAZ, -6 and +6 for HAZ, -5 and +5 for WHZ, and -5 and +5 for BAZ). These flagged observations were coded as missing and were not included in complete case analyses.

[i] Households were asked to supply the child's birth registration card so that the official date could be recorded. If the birth registration card was unavailable, households were asked to recall the date of birth.

[ii] Nutrition outcomes (WAZ, HAZ, WHZ, and BAZ) were also calculated for pre-school children (2–5 years of age, that is those with reported ages of 2, 3, and 4 years of age) using the Stata macro of the WHO Anthro software (version 3.2.2; WHO, Geneva, Switzerland). However, the pre-school results are not reported here due to the effects of imprecise age data on z-scores in this younger age group (Oshaug *et al.* 1994).

Because many dates of birth were missing,[i] the reported ages were used for the z-score computations.[ii] The age of each child was assumed to be the mid-year age, as birth dates during the year may be randomly distributed across the individuals.[iii] As an accuracy check of the mid-year age assumption, for children with birth month and years available, z-scores were calculated with age in months (derived from the birth month and year data) and were compared with z-scores for these children that were calculated using the reported age in years.[iv] As a further check, age in years derived from the birth month and year data was compared with reported age. Eighty-nine percent of ages in years from birth month and year data were one year less than the reported age in years.[v] To test for sensitivity to over-reporting of age, z-scores for children with birth month and year data were also calculated using reported age in years minus one year[vi] and compared with the z-scores from ages in months. This analysis was extended with a calculation of z-scores for all of school-age children using reported age in years minus one year, the results of which were compared with the findings from reported age in years.

To examine potential impacts of age-related changes of SD on HAZ measures (Leroy, Ruel, and Habicht 2013; Leroy *et al.* 2014), absolute height-for-age differences (HAD) in centimeters were also calculated. Using an approach similar to Leroy *et al.* (2014), HAD for school-age children was calculated by subtracting the median height of the growth reference (at the child's

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[i] Of school-age children measured for anthropometry, 73% of birth months were missing. Of the non-missing observations, there was marked heaping of birth month on December, at 66% of responses. Responses were fairly evenly spread throughout the other eleven months; these January through November observations represented less than 10% of the school-age children with anthropometric data. Similar patterns were observed for birth days, with 74% missing. There was noticeable heaping on the 31st days of the month, representing 68% of non-missing responses. Again, responses were evenly distributed across the rest of the days of the month, representing less than 9% of school-age children with anthropometric observations.

[ii] Many in Mali do not possess birth registration cards. Findings from the DHS 2006 survey (conducted between May and December 2006) indicate that of children under the age of 5, birth registration was around 50% in Kayes, 52% in Koulikoro, and 38% in Mopti (CPS/MS, DNSI/MEIC, and Macro International Inc. 2007). In their study of age reporting in relation to anthropometrics of 6–60 month olds in northern Mali (where fewer than 10% of study children had birth registration cards), Oshaug *et al.* (1994) reported a number of sources of potential error. When birth registration cards were unavailable, the highly trained enumerators used event history and lunar calendars to estimate age. For the date of birth, there was heaping around the 5th, 10th, 15th, and 20th days of the month, likely due to respondent and enumerator estimation when birth registration cards were not available. Even with registration cards, there were indications that the travel burden and the time dependence of public registration may have resulted in some children being registered as younger than they were (potentially several months younger). For the month of birth, results suggested heaping around the month of the survey as well as heaping at 6, 12, 24, 36, and 48 months of age. While the day of the month heaping may not overly bias estimations, the authors suggest that errors in month of the year and age in months may have resulted in an underestimation of undernutrition.

[iii] Other studies that have taken a similar mid-year age approach in studies of school-age children include PCD (1999); Ulukanligil and Seyrek (2004); and Konishi *et al.* (2014).

[iv] Because of birth month heaping on December, only children with birth months of January through November were included.

[v] Eleven percent were equal, and no ages in years from birth month and year data were greater than reported age in years. These differences in derived and reported ages in years could be due to the first year of life being considered age 1 in years by the respondents and/or the enumerators. However, this does not always seem to be the case as, in the ages reported in the household member module, of children under the age of 5 (not including those aged 5), 10% were reported to be 0 years of age.

[vi] Ages were again assumed to be the mid-year age.

mid-year age and for the child's gender)[i] from the observed height of the child. Any child whose z-score was flagged as extreme was not included in the subsequent HAD analyses.

3.3.4.2 Household socioeconomic status

Socioeconomic data collected in the household questionnaire included income earned by all household members, non-food and food expenditures, agricultural tools owned, livestock owned, small business activities undertaken, and non-food transfers received. Relevant considerations for measuring income, expenditure, wealth, and unearned income are discussed below.

Income

In analyses of the socioeconomic data collected, Masset and Gelli (2014) reported that the household income figures were likely to be significantly underestimated, with expenditure being much higher than income. Thus, expenditure and wealth, discussed below, are the preferred measures of socioeconomic status in the dataset.

Expenditure

For expenditure, data were collected on low frequency non-food expenditures over the past 12 months, high frequency non-food expenditures over the past 30 days, and food expenditures over the past seven days. These figures were annualized and summed to generate a measure of household expenditure, which was in turn used to calculate household per capita expenditures, as a proxy for income. However, as detailed in the food consumption section below, Masset and Gelli (2014) highlight that the variety of imputation and conversions used to calculate the value of food purchased and consumed add to the error already existing in the reporting and recording process. They suggest that these errors are important to consider particularly in this deprived study population where monetary expenditures are relatively infrequent and where food expenditure as a proportion of total expenditure is high.

Wealth

With the unreliability of self-reported income, particularly in areas where wage labor is uncommon (Deaton 1997), asset-based proxies of wealth may provide a more reliable, longer term measure of socioeconomic status (Morris *et al*. 2000). Additionally, in this dataset, Masset and Gelli (2014) reported that household stock of wealth had much greater explanatory power than household income for total household expenditure. Stock of wealth here was calculated by summing the value of all the agricultural production assets owned by each household, which

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[i] Median values for mid-year ages by gender were obtained from the WHO online documentation for the 2007 growth reference for children and adolescents, 5–19 years of age (www.who.int/growthref).

included animals but excluded land (as land value was not surveyed). Per capita wealth figures were calculated for each household as well.

For some analyses, households were categorized as belonging to the poorest 40%, the middle 40%, or the wealthiest 20%, similar to the categorization approach of Filmer and Pritchett (2001).

Unearned income

Unearned income was a measure of the non-food transfers received by the household over the past 12 months, both in cash (in CFA) and in kind (value in CFA). Categories surveyed included gifts from people outside the household, transfers received from projects of NGOs and other related agencies, transfers received from the government, and pensions.

3.3.4.3 Household food consumption

As mentioned above, in the food consumption and expenditure module of the household questionnaire, data were collected on which foods the household consumed in the last seven days from a food list of 51 items.[i] Quantity and units[ii] were recorded for food items purchased as well as for food items consumed from own production. Value in CFA francs was also asked for food items purchased.

After the survey, to convert all of the units of measurement to kilograms, each of the different combinations of food item and unit of measurement (e.g. one large bowl of millet, one pot of millet, etc.) was weighed twice at market and the average value was calculated. Whether different sizes of units (e.g. different sizes of calabashes) were used in different geographic areas was investigated and appropriate adjustments were made. Additionally, if different sizes of units were used within the same geographic area, the most common size was employed for conversions. For sacks in particular, as they have different standard weights for different food items (e.g. 50 kg sacks of rice, 20 kg sacks of millet), the standard selling weight was determined for each food item and used for conversions.

The kilogram quantities of the different food items that the household had consumed over seven days were then converted into nutrient content of energy, protein, iron, vitamin A, iodine, and zinc using a food composition table for Mali (Barikmo, Ouattara, and Oshaug 2004) and household daily nutrient values were calculated.

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[i] The food list items were developed based on other food consumption surveys undertaken in Mali and in consultation with local staff. The 51 food items were millet, sorghum, rice, maize, fonio, bread, wheat, beans, potato, sweet potato, cassava, tomato, carrot, onion, okra, squash/zucchini, parsley, cola nut, papaya, lemon, banana, mango, orange, guava, pineapple, wild date, wild fruit, jujubes/nenuphar, beef, chicken, sheep, goat, giblets, guinea fowl, bird, pork, dried fish, smoked fish, fresh fish, milk, shea butter, oils, butter, groundnut paste, sugar, Maggi cube, salt, green tea, black tea, soft drinks, and alcoholic beverages.

[ii] The 21 units of measurement included kilogram, liter, large bowl, pot, mouré, moudé, calabash, sack, small bowl, box, heap, sachet, packet, handful, glass, spoon, loaf, unit, cart, paani, and other.

In generating food item expenditures, unit values were calculated based on kilograms. These unit values were used to input values of own consumption and values of quantities that were purchased when the purchase value was not reported. Outliers were corrected for each food item using a procedure that included calculating the log of the per capita expenditure and then replacing any outliers more than 3 SD from the mean with the value of the mean. This was undertaken in two separate iterations for Kayes, Koulikoro, and Mopti separately.

The measures that the household food consumption and expenditure 7-day recall data were used to calculate are described below. While 24-hour recall or observed-weighed food intake data at the individual level may be the gold standard for nutrition studies, they are often prohibitively expensive and time-consuming for larger studies (Fiedler *et al*. 2012). Limitations of the household-level, longer-recall approach taken here include that it does not account for food waste and spoilage[i] or food purchased but not consumed during the recall period (potentially leading to overestimation of consumption). It also does not account for food purchased prior to the recall period but consumed during, food consumed outside the home, or food received as gifts (potentially leading to underestimation of consumption). Additionally, intrahousehold allocation of food is not accounted for. While the net effect of these various limitations is uncertain (Fiedler *et al*. 2012), household consumption and expenditure data is increasingly being utilized in similar studies (e.g. Bhagowalia, Headey, and Kadiyala 2012) as providing insight into household food security as a precondition for individual food security.

<u>Frequency of food group and food item usage</u>

Household food group and food item usage (purchase or consumption from own production) over the seven day recall period was calculated, with the 51 food items being grouped into the following nine food groups: cereals/staples, tubers, vegetables, fruit, meat, fish, milk, oils/sugars, and others. The percentage of households reporting using each food group and food item is reported, along with the mean number of food items per food group.

<u>Dietary diversity and food variety scores</u>

Household dietary diversity and food variety scores were calculated based on methods employed by Hatløy *et al*. (2000), Steyn *et al*. (2006), and Swindale and Bilinsky (2006). As a measure of the different kinds of food consumed, the household dietary diversity score (DDS) was calculated as a simple count of the number of food groups that each household reported consuming

[i] However, estimates from FAO (2011) discussed above indicate that food losses and food waste at the household level may be less in sub-Saharan Africa than other regions of the world.

in the week prior to the survey. Nine food groups were included,[i] thus the scale of the scores was 0 to 9.

As a measure of the number of different food items consumed, the household food variety score (FVS) was calculated as a simple count of the number of individual food items that the household reported consuming in the previous week. With the 51 food items included in the food consumption model, the scale of the scores was 0 to 51.

Food group shares in total food expenditure

Another measure of dietary diversity that Bhagowalia, Headey, and Kadiyala (2012) used to complement DDS findings was food group shares in total food expenditure. Here food group expenditures for nine food groups[ii] were divided by total food expenditure to calculate shares for each of the food groups.

Energy and nutrient adequacy

The mean adequacy ratio (MAR) was calculated for each household. The numbers of males and females household members in the following age groups were calculated: 0–2 year olds, 2–6 year olds, 6–13 year olds, 13–17 year olds, and 17 years old and over.[iii] The nutrient adequacy ratios (NARs) of energy, protein, iron, vitamin A, iodine, and zinc were then determined for each of the age groups. NAR is defined as the ratio of a subject's intake of energy or a particular nutrient to the recommended intake for the subject's sex and age (Hatløy, Torheim, and Oshaug 1998). The daily requirements for energy (in kilocalories)[iv] were determined for males and females in each of the age groups based on FAO (2004). Similar sex and age group calculations were made for: 1) safe levels of daily protein intake (in grams)[v] based on WHO (2007a); 2) daily recommended iron intake (in milligrams)[vi] based on FAO (2001); 3) daily recommended iodine intake (in micrograms)[vii] based on FAO (2001); 4) daily recommended safe vitamin A intake (in micrograms

[i] The same as in the food frequency calculations.
[ii] The same as in the food frequency and DDS calculations.
[iii] The 0–2 year olds included all children under the age of 2, the 2–6 year olds included all children greater than or equal to 2 years but less than 6 years, the 6–13 year olds included all children greater than or equal to 6 years but less than 13 years, the 13–17 year olds included all children greater than or equal to 13 years but less than 17 years, and the 17 years old and over included all children greater than or equal to 17 years.
[iv] For pregnant and lactating females, the recommended daily requirements are higher than for other females. As these characteristics were not assessed, energy deficiency may be underestimated.
[v] For pregnant and lactating females, the recommended daily intakes are higher than for other females. As these characteristics were not assessed, protein deficiency may be underestimated.
[vi] Values were calculated both for medium (10%) and low (5%) dietary iron bio-availability levels to allow comparisons between the two. For post-menopausal and lactating females, the recommended daily intakes are lower than for other females. As these characteristics were not assessed, iron deficiency may be overestimated.
[vii] For pregnant and lactating females, the recommended daily intakes are higher than for other females. As these characteristics were not assessed, iodine deficiency may be underestimated.

retinol equivalent)[i] based on FAO (2001); and 5) daily recommended zinc intake (in milligrams)[ii] based on FAO (2001). Household consumption data as a proportion of household requirements for energy and the five nutrients resulted in NAR for each. The mean NAR was calculated across energy and the five nutrients to determine overall household MAR.[iii] Each of the six NARs was truncated at 1 so that over-consumption of one nutrient could not compensate for under-consumption of another (Torheim *et al*. 2003). Interpreting the MAR, a value of 1 indicates that household intake of energy and the nutrients is at or above recommended amounts, while values lower than 1 indicate that household intake of one or more is below recommended amounts.

3.3.4.4 Household agriculture

<u>Crop production and food-production livestock ownership, frequency by food group and food item</u>

Based on the crops that households reported harvesting in the last twelve months from a list of 25 crops,[iv] percentages of households that harvested were calculated for each crop. Percentages of households harvesting any crop within five food crop groups (cereals, tubers, vegetables, fruit, and legumes/seeds) were also examined, along with numbers of items within each food crop group.

A similar approach was taken with ownership over the past year of seven different food-producing livestock.[v] Percentages of households that owned were calculated for each livestock. Livestock were also categorized into two food groups, meat-producing (which included all seven) and milk-producing (which included cows, goats, sheep, and camels). The percentage of households owning livestock within these categories was calculated as were the numbers of different livestock in each category.

<u>Production diversity and variety</u>

Similar to the household dietary diversity and food variety scores, household agricultural production diversity and variety scores were also calculated, following a similar approach to measuring production diversity by Malapit *et al*. (2013). Based on findings from the crop production and food-production livestock ownership analysis described above, five agricultural food groups (cereals/tubers, vegetables/fruit, legumes/seeds, meat, and milk) were used to construct

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[i] For pregnant and lactating females, the recommended daily intakes are higher than for other females. As these characteristics were not assessed, vitamin A deficiency may be underestimated.
[ii] Values were calculated both for medium (30%) and low (15%) dietary zinc bio-availability levels to allow comparisons between the two. For pregnant and lactating females, the recommended daily intakes are higher than for other females. As these characteristics were not assessed, zinc deficiency may be underestimated.
[iii] To test sensitivity to the different numbers of nutrients included, MAR was also calculated using energy and four nutrients (protein, iron, iodine, and vitamin A) and energy and three nutrients (protein, iron, and vitamin A).
[iv] The crop list included rice, millet, sorghum, maize, fonio, cassava, sweet potato, yam, potato, tomato, onion, okra, lettuce, cabbage, squash, hot pepper, cucumber, eggplant, watermelon, melon, beans, groundnut, sesame, cotton, and other.
[v] The seven food-producing livestock included in the survey were cow, calf, goat, sheep, camel, pig, and poultry.

the agricultural production diversity score (PDS). Households were scored from 0 to 5 based on the number of different agricultural food groups produced. As a measure of the number of different food items produced, production variety scores (PVS) were constructed, ranging from 0 to 30.

3.3.4.5 School feeding

At baseline, no schools were expected to be providing school feeding, but preliminary analysis of the data indicated that 9% of schools reported provision of school feeding and that over 22% of households with children of school-age reported their children receiving school feeding during the week before the interview (Masset and Gelli 2014). Additionally, only 32% percent of villages were found to have no child receiving school feeding. Great variation was observed in the data, with children frequently reported as receiving school feeding in the catchment area of schools that did not report providing feeding. The converse was also frequently observed, with children not reported as receiving school feeding in the catchment area of schools that did report providing it. Masset and Gelli (2014) suggest that this may be due to reporting errors and mismatches between households and the catchment areas of schools. Little more is known about the school feeding occurring in the area, including what type of meals/snacks/rations were provided, what the menu composition was like, and when the meals were delivered. A number of different non-governmental organizations (NGOs) were likely to be the implementers, providing school feeding in various forms, perhaps the most common taking the form of traditional school feeding in Mali, involving a mid-day meal that all the children in the school share from the same pots (Masset and Gelli 2014).[i]

3.3.4.6 Geographic

Although the sample was not designed to provide regionally-representative estimates, regional comparisons are made for a number of variables to examine differences within the sample. An urban/rural variable was included as well, though caution is warranted in interpretation as relatively few urban households were surveyed.

3.3.5 Statistical analyses and estimation techniques

The summary statistics presented in Table 3.3, Chapter 4, and Chapter 5 are described below, followed by a detailing of the estimation techniques used in Chapter 6.

Statistical analyses were performed using Stata version 11.2 (Stata Corporation, College Station, TX, USA).

[i] This collective eating suggests that food cannot be taken home, sold, or bartered (Masset and Gelli 2014).

3.3.5.1 Summary statistics

Descriptive statistics on the variables of interest in subsequent analyses are presented in Table 3.3 for children 5–15 years of age. Statistical analyses presented in Chapter 4 and Chapter 5 are conducted using the tests described below.

To compare means of a normally distributed interval dependent variable between two groups, Student's t-test is used. When the dependent variable is not assumed to be interval and normally distributed, the non-parametric Wilcoxon-Mann-Whitney test is employed.

To test for differences in means among two or more categories of a categorical independent variable with a normally distributed dependent variable, one-way analysis of variance (ANOVA) is used. Post-hoc pairwise comparisons are then performed using the Tukey-Kramer method if a significant effect is detected. With the same type of categorical independent variables but a non-parametric dependent variable, the Kruskal-Wallis test is used (without post-hoc pairwise comparisons).

To test whether there are relationships between two categorical variables, Pearson's chi-squared is used (or Fisher's exact when one or more cells are expected to have a frequency of five or less).

3.3.5.2 Estimation

As much of what is produced in the sample households appears to be consumed rather than sold,[i] it is hypothesized that households that produce a more diversified range of crops and livestock will also consume a more diversified diet.[ii] In turn, as dietary diversity has been associated with improved nutrition outcomes (Arimond and Ruel 2004; Menon *et al*. 2013; Himaz 2009), it is expected that school-age children from households with more diversified diets will exhibit better nutritional outcomes, as measured by anthropometrics. These analyses are presented in turn in Chapter 6.

<u>Nutrition outcome model</u>

The nutrition outcome model of individual utility maximization is well known; the approach taken here includes village cluster robust standard errors. The nutrition outcome variable used is HAZ, preferred to the other anthropometric outcomes measured as it is an indicator of accumulated nutrition over the long-term. For the school-age children, because of the delay in the adolescent growth spurt and the onset of puberty compared to the reference population observed in Mali (Pawloski 2002) and other low-income settings (see Section 2.5.2), in regressions involving z-score

[i] Of the 2,324 households that reported harvesting food crops over the past years, only 16% reported selling any part of their harvest.
[ii] The methodological approach taken is modelled on Bhagowalia, Headey, and Kadiyala (2012).

outcomes it may be inappropriate to include children beyond the age which adolescent growth spurt delays could contribute to variability in the outcomes. As the closest Malian reference (Pawloski 2002) indicates this break-point occurs after 11 years of age, school-age regressions in this analysis are run for a restricted 5–11 years of age group.[i]

The explanatory variables include a range of child-, household-, and community-level observed characteristics, in line with the literature review presented above. The base model includes child age, gender, and birth order variables as well as mother and household head education, female household headship, mother's age, household size and composition, and polygamy measures.[ii] An urban/rural variable and regional dummies are included as well. The basic equation for the child nutrition outcome model for HAZ is as follows:

$$Y_i = \beta_0 + \beta_1 I + \beta_2 H + \beta_3 C + \varepsilon,$$

where β_j are the parameters to be estimated, I is a vector of individual characteristics, H is a vector of household characteristics, C is a vector of community characteristics, and ε is an error term.

In subsequent model building, log per capita expenditure, agricultural production, and food consumption measures are added to the analyses.

Endogeneity and instrumentation

Income (or proxies for income like consumption expenditure), production diversity, and food consumption may be endogenous to the model, being functions of many of the same characteristics that also determine the nutrition outcomes measured. To attempt to address this endogeneity and present unbiased standard error estimates, a simple instrumental variable (IV) approach is taken using two-stage least squares (2SLS) procedures.

The proxy variable for income used is log per capita expenditure, which is instrumented for using log per capita wealth and unearned income. Wealth (in this study, a measure of agricultural production assets including tools and livestock) along with unearned income may be expected to be correlated with expenditure. Wealth and unearned income could be correlated with nutrition outcomes in ways other than through expenditure, the possibility of which will be examined in IV diagnostics. Other nutrition determinants studies have employed similar assets and unearned income approaches. Examples of instruments for income include log of value of tools, log of value

[i] While boys tend to experience their adolescent growth spurt two years later than girls (Tanner, Whitehouse, and Takaishi 1966), thus potentially expanding the range of ages that may be appropriate to compare with the reference population, the restricted age group of 5–11 years is used for both boys and girls to simplify analysis and discussion.
[ii] One limitation of note is the lack of maternal or paternal height data in the survey, of particular concern in relation to any parental education effects observed. These effects may be spurious if maternal and paternal education proxies for unobserved family background characteristics (Behrman and Wolfe 1987; Wolfe and Behrman 1987). As discussed previously, Thomas, Strauss, and Henriques (1990) included parental height in their determinants estimations, suggesting that if parental height is a better proxy of the unobserved characteristics, the effect of education would disappear if it were fully proxying. Any education effects found will be discussed with the parental height data limitation in mind.

of business assets, log of value of equipment, and log of value of land (Sahn 1990); unearned income (Haughton and Haughton 1997); and household assets and education of other household members besides the father and mother (Sahn and Alderman 1997).[i]

In instrumenting for production diversity, weather instruments may be the most preferable in avoiding reverse causation. However, as high resolution climate data were unavailable such as Malapit *et al*. (2013) used, irrigation and the log of land cultivated were employed as potentially being correlated with production diversity but not nutrition outcomes. With the instruments potentially affecting nutrition outcomes through other means than production diversity (e.g. irrigation potentially increasing water-associated pathogens and diseases, which then could have a deleterious effect on nutrition), IV diagnostics are employed to examine suitability.

For food consumption variables, log per capita wealth was often used as an instrument, in conjunction with other socio-economic and agricultural production variables found to be associated with the food consumption variable of interest but unlikely to be associated with the nutrition outcome.

Fertility decisions may also be endogenous to the model; however, as others including Sahn and Stifel (2002) and Alderman and Garcia (1994) contend, suitable instruments are lacking. Similar to the approach taken in other studies, whether the inclusion or exclusions of variables such as household size, dependency ratio, and children under the age of 2 affected key results was examined.

First-stage regressions are reported for each of the IV/2SLS estimations, as are IV diagnostic tests including an overidentification test of all instruments (Hansen J statistic; H_0: the instruments are valid, that is uncorrelated with the error term and correctly excluded from the estimation), an underidentification test (Kleibergen-Paap rk LM statistic; H_0: the equation is underidentified, identified meaning that the instruments are correlated with the endogenous regressors), a weak identification test (Kleibergen-Paap rk Wald F-statistic; if the statistic is less than Stock and Yogo critical values, weak identification is indicated), weak instrument robust inference tests (Anderson-Rubin Wald F test and chi-squared test; H_0: the endogenous regressor coefficients in the structural equation jointly equal zero), and an endogeneity test of endogenous regressors (the difference between two Sargan-Hansen statistics; H_0: endogenous regressors can be treated as exogenous) (Baum, Schaffer, and Stillman 2003; Baum, Schaffer, and Stillman 2007).

[i] As Handa (1999) highlights, others have argued that the use of unearned income as an instrument is inappropriate because it may reflect past labor supply as well as productivity and tastes that are unobserved but correlated with child health. Additionally, child health may be jointly determined with the decision to purchase certain household assets.

3.3.5.3 Missing data and multiple imputation

In order to address missing data and the resultant potential for biased parameter estimates, an imputation model was built for HAZ of children between the ages of 5 and 11, using the multiple imputation by chained equations (MICE) technique and assuming that the data are missing at random (van Buuren, Boshuizen, and Knook 1999; Royston 2004).

Of the variables included in the complete case analyses, the majority of missing data was for three variables, HAZ (16% missing), mother's age (15%), and mother's education/any schooling (14%).[i] To examine the drivers of this missingness, based on household questionnaire data as well as feedback from enumerators and field staff, some of the reasons why children may not have been measured as part of the anthropometric module include: 1) language barriers in communicating with the children; and 2) child absence due to agricultural work (including livestock herding) or school enrollment.[ii] For the missing data on mother's education and age, the variables were constructed using observations of the child's mother's identification number in the household and then linking that to observations of the mother's education and age. The missingness of the maternal education and age data was driven by missing child's mother's identification numbers rather than missing education and age observations themselves.[iii] Reasons for the missing identification numbers include: 1) mother's death or migration; and 2) child within the household (away from his or her mother) because of schooling or work in the area. To strengthen the missing at random assumption of the multiple imputation model, variables on child's current school attendance, child labor, number of kids in the household, and household language were included to help explain the missingness of the anthropometric and maternal characteristics data.[iv] All of the variables from the complete case analyses were also included in the imputation model,[v] some of which could also help explain missingness.

Following Graham, Olchowski, and Gilreath (2007) and White, Royston, and Wood (2011), 50 imputations were used as recommended for the levels of missing data in the imputation model.

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[i] The other variables with missing data included log per capita expenditure, dietary diversity and food variety, and food group shares (all 0.7% missing); log per capita wealth (0.6%); polygamous (0.4%); and dependency ratio (0.01%).

[ii] From the household questionnaire, of the 5,337 children reported to be between the ages of 5 and 11, 2% were said to have not lived in the household for fewer than nine months in the past year. Of those 2%, 75% were reported to be living with another household, 32% of those due to schooling outside the area, 2% due to work outside the area, and 66% for other reasons.

[iii] From the household questionnaire, 14% of the 5,337 children reported to be between the ages of 5 and 11 were reported not to have a mother living in the household. Of those 14%, 32% was due to the mother's migration or death, 1% was due to the child attending school in the area, 4% was due to the child working in the area, and 63% was due to other reasons.

[iv] For the principle language of the household, 50% of the households surveyed spoke Dogon, 19% Soninke, 16% Fula, 6% Bambara, and fewer than 2% spoke Moorish, Kassonke, Bozo, Songhay, Tamasheq, Arabic, Mossi, or Malingue. The languages with fewer than 2% of households speaking were assumed to be language that could present the greatest questionnaire communication barriers and thus were grouped together in one category in the language variable.

[v] The variables for HAZ, mother's age, dietary diversity, and food group shares were interval censored using the approach outlined by Royston (2007).

Along with the coefficient estimates, the average relative variance increase (RVI) and average degrees of freedom are reported and the fractions of missing information (FMI) are discussed, in line with Bouhlila and Sellaouti (2013). Because of the highly problematic matter of running IV diagnostics on imputed data, only OLS estimates were generated for the imputation models.

Table 3.3 Descriptive statistics of variables used in the analyses, for children 5–15 years of age

Variable	Description	Obs.	Mean	SD	Min.	Max.
Nutrition outcomes						
WAZ	weight-for-age z-score	3,477	-1.31	1.48	-5.98	3.71
HAZ	height-for-age z-score	6,225	-1.42	1.74	-6	5.95
HAD	height-for-age difference (in cm)	6,225	-8.90	10.83	-45.20	33.54
BAZ	BMI-for-age z-score	6,225	-0.96	1.27	-4.98	4.93
Independent variables						
Child-level						
Age	reported age in years at the time of the survey	6,526	9.19	3.04	5	15
Age squared	square of reported age in years at the time of the survey	6,526	93.70	59.59	25	225
Female	1 if female, 0 if male	6,526	1.48	0.50	1	2
Morbidity	1 if the child had fallen ill in the seven days prior to the survey, 0 otherwise	6,504	3.87	2.14	1	17
Birth order	order of birth of child within the children in the household, 1 being the youngest	6,504	19.56	22.60	1	289
Birth order squared	square of birth order of child within children in the household	6,526	0.41	0.49	0	1
Current school attendance	1 if the child is currently attending formal schooling, 0 otherwise	6,526	0.35	0.62	0	2
Child labor	for the economic activities (excluding household chores but including farm labor) of the child during the past 12 months, 0 if the child has not worked any days, 1 if the child has worked between 1 and 100 days, and 2 if the child has worked more than 100 days	6,526	9.19	3.04	5	15
Household-level						
Per capita expenditure	annual household total expenditure per capita (in CFA)	6,469	1.76e5	1.37e5	1.07e4	1.73e6
Log per capita expenditure	log of annual household total expenditure per capita	6,469	11.87	0.64	9.28	14.36
Stock of wealth	sum of the value of all the agricultural production assets owned by each household (in CFA)	6,499	1.12e6	2.36e6	0	6.81e7
Stock of wealth categories	1 if in poorest 40% of households by wealth, 2 if in middle 40%, 3 if in wealthiest 20%	6,499	1.88	0.76	1	3
Per capita wealth	household wealth per capita (in CFA)	6,499	1.31e5	2.95e5	0	9.73e6
Log per capita wealth	log of household wealth per capita	6,464	10.88	1.48	4.28	16.09
Unearned income	amount of unearned income received by the household in the past 12 months (in CFA)	6,526	5.86e4	1.74e5	0	3.12e6
Any schooling mother	1 if mother has received any formal schooling, 0 otherwise	5,545	0.08	0.26	0	1
Mother's education	highest level of schooling completed: 0 if no schooling, 1 if first year, 2 if second year, 3 if third year, 4 if fourth year, 5 if fifth year, 6 if sixth year, 7 if seventh year, 8 if eighth year[i]	6,505	0.05	0.52	0	8
Any schooling any wife	1 if any wife of the household head (or the household head herself if female) has received any formal schooling, 0 otherwise	6,505	0.10	0.31	0	1
Head of household's education	highest level of schooling completed: 0 if no schooling, 1 if first year, 2 if second year, 3 if third year, 4 if fourth year, 5 if fifth year, 6 if sixth year, 7 if seventh year, 8 if eighth year	6,505	0.00	0.14	0	5
Any schooling household head	1 if the household head has received any formal schooling, 0 otherwise	6,505	0.12	0.33	0	1
Female household head	1 if the household head is female, 0 otherwise	6,526	0.02	0.13	0	1
Mother's age	age of the mother in years at the time of the survey	5,526	35.68	8.75	12	72

[i] Higher levels of education were surveyed for, but no mothers or household heads were reported to have completed schooling beyond the eighth year.

Variable	Description	Obs.	Mean	SD	Min.	Max.
First wife's age	age of the household's first wife (or household head if female) in years at the time of survey	6,423	37.91	10.33	15	82
Household size	number of household members	6,505	8.93	3.29	3	21
Dependency ratio	ratio of the number of household members under the age of 18 to the number 18 years or older	6,505	1.98	0.90	0.1	7
Number of children	number of children in the household under the age of 18	6,526	5.68	2.67	0	17
Number of children <2 years	number of children in the household under the age of 2	6,505	0.45	0.63	0	3
Polygamous	1 if the household is polygamous, 0 otherwise	6,476	0.46	0.50	0	1
Household head farm laborer	1 if the main occupation of the household head is farm labor, 0 otherwise	6,476	0.87	0.34	0	1
Household head wage laborer	1 if the main occupation of the household head is wage labor, 0 otherwise	6,476	0.04	0.20	0	1
Log of land cultivated	log of household amount of total land cultivated (in hectares)	6,505	4.10	4.77	0	80
Log of farm capital	log of value of household farm capital (in CFA)	6,505	2.86e5	4.13e5	0	7.06e6
Irrigation	1 if household uses any man-made water sources to water crops, 0 otherwise	6,505	0.09	0.28	0	1
PDS (production diversity score)	number of different agricultural food groups the household produced the year before (scale: 0 to 5)	6,505	3.19	0.98	0	5
PVS (production variety score)	number of different agricultural food items the household produced the year before (scale: 0 to 30)	6,505	4.80	2.10	0	11
Household agricultural production per capita	value of the total agricultural output produced by the household in the past 12 months (in CFA)	6,505	4.74e4	2.03e5	0	6.38e6
FO (farmers' organization) member	1 if at least one household member is a member of a FO, 0 otherwise	6,505	0.20	0.40	0	1
Own cow(s)	1 if the household has owned at least one cow in the past 12 months, 0 otherwise	6,505	0.36	0.48	0	1
Own goat(s)	1 if the household has owned at least one goat in the past 12 months, 0 otherwise	6,505	0.65	0.48	0	1
Own sheep	1 if the household has owned at least one sheep in the past 12 months, 0 otherwise	6,505	0.78	0.42	0	1
Own camel(s)	1 if the household has owned at least one camel in the past 12 months, 0 otherwise	6,505	0.09	0.28	0	1
Own poultry	1 if the household has owned at least one poultry animal in the past 12 months, 0 otherwise	6,505	0.74	0.44	0	1
Family labor on the farm per capita (in days)	per capita number of days in the past 12 months that household members have engaged in economic activities (including household chores)	6,505	36.38	26.90	0	201.6
DDS (dietary diversity score)	number of different food groups the household consumed in the week prior to the survey (scale: 0 to 9)	6,469	6.92	1.39	1	9
FVS (food variety score)	number of different food items the household consumed in the week prior to the survey (scale: 0 to 51)	6,469	13.88	4.38	1	35
Cereals/staples share	household expenditure on cereal/staples as proportion of total household food expenditure	6,469	0.49	0.20	0	0.98
Vegetables share	household expenditure on vegetables as proportion of total household food expenditure	6,469	0.05	0.05	0	0.49
Fruit share	household expenditure on fruit as proportion of total household food expenditure	6,469	0.02	0.03	0	1
Meat share	household expenditure on meat as proportion of total household food expenditure	6,469	0.12	0.10	0	1
Milk share	household expenditure on milk as proportion of total household food expenditure	6,469	0.03	0.05	0	1
MAR (medium bio-availability)	household mean adequacy ratio across energy and five nutrients	6,526	0.66	0.22	0	1
MAR (low bio-availability)	household mean adequacy ratio across energy and five nutrients	6,526	0.60	0.23	0	1
Language	primary language spoken in the household, 1 if Dogon, 2 if Soninke, 3 if Fula, 4 if Bambara, 5 if other	6,444	1.94	1.25	1	5
Community-level						
Urban	1 if urban, 0 if rural	6,505	1.02	0.15	1	2
Region dummies						
Kayes (omitted)	including the cercles of Kayes, Diéma, and Nioro du Sahel	6,505	0.26	0.44	0	1
Koulikoro	including the cercle of Nara	6,505	0.08	0.28	0	1
Mopti	including the cercles of Mopti, Bandiagara, Koro, and Douentza	6,505	0.65	0.48	0	1

Chapter 4. Nutritional status of school-age children in three regions of Mali

This chapter presents data on anthropometry of school-age children (those between the ages of 5 and 15 years) in the study population, including exploratory analysis of the nutrition outcomes calculated. Data on WAZ, HAZ, and BAZ by gender are first reported, along with percentages above and below certain cut-offs. Means by age year are then calculated and trends across ages and genders are examined for HAZ. As HAZ may mask growth deficit changes over time, the same analysis is conducted for HAD and the results are compared. Comparisons among and between regions and wealth categories are also analyzed for HAZ, including sub-groupings of 5–11 year olds and 12–15 year olds. The last set of analyses assesses the effect of age assumptions and potential age misreporting, previously mentioned in Chapter 3.

Approximately 31% of school-age children were found to be moderately underweight and around 13% severely underweight. Moderate stunting was observed in 37%, with severe stunting in around 17%. For age patterns of HAZ, there appear to be gains relative to the reference population from ages 5 to 7, with similar means across the genders, followed by declines to age 13 for both genders. Around age 13, mean HAZ for boys continues to decrease while mean HAZ for girls starts to increase again, potentially driven by differences in the adolescent growth spurt. A very similar pattern is observed for HAD by age of boys and girls, suggesting that changes in HAZ over the ages may be driven more by changes in the magnitude of difference in height-for-age than changes in SDs for height. In regional analysis, children in Mopti had significantly lower mean HAZ than children in the other two regions (no significant differences were observed between the Kayes and Koulikoro samples). Finally, assessments of age reporting indicate that the prevalences of undernutrition above may be overestimated due to over-reporting of the age in years used to calculate z-scores. However, when ages in years that appear to be closer to ages calculated from birth month and year data are used, stunting appears to be slightly underestimated but much nearer values calculated using birth month and year data.

The anthropometry data checks examined here are expanded on in Chapter 6 to examine effects on parameter estimates of substituting HAD for HAZ as the outcome variable and of addressing potential misreporting of age.

4.1 Results

The anthropometry results section begins with estimates of the prevalence of undernutrition in the school-age children studied. Trends in HAZ and HAD across ages and gender are subsequently examined, followed by analyses of differences in HAZ among and between regions and wealth categories and then by tests of age assumptions and potential age misreporting.

4.1.1 Nutritional status of school-age children

Of the 6,225 school-age children between the ages of 5 and 15 years for whom age, sex, and anthropometrics data were observed and who did not have extreme WAZ, HAZ, and/or BAZ scores, 3,256 were boys and 2,969 were girls. Means and SD for HAZ and BAZ are presented in Table 4.1, disaggregated by gender. The mean and SD for WAZ are also presented for the 3,477 children 61–120 months of age, for whom WAZ is applicable. Additionally, percentage <-3 SD and <-2 SD below the reference for WAZ, HAZ, and BAZ are included, along with percentage +2 SD for BAZ.[i]

Overall mean WAZ, HAZ, and BAZ were -1.31, -1.42, and -0.96 respectively. Approximately 31% of school-age children were moderately underweight and around 13% severely underweight. Moderate stunting was observed in 37%, with severe stunting in around 17%. For overnutrition, around 1% had a BAZ higher than +2 SD. Significant gender differences were observed both in mean WAZ and mean HAZ, with boys having lower means for each.

Table 4.1 Mean, SD, and percentage above and below SD cut-offs for WAZ, HAZ, and BAZ of school-age children, disaggregated by gender

Indicator	N	%<-3 SD	%<-2 SD	%>+2 SD	Mean	SD	p-value[a]
WAZ							
Total	3,477	13.2%	31.4%	—	-1.31	1.48	—
Boys	1,807	13.8%	33.0%	—	-1.36	1.49	0.05
Girls	1,670	12.5%	29.6%	—	-1.26	1.46	
HAZ							
Total	6,225	17.1%	37.0%	—	-1.42	1.74	—
Boys	3,256	18.2%	40.0%	—	-1.51	1.73	<0.01
Girls	2,969	15.9%	33.7%	—	-1.32	1.76	
BAZ							
Total	6,225	6.0%	18.3%	1.3%	-0.96	1.27	—
Boys	3,256	6.4%	19.0%	1.4%	-0.95	1.31	0.93
Girls	2,969	5.6%	17.6%	1.2%	-0.96	1.23	

[a] From Student's t-test for gender differences in the respective z-score.

4.1.2 Trends in HAZ and HAD across ages and gender

To examine trends in HAZ across ages, mean z-scores by age in years for boys and girls aged 5–15 years are presented in Table 4.2 and depicted in Figure 4.1. With the caveat that the data are cross-sectional, there appear to be gains in HAZ relative to the reference population from ages 5

[i] Distributions of WAZ, HAZ, and BAZ are presented in Figure B-1.

to 7, with similar means across the genders. Declines in HAZ relative to the reference seem to occur from age 7 to age 13 for both genders. Around age 13, mean HAZ for boys continues to decrease while mean HAZ for girls starts to increase again, consistent with the earlier onset of the adolescent growth spurt for females compared with males, discussed above.[i] Additionally, assessing whether differences between the gender means are significant, nothing significant is observed until ages 14 and 15. This suggests that the overall lower mean HAZ for boys reported above may be driven by differences in timing of the adolescent growth spurt.

Leroy *et al*. (2014) argue that HAD rather than HAZ should be used to assess population-level mean growth deficit changes over time. They present the case that, for pre-school children, SDs for height increase considerably between birth and age 5. As HAZ is calculated as HAD divided by SD, if height deficits stay the same as children age, over this time HAZ will tend towards zero as the denominator (SD) is increasing. Thus, it is difficult to disentangle whether improvements in HAZ are due to reductions in the magnitude of difference calculated in the numerator or to increases in the denominator. Furthermore, HAZ may mask continued accrual of growth deficits, which HAD is better able to detect (Leroy *et al*. 2014).

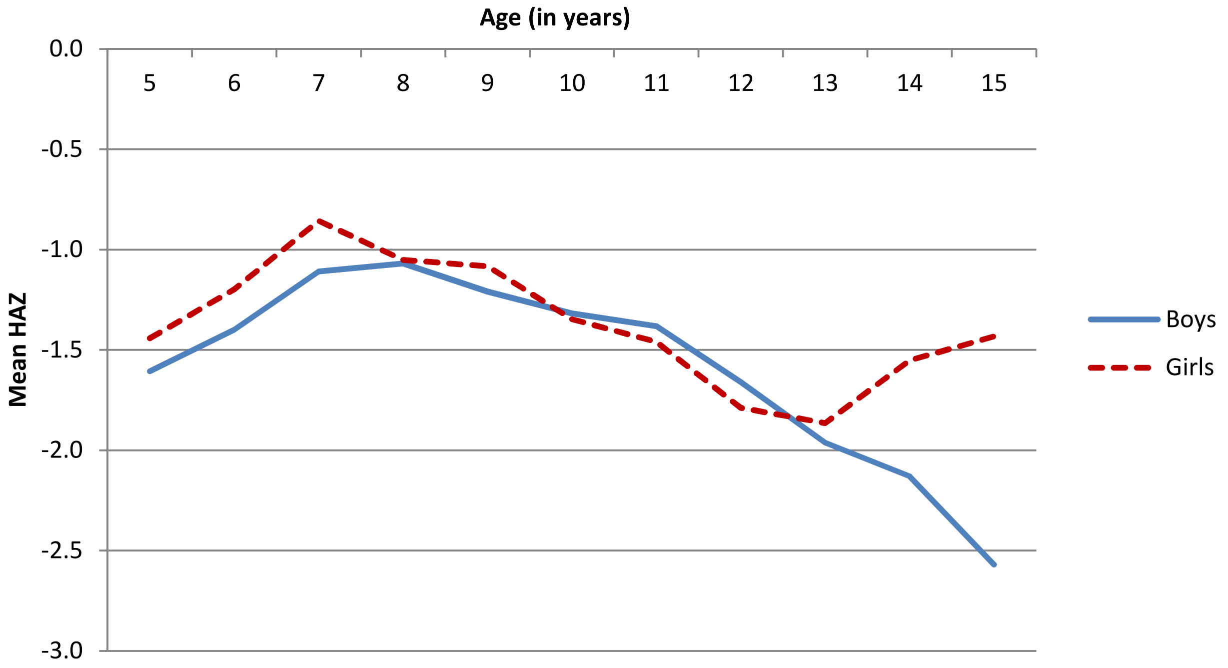
Table 4.2 Mean height-for-age z-scores (HAZ) for boys and girls aged 5–15 years, by age in years

Age (in years)	HAZ						p-value[a]
	Boys			Girls			
	N	Mean	SD	N	Mean	SD	
5	409	-1.61	2.05	324	-1.44	1.89	0.26
6	400	-1.40	1.99	380	-1.20	1.92	0.15
7	358	-1.11	1.81	354	-0.86	1.82	0.06
8	391	-1.07	1.80	352	-1.05	1.79	0.89
9	249	-1.21	1.58	260	-1.08	1.88	0.41
10	351	-1.32	1.37	348	-1.35	1.64	0.81
11	158	-1.38	1.49	168	-1.46	1.66	0.66
12	330	-1.66	1.47	254	-1.79	1.50	0.30
13	221	-1.96	1.34	198	-1.86	1.48	0.48
14	193	-2.13	1.40	186	-1.55	1.64	<0.01
15	196	-2.57	1.33	145	-1.43	1.36	<0.01

[a] From Student's t-test for gender differences in mean HAZ.

[i] A similar pattern in HAZ across ages and gender is observed by other cross-sectional studies including Prentice *et al*. (2013) and Hirvonen (2014).

Figure 4.1 Mean height-for-age z-scores (HAZ) for boys and girls aged 5–15 years, by age in years



Examining changes in SDs for height through school-age, SDs continue to increase for both boys and girls up to points in adolescence, after which they decrease. For girls, the SD of the WHO reference increases from 4.77 at 5 years 1 month to a peak of 6.95 at 13 years 6 months, from which it decreases to 6.54 at 19 years 0 months. A similar pattern is observed for boys, with the peak shifted nearly two years to the right. The SD of the reference increases from 4.59 at 5 years 1 month, peaks at 7.81 at 15 years 3 months, and decreases from there to 7.30 at 19 years 0 months.[i] Thus, increases in SDs pre-adolescence could be contributing to any improvements in HAZ across school ages observed above and may be masking potential further deteriorations in growth deficits.

To address this, mean HADs by age in years for boys and girls aged 5–15 years are presented in Table 4.3 and depicted in Figure 4.2. Compared with HAZ, a very similar pattern is observed for HAD by age of boys and girls. This suggests that changes in HAZ over the ages may be driven more by changes in the magnitude of difference in height-for-age than changes in SDs for height.[ii]

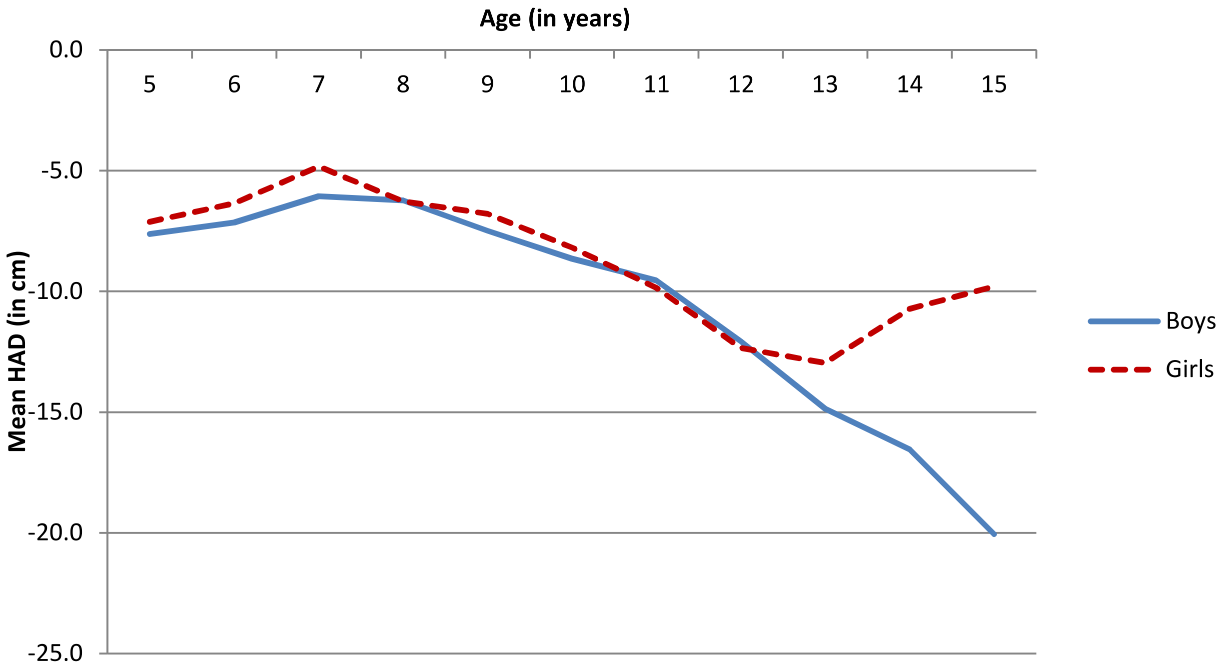
[i] SDs were obtained from the WHO online documentation for the 2007 growth reference for children and adolescents, 5–19 years of age (www.who.int/growthref).
[ii] The effect on nutrition determinants parameter estimates of using HAD as the outcome variable instead of HAZ is examined in Chapter 6.

Table 4.3 Mean height-for-age differences (HAD) for boys and girls aged 5–15 years, by age in years

Age (in years)	HAD (in cm)						p-value[a]
	Boys			Girls			
	N	Mean	SD	N	Mean	SD	
5	409	-7.63	9.72	324	-7.11	9.35	0.47
6	400	-7.14	10.15	380	-6.35	10.14	0.27
7	358	-6.06	9.88	354	-4.83	10.25	0.10
8	391	-6.23	10.52	352	-6.26	10.64	0.97
9	249	-7.49	9.79	260	-6.78	11.74	0.46
10	351	-8.64	8.99	348	-8.18	10.71	0.54
11	158	-9.55	10.27	168	-9.85	11.21	0.80
12	330	-12.06	10.64	254	-12.35	10.38	0.75
13	221	-14.86	10.17	198	-12.96	10.28	0.06
14	193	-16.55	10.87	186	-10.73	11.33	<0.01
15	196	-20.05	10.38	145	-9.79	9.33	<0.01

[a] From Student's t-test for gender differences in mean HAD.

Figure 4.2 Mean height-for-age differences (HAD) for boys and girls aged 5–15 years, by age in years



4.1.3 Mean HAZ by region, gender, and age group

In comparing mean HAZ among regions, there appear to be significant differences by gender and age group in the sample. Table 4.4 presents regional HAZ means for boys and girls of school-age, with sub-group means for 5–11 year olds and 12–15 year olds as well. Significant differences for both genders were found for all the school-age groupings. In each case, children in Mopti had significantly lower mean HAZ than children in the other two regions (pairwise comparison tests not reported in the table). There were no significant differences observed between the Kayes and Koulikoro samples.

Table 4.4 Mean height-for-age z-scores (HAZ) by region and by gender and age group

Age and gender groups	Kayes			Koulikoro			Mopti			p-value[a]
	N	Mean	SD	N	Mean	SD	N	Mean	SD	
School-age (5–15 years of age)										
Boys	855	-1.14	1.70	268	-1.04	2.02	2,124	-1.72	1.66	<0.01
Girls	789	-0.88	1.71	236	-0.71	1.96	1,932	-1.57	1.70	<0.01
School-age (5–11 years of age)										
Boy	623	-1.01	1.80	213	-0.90	2.12	1,475	-1.48	1.71	<0.01
Girls	577	-0.86	1.81	182	-0.57	2.03	1,417	-1.40	1.76	<0.01
School-age (12–15 years of age)										
Boys	232	-1.50	1.34	55	-1.57	1.47	649	-2.24	1.41	<0.01
Girls	212	-0.94	1.37	54	-1.16	1.65	515	-2.05	1.42	<0.01

[a] From ANOVA for differences among regions in mean HAZ.

4.1.4 Mean HAZ by wealth category, gender, and age group

Table 4.5 presents a similar analysis by household wealth category rather than by region. Significant differences among wealth categories were observed for school-age girls overall and school-age girls 5–11 years old in particular (but not for those 12–15 years old). However, only the difference between the poorest and the wealthiest groups is significant (pairwise comparison tests not reported in the table).

Table 4.5 Mean height-for-age z-scores (HAZ) by wealth category and by gender and age group

Age and gender groups	Poorest 40%			Middle 40%			Wealthiest 20%			p-value[a]
	N	Mean	SD	N	Mean	SD	N	Mean	SD	
School-age (5–15 years of age)										
Boys	1,171	-1.54	1.72	1,314	-1.53	1.68	760	-1.43	1.82	0.37
Girls	1,038	-1.45	1.77	1,211	-1.25	1.73	704	-1.24	1.80	0.01
School-age (5–11 years of age)										
Boy	862	-1.38	1.76	902	-1.31	1.74	545	-1.17	1.90	0.10
Girls	782	-1.35	1.82	895	-1.09	1.78	496	-1.10	1.89	0.01
School-age (12–15 years of age)										
Boys	309	-1.99	1.50	412	-2.00	1.41	215	-2.11	1.39	0.60
Girls	256	-1.74	1.56	316	-1.71	1.47	208	-1.57	1.52	0.46

[a] From ANOVA for differences among wealth categories in mean HAZ.

4.1.5 Assessing the effect of age assumptions and potential misreporting

To evaluate the mid-year age assumption, for children with birth month and years available, their z-scores calculated using age in months (derived from the birth month and year data) are reported in Table 4.6, alongside their z-scores calculated using reported age in years. For all age groupings, the mean HAZ calculated using age in months was significantly higher than the mean HAZ calculated using reported age in years for both boys and girls, with differences ranging from 0.49 to 0.89 SD. As reported age in years was one year higher than age in years derived from birth month and year data in nearly 90% of these children, HAZ was also calculated using reported age in years minus one year (Table 4.6). This method appeared to be much closer to the method using age in months. The means using age in years minus one year were significantly higher for all age groupings, but the differences only ranged from 0.05 to 0.11 SD.

These results suggest that the estimates of undernutrition indicators presented above may be overestimated due to over-reporting of the age in years used to calculate z-scores. However, when ages in years that appear to be closer to ages calculated from birth month and year data are used (along with the mid-year age assumptions), stunting appears to be slightly underestimated but much nearer values calculated using birth month and year data.

Table 4.6 Comparison between methods of calculating mean height-for-age z-scores (HAZ), for children with reported birth months and years

Age and gender groups	N	Calculated using age in months		Calculated using reported age in years		Calculated using reported age in years minus one year		p-value[a]	p-value[b]
		Mean	SD	Mean	SD	Mean	SD		
School-age (5–15 years of age)									
Boys	263	-0.97	1.73	-1.78	1.61	-0.91	1.72	<0.01	<0.01
Girls	248	-0.81	1.69	-1.58	1.57	-0.71	1.69	<0.01	<0.01
School-age (5–11 years of age)									
Boy	183	-0.70	1.84	-1.56	1.72	-0.65	1.84	<0.01	<0.01
Girls	175	-0.41	1.67	-1.30	1.56	-0.30	1.65	<0.01	<0.01
School-age (12–15 years of age)									
Boys	80	-1.57	1.26	-2.28	1.19	-1.50	1.25	<0.01	<0.01
Girls	73	-1.77	1.33	-2.26	1.38	-1.70	1.35	<0.01	<0.01

[a] From Student's t-test for differences in the means between the z-score calculation method using age in months and the method using reported age in years.
[b] From Student's t-test for differences in the means between the z-score calculation method using age in months and the method using reported age in years minus one year.

To examine the effect of using reported age in years minus one year on the anthropometric measures reported in Table 4.1 (which used reported age in years), mean, SD, and percentage above and below SD cut-offs for WAZ, HAZ, and BAZ of school-age children are presented in Table 4.7.[i] Mean z-scores for all three measures were higher than Table 4.1 values, with the greatest increases being for HAZ and WAZ. As would be expected with increased z-scores, prevalences of underweight and stunting are lower, by about half in each case. The gender difference is no longer significant for mean WAZ, but boys still seem to have significantly lower HAZ than girls.

[i] The number of observations for the respective anthropometric measures are different between Table 4.1 and Table 4.7 due to the shift in calculated ages. For instance, the children reported to be 5 years of age would be included in the Table 4.1 calculations but not the Table 4.7 calculations, which would have taken them to be 4 years of age (below the cut-off for school-age children z-score computation).

Table 4.7 Mean, SD, and percentage above and below SD cut-offs for WAZ, HAZ, and BAZ of school-age children, disaggregated by gender, calculated using reported age in years minus one year

Indicator	N	%<-3 SD	%<-2 SD	%>+2 SD	Mean	SD	p-value[a]
WAZ							
Total	3,476	7.2%	18.7%	—	-0.62	1.45	—
Boys	1,767	7.6%	19.6%	—	-0.63	1.47	0.71
Girls	1,709	6.8%	17.9%	—	-0.61	1.43	
HAZ							
Total	5,562	8.2%	20.5%	—	-0.56	1.81	—
Boys	2,877	7.8%	21.0%	—	-0.63	1.78	<0.01
Girls	2,685	8.5%	20.0%	—	-0.48	1.84	
BAZ							
Total	5,562	4.5%	14.2%	1.7%	-0.78	1.25	—
Boys	2,877	4.6%	14.7%	1.8%	-0.76	1.28	0.27
Girls	2,685	4.5%	13.6%	1.6%	-0.80	1.21	

[a] From Student's t-test for gender differences in the respective z-score.

4.2 Discussion

Initially, estimates of nutrition outcomes using reported age in years to calculate z-scores found 31% of the school-age children surveyed to be moderately underweight, 13% severely underweight, 37% moderately stunted, and 17% severely stunted. However, when potential age over-reporting is accounted for, prevalences of underweight and stunting are lower, by about half in each case. Additionally, significant gender differences were observed both in mean WAZ and mean HAZ, with boys having lower means for each, potentially driven by differences in timing of the adolescent growth spurt.

In regional analysis, children in Mopti had significantly lower mean HAZ than children in the other two regions (no significant differences were observed between the Kayes and Koulikoro samples). Among wealth categories, significant differences were observed for school-age girls overall and school-age girls 5–11 years old in particular (but not for those 12–15 years old). This suggests that other factors besides wealth may be influencing the timing of the adolescent growth spurt, as were wealth the driver alone, differences in the 12–15 age group might be expected. Additionally, no significant differences were found for boys in any of the age categories, suggesting that girls may be disproportionately affected in poorer households compared with boys.

The similar age patterns observed for HAZ and HAD suggest that changes in HAZ over the ages may be driven more by changes in the magnitude of difference in height-for-age than changes in SDs for height. Finally, assessments of age reporting indicate that the prevalences of undernutrition above may be overestimated due to over-reporting of the age in years used to calculate z-scores. However, when ages in years that appear to be closer to ages calculated from birth month and year data are used, stunting appears to be slightly underestimated but much nearer values calculated using birth month and year data.

The findings in this chapter are used in Chapter 6 to examine effects on parameter estimates of substituting HAD for HAZ as the outcome variable and of correcting for potential over-reporting of age. Before these models are estimated, the next chapter explores food consumption, dietary quality, and agricultural production of the study population at the household level.

Chapter 5. Household food consumption, dietary quality, and agricultural production in three regions of Mali

This chapter presents findings on food consumption, dietary quality, and agricultural production at the household level. The different measures of food consumption and dietary quality that are presented include frequency of food group and food item usage, dietary diversity and food variety scores, food group shares in total food expenditure, and energy and nutrient adequacy. For agricultural production, data on crop production and food-producing livestock ownership, production diversity and variety scores, and shares of food expenditures consumed from are production are reported.

Significant differences in the food consumption measures were observed among and between regions and wealth categories as well as between urban and rural households. Differences in kinds of cereals/staples used were reported, as were differences in frequencies of food group usage for vegetables, meat, fish, and milk. For dietary diversity and food variety, urban households had higher means scores for both measures, consistent with findings from other studies. From energy and nutrient adequacy analyses, around two-thirds of sampled households consumed less energy than requirements, half consumed less vitamin A and zinc, and one-third consumed less protein. Iron and iodine appeared to have the highest percentage of households with inadequate consumption, and less than 3% of households were meeting the requirements for the MAR measure.

For household agricultural production, around 77% of households reported producing any kind of cereal/staple crop, 38% produced legumes/seeds, and 12% produced vegetables. For livestock, around 93% and 88% of households reported owning meat-producing and milk-producing animals, respectively. In measures of production diversity and variety, the mean number of different food groups produced was just over 3 in the overall sample, while the mean number of different food items produced was around 4.5. Significant differences were observed among and between each of the three regions, with the mean scores for each measure being lowest in Kayes and highest in Mopti. Overall, households were found to purchase more than they consumed from own production. The greatest own production share was observed in Mopti (0.413), followed by Koulikoro (0.255), then Kayes (0.155).

The chapter concludes with reliability considerations for measuring consumption and production (including issues such as recall bias and seasonality) and discusses the findings in relation to results from similar studies. The measures of household-level food consumption and agricultural production detailed in this chapter are then used to examine effects on child nutrition in Chapter 6.

5.1 Results

The first set of analyses presented is on measures of food consumption and dietary quality, which is followed by results that examine household agricultural production.

5.1.1 Household food consumption and dietary quality

Four different measures of food consumption and dietary quality are reported on at the household level, including frequency of food group and food item usage, dietary diversity and food variety scores, food group shares in total food expenditure, and energy and nutrient adequacy. These measures are presented in turn below.

5.1.1.1 Frequency of food group and food item usage

Table 5.1 presents the food groups and food items that households reported using (purchasing or consuming from their own production) in the seven days prior to the survey interview, in total and by rural and urban. Of the food groups, nearly all households reported consuming some kind of food item in the cereals/staples group, energy-dense oils and sugars group, and other items group (including salt, Maggi cubes, and beverages). Many reported consuming vegetables, meat, and fish; about half consumed milk and fruit; and around one-third consumed tubers.

Examining rural and urban differences in food group frequency of use, for most food groups similar percentages of households' usage in both areas were found. However, a greater percentage of urban households used fruit and milk than rural households, and differences in usage of food items within food groups were also found.[i] A greater percentage of urban households were found to use a number of food items, including rice, bread, potato, tomato, carrot, squash, parsley, papaya, lemon, banana, orange, beef, chicken, smoked fish, fresh fish, oils, groundnut paste, and sweetened drinks. The only food items that a greater percentage of rural households used were okra, cola nut, and goat. Urban households also used a greater number of items per food group for all of the food groups compared to rural households.

A number of significant differences were observed among and between regions as well, as presented in Table 5.2. A greater percentage of households in Kayes used vegetables, especially compared with Koulikoro. However, Koulikoro had higher frequency use of tubers, fruit, meat, as well as milk, while Mopti had higher frequency use of fish. Similar patterns in significant

[i] Difference tests for food item frequency are not reported in the frequency of food group and food item usage tables.

differences for mean number of items per food group were also observed.[i] Kayes had a higher mean number of cereals and vegetables than the other two regions; Koulikoro had a higher mean number of tubers, fruit, meat, and milk; and Mopti had a higher mean number of fish.[ii] Many significant differences were observed in food item frequencies as well. Among cereals/staples, sorghum, rice, maize, bread, and beans usage was highest in Kayes and millet and fonio usage was highest in Mopti. Among tubers, sweet potato usage was highest in Koulikoro. Significant differences were found among vegetables as well, including usage of tomato and onion (highest in Kayes) and okra (highest in Mopti). Koulikoro had the highest usage of a number of fruits (including lemon, orange, wild fruit, and jujube/nenuphar) as well as meat (including beef, chicken, sheep, goat, and guinea fowl). For fish, Mopti had the highest usage of dried while Koulikoro had the highest usage of smoked. Shea butter usage was highest in Mopti, oils in Kayes, and butter in Koulikoro.

Examining the food usage data by wealth category (see Table 5.3), a number of significant differences were also observed. A greater percentage of households in the wealthiest 20% reported higher frequency use of in all food groups except fish, oils/sugars, and others. The mean number of food items per food group generally increased from the poorest to the wealthiest group, though in pairwise comparison tests (not reported in the table), more differences were observed between the poorest 40% and the middle 40% than between the middle 40% and the wealthiest 20%. For frequency of food item usage, fewer significant differences were found among wealth categories than among regions. Some of the more prominent food item frequency differences were for beef, chicken, sheep, goat, milk, oils, and butter.

[i] In addition to the ANOVA test among regions reported in the table, Tukey-Kramer pairwise comparisons were used to test for differences between regions. Results from these pairwise tests are not reported in the table.
[ii] In other pairwise comparisons, Mopti had a higher mean number of fruit than Kayes, Kayes had a higher mean number of meat than Mopti, and Koulikoro had a higher mean number of fish than Kayes.

Table 5.1 Household use of food groups and food items the week before the survey, in total and by rural and urban

Food group	Total (N = 2,702)			Rural (N = 2,638)			Urban (N = 64)			p-value[a]	p-value[b]
	Food group frequency of use	Mean number of food items	Food item frequency of use (items > 5%)	Food group frequency of use	Mean number of food items	Food item frequency of use (items > 5%)	Food group frequency of use	Mean number of food items	Food item frequency of use (items > 5%)		
Cereals/staples	98.4%	2.73	73.3% Millet 71.5% Rice 41.0% Sorghum 39.0% Beans 30.5% Bread 9.0% Fonio 5.4% Maize	98.5%	2.71	73.2% Millet 71.0% Rice 41.3% Sorghum 38.7% Beans 29.5% Bread 8.6% Fonio 5.4% Maize	96.9%	3.56	92.2% Rice 79.7% Millet 68.8% Bread 53.1% Beans 29.7% Sorghum 23.4% Fonio 7.8% Maize	0.26	<0.01
Tubers	34.3%	0.39	28.9% Sweet potato 6.6% Cassava	34.0%	0.38	29.1% Sweet potato 6.6% Cassava	45.3%	0.58	28.1% Potato 21.9% Sweet potato 7.8% Cassava	0.06	0.01
Vegetables	87.3%	1.69	79.7% Onion 46.5% Okra 38.6% Tomato	87.1%	1.66	79.4% Onion 46.7% Okra 37.5% Tomato	95.3%	2.86	90.6% Onion 84.4% Tomato 35.9% Okra 35.9% Squash 25.0% Carrot 14.1% Parsley	0.06	<0.01
Fruit	50.0%	0.72	36.4% Cola nut 7.4% Wild date 6.7% Jujube/nenuphar 5.1% Lemon	49.4%	0.70	37.1% Cola nut 7.5% Wild date 6.2% Jujube/nenuphar	76.6%	1.77	39.1% Lemon 29.7% Jujube/nenphar 29.7% Orange 26.6% Banana 20.3% Papaya 9.4% Cola nut 9.4% Guava	<0.01	<0.01
Meat	84.6%	1.36	60.0% Beef 33.9% Sheep 20.0% Goat 16.7% Chicken	84.5%	1.35	59.6% Beef 33.7% Sheep 20.3% Goat 16.4% Chicken	87.5%	1.64	76.6% Beef 43.8% Sheep 29.7% Chicken 6.3% Goat	0.60	0.02
Fish	78.3%	0.92	61.7% Dried 26.7% Smoked	78.1%	0.91	61.7% Dried 26.1% Smoked	85.9%	1.34	60.9% Dried 51.6% Smoked 21.9% Fresh	0.17	<0.01
Milk	56.4%	—	—	56.0%	—	—	71.9%	—	—	0.02	—
Oils/sugars	98.7%	2.15	97.3% Sugar 69.8% Oils 45.3% Shea butter	98.7%	2.15	97.3% Sugar 69.3% Oils 45.3% Shea butter	100.0%	2.33	95.3% Sugar 90.6% Oils 42.2% Shea butter	1.00	0.02
Others	98.5%	—	86.1% Salt 82.5% Maggi cube 82.3% Green tea 32.5% Groundnut paste 30.3% Black tea	98.5%	—	86.1% Salt 82.5% Maggi cube 83.1% Green tea 31.8% Groundnut paste 30.3% Black tea	98.4%	—	90.6% Green tea 87.5% Salt 82.8% Maggi cube 57.8% Groundnut paste 32.8% Black tea 20.3% Soft drinks	1.00	—

[a] From Fisher's exact test for rural/urban differences in frequency of food group usage.
[b] From Student's t-test for rural/urban differences in the mean number of food items per food group.

Table 5.2 Household use of food groups and food items the week before the survey, by region

Food group	Kayes (N = 726) Food group frequency of use	Kayes Mean number of food items	Kayes Food item frequency of use (items > 5%)	Koulikoro (N = 261) Food group frequency of use	Koulikoro Mean number of food items	Koulikoro Food item frequency of use (items > 5%)	Mopti (N = 1,715) Food group frequency of use	Mopti Mean number of food items	Mopti Food item frequency of use (items > 5%)	p-value[a]	p-value[b]
Cereals/staples	96.0%	3.07	82.4% Rice 60.6% Bread 59.0% Sorghum 55.9% Beans 32.4% Millet 16.3% Maize	98.1%	2.75	69.3% Rice 59.4% Millet 55.2% Bread 42.5% Beans 41.0% Sorghum	99.5%	2.58	92.8% Millet 67.2% Rice 33.5% Sorghum 31.4% Beans 13.9% Bread 13.8% Fonio	<0.01	<0.01
Tubers	30.7%	0.34	27.7% Sweet potato 5.6% Potato	48.3%	0.56	47.5% Sweet potato 7.3% Cassava	33.6%	0.38	26.6% Sweet potato 8.8% Cassava	<0.01	<0.01
Vegetables	89.7%	1.99	83.3% Onion 68.2% Tomato 42.4% Parsley 40.8% Okra	79.7%	1.47	75.5% Onion 38.3% Okra 28.4% Tomato	87.5%	1.60	78.8% Onion 50.1% Okra 27.6% Tomato	<0.01	<0.01
Fruit	49.4%	0.60	42.4% Cola nut	58.6%	0.99	37.2% Cola nut 15.3% Orange 10.7% Lemon 10.7% Jujube/nenuphar 9.2% Wild date 5.4% Wild fruit	48.9%	0.73	33.8% Cola nut 9.3% Wild date 7.3% Jujube/nenuphar 5.4% Lemon	0.01	<0.01
Meat	88.8%	1.37	68.3% Beef 36.8% Sheep 16.0% Goat 12.4% Chicken	91.2%	2.02	81.2% Beef 46.4% Sheep 28.7% Chicken 23.4% Goat 8.4% Guinea fowl 6.9% Giblets 6.5% Bird	81.8%	1.25	53.2% Beef 30.8% Sheep 21.2% Goat 16.7% Chicken	<0.01	<0.01
Fish	53.9%	0.57	29.1% Dried 22.3% Smoked 5.2% Fresh	70.9%	0.79	40.2% Dried 34.9% Smoked	89.8%	1.10	78.8% Dried 27.3% Smoked	<0.01	<0.01
Milk	59.0%	—	—	66.3%	—	—	53.8%	—	—	<0.01	—
Oils/sugars	97.8%	1.98	95.9% Sugar 83.5% Oils 15.2% Shea butter	98.9%	2.23	98.5% Sugar 70.1% Oils 47.5% Shea butter 7.3% Butter	99.1%	2.21	97.7% Sugar 64.0% Oils 57.7% Shea butter	0.03	<0.01
Others	97.7%	—	90.9% Maggi cube 89.4% Salt 89.4% Green tea 63.6% Groundnut paste 27.7% Black tea	98.9%	—	91.2% Maggi cube 88.9% Green tea 88.1% Salt 53.3% Groundnut paste 41.4% Black tea	98.8%	—	84.4% Salt 78.4% Green tea 77.7% Maggi cube 29.8% Black tea 16.1% Groundnut paste	0.13	—

[a] From Fisher's exact test for differences among regions in frequency of food group usage.
[b] From ANOVA for differences among regions in the mean number of food items per food group.

Table 5.3 Household use of food groups and food items the week before the survey, by wealth category

Food group	Poorest 40% (N = 1,080)			Middle 40% (N = 1,080)			Wealthiest 20% (N = 539)			p-value[a]	p-value[b]
	Food group frequency of use	Mean number of food items	Food item frequency of use (items > 5%)	Food group frequency of use	Mean number of food items	Food item frequency of use (items > 5%)	Food group frequency of use	Mean number of food items	Food item frequency of use (items > 5%)		
Cereals/staples	97.2%	2.65	70.5% Millet 69.2% Rice 41.9% Sorghum 37.3% Beans 28.3% Bread 10.6% Fonio	99.2%	2.78	76.4% Millet 72.9% Rice 40.6% Beans 40.4% Sorghum 30.6% Bread 8.8% Fonio 5.4% Maize	99.4%	2.78	73.8% Rice 72.7% Millet 40.4% Sorghum 39.7% Beans 34.7% Bread 7.4% Maize 5.9% Fonio	<0.01	0.02
Tubers	31.9%	0.36	27.0% Sweet potato 6.1% Cassava	34.6%	0.39	29.2% Sweet potato 6.7% Cassava	38.4%	0.43	32.5% Sweet potato 7.4% Cassava	0.04	0.03
Vegetables	84.7%	1.67	76.8% Onion 44.1% Okra 39.7% Tomato	88.7%	1.69	80.7% Onion 79.9% Okra 37.1% Tomato	89.8%	1.73	83.3% Onion 48.4% Okra 39.3% Tomato	<0.01	0.47
Fruit	45.6%	0.67	31.6% Cola nut 7.1% Jujube/nenuphar 6.8% Wild date	51.4%	0.74	37.7% Cola nut 5.7% Lemon 7.4% Wild date 6.8% Jujube/nenuphar	56.0%	0.81	43.6% Cola nut 8.7% Wild date 5.9% Jujube/nenuphar 5.8% Orange	<0.01	0.03
Meat	79.2%	1.18	52.6% Beef 30.7% Chicken 16.1% Goat 14.4% Chicken	87.6%	1.44	61.7% Beef 35.7% Sheep 22.6% Goat 18.4% Chicken	89.8%	1.56	71.6% Beef 36.9% Sheep 22.4% Goat 18.2% Chicken	<0.01	<0.01
Fish	76.4%	0.90	62.0% Dried 24.0% Smoked	80.6%	0.96	63.7% Dried 28.6% Smoked	77.6%	0.91	57.0% Dried 28.4% Smoked 5.4% Fresh	0.05	0.05
Milk	49.1%	—	—	59.4%	—	—	64.6%	—	—	<0.01	—
Oils/sugars	98.2%	2.08	95.9% Sugar 66.0% Oils 44.4% Shea butter	99.1%	2.18	97.8% Sugar 70.7% Oils 47.0% Shea butter	99.1%	2.23	98.9% Sugar 75.5% Oils 43.4% Shea butter 5.2% Butter	0.19	<0.01
Others	98.0%	—	85.4% Salt 81.9% Maggi cube 79.0% Green tea 30.6% Groundnut paste 28.0% Black tea	98.7%	—	87.6% Salt 84.4% Green tea 83.5% Maggi cube 33.5% Groundnut paste 30.0% Black tea	99.1%	—	85.2% Green tea 84.6% Salt 81.6% Maggi cube 35.8% Black tea 34.3% Groundnut paste 5.6% Soft drinks	0.20	—

[a] From Fisher's exact test for differences among wealth categories in frequency of food group usage.
[b] From ANOVA for differences among wealth categories in the mean number of food items per food group.

5.1.1.2 Dietary diversity and food variety scores

Household dietary diversity and food variety scores are presented in Table 5.4, including the scores for the whole sample and by rural and urban. Urban households were found to have significantly higher mean scores for both measures, consistent with rural/urban differences observed in the frequency of use analyses reported above.

Significant differences among and between regions were also observed, as reported in Table 5.5. In Tukey-Kramer pairwise comparisons (not reported in the table), the mean DDS of Koulikoro was found to be significantly higher than Kayes. While the mean DDS for Mopti was also found to be significantly higher than Kayes, no significant difference between Koulikoro and Mopti was observed. Significant differences between each of the pair of regions were found for FVS, with Koulikoro being the highest, followed by Kayes, and then by Mopti.

Wealth category data are presented in Table 5.6, with each score increasing from the poorest to the wealthiest categories. In pairwise comparisons (not reported in the table), the poorest 40% have significantly lower DDS and FVS than the other two groups, but the difference between the middle 40% and wealthiest 20% categories are not significant, which is consistent with the previous frequency of food usage findings.

Table 5.4 Household dietary diversity and food variety scores, in total and rural and urban

	Total (N = 2,702)		Rural (N = 2,638)		Urban (N = 64)		
Score	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p-value[a]**
DDS	6.87	1.41	6.85	1.41	7.58	1.14	<0.01
FVS	13.71	4.39	13.60	4.31	18.56	5.23	<0.01

[a] From Student's t-test for rural/urban differences in the respective scores.

Table 5.5 Household dietary diversity and food variety scores, by region

	Kayes (N = 726)		Koulikoro (N = 261)		Mopti (N = 1,715)		
Score	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p-value[a]**
DDS	6.63	1.52	7.11	1.56	6.93	1.31	<0.01
FVS	14.17	4.50	15.14	5.49	13.30	4.09	<0.01

[a] From ANOVA for differences among regions in the respective scores.

Table 5.6 Household dietary diversity and food variety scores, by wealth category

	Poorest 40% (N = 1,080)		Middle 40% (N = 1,080)		Wealthiest 20% (N = 539)		
Score	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p-value[a]**
DDS	6.60	1.50	6.99	1.31	7.14	1.31	<0.01
FVS	13.10	4.45	14.01	4.24	14.36	4.45	<0.01

[a] From ANOVA for differences among wealth categories in the respective scores.

5.1.1.3 Food group shares in total food expenditure

Another measure of dietary diversity, food group shares in total food expenditure, is presented in Table 5.7 in total and by region. In the total sample, the greatest food group share was observed for cereals/staples (47%), followed by oils/sugars (13%), meat (13%), others (10%), fish (6%), vegetables (5%), milk (3%), fruit (2%), and tubers (1%). Significant differences were observed among regions for all food groups except fruit. The highest cereals/staples and fish shares were observed in Mopti, the highest oils/sugars and milk shares in Kayes, and the highest meat share in Koulikoro.

Food group shares are compared by wealth category in Table 5.8. Fewer significant differences were observed among wealth categories than among regions. As may be expected, the wealthiest category had the lowest cereals/staples share and the highest meat and milk shares, consistent with the food frequency data discussed above.

Table 5.7 Household food group shares in total food expenditure, in total and by region

Food group share in total food expenditure	Total (N = 2,702)		Kayes (N = 726)		Koulikoro (N = 261)		Mopti (N = 1,715)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	p-value[a]
Cereals/staples	0.472	0.197	0.415	0.171	0.458	0.206	0.499	0.200	<0.01
Tubers	0.014	0.031	0.015	0.033	0.020	0.040	0.013	0.028	<0.01
Vegetables	0.052	0.053	0.054	0.048	0.040	0.051	0.053	0.055	<0.01
Fruit	0.016	0.036	0.017	0.048	0.019	0.034	0.016	0.029	0.11
Meat	0.125	0.108	0.143	0.107	0.154	0.122	0.113	0.105	<0.01
Fish	0.061	0.069	0.032	0.052	0.053	0.075	0.074	0.070	<0.01
Milk	0.034	0.057	0.044	0.066	0.037	0.076	0.029	0.049	<0.01
Oils/sugars	0.130	0.084	0.143	0.092	0.119	0.089	0.126	0.080	<0.01
Others	0.095	0.081	0.136	0.107	0.099	0.077	0.077	0.059	<0.01

[a] From Kruskal-Wallis test for differences among regions in food group shares in food budgets.

Table 5.8 Household food group shares in total food expenditure, by wealth category

Food group share in total food expenditure	Poorest 40% (N = 1,080)		Middle 40% (N = 1,080)		Wealthiest 20% (N = 539)		
	Mean	SD	Mean	SD	Mean	SD	p-value[a]
Cereals/staples	0.476	0.202	0.477	0.194	0.454	0.193	0.02
Tubers	0.014	0.030	0.014	0.030	0.016	0.033	0.23
Vegetables	0.056	0.057	0.050	0.050	0.049	0.050	0.06
Fruit	0.017	0.034	0.016	0.041	0.016	0.027	0.11
Meat	0.113	0.107	0.128	0.105	0.143	0.114	<0.01
Fish	0.059	0.069	0.063	0.070	0.058	0.066	0.10
Milk	0.025	0.045	0.033	0.053	0.053	0.078	<0.01
Oils/sugars	0.137	0.094	0.127	0.081	0.124	0.071	0.07
Others	0.101	0.097	0.091	0.067	0.089	0.067	0.15

[a] From Kruskal-Wallis test for differences among wealth categories in food group shares in food budgets.

5.1.1.4 Energy and nutrient adequacy

Household energy and nutrient consumption data as a proportion of household requirements is presented in Table 5.9, including energy, protein, iron (for both medium and low bio-availability assumptions), iodine, vitamin A (for both medium and low bio-availability assumptions), and for three measures of MAR made up of energy and five nutrients, energy and four nutrients, and energy and three nutrients (see table notes). Means, SDs, medians, and 25th and 75th percentiles are reported to demonstrate the effect of truncation at 1 for each nutrient (for the purposes of constructing MARs). For instance, truncation appears to have a large effect on protein, vitamin A, and zinc as compared with the more muted effects on energy, iron, and iodine. As there does not seem to be much variation between the three measures of MAR, the measure with energy and five nutrients is preferred for completeness and is retained for subsequent analyses. For analysis of individual NARs, the measures without truncation are retained.

Truncation of course does not affect the percent of households consuming below the household requirements for each NAR. As reported in Table 5.9, around two-thirds of households consumed less energy than requirements, half consumed less vitamin A and zinc (low bio-availability assumption), and one-third consumed less protein. Iron and iodine appeared to have the highest percentage of households with inadequate consumption, at around 90% for each (low iron bio-availability assumption). Less than 3% of households were meeting the requirements for the MAR measure at both levels of bio-availability assumptions.

Table 5.9 Household energy and nutrient adequacy (consumption as a proportion of household requirements) (N = 2,702)

NAR or MAR	Bio-availability assumption	Truncated at 1	Mean	SD	25th percentile	Median	75th percentile	% below requirements
NAR energy	—	no	0.885	0.678	0.430	0.738	1.158	66.1%
	—	yes	0.686	0.307	0.430	0.738	1.000	
NAR protein	—	no	1.626	1.236	0.797	1.354	2.119	33.6%
	—	yes	0.855	0.256	0.797	1.000	1.000	
NAR iron	medium	no	1.004	0.931	0.424	0.774	1.286	63.4%
	medium	yes	0.691	0.316	0.424	0.774	1.000	
	low	no	0.503	0.466	0.212	0.387	0.644	90.2%
	low	yes	0.447	0.293	0.212	0.387	0.644	
NAR iodine	—	no	0.420	0.516	0.123	0.275	0.537	91.5%
	—	yes	0.362	0.300	0.123	0.275	0.537	
NAR vitamin A	—	no	1.641	2.529	0.157	0.877	2.141	53.4%
	—	yes	0.622	0.414	0.157	0.877	1.000	
NAR zinc	medium	no	2.845	2.890	0.994	2.111	3.729	25.2%
	medium	yes	0.882	0.246	0.994	1.000	1.000	
	low	no	1.424	1.446	0.497	1.055	1.867	47.4%
	low	yes	0.757	0.318	0.497	1.000	1.000	
MAR (from six NARs)[a]	medium	yes	0.683	0.222	0.565	0.735	0.851	97.4%
	low	yes	0.622	0.227	0.477	0.665	0.793	98.7%
MAR (from five NARs)[b]	medium	yes	0.643	0.228	0.500	0.686	0.823	97.3%
	low	yes	0.595	0.222	0.450	0.623	0.761	98.7%
MAR (from four NARs)[c]	medium	yes	0.714	0.258	0.559	0.768	0.933	83.8%
	low	yes	0.653	0.249	0.495	0.696	0.849	93.4%

[a] Energy, protein, iron, iodine, vitamin A, and zinc. For each of the MARs, the bio-availability categories indicate the levels that were assumed for iron and zinc.
[b] Energy, protein, iron, iodine, and vitamin A.
[c] Energy, protein, iron, and vitamin A.

Household energy and nutrient adequacy is presented by region in Table 5.10. Significant differences occurred among the regions for each measure except for the NAR for energy. The higher NAR for protein in Koulikoro[i] could be driven by the higher frequency of meat usage in the region reported above. Mopti has the lowest NARs for protein (significantly lower than in Koulikoro), iron (significantly lower than in Kayes), and vitamin A (significantly lower than in both of the other regions). While the NAR for zinc was significantly higher in Mopti than in the other two regions, MAR was still lowest in Mopti.

Table 5.10 Household energy and nutrient adequacy (consumption as a proportion of household requirements), by region

NAR or MAR	Bio-availability assumption	Kayes (N = 726)		Koulikoro (N = 261)		Mopti (N = 1,715)		p-value[a]
		Mean	SD	Mean	SD	Mean	SD	
NAR energy	—	0.906	0.585	0.904	0.736	0.873	0.705	0.47
NAR protein	—	1.655	1.131	1.835	1.404	1.582	1.248	0.01
NAR iron	medium	1.087	1.003	1.085	0.992	0.957	0.886	<0.01
	low	0.544	0.502	0.543	0.496	0.479	0.444	<0.01
NAR iodine	—	0.350	0.439	0.522	0.721	0.434	0.505	<0.01
NAR vitamin A	—	2.742	2.967	2.315	3.646	1.073	1.854	<0.01
NAR zinc	medium	1.968	1.704	2.428	2.912	3.279	3.180	<0.01
	low	0.985	0.852	1.214	1.454	1.642	1.590	<0.01
MAR (from six NARs)	medium	0.721	0.217	0.709	0.216	0.663	0.222	<0.01
	low	0.650	0.222	0.640	0.230	0.607	0.227	<0.01

[a] From ANOVA for differences among regions for all variables except MAR, whose p-values are from Kruskal-Wallis tests.

Fewer significant differences were found among wealth categories (see Table 5.11). The only NARs with significant differences were protein and iron, potentially driven by the higher meat and dairy frequencies reported above. The wealthiest had significantly higher NAR for protein than the poorest as well as a significantly higher NAR for iron than both of the other wealth categories (pairwise comparisons not reported in the table). Significant differences among categories were also found for the MAR measures, with the trend of increasing mean with increasing wealth category.

[i] In pairwise comparison tests not reported in the table, mean NAR protein in Koulikoro was significantly higher than in Mopti but no significant difference was observed with Kayes.

Table 5.11 Household energy and nutrient adequacy (consumption as a proportion of household requirements), by wealth category

NAR or MAR	Bio-availability assumption	Poorest 40% (N = 1,080)		Middle 40% (N = 1,080)		Wealthiest 20% (N = 539)		p-value[a]
		Mean	SD	Mean	SD	Mean	SD	
NAR energy	—	0.879	0.714	0.885	0.676	0.901	0.608	0.82
NAR protein	—	1.562	1.243	1.634	1.236	1.745	1.214	0.02
NAR iron	medium	0.960	0.973	0.996	0.914	1.113	0.870	0.01
	low	0.481	0.488	0.499	0.458	0.557	0.436	0.01
NAR iodine	—	0.426	0.527	0.430	0.542	0.388	0.435	0.27
NAR vitamin A	—	1.607	2.706	1.632	2.555	1.738	2.078	0.61
NAR zinc	medium	2.751	2.924	2.873	2.985	2.985	2.618	0.29
	low	1.377	1.460	1.439	1.495	1.495	1.311	0.28
MAR (from six NARs)	medium	0.664	0.233	0.688	0.214	0.714	0.207	<0.01
	low	0.603	0.236	0.624	0.220	0.657	0.216	<0.01

[a] From ANOVA for differences among wealth categories for all variables except MAR, whose p-values are from Kruskal-Wallis tests.

5.1.2 Household agricultural production

The three measures of household agricultural production presented below are crop production and food-producing livestock ownership (frequency by food group and food item), production diversity and variety scores, and shares of food expenditures consumed.

5.1.2.1 Crop production and food-producing livestock ownership, frequency by food group and food item

In assessing household crop production and food-producing livestock ownership the year before the survey, crops produced and livestock owned are broken down into food groups in Table 5.12 and the food group frequency, the mean number of food items, and the food item frequencies are reported. For crops, around 77% of households reported producing any kind of cereal/staple crop, 38% produced legumes/seeds, and 12% produced vegetables. Fewer than 1% of households produced tubers or fruit. The most commonly produced cereals/staples were millet (65% of households) and sorghum (34%) while among legumes/seeds, groundnut (29%) was the most common. For livestock, around 93% and 88% of households reported owning meat-producing and milk-producing animals, respectively. In descending order, the most commonly owned food-producing animals were sheep, poultry, goats, cows, calves, and camels.

Significant differences among and between regions in crop production and livestock ownership were observed, also reported in Table 5.12. The households surveyed in Mopti produced a significantly greater number of different cereals/staple crops than in Kayes or Koulikoro.[i] Greater

[i] In addition to the ANOVA test among regions reported in the table, Tukey-Kramer pairwise comparisons were used to test for differences between regions. Results from these pairwise tests are not reported in the table.

percentages of households in Mopti produced millet (especially compared with Kayes), fonio, and rice, while a greater percentage of households in Koulikoro produced sorghum.[i] The mean number of vegetables produced by households in Kayes was significantly greater than that in Koulikoro or Mopti. No more than 3% of households in Koulikoro produced any one kind of vegetable crop. Households in Mopti produced a significantly greater number of legume/seed crops as well, compared with the other two regions, potentially driven by the greater percentage of households growing beans. For livestock, households in Koulikoro and Mopti reported owner significantly more kinds of food-producing animals than those in Kayes. The greatest percentage of cow, calf, and goat ownership was reported in Koulikoro while Mopti had the greatest percentage of sheep, camel, and poultry ownership.[ii]

Differences among and between wealth categories were also analyzed, presented in Table 5.13, with the most pronounced variations between the poorest 40% and the other two wealthier categories. No significant differences are observed for vegetable production, but the poorest households produce fewer different kinds of cereals/staples and legumes/seeds than the middle and wealthiest households. Crop food item frequency seems to be fairly consistent across the wealth categories, though a greater percentage of poorest and middle households produce fonio compared with the wealthiest. Additionally, a greater percentage of the wealthiest produce sesame. As the wealth indicator includes measures of the value of livestock owned, the increases in meat-producing and milk-producing livestock across the wealth categories is consistent with what would be expected. Of the poorest households, fewer than 3% own cows, calves, or camels, while in the wealthiest category, 88% own cows, 81% own calves, and 23% own camels.

[i] Difference tests for food item frequency are not reported in the household crop production and food-producing livestock ownership tables but are available upon request. These regional differences correspond with the main crops of different livelihood zones characterized by FEWS NET in Figure 3.1 and Table 3.2.
[ii] Significant differences among regions was found for percentage ownership for each of these food-producing animals.

Table 5.12 Household crop production and food-producing livestock ownership the year before the survey, in total and by region

Crops and livestock food groups	Total (N = 2,718) Food group freq.	Total Mean number of food items	Total Food item frequency (items > 3%)	Kayes (N = 739) Food group freq.	Kayes Mean number of food items	Kayes Food item frequency (items > 3%)	Koulikoro (N = 262) Food group freq.	Koulikoro Mean number of food items	Koulikoro Food item frequency (items > 3%)	Mopti (N = 1,717) Food group freq.	Mopti Mean number of food items	Mopti Food item frequency (items > 3%)	p-value[a]	p-value[b]
Crops produced														
Cereals/staples	77.3%	1.13	65.0% Millet 33.9% Sorghum 6.8% Fonio 4.4% Rice	47.8%	0.64	35.5% Sorghum 18.8% Millet 7.7% Maize	78.2%	1.02	50.8% Sorghum 46.6% Millet	89.9%	1.36	87.7% Millet 30.7% Sorghum 10.8% Fonio 6.0% Rice	<0.01	<0.01
Tubers	0.8%	0.01	—	0.5%	0.01	—	0.4%	0.00	—	0.9%	0.01	—	0.586	0.45
Vegetables	11.5%	0.14	6.0% Onion 4.6% Okra	12.2%	0.18	5.5% Okra 4.9% Onion 3.7% Lettuce	5.3%	0.08	—	12.2%	0.13	7.0% Onion 4.8% Okra	<0.01	<0.01
Fruit	0.7%	0.01	—	1.1%	0.01	—	1.9%	0.02	—	0.3%	0.00	—	<0.01	<0.01
Legumes/seeds	38.1%	0.48	29.2% Groundnut 16.3% Beans	38.4%	0.44	35.2% Groundnut 9.2% Beans	21.0%	0.23	17.9% Groundnut 4.6% Beans	40.5%	0.53	28.3% Groundnut 21.2% Beans 3.6% Sesame	<0.01	<0.01
Livestock owned														
Meat producing	92.9%	2.79	74.4% Sheep 71.7% Poultry 63.0% Goat 32.9% Cow 28.6% Calf 7.5% Camel	84.6%	2.15	64.0% Sheep 49.4% Chicken 47.9% Goat 28.8% Cow 24.6% Calf	93.1%	3.00	72.5% Goat 70.6% Sheep 63.7% Poultry 51.5% Cow 41.6% Calf	96.5%	3.03	82.5% Poultry 79.4% Sheep 68.0% Goat 31.8% Cow 28.3% Calf 11.8% Camel	<0.01	<0.01
Milk producing	88.1%	1.78	74.4% Sheep 63.0% Goat 32.9% Cow 7.5% Camel	77.7%	1.41	64.0% Sheep 47.9% Goat 28.8% Cow	89.7%	1.95	72.5% Goat 70.6% Sheep 51.5% Cow	92.3%	1.91	79.4% Sheep 68.0% Goat 31.8% Cow 11.8% Camel	<0.01	<0.01

[a] From Fisher's exact test for differences among regions in frequency of food group usage.
[b] From ANOVA for differences among regions in the mean number of food items per food group.

Table 5.13 Household crop production and food-producing livestock ownership the year before the survey, by wealth category

Crops and livestock food groups	Poorest 40% (N = 1,080) Food group freq.	Poorest 40% Mean number of food items	Poorest 40% Food item frequency (items > 3%)	Middle 40% (N = 1,080) Food group freq.	Middle 40% Mean number of food items	Middle 40% Food item frequency (items > 3%)	Wealthiest 20% (N = 539) Food group freq.	Wealthiest 20% Mean number of food items	Wealthiest 20% Food item frequency (items > 3%)	p-value[a]	p-value[b]
Crops produced											
Cereals/staples	71.5%	1.05	61.0% Millet 30.5% Sorghum 7.6% Fonio 4.1% Rice	81.1%	1.19	68.5% Millet 35.1% Sorghum 8.1% Fonio 4.8% Rice	81.6%	1.16	66.5% Millet 38.7% Sorghum 3.5% Maize 4.4% Rice	<0.01	<0.01
Tubers	0.8%	0.01	—	0.8%	0.01	—	0.6%	0.01	—	0.88	0.81
Vegetables	12.2%	0.15	6.4% Onion 5.3% Okra	11.3%	0.13	5.8% Onion 4.2% Okra	10.5%	0.14	5.5% Onion 3.9% Okra	0.57	0.72
Fruit	0.4%	0.00	—	0.6%	0.01	—	1.5%	0.02	—	0.04	0.02
Legumes/seeds	35.4%	0.42	26.9% Groundnut 13.4% Beans	40.1%	0.53	30.8% Groundnut 19.3% Beans	39.6%	0.51	30.6% Groundnut 16.2% Beans 4.1% Sesame	0.05	<0.01
Livestock owned											
Meat producing	84.7%	1.78	66.3% Poultry 60.5% Sheep 45.1% Goat	98.2%	3.01	81.9% Sheep 76.3% Poultry 71.2% Goat 35.6% Cow 28.2% Calf 7.0% Camel	99.4%	4.37	88.4% Cow 87.5% Sheep 82.7% Goat 81.0% Calf 73.7% Poultry 23.0% Camel	<0.01	<0.01
Milk producing	74.4%	1.08	60.5% Sheep 45.1% Goat	96.3%	1.96	81.9% Sheep 71.2% Goat 35.6% Cow 7.0% Camel	99.4%	2.82	88.4% Cow 87.5% Sheep 82.7% Goat 23.0% Camel	<0.01	<0.01

[a] From Fisher's exact test for differences among wealth categories in frequency of food group usage.
[b] From ANOVA for differences among wealth categories in the mean number of food items per food group.

5.1.2.2 Production diversity and variety scores

Measures of household production diversity and variety (PDS and PVS, respectively) over the previous year are presented in Table 5.14 (in total and by region) and Table 5.15 (by wealth category). In the overall sample, the mean number of different food groups produced was just over 3 while the mean number of different food items produced was around 4.5. Significant differences were observed among and between each of the three regions, with the mean scores for each measure being lowest in Kayes and highest in Mopti. Both scores also increase along the wealth categories, with all differences between categories significant except for the difference between middle and wealthiest for PDS. So while households in the wealthiest category may produce a greater number of different food items than the middle category, they may not be producing a greater number of different kinds of food.

Table 5.14 Household production diversity and variety scores in the year before the survey, in total and by region

	Total (N = 2,718)		Kayes (N = 739)		Koulikoro (N = 262)		Mopti (N = 1,717)		
Score	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p-value[a]**
PDS	3.09	1.01	2.62	1.25	2.89	0.89	3.32	0.82	<0.01
PVS	4.55	2.09	3.42	2.17	4.34	1.84	5.06	1.88	<0.01

[a] From ANOVA for differences among regions in the respective scores.

Table 5.15 Household production diversity and variety scores in the year before the survey, by wealth category

	Poorest 40% (N = 1,086)		Middle 40% (N = 1,086)		Wealthiest 20% (N = 543)		
Score	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p-value[a]**
PDS	2.79	1.17	3.28	0.83	3.32	0.79	<0.01
PVS	3.40	1.80	4.87	1.82	6.20	1.75	<0.01

[a] From ANOVA for differences among wealth categories in the respective scores.

5.1.2.3 Share of food expenditures consumed from own production

Table 5.16 provides indications of the relative importance of consumption of own production as a share of total food expenditures at the time of the survey. Shares by food groups are presented in total and by the three regions, along with food items whose shares were greater than 0.030 in any of the regions. Overall, households purchased more than they consumed from own production. The greatest own production share was observed in Mopti (0.413), followed by Koulikoro (0.255), then Kayes (0.155). Around half of cereals/staples expenditure was consumed from own production across the three regions, with relatively higher shares of millet, beans, and fonio from own production found in Mopti. For vegetables, relatively higher shares of onion and okra were observed in Mopti as well. Overall, shares of meat from own production was 0.100 and milk was 0.169, with the highest share of milk observed in Koulikoro (0.332).

Table 5.17 presents the same type of information by wealth category. Examining trends, overall own production as a share of food expenditure tends to increase along the wealth categories. For food groups, this pattern is strongest for milk and holds for cereals and meat as well. For vegetables, shares tend to decrease along the wealth categories.

Table 5.16 Share of food expenditures consumed from own production the week before the survey, in total and by region

Food groups and food items	Total (N = 2,702)		Kayes (N = 726)		Koulikoro (N = 261)		Mopti (N = 1,715)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cereals/staples	0.512	0.421	0.205	0.324	0.353	0.405	0.666	0.377
Millet	0.522	0.495	0.098	0.296	0.330	0.466	0.730	0.436
Sorghum	0.249	0.429	0.206	0.402	0.179	0.380	0.277	0.445
Beans	0.159	0.365	0.080	0.270	0.047	0.210	0.210	0.406
Rice	0.094	0.289	0.083	0.276	0.054	0.226	0.105	0.302
Fonio	0.070	0.255	0.001	0.037	0.004	0.062	0.109	0.311
Tubers	0.035	0.183	0.005	0.068	0.013	0.107	0.051	0.220
Sweet potato	0.024	0.153	0.001	0.037	0.004	0.062	0.037	0.188
Vegetables	0.172	0.337	0.091	0.251	0.077	0.234	0.220	0.372
Okra	0.134	0.340	0.065	0.246	0.083	0.275	0.171	0.376
Onion	0.127	0.332	0.067	0.249	0.027	0.162	0.167	0.372
Tomato	0.033	0.179	0.025	0.156	0.023	0.150	0.038	0.191
Fruit	0.063	0.222	0.033	0.163	0.077	0.234	0.074	0.240
Jujube/nenuphar	0.042	0.202	0.028	0.164	0.088	0.284	0.042	0.200
Wild date	0.031	0.174	0.001	0.037	0.011	0.107	0.047	0.211
Wild fruit	0.012	0.108	0.017	0.128	0.038	0.192	0.006	0.076
Meat	0.100	0.262	0.046	0.178	0.109	0.258	0.121	0.289
Chicken	0.098	0.296	0.050	0.217	0.111	0.315	0.116	0.319
Goat	0.028	0.165	0.004	0.064	0.039	0.189	0.037	0.188
Sheep	0.018	0.133	0.012	0.111	0.036	0.182	0.018	0.133
Bird	0.010	0.101	0.004	0.064	0.054	0.226	0.006	0.080
Giblets	0.009	0.092	0.006	0.074	0.038	0.192	0.005	0.072
Guinea fowl	0.006	0.076	0.006	0.074	0.033	0.178	0.002	0.042
Fish	0.019	0.130	0.018	0.132	0.010	0.093	0.021	0.134
Milk	0.169	0.372	0.172	0.374	0.332	0.469	0.143	0.348
Oils/sugars	0.014	0.084	0.016	0.096	0.015	0.088	0.012	0.078
Others	0.054	0.174	0.100	0.235	0.133	0.253	0.023	0.108
Groundnut paste	0.111	0.314	0.173	0.378	0.264	0.440	0.062	0.240
Total	0.329	0.262	0.155	0.201	0.255	0.245	0.413	0.247

Table 5.17 Share of food expenditures consumed from own production the week before the survey, by wealth category

Food groups and food items	Poorest 40% (N = 1,080)		Middle 40% (N = 1,080)		Wealthiest 20% (N = 539)	
	Mean	SD	Mean	SD	Mean	SD
Cereals/staples	0.481	0.425	0.535	0.421	0.523	0.407
Millet	0.479	0.494	0.558	0.493	0.531	0.494
Sorghum	0.234	0.421	0.256	0.434	0.258	0.434
Beans	0.145	0.351	0.168	0.372	0.171	0.376
Rice	0.081	0.268	0.103	0.303	0.104	0.300
Fonio	0.080	0.270	0.074	0.261	0.041	0.198
Tubers	0.040	0.195	0.032	0.175	0.032	0.175
Sweet potato	0.031	0.172	0.020	0.141	0.019	0.135
Vegetables	0.188	0.351	0.170	0.337	0.143	0.310
Okra	0.137	0.343	0.139	0.345	0.119	0.323
Onion	0.146	0.353	0.121	0.325	0.099	0.297
Tomato	0.042	0.200	0.033	0.177	0.018	0.130
Fruit	0.060	0.218	0.068	0.231	0.060	0.210
Jujube/nenuphar	0.042	0.201	0.039	0.193	0.050	0.218
Wild date	0.025	0.156	0.037	0.189	0.030	0.170
Meat	0.091	0.253	0.103	0.266	0.113	0.273
Chicken	0.088	0.282	0.106	0.306	0.103	0.302
Goat	0.020	0.139	0.029	0.168	0.044	0.203
Fish	0.022	0.140	0.017	0.122	0.017	0.125
Milk	0.063	0.241	0.182	0.384	0.351	0.474
Oils/sugars	0.010	0.070	0.015	0.092	0.019	0.092
Others	0.041	0.151	0.058	0.181	0.071	0.197
Groundnut paste	0.091	0.287	0.118	0.321	0.140	0.346
Total	0.308	0.268	0.339	0.262	0.347	0.242

5.2 Discussion

The findings on food consumption and agricultural production presented above indicate variations by region and by wealth category, both of which seem to influence the food groups and food items consumed and produced. Based on the energy and nutrient adequacy findings, there would appear to be food intake constraints in the study population as less than 3% of households were meeting the requirements for the MAR measure.

Further discussion on both consumption and production is detailed below, including both reliability considerations and contextualization of the findings.

5.2.1 Household food consumption and dietary quality

This section first presents some reliability considerations related to the food consumption data, including issues related to recall bias, food consumed outside the home, seasonality, actual energy expenditures, and errors arising from imputation and conversions. Some specific considerations are then presented for the energy and nutrient adequacy measures, with comparisons to findings from similar studies and discussion of intrahousehold allocation.

5.2.1.1 Reliability considerations

Two systematic biases known to arise during household expenditure surveys are recall bias and telescoping bias.[i] Recall bias is generally regarded as the more problematic of the two for food acquisitions, with the high frequency, small size nature of food expenditures compared with non-food expenditures (Smith, Alderman, and Aduayom 2006). Thus, the food expenditures here could be underestimates.

Further underestimation could result from food consumed outside the home not being captured. For instance, a study of households in Bamako reported that children were receiving 8–17% of their daily energy from food consumed outside the home (Ag Bendech, Chauliac, and Malvy 1998). However, the proportion of outside the home food may be expected to be smaller in more rural areas where sources such as street food may be less important.

Another source of bias may arise if the food consumption observed at the time of the survey (post-harvest) is different than that consumed at other times of the year. As highlighted above, in her study in Mali, Adams (1992) did not report significant seasonal variation in overall energy intake; sources of food were found to vary, along with protein and micronutrient intake. If similar seasonal patterns occur in the study population here, findings from Adams (1992) indicate that protein and vitamin A intake may be overestimated.

As actual energy expenditure of household members is unknown, MAR could be biased upward or downward if energy expenditure is less than that assumed or greater than that assumed, respectively. Further discussion of such matters related to energy expenditure is detailed in Chapter 6.

Additionally, it should be noted again that the variety of imputation and conversions used to calculate the value of food purchased and consumed add to the error already existing in the reporting and recording process; these errors may be particularly important to consider in this

[i] Recall bias results from the difficulty respondents may experience in recalling food purchases and consumption, resulting in underestimation of expenditure, while telescoping bias results from individuals including purchases and consumption prior to the recall period, resulting in overestimation of expenditure (Smith, Alderman, and Aduayom 2006).

deprived study population where monetary expenditures are relatively infrequent and where food expenditure as a proportion of total expenditure is high (Masset and Gelli 2014).[i]

5.2.1.2 Energy and nutrient adequacy

Comparing the overall sample findings with results from previous studies in similar areas of Mali, the mean NARs and MAR observed seem to be broadly in line with prior observations. In a study mentioned above of individual-level nutrient adequacy in rural agriculturalists in the Bafoulabé district in Kayes Region in western Mali, Torheim *et al*. (2004) reported the mean (SD) NAR for energy to be 1.29 (0.53), protein 2.12 (1.03), iron 1.35 (1.00),[ii] and vitamin A 0.81 (0.61) and the mean (SD) MAR to be 0.87 (0.11).[iii] The means here are lower for each measure except vitamin A. Though differences observed could be due to a host of factors and may not even be significant, some conjectures on potential sources of the variation are presented below.

One possible source for the higher values observed by Torheim *et al*. (2004) could be their capturing of a greater number of food items (104). However, very similar lists of cereals/staples and other high-energy items as well as meats and dairy seem to have been surveyed as here, with their lists of fruits and vegetables being relatively longer (Parr *et al*. 2002; Torheim *et al*. 2004). Thus, lower micronutrient NARs might be expected here but not necessarily lower energy and protein NARs. As Torheim *et al*. (2004) surveyed adult men and women (15–45 years of age) and measured individual-level adequacy, the lower overall household levels reported here may indicate intrahousehold allocation of food favoring adults.

5.2.2 Household agricultural production

One consideration related to production is that with the week prior recall period, any annual variations in consumption from own production is not accounted for in this analysis. These variations may be particularly marked in perishable foods. In these highly rural agriculturalist areas, the importance of food purchases relative to consumption from own production may mean harvested crops being sold to purchase other food items as well as crops being sold after harvest and the same items being purchased later in the year from wage income, as Alderman (1990) suggested in his similar analysis in Ghana. This latter reason may contribute to the trends observed across wealth categories as wealthier households may be able to store food longer than poorer households who may need to sell immediately after harvest to supply cash needs.

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[i] Furthermore, if, as Masset and Gelli (2014) suggest, food expenditure is overestimated, MAR may be overestimated as well.

[ii] Low iron bio-availability levels were assumed.

[iii] MAR was calculated as the mean of the NARs for energy, protein, fat, vitamin A, thiamine, riboflavin, niacin, vitamin C, calcium, and iron, each truncated at 1. NARs for iodine and zinc were not reported.

Chapter 6. Determinants of child nutritional status in three regions of Mali

This chapter tests two main hypotheses: 1) households that produce a more diversified range of crops and livestock will also consume a more diversified diet; and 2) school-age children from households with more diversified agricultural production and diets will exhibit better nutritional outcomes, as measured by anthropometrics. As a number of children lacked HAZ data, parameter effects are estimated using imputed data as well and compared with the complete case analyses. Due to potential age misreporting, sensitivity analyses of estimates of determinants of HAZ to different age calculations are also conducted.

Results from analyses on relationships between agricultural production and food consumption indicate that production variety (but not production diversity) is positively correlated with dietary diversity and food variety. Additionally, ownership of milk-producing livestock was associated with higher milk shares of total consumption and that ownership of poultry was associated with higher meat shares, suggesting consumption from own production may be important for these two food groups.

Results from nutrition outcome models found no significant effects of household agriculture or food consumption measures on HAZ of children between the ages of 5 and 11, in complete case analyses. Similar no effects were observed with an imputation model and when potential over-reporting of age was accounted for.

Agriculture-nutrition frameworks previously described provide a structure for discussing disconnects observed and how "leakages" may occur along various pathways in the framework. The chapter concludes with consideration of these leakages in the context of this study, particularly those related to nutrition education and time allocation, disease burdens, energy expenditures, intrahousehold food allocation, and seasonality and time of data collection.

6.1 Results

As much of what is produced in the sample households appears to be consumed rather than sold,[i] it is hypothesized that households that produce a more diversified range of crops and livestock will also consume a more diversified diet. In turn, it is expected that school-age children from households with more diversified diets will exhibit better nutritional outcomes, as measured by anthropometrics. Results on tests of these hypotheses are presented in turn below.

[i] Of the 2,324 households that reported harvesting food crops over the past years, only 16% reported selling any part of their harvest.

Subsequently, parameter effects are estimated using imputed data as well and compared with the complete case analyses, as a number of children lacked HAZ data. With the potential age misreporting found in Chapter 4, the last set of analyses presented examine how sensitive estimates of determinants of HAZ are to different age calculations.[i]

6.1.1 Estimates of effects on household food consumption measures

Estimates of effects on household food consumption measures (including DDS, FVS, food group shares, and MAR) are explored first by household demographic and socio-economic characteristics as well as regional variables. Second, to examine aspects of household agriculture in relation to the same food consumption measures, effects of economic status and various agricultural variables are estimated, similar to the approach taken by Bhagowalia, Headey, and Kadiyala (2012) in the Indian context.

6.1.1.1 Effects of household demographic and socio-economic characteristics as well as regional variables on household food consumption measures

Estimates of the effects of household demographic and socio-economic characteristics along with regional variables on household dietary diversity, food variety, food group shares, and MAR are presented in Table 6.1. As may be expected, economic status (measured by log per capita expenditure) had a significant positive correlation with both dietary diversity and food variety, as did any wife in the household having received any formal schooling. Household size and the number of children under the age of 2 was associated with increased DDS and FVS, similar to findings by Bhagowalia, Headey, and Kadiyala (2012). In measures of types of occupation, the main occupation of the household head being farm labor had a significant positive correlation, as did the main occupation being wage labor, the latter having the larger coefficient. Regional coefficients were also significant, with Kayes (the omitted region) appearing to have less diversified diets than Koulikoro and Mopti.

In measures of food group shares of total food expenditure, cereals/staples shares appear to be positively correlated with household size, household head being farm laborer, household head being wage laborer, and with regional measures (Kayes having lower cereal/staples shares than the other two regions). For vegetables shares, the surveyed households in Koulikoro seem to spend less of total food expenditure on vegetables than households in Kayes. The only food group shares that economic status were associated with are meat and milk shares, with positive correlation observed for both. There appear to be significant negative correlations with milk shares and any schooling

[i] As with Chapter 4 and Chapter 5, methods for this chapter are presented in Section 3.3, particularly Sections 3.3.5.2 and 3.3.5.3.

for any wife or the household head, first wife's age, household head being a farm laborer, and the Mopti region variable.

For MAR under both medium- and low-bioavailability assumptions, economic status was positively correlated, as was the dependency ratio. Both of the regional coefficients were significant, with Koulikoro appearing to have lower MAR than Kayes, and with Mopti appearing to have higher.

6.1.1.2 Effects of household economic status and agricultural variables on household food consumption measures

Focusing on household agricultural variables, regressions of these variables along with household economic status on the same household food consumption measures as above are presented in Table 6.2. Both the log per capita expenditure and the log of farm capital are positively correlated with dietary diversity and food variety. While the production diversity score is not significantly correlated with either dietary diversity or food variety, production variety (the number of different crops grown) appears to have a significant positive correlation with both.[i] Ownership of some larger livestock animals seems to exhibit some negative correlations, with ownership of cows decreasing DDS and ownership of cows, goats, and camels decreasing FVS.[ii] Ownership of poultry, however, was positively correlated with dietary diversity.

For food group shares, as may be expected, economic status was negatively correlated with cereals/staples shares but positively correlated with fruit, meat, and milk shares. Log of land cultivated was positively correlated with cereals/staples shares and negatively with meat shares. Similar to Bhagowalia, Headey, and Kadiyala (2012), ownership of milk-producing livestock (cows, goats, and sheep) was associated with higher milk shares while ownership of poultry was associated with higher meat shares, suggesting consumption from own production may be important for these two food groups. However, the coefficients were small in magnitude.[iii]

MAR was again positively correlated with economic status, but few significant correlations with agricultural variables were observed.

[i] That, in turn, production variety may be a stronger predictor of nutrition outcomes than production diversity is examined in subsequent analyses.
[ii] This could potentially be due to households with larger livestock focusing more on income generation from these livestock rather than from crop production.
[iii] For reference, as reported in Section 5.1.1.3, the mean meat share for the sample was 0.125 and the mean milk share was 0.034.

Table 6.1 Estimation of effects of household demographic and socio-economic characteristics as well as regional variables on household food consumption measures

	DDS	FVS	Cereals/staples share	Vegetables share	Fruit share	Meat share	Milk share	MAR[a]	MAR[b]
Intercept	-7.341***	-35.999***	0.257*	0.116***	-0.014	-0.213***	-0.027	-2.050***	-2.179***
Log per capita expenditure	1.020***	3.746***	-0.005	-0.004	0.002	0.033***	0.010**	0.223***	0.230***
Any schooling any wife	0.179*	0.644**	-0.002	0.004	0.001	-0.003	-0.008**	0.002	0.006
Any schooling household head	0.018	0.478*	-0.002	0.000	0.000	-0.009	-0.007**	-0.017	-0.018
Female household head	-0.136	-0.323	-0.006	0.003	-0.006*	-0.023*	-0.011	0.008	0.006
First wife's age	0.018	0.032	0.004**	0.000	0.001	-0.002*	-0.002**	0.002	0.002
Household size	0.086***	0.384***	0.008***	-0.001*	0.000	0.000	0.000	-0.003*	-0.004**
Dependency ratio	-0.008	-0.075	-0.004	-0.001	-0.002*	0.004	0.004**	0.017***	0.017***
Number of children <2 years	0.151***	0.326**	-0.002	0.002	0.000	0.003	-0.002	0.011	0.010
Household head farm laborer	0.220**	0.488*	0.083***	-0.001	-0.002	-0.012	-0.020***	-0.005	-0.009
Household head wage laborer	0.552***	0.779	0.061***	0.000	0.008	-0.020	0.002	0.019	0.021
Koulikoro	0.394**	0.558	0.048***	-0.013***	0.002	0.005	-0.007	-0.052***	-0.052***
Mopti	0.865***	1.204***	0.085***	-0.004	-0.001	-0.011	-0.010**	0.040***	0.058***
Number	2,563	2,563	2,563	2,563	2,563	2,563	2,563	2,579	2,579
***F*-statistic**	23.68	29.71	8.40	2.03	3.88	10.16	9.02	57.20	66.40
R^2	0.23	0.31	0.07	0.01	0.01	0.07	0.05	0.46	0.47

[a] Medium bio-availability assumption.
[b] Low bio-availability assumption.
* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01
OLS estimates, with standard errors clustered at the village level. First wife's age squared and polygamous variables are not shown for brevity but are available upon request.

Table 6.2 Estimation of effects of household household economic status and agricultural variables on household food consumption measures

	DDS	FVS	Cereals/staples share	Vegetables share	Fruit share	Meat share	Milk share	MAR[a]	MAR[b]
Intercept	-3.491***	-26.995***	0.918***	0.077**	-0.022	-0.365***	-0.112***	-1.881***	-2.004***
Log per capita expenditure	0.672***	2.871***	-0.035***	-0.003	0.003***	0.033***	0.012***	0.213***	0.220***
Log of land cultivated	-0.007	-0.087	0.021***	-0.001	0.001*	-0.008***	-0.002*	-0.006	-0.008*
Log of farm capital	0.122***	0.397***	-0.004	0.001	0.000	0.007***	-0.001	0.001	-0.002
Irrigation	-0.102	0.179	0.041	-0.007	0.006*	-0.010	0.000	-0.005	-0.008
PDS	0.087	-0.054	-0.004	0.000	0.000	0.002	0.001	0.005	0.004
PVS	0.097***	0.560***	0.000	0.002	0.001	-0.003	-0.001	0.005	0.007
FO member	0.067	0.404	-0.009	-0.003	0.000	0.010	-0.005*	-0.006	-0.003
Own cow(s)	-0.207**	-1.072***	-0.007	-0.008**	-0.003	0.008	0.014***	-0.020	-0.020
Own goat(s)	-0.019	-0.666***	0.034***	-0.010***	-0.003	-0.002	0.009***	-0.004	-0.003
Own sheep	0.096	0.016	-0.004	-0.005	0.002	0.010*	0.006**	-0.015	-0.016
Own camel(s)	0.099	-1.286***	-0.001	-0.003	0.004	0.018	-0.003	0.033	0.042*
Own poultry	0.287***	0.273	0.009	0.000	0.001	0.011*	-0.004	0.003	0.006
Number	2,535	2,535	2,535	2,535	2,535	2,535	2,535	2,541	2,541
***F*-statistic**	21.87	40.81	4.45	2.7	2.67	15.66	8.59	86.39	99.67
R^2	0.20	0.27	0.03	0.02	0.02	0.07	0.06	0.47	0.47

[a] Medium bio-availability assumption.
[b] Low bio-availability assumption.
* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01
OLS estimates, with standard errors clustered at the village level.

6.1.2 Determinants of HAZ for children aged 5 to 11 years

Estimates of child-, household-, and community-level determinants of HAZ for children aged 5 to 11 years are presented for three different models in Table 6.3. The first model is of OLS estimates and includes only regressors assumed to exogenous, while the second model is also of OLS estimates but includes log per capita expenditure, which could be endogenous. The third model instruments for log per capita expenditure using IV/2SLS, with log per capita wealth and unearned income as the excluded instruments.

Results from the first-stage regression of model 3 are reported in Table B-1. Examining the diagnostic tests in Table 6.3, the results from the overidentification test (the Hansen J statistic) indicate that the instruments are valid. The null of underidentification is also rejected, signifying correlation between the excluded instruments and the endogenous regressor. Additionally, the instruments do not appear to be weak as the F statistic for weak identification exceeds the Stock and Yogo critical values. However, the endogeneity test from model 3 indicates that log per capita expenditure can be treated as exogenous (p-value: 0.299), thus model 2 is preferred as the more efficient method of estimation.[i]

6.1.2.1 Child-level determinants

From the coefficients in model 2, both the child-level age coefficients are significant, with age exhibiting a positively correlation with HAZ that lessens with increasing years. These findings suggest some gains relative to the reference population during the early school-age years. Though determinants of any catch-up growth are difficult to elucidate in this cross-sectional study, findings from birth cohort studies may indicate some factors that could be contributing to individuals gaining in growth in school-age. The HAZ pattern observed here across the childhood ages is similar to that observed in non-intervention, longitudinal studies such as Adair (1999) in the Philippines and Himaz (2009) in India. As discussed in Section 2.3.3, determinants of catch-up and improved growth between the ages of 2 and 12 years reported by Adair (1999) included greater potential for growth at birth, improvements in socioeconomic status, and increases in energy intake. Himas (2009) reported that key factors in children moving from being stunted at ages 7 and 8 to not being stunted at ages 11 and 12 included mother's education and coming from a prosperous area, with consuming a diet high in protein potentially being important as well.

Females appear to have higher height-for-age z-scores than males, extending the gender bias reported in summary statistics for 14 and 15 year olds to the 5 to 11 year age group. These findings

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[i] To examine whether increases in height SDs from 5 to 11 years could influence parameter estimates, these same models were run with HAD as the outcome rather than HAZ. All of the same parameters were found to be significant, with similar relative magnitudes of coefficients, suggesting that age-related changes in SDs do not impact the relationships of the determinants with HAZ.

are consistent with a meta-analysis of other populations of school-age children in sub-Saharan Africa (Svedberg 1990). With the importance of farming and livestock in the study areas, Svedberg's (1990) hypothesis that the gender bias could be attributable to females being given preferential treatment in accordance with their relative importance for agricultural labor could hold true. However, the gender findings should be interpreted with caution as Sahn and Stifel (2002) contend age may be misreported, with boys' ages potentially being overstated to gain earlier admission to school and girls' ages potentially being understated to improve marriage prospects. In a crude analysis of the pattern of male to female ratios by age year for the children 2–15 years of age for whom anthropometric data were recorded (Table B-2), there appear to be variations that could indicate age mis-reporting, such as the spike in the male to female ratio at ages 4 and 5.

Birth order exhibits a positive correlation with HAZ, a relationship that appears to be linear as the quadratic version of birth order is not significant. This positive correlation is contrary to the negative correlation findings reported in frequently cited birth order nutrition outcomes literature, including Behrman (1988) and Horton (1988). However, one study has reported a positive relationship of birth order with nutrition intake, finding adequacy of caloric intake to increase with birth order in children between the ages of 3 and 13 in southern Ethiopia (Kimhi 2004). In support of this, Collin (2006) argues that if households are credit-constrained but their incomes are rising over time, higher birth order children may benefit from having wealthier parents. He also contends that households may attempt to compensate for disadvantages experienced by later born children, potentially by sending earlier born children to work to help provide for younger siblings, as suggested by a child labor and schooling study in Brazil (Emerson and Souza 2008).

6.1.2.2 Household-level determinants

Turning to household-level determinants, expenditure, maternal education, household head education, and female household headship did not exhibit significant correlations with HAZ while mother's age, polygamy, and household size and composition were observed to have significant effects.

For income, while positive effects have been observed in Côte d'Ivoire (Sahn 1990; Strauss 1990) and in Brazil (Thomas, Strauss, and Henriques 1990), Handa (1999) found log per capita expenditure to be only marginally significantly in an OLS specification and in a specification with an expanded set of instruments and not significant in a specification with a restricted set of instruments in a study in Jamaica. The lack of effect observed here should be interpreted with caution given the measurement errors in relation to expenditure discussed in Section 3.3.4.2.

As Alderman (1990) hypothesized in his Ghana nutrition determinants study, the lack of effect for education could be attributed to education in the study areas potentially being of low quality during the time that parents were of school age. Additionally, effects could also be limited as the measures were of any formal schooling received, regardless of attainment, and as the adult educational attainment that was reported was found to be very low. To test for any education attainment effects, a model with attainment in place of receiving any schooling for both the mother and the household head is presented in Table B-3. The maternal effect again is not significant, but the household head effect in this specification is significant and negative. Alderman (1990) observed similarly puzzling results and presented the low quality of education hypothesis as above. Another specification with any schooling received by any mother in the household is also reported in Table B-3, with similarly non-significant effects observed as with any schooling received by the mother specifically. This suggests that at least in this low education levels context, no improvement occurred in child nutrition outcomes with increases in education for any mother in the household.

The lack of effect of female household headship suggests that increased control of household income (proxied by female headship) is not associated with improved child nutrition outcomes in this context. Regarding female headship's contradictory means of impacting child nutrition, even as female-headed household tends to earn less (Charmarbagwala *et al*. 2004), there is no appreciable negative effect observed either. This no effect of female headship is consistent with findings from a regional analysis of other West African studies, which the authors suggest could be attributable to the greater financial and decision-making powers of women typical in the region (Charmarbagwala *et al*. 2004). It could also be argued that female headship is a crude measure of female decision-making powers and that studies examining unearned income controlled by the mother compared to the father (as in Thomas [1990]) or studies of women's empowerment in agriculture (as in Malapit *et al*. [2013]) may be best suited to assess these gender effects.

Consistent with studies such as Strauss (1990), HAZ was found to improve with increased maternal age. Thus, a quality-quantity trade-off may be at work (child-bearing begun early to produce more children), as may very young mothers experiencing constrained resources. When a quadratic version of mother's age is introduced into model 2, the term is not significant, suggesting a linear relationship between maternal age and child nutrition outcomes.[i]

Household size, dependency ratio (of children to adults), and number of children under the age of 2 were all found to have significant negative effects on HAZ, similar to findings from some of the studies reviewed by Charmarbagwala *et al*. (2004). The number of children under the age of 2 appears to have the largest effect, followed by dependency ratio, followed by household size (whose effect is only marginally significant). These findings suggest that the household demands of caring for children (young children especially) may have more of an effect on school-age child nutrition outcomes than the demands of providing for additional older households members.

[i] This specification is not reported in full but is available upon request.

The negative effect of polygamy suggests that sharing a husband's contribution to household income may be an important constraint to nutrition outcomes in this setting, contrary to the no significant effect findings of Desai (1992) discussed earlier. As household size was also accounted for, the additional burden of providing for children of the same or similar ages in polygamous unions may be contributing to the observed effect.

6.1.2.3 Community-level determinants

Turning to community-level and geographic variables, no significant effect between urban and rural households was observed. Alderman (1990) similarly did not observe an urban bias in his study of child nutrition determinants in Ghana.

However, regional differences were observed, with children surveyed in Mopti significantly shorter than children in Kayes (the omitted region).[i] The difference was large in magnitude, more than half a standard deviation. No significant difference was found between Kayes and Koulikoro, which are bordering regions. Alderman (1990) also included an interaction between region and age and found older children to be smaller in one of the regions but not the other. For the region in which a significant interaction was observed, he hypothesized that improvements in conditions in that region but not elsewhere may have contributed to the differences observed. A model specification that included such an interaction in this dataset did not find significant effects in either Koulikoro or Mopti relative to Kayes, which may suggest that changes in conditions in the regions have been relatively similar over time.

6.1.3 Determinants of HAZ for children aged 5 to 11 years, including production diversity and variety

To examine effects of agricultural production, the household production diversity score is included in the two models presented in Table 6.4. In the OLS estimation of model 4, PDS is included as a regressor, while in the IV/2SLS estimation of model 5, PDS is instrumented for using household irrigation and the amount of household land cultivated.[ii] For the IV regression, the results from the diagnostic tests indicate that the instruments are valid, are correlated with the endogenous regressor, and do not appear to be weak, but the endogeneity test suggests that production diversity can be treated as exogenous (p-value: 0.767). As such, the estimates from

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[i] As Haas and Campriano (2006) have reported limited variation in preadolescent growth between geographic and ethnic groups, these regional differences are unlikely to be explained by variations in attained height by different ethnic groups in the three regions. (Examples of the different ethnic group make-ups of the three regions include all children 5 to 11 years old reported to be Arabic, Kassonke, or Moorish residing in Kayes or Koulikoro and all those reported to be Dogon residing in Mopti.) When ethnic groups were introduced into the model, no significant differences were found for the dummy variables (results not reported here but available upon request), consistent with Haas and Campriano's (2006) findings.

[ii] The first stage regression is reported in Table B-4.

model 4 are preferred. While the coefficient went from negative in the OLS regression to positive in the IV regression, production diversity was not significantly correlated with HAZ of 5 to 11 year olds in either specification.

To assess whether the number of crops grown may have an effect (as opposed to the number of different types of crops grown), PDS was replaced with PVS and similar OLS and IV/2SLS estimates were calculated (presented in Table B-5 and Table B-6). The same conclusions about the instruments and the ability to treat production variety as exogenous are drawn, and as with production diversity, no significant correlations are observed.

Malapit *et al*. (2013) also did not observe significant correlations between household production diversity and the HAZ of children under the age of 5 but did report a significant positive correlation for children over the age of 2 when production diversity was interacted with age. The interaction was introduced as diets may vary across the under 5 age group and as the time between birth and 2 years of age may be especially critical for growth and development. While there may be less variation in diet and in growth across the 5 to 11 age range, an interaction was introduced between PDS and whether the child was between the ages of 5 and 7 years (inclusive).[i] No effect was observed for the interaction term, indicating that the relationship between PDS and HAZ may not be mediated through age in this context.

6.1.4 Determinants of HAZ for children aged 5 to 11 years, including food consumption

Effects of food consumption, as measured by household dietary diversity, are estimated using OLS and IV/2SLS and reported in Table 6.5.[ii] In the IV estimates, the instruments appear to be valid and correlated with the endogenous regressor. They also do not seem to be weak,[iii] but again the endogeneity test indicates that dietary diversity can be treated as exogenous (p-value: 0.200) and the OLS estimates are preferred as more efficient. The coefficient for dietary diversity changes from negative to positive between the OLS and IV estimations, but no significant correlations are observed in either specification. Similar no effect results were obtained in OLS and IV/2SLS specifications for food variety, cereals/staples share, vegetables share, fruit share, meat share, milk share, and MAR.[iv]

[i] Results of the OLS estimation including the interaction are not reported here but are available upon request.
[ii] For the IV estimation, dietary diversity is instrumented for using log per capita wealth and ownership of poultry, and the results from the first stage regression are reported in Table B-7.
[iii] The *F*-statistic for weak identification is lower than the Stock-Yogo critical value at 10% maximal IV size but exceeds the critical values at 15%, 20%, and 25%.
[iv] These estimations are not presented here but are available upon request.

Table 6.3 Estimation of child-, household-, and community-level determinants of height-for-age z-scores for children between 5 and 11 years of age

	Height-for-age z-score		
	(1) OLS	(2) OLS	(3) IV/2SLS
Intercept	-4.960 (0.623)***	-5.662 (1.011)***	-8.739 (3.208)***
Age	0.769 (0.151)***	0.760 (0.152)***	0.757 (0.152)***
Age squared	-0.056 (0.009)***	-0.056 (0.010)***	-0.056 (0.010)***
Female	0.109 (0.051)**	0.112 (0.051)**	0.115 (0.053)**
Birth order	0.414 (0.068)***	0.418 (0.069)***	0.444 (0.080)***
Birth order squared	-0.007 (0.008)	-0.007 (0.008)	-0.009 (0.009)
Log per capita expenditure [a]		0.064 (0.066)	0.318 (0.255)
Any schooling mother	0.005 (0.116)	-0.032 (0.114)	-0.074 (0.122)
Any schooling household head	-0.021 (0.100)	-0.021 (0.102)	-0.042 (0.102)
Female household head	0.139 (0.355)	0.133 (0.356)	0.139 (0.360)
Mother's age	0.032 (0.005)***	0.032 (0.005)***	0.031 (0.005)***
Household size	-0.035 (0.019)*	-0.036 (0.019)*	-0.030 (0.021)
Dependency ratio	-0.208 (0.050)***	-0.205 (0.050)***	-0.194 (0.049)***
Number of children <2 years	-0.429 (0.065)***	-0.429 (0.065)***	-0.427 (0.065)***
Polygamous	-0.219 (0.108)**	-0.220 (0.108)**	-0.234 (0.110)**
Urban	0.050 (0.139)	0.036 (0.135)	-0.047 (0.138)
Koulikoro	0.227 (0.194)	0.198 (0.190)	0.121 (0.211)
Mopti	-0.537 (0.100)***	-0.526 (0.106)***	-0.418 (0.136)***
Number	3,808	3,780	3,766
F-statistic	14.79	13.83	13.86
R-squared	0.10	0.10	0.09
Hansen J statistic			2.05
p-value of Hansen J statistic			0.152
LM test statistic for underidentification			38.27
p-value of underidentification LM statistic			0.000
F statistic for weak identification			44.47
p-value of Anderson-Rubin F-test			0.171
p-value of Anderson-Rubin chi-sq test			0.162

[a] Potentially endogenous variable.

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

For all models, standard errors (in parentheses) are clustered at the village level. For model 3, the excluded instruments for log per capita expenditure are log per capita wealth and unearned income.

Table 6.4 Estimation of child-, household-, and community-level determinants of height-for-age z-scores for children between 5 and 11 years of age, including production diversity

	Height-for-age z-score	
	(4) OLS	(5) IV/2SLS
Intercept	-5.653	-5.704
	(1.014)***	(1.004)***
Age	0.760	0.756
	(0.152)***	(0.149)***
Age squared	-0.056	-0.056
	(0.010)***	(0.009)***
Female	0.113	0.112
	(0.051)**	(0.052)**
Birth order	0.417	0.420
	(0.070)***	(0.069)***
Birth order squared	-0.007	-0.007
	(0.008)	(0.008)
Log per capita expenditure [a]	0.064	0.061
	(0.066)	(0.068)
Any schooling mother	-0.032	-0.028
	(0.115)	(0.114)
Any schooling household head	-0.021	-0.021
	(0.102)	(0.102)
Female household head	0.132	0.140
	(0.356)	(0.357)
Mother's age	0.032	0.032
	(0.005)***	(0.005)***
Household size	-0.035	-0.037
	(0.019)*	(0.022)*
Dependency ratio	-0.205	-0.206
	(0.050)***	(0.050)***
Number of children <2 years	-0.429	-0.428
	(0.065)***	(0.065)***
Polygamous	-0.220	-0.219
	(0.108)**	(0.108)**
PDS [a]	-0.006	0.031
	(0.037)	(0.157)
Urban	0.035	0.045
	(0.134)	(0.139)
Koulikoro	0.199	0.192
	(0.192)	(0.194)
Mopti	-0.521	-0.547
	(0.111)***	(0.155)***
Number	3,780	3,780
F-statistic	13.10	13.09
R-squared	0.10	0.10
Hansen J statistic		1.44
p-value of Hansen J statistic		0.231
LM test statistic for underidentification		30.66
p-value of underidentification LM statistic		0.000
F statistic for weak identification		31.52
p-value of Anderson-Rubin F-test		0.444
p-value of Anderson-Rubin chi-sq test		0.436

[a] Potentially endogenous variable.

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

For all models, standard errors (in parentheses) are clustered at the village level. For model 5, only PDS is instrumented for, using household irrigation and household cultivated land.

Table 6.5 Estimation of child-, household-, and community-level determinants of height-for-age z-scores for children between 5 and 11 years of age, including dietary diversity

	Height-for-age z-score	
	(6) OLS	(7) IV/2SLS
Intercept	-5.922	-4.524
	(0.960)***	(1.388)***
Age	0.755	0.784
	(0.153)***	(0.154)***
Age squared	-0.056	-0.058
	(0.010)***	(0.010)***
Female	0.112	0.114
	(0.052)**	(0.052)**
Birth order	0.422	0.403
	(0.069)***	(0.067)***
Birth order squared	-0.008	-0.005
	(0.008)	(0.007)
Log per capita expenditure [a]	0.103	-0.106
	(0.063)	(0.176)
Any schooling mother	-0.026	-0.060
	(0.114)	(0.124)
Any schooling household head	-0.020	-0.033
	(0.102)	(0.105)
Female household head	0.136	0.122
	(0.352)	(0.371)
Mother's age	0.032	0.031
	(0.005)***	(0.005)***
Household size	-0.033	-0.045
	(0.019)*	(0.020)**
Dependency ratio	-0.205	-0.205
	(0.050)***	(0.050)***
Number of children <2 years	-0.421	-0.466
	(0.064)***	(0.078)***
Polygamous	-0.221	-0.218
	(0.108)**	(0.109)**
DDS [a]	-0.040	0.173
	(0.031)	(0.169)
Urban	0.058	-0.086
	(0.137)	(0.169)
Koulikoro	0.207	0.153
	(0.192)	(0.197)
Mopti	-0.494	-0.667
	(0.108)***	(0.178)***
Number	3,780	3,766
F-statistic	13.13	12.54
R-squared	0.10	0.08
Hansen J statistic		0.70
p-value of Hansen J statistic		0.403
LM test statistic for underidentification		28.05
p-value of underidentification LM statistic		0.000
F statistic for weak identification		19.72
p-value of Anderson-Rubin F-test		0.453
p-value of Anderson-Rubin chi-sq test		0.446

[a] Potentially endogenous variable.
* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01
For all models, standard errors (in parentheses) are clustered at the village level. For model 7, only DDS is instrumented for, using log per capita wealth and ownership of poultry.

6.1.5 Determinants of HAZ for children aged 5 to 11 years, including imputed values

As a first step in examining potential effects of missing anthropometric data and whether children 5 to 11 years old without HAZ data were systematically different than those with such data, other observed characteristics were explored, including all of the determinants variables used in the models above. Children without HAZ data had higher birth orders; came from households with greater log per capita expenditure, were more likely to come from households with female household heads, were more likely to come from polygamous households, came from larger households, and were less likely to be in Mopti and more likely to be in Kayes and Koulikoro than expected, compared to children with HAZ data.[i] Examining agricultural variables, they also came from households with lower production diversity and production variety scores, and they were less likely to own goats, sheep, camels, or poultry.[ii] For food consumption, children without HAZ data had lower household dietary diversity scores and lower cereals/staples shares as well.[iii] Accounting for the variables found to have significant effects on HAZ above, the missing data bias in estimating HAZ for the study sample may not be in one direction, as for instance, higher birth order was found to have a positive effect on height-for-age z-scores while household size had a negative effect.

To further examine effects of missing data, a multiple imputation model for HAZ was built. With inputted data, the mean HAZ for children between the ages of 5 and 11 was found to be -1.23 (N = 5,337). This finding is very similar to the mean of -1.25 observed in complete case analysis (N = 4,479) and is consistent with the bi-directional potential for the missing data bias.

In assessing whether imputation affects parameter estimates of determinants of HAZ, models including imputed values are presented in Table 6.6. Four OLS specifications are presented: model 8 does not include log per capita expenditure, model 9 does, model 10 includes production diversity, and model 11 includes dietary diversity. Examining imputation diagnostics, the average relative variance increase (RVI) due to missing data is moderate across the models at around 0.19.[iv] Additionally, the largest fraction of missing information (FMI) for any parameter in any of the models is around 0.40, suggesting the number of imputations (50) was sufficient as it exceeds 100 times FMI (White, Royston, and Wood 2011).

Compared to the complete case analyses, the estimates are similar, with coefficients generally slightly smaller in magnitude and standard errors lower. The only difference in

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[i] No difference between children with and without HAZ data was observed for age, sex, any schooling mother, any schooling household head, mother's age, dependency ratio, number of children <2 years, and urban/rural variables. All the statistical difference tests for differences between children with and without HAZ data are available upon request.
[ii] No difference was observed for irrigation, land cultivated, and cow ownership variables.
[iii] No difference was observed for household food variety, vegetables shares, fruit shares, meat shares, milk shares, and MAR variables.
[iv] The closer the value of average RVI is to 0, the less the effect that missing data have on estimate variance (Bouhlila and Sellaouti 2013).

significance levels is for polygamy, which is no longer significant with the imputed dataset. As Desai (1992) suggests, women could be providing the majority of food and subsistence needs for themselves and their children; thus any potentially negative effects of resource constraints in polygamous households may be mitigated.

6.1.6 Sensitivity of estimates of determinants of HAZ to age calculations

To examine how sensitive the complete case HAZ determinants estimates are to the age used in the z-score calculations, Table 6.7 presents estimates of HAZ determinants, with z-scores calculated using reported age in years minus one year.[i] In comparison to Table 6.3, which presents the same models for reported age in years, coefficient estimates are generally of similar magnitude and significance. Of the child-level characteristics, the magnitude of the coefficient for age appears to be slightly smaller using reported age in years minus one year. This suggests that the z-scores for the youngest year group included in the reported age in years estimations (5 years of age), which was not included in the reported age in years minus one year estimations, were more stunted relative to other age years, consistent with findings from Section 4.1.2. The estimates were similar for nearly all of the household-level characteristics, though, whether the household was polygamous was no longer significant (as was found in the multiple imputation estimates). The community-level determinants also have similar estimates, with the coefficient for Mopti around one SD lower in the reported age in years minus one year estimates. This could indicate that the difference between Kayes and Mopti in mean z-scores of the youngest year group in the reported age in years estimations was smaller than the differences between the regions in the older children. Models were also built similar to the ones above incorporating agricultural production and food consumption measures, with no effects of these variables again observed.[ii]

[i] As previous estimates were for children with reported ages between 5 and 11 years, with one year subtracted, the age range for estimates using reported age minus one year is 5 to 10 years old (those taken to be 4 year olds are not included because they would be pre-school age).

[ii] These regressions are not presented here but are available upon request.

Table 6.6 Estimation of child-, household-, and community-level determinants of height-for-age z-scores for children between 5 and 11 years of age with imputed data, including income, production diversity, and dietary diversity

	Height-for-age z-score			
	(8) OLS	(9) OLS	(10) OLS	(11) OLS
Constant	-4.050 (0.531)***	-4.600 (0.948)***	-4.610 (0.948)***	-4.807 (0.927)***
Age	0.582 (0.131)***	0.582 (0.131)***	0.581 (0.131)***	0.578 (0.132)***
Age squared	-0.045 (0.008)***	-0.045 (0.008)***	-0.045 (0.008)***	-0.045 (0.008)***
Female	0.100 (0.048)**	0.100 (0.048)**	0.100 (0.048)**	0.100 (0.048)**
Birth order	0.352 (0.057)***	0.356 (0.058)***	0.356 (0.058)***	0.359 (0.058)***
Birth order squared	-0.002 (0.006)	-0.002 (0.006)	-0.002 (0.006)	-0.003 (0.006)
Log per capita expenditure [a]		0.045 (0.058)	0.044 (0.058)	0.077 (0.059)
Any schooling mother	0.023 (0.111)	0.016 (0.110)	0.016 (0.110)	0.021 (0.110)
Any schooling household head	-0.030 (0.098)	-0.032 (0.098)	-0.032 (0.098)	-0.029 (0.098)
Female household head	0.044 (0.265)	0.047 (0.266)	0.048 (0.266)	0.043 (0.265)
Mother's age	0.033 (0.004)***	0.033 (0.004)***	0.033 (0.004)***	0.033 (0.004)***
Polygamous	-0.137 (0.093)	-0.138 (0.093)	-0.138 (0.093)	-0.136 (0.093)
Household size	-0.049 (0.017)***	-0.048 (0.017)***	-0.048 (0.017)***	-0.046 (0.017)***
Dependency ratio	-0.124 (0.047)***	-0.122 (0.047)**	-0.122 (0.047)**	-0.122 (0.047)**
Number of children <2 years	-0.437 (0.061)***	-0.436 (0.061)***	-0.436 (0.061)***	-0.430 (0.060)***
Urban	-0.088 (0.137)	-0.097 (0.135)	-0.096 (0.135)	-0.078 (0.136)
Koulikoro	0.166 (0.158)	0.155 (0.155)	0.154 (0.156)	0.164 (0.157)
Mopti	-0.523 (0.086)***	-0.502 (0.091)***	-0.507 (0.097)***	-0.475 (0.096)***
PDS [a]			0.006 (0.033)	
DDS [a]				-0.034 (0.028)
Number	5,337	5,337	5,337	5,337
Average RVI	0.19	0.19	0.19	0.19
Average degrees of freedom	87.72	88.20	88.44	88.01

[a] Potentially endogenous variable.
* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01
For all models, standard errors (in parentheses) are clustered at the village level.

Table 6.7 Estimation of child-, household-, and community-level determinants of height-for-age z-scores calculated using reported age in years minus one year, for children with reported age in years minus one year of between 5 and 10 years of age

	Height-for-age z-score		
	(12) OLS	(13) OLS	(14) IV/2SLS
Intercept	-2.466 (0.738)***	-2.776 (1.221)**	-6.128 (3.619)*
Age	0.526 (0.195)***	0.533 (0.196)***	0.511 (0.195)***
Age squared	-0.052 (0.013)***	-0.052 (0.013)***	-0.051 (0.013)***
Female	0.132 (0.057)**	0.138 (0.058)**	0.137 (0.059)**
Birth order	0.453 (0.073)***	0.452 (0.075)***	0.480 (0.087)***
Birth order squared	-0.006 (0.008)	-0.005 (0.008)	-0.007 (0.009)
Log per capita expenditure [a]		0.026 (0.072)	0.310 (0.294)
Any schooling mother	-0.110 (0.130)	-0.149 (0.126)	-0.203 (0.130)
Any schooling household head	-0.058 (0.116)	-0.051 (0.116)	-0.078 (0.116)
Female household head	0.160 (0.397)	0.151 (0.398)	0.140 (0.406)
Mother's age	0.036 (0.005)***	0.036 (0.005)***	0.036 (0.005)***
Household size	-0.075 (0.022)***	-0.077 (0.022)***	-0.071 (0.023)***
Dependency ratio	-0.262 (0.061)***	-0.261 (0.062)***	-0.249 (0.062)***
Number of children <2 years	-0.444 (0.077)***	-0.440 (0.077)***	-0.435 (0.076)***
Polygamous	-0.197 (0.121)	-0.198 (0.122)	-0.217 (0.122)*
Urban	0.089 (0.145)	0.085 (0.143)	-0.017 (0.151)
Koulikoro	0.205 (0.182)	0.190 (0.178)	0.104 (0.201)
Mopti	-0.640 (0.101)***	-0.644 (0.108)***	-0.521 (0.151)***
Number	3,177	3,158	3,148
F-statistic	12.60	12.01	12.12
R-squared	0.11	0.11	0.10
Hansen J statistic			1.78
p-value of Hansen J statistic			0.182
LM test statistic for underidentification			35.66
p-value of underidentification LM statistic			0.000
F statistic for weak identification			36.72
p-value of Anderson-Rubin F-test			0.257
p-value of Anderson-Rubin chi-sq test			0.248

[a] Potentially endogenous variable.
* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01
For all models, standard errors (in parentheses) are clustered at the village level. For model 14, the excluded instruments for log per capita expenditure are log per capita wealth and unearned income. First stage regressions are reported in

6.2 Discussion

While associations were found between agricultural production and food consumption, no effects of agricultural production or food consumption on child nutritional status were observed. Other food consumption-nutrition outcome disconnects were observed. For instance, households surveyed in Mopti had significantly higher DDS, FVS, and MAR than those in Kayes, while children between the ages of 5 and 11 in Mopti had significantly lower HAZ than those in Kayes.[i] Agriculture-nutrition frameworks previously described in Section 3.2.4 provide a structure for discussing these disconnects and how "leakages" may occur along various pathways in the framework. Considerations related to nutrition education and time allocation, disease burdens, energy expenditures, intrahousehold food allocation, and seasonality and time of data collection are discussed in turn below.

6.2.1 Nutrition education and time allocation

One potential leakage between food consumption and nutrition outcomes often discussed is nutrition education (Ruel 2001; Block 2003). Even if these households were not limited in their access to nutritious foods, knowledge on the importance of consuming these foods or on methods of preparation to maximize nutritional gain could have been lacking. While nutrition knowledge and behavior were not measured in this survey, the low levels of maternal and household head general education observed may indicate that nutrition education may be low as well.

Even with increased nutrition knowledge, time or income constraints may hinder the ability of households to implement change. Barriers to improved child feeding practices among caregivers reported by Jones *et al*. (2012) included women's time spent in agricultural labor and other adult family members not showing support for child feeding. While time allocation was not measured in this survey, findings from the Adams (1992) study in Koulikoro, mentioned previously, suggest that these factors could be constraints in the study areas here as well. Relevant observations include that during the waking day, adult women surveyed spent 26% less time on average resting than men and that men spent 40% more time engaged in social activities.[ii] Another barrier reported by Jones *et al*. (2012) was low household agricultural production diversity. While measures of production diversity and production variety may be difficult to benchmark, the mean PDS and PVS observed here were around 3 and 4.5, respectively. With fewer than five different crops grown on average, low production diversity could indeed be a barrier to improved child feeding practices.

[i] As authors such as Haughton and Haughton (1997) and Charmarbagwala *et al*. (2004) highlight, interpretation of regional differences is difficult as regional dummy variables may be proxying for characteristics that are not observed or not possible to observe.

[ii] Women's activities included agricultural tasks (tending the household field as well as weeding and winnowing), food preparation (including shea nut and cereal processing), household chores (including fuel, water, and shea nut gathering), spinning cotton, child care, and hygiene.

6.2.2 Disease burdens

The influence of agricultural production and food consumption on nutrition outcomes may also be mediated by disease burdens. In addition to negative impacts of chronic enteropathy on child growth (Scharf, Deboer, and Guerrant 2014), nutrient intake may decrease during illness (Brown *et al*. 1985), as may agricultural productivity (Adams 1992). While illness during the past seven days was not significantly associated with HAZ of children 5 to 11 years,[i] chronic conditions or illnesses during other times of the year (especially the rainy season [Adams 1992]) could well be affecting child nutrition outcomes. As indication of the potential disease burdens of the sample population, the prevalence of *Schistosoma haematobium* among school-age children in Mali is estimated to be nearly 40%, with hotspots reported in the study areas here (Clements *et al*. 2009).[ii] For malaria, the latest DHS reported that 10%, 6%, and 5% of children under the age of five had fever (the main clinical sign of the disease) in the two weeks prior to the survey in Mopti, Kayes, and Koulikoro regions, respectively (CPS/SSDSPF *et al*. 2014). Many more children may be asymptomatic, and the burden of disease extends into school-age. For instance, in the southern region of Sikasso, 80% of schoolchildren surveyed were found to have malarial parasites in their blood and only 5% of infected children had fever (Save the Children *et al*. 2013). Furthermore, the relationship between livestock ownership and child nutrition in particular may be influenced by zoonoses, which Mali has been classified as a hotspot for (Grace *et al*. 2012).

6.2.3 Energy expenditure

Nutrition outcomes could also have been affected by unobserved variations in energy expenditure. The relationship between the two is not straightforward though as nutrition status may influence how much energy an individual expends and, conversely, energy expenditure may also affect nutritional status. Evidence of the former includes a reduction in energy expenditure that was reported in a study of malnourished children between the ages of 1 and 3 in Uganda (Rutishauser and Whitehead 1972). As evidence of the latter, Bénéfice, Garnier, and Ndiaye (2001) suggest that older children may be less likely to reduce physical activity levels in response to undernutrition, citing a study in a rural area of Senegal that reported adolescent girls maintaining high levels of physical activity while demonstrating delays in physical growth and maturation (Bénéfice and

[i] Results of the model are not presented here but are available upon request.
[ii] Mapped survey data from This Wormy World (http://www.thiswormyworld.org/maps/2013/distribution-of-soil-transmitted-helminth-survey-data-in-mali) of combined soil-transmitted helminth prevalence indicates that low prevalences (often less than 1%) among the entire age population have been observed in the study areas (higher prevalences have been observed in the south of the country). However, as school-age children suffer higher worm burdens than other age groups (Anderson and May 1985; Bundy 1986); they may be disproportionately affected by infection.

Cames 1999).[i] Further indications of energy expenditure affecting nutritional status has been reported in child labor studies. For instance, in a study in India that included comparisons with matched controls, child laborers were found to have no difference in calorie intake but were observed to have significantly lower nutrition outcomes, especially for older males (Ambadekar *et al*. 1999). Similar findings were reported in a longitudinal study in rural Andhra Pradesh (Satyanarayana, Prasanna Krishna, and Narasinga Rao 1986).

The only approximate measure of energy expenditure included in this survey was the number of day household members over the age of five were engaged in economic activities over the previous year (including farm labor, household chores, and wage labor). When child-level categories of number of days worked were introduced into the base OLS model, a significant positive association with HAZ was observed.[ii] This finding could be due to a reduction in work capacity in smaller children and is consistent with nutrition status influencing energy expenditure. Additionally, individuals may be adjusting energy expenditures to align with energy intake.

In addition to energy expenditure effects at the child-level, activity levels of other household members could also influence school-age child nutrition outcomes. For instance, if adult household members are expending high levels of energy and are in turn consuming greater proportions of household food to compensate, the nutrition of child household members may suffer. To attempt to address this, a proxy for household adult energy expenditure was created[iii] and introduced into the base OLS model.[iv] No significant association was found; however, the potential bluntness of the measure cannot be ruled out.

6.2.4 Intrahousehold food allocation

Furthermore, as the household food consumption survey approach does not address intrahousehold food allocation, effects of uneven allocation may be masked. If the indications of allocation favoring adults that were found in Chapter 5 are true, negative effects of food intake constraints for children may be underestimated. One potential source of unequal food distribution in the household in Mali is the general practice of adult males and guests being the first to eat from communal bowls (Ag Bendech, Chauliac, and Malvy 1998).

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[i] A study of nutrition outcomes and physical activity levels among children 6 to 18 years of age in Maputo, Mozambique, reported few differences in physical activity levels between children of low and normal nutritional statuses (Prista *et al*. 2003). However, this lack of association could be due to the urban environment setting, and differences may be more likely to be discerned in rural areas, where the physical requirements for and intensity of activity may be higher.

[ii] Results of the model are not presented here but are available upon request.

[iii] The household sum of the number of days household members 18 years of age or older were engaged in economic activities (including farm labor, household chores, and wage labor) in the past year was generated, which was then divided by the number of household members 18 years of age or older.

[iv] Results of the model are not presented here but are available upon request.

6.2.5 Seasonality and timing of data collection

Another disconnect could arise from the different time frames over which agricultural production and food consumption were measured. While agricultural production was assessed over the past year, food consumption was measured over the past seven days. The strength of the relationship between agricultural production and food consumption may be expected to differ across the course of a year, due to times of harvest and to the length of time different crops can be stored. For instance, with relatively short food consumption recall periods as here, the relationship between production and food consumption may be strongest at harvest time, weaken in subsequent months as perishable crops become less available, and be weakest during the hungry period when stores of both perishable and non-perishable crops may have been depleted. In this population, where associations between production variety and dietary diversity as well as food variety were observed in a post-harvest period, collecting the same food consumption data during a hungry period may not have resulted in significant correlations. Additionally, if food intake constraints are seasonal, collecting data during a hungry period may have been more likely to capture relationships between nutrition outcomes and food consumption. However, Adams (1992) argued that seasonal nutrition status declines among adults in Mali could be more attributable to concurrent increases in agricultural labor intensity than declines in food intake.

It is also important to note that the agricultural production measures included in the analyses were not measures of quantity or of the macro- and micronutrients produced but rather the number of crops and number of different kinds of crops grown. Thus, even if a household produced large numbers of crops or large numbers of different kinds of crops but the quantities of each were very low, an appreciable impact on household food consumption and child nutrition outcomes may not be expected.[i]

The year of observation may also influence relationships between production, consumption, and nutrition outcomes. The 2011–12 rains and harvest were both very poor in Mali.[ii] If the range of household agricultural production quantity and quality is increased in years of good harvest, there may be greater potential to observe associations with child nutrition.

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[i] To try to capture quantity effects, household agricultural production per capita (value in CFA) was introduced into the nutrition outcome model. No significant effect was observed (results available upon request). To simultaneously measure both production quantity and production quality, constructing a production variable similar to food consumption MAR may be of interest in future studies, accounting for amounts sold/stored for seed versus amount consumed.

[ii] Brecher. A., "Mali: Waiting For The Rain," World Food Programme, www.wfp.org/stories/mali-waiting-rain.

Chapter 7. School feeding and the school environment: Correlations with education participation outcomes in 101 schools in Kenya

7.1 Background

This chapter provides an opportunity to examine programmatic aspects of school feeding, including whether school feeding is related to increased education participation (and thus access to nutritional inputs through the programs). Here, the relationship between school feeding and education participation outcomes is analyzed using cross-sectional data at the school level in Kenya. The primary research aim is to determine whether the presence of school feeding is associated with increased school participation outcomes including enrollment, attendance, girl-to-boy enrollment ratio, and retention. Other school environment variables observed are also tested to determine whether deworming, school facilities and school quality, water and sanitation facilities, and distance to school are related to the outcome variables mentioned above. Additional information on the school feeding programs surveyed is examined to provide further context for the findings, including program status over time, the type of meal/snack/ration provided, the type of transfer (food or cash), the quality of service delivery, the types of foods served, information on food preparation and cooking, and information on linkages with smallholder farmers.

Among the principal findings was that no significant associations were found between school feeding and the education participation outcomes measured, which could be due in part to the dynamic nature of school feeding programs observed in the study area. From the data collected, some opportunities were highlighted for strengthening of cash transfer school feeding programs and sourcing from local producers specifically. These included bio-control advances for aflatoxin (which affects production and marketing of crops for smallholder farmers particularly), revision of procurement procedures to be more smallholder farmer friendly, and utilization of menu planning tools to support food basket flexibility while maintaining nutritional quality. For the other school environment variables observed, desk-to-student ratios, hand washing facilities at school, types of latrines, and distance to school were all found to have associations with education participation in the study area, with types of latrines potentially being important for girls of pubertal age.

With the summary of HGSF globally provided in Chapter 3, this chapter begins with an overview of government-led HGSF in Kenya as well as an introduction to the study and main aims of the analysis here. A brief literature review is presented on the relationships between the education participation outcomes mentioned above and school feeding and the school environment, which helped inform the research aims of this analysis. The methodology then provides further detail on the study population and data collection as well as the data analysis techniques employed. Results from the summary statistics and the inferential statistics are reported, and the chapter concludes with a discussion of the findings.

7.1.1 Home Grown School Feeding in Kenya

The Government of Kenya is demonstrating strong leadership in the field of HGSF, implementing two programs, led by the Ministry of Agriculture (MoA) and the Ministry of Education (MoE), respectively, which have received broad-based support at local, national, and international levels.

The Ministry of Agriculture-led program "Njaa Marufuku Kenya (NMK) – Eradicate Hunger in Kenya," which currently reaches over 44,000 schoolchildren, was launched in 2005 to target areas of high poverty with potential to grow food (Republic of Kenya 2012). The NMK program supplies cash grants to schools for food procurement alongside transfers to smallholder farmers to support production (the farmers can repay the transfers in the form of food for the schools). The grants for food purchases are scaled down over a period of three years, at the end of which the program is "handed over" to the community.

The second school feeding program came about as part of the Government's social safety net response to the severe drought in 2009 as well as part of the transition process from World Food Programme (WFP)-supported school feeding to government ownership and implementation (Republic of Kenya 2012). The Home Grown School Meals (HGSM) program implemented by the Ministry of Education targets 593,000 children in over 1,800 schools in 72 semi-arid districts, providing one cooked meal per child per day. Cash is transferred directly to schools, with the implementation at school-level being coordinated by School Meals Programme Committees. A competitive procurement process for food and transport with registered/licensed local farmers or suppliers is used.

Further information on these programs can be found at www.hgsf-global.org.

7.1.2 Informing the design of an impact evaluation of Home Grown School Feeding in Kenya

As part of a technical development plan to improve the policy and programming of HGSF in Kenya, the government requested assistance in strengthening the monitoring and evaluation of school feeding, including documenting the impact of different models (Republic of Kenya 2012). To scope potential geographic areas to study and to inform the design of school-level instruments for the impact evaluation baseline, a school feeding questionnaire was administered in 101 schools being studied as part of the Health and Literacy Intervention (HALI) project. HALI is a cluster randomized trial evaluating the impact of school-based malaria prevention and enhanced literacy instruction on the health and educational achievement of school children living in four divisions (Diani, Kubo, Lunga Lunga, and Msambweni) on the Kenya coast (Brooker *et al*. 2010). This area is characterized by poor education outcomes (Dubeck, Jukes, and Okello 2012), undernutrition of school-age children (Halliday *et al*. 2014), and intense year-round malaria transmission (Snow *et al*. 1993).

In the analysis of the school-level school feeding questionnaire data undertaken here, the primary aim was to determine whether the presence of school feeding was associated with increased school participation outcomes including enrollment, attendance, girl-to-boy enrollment ratios, and retention. Whether shorter distances to school and snacks being sold on school grounds also reduce this percentage was also tested. Information on school feeding program status over time, the type of meal/snack/ration provided, the type of transfer (food or cash), the quality of service delivery, the types of foods served, and information on food preparation and cooking was examined as well to provide further context for the findings.

Other school environment variables observed were also tested to determine whether deworming, school facilities and school quality (including electricity, student-to-classroom ratios, and student-to-teacher ratios), water and sanitation facilities, and distance to school were related to the outcome variables mentioned above. The specific questions examined included whether deworming was associated with increased attendance; whether better school facilities and school quality were associated with increased enrollment, girl-to-boy enrollment ratios, and retention; whether improved water and sanitation facilities were associated with increased enrollment, attendance, and girl-to-boy enrollment ratios; and whether shorter distances to school were associated with increased enrollment and attendance. Additionally, whether a higher percentage of female teachers was associated with a higher girl-to-boy enrollment ratio was examined.

7.1.3 Literature review: The relationships between the school environment and school participation outcomes

The literature on evidence of relationships between the school environment variables and school participation outcomes that informed the development of the research aims mentioned above is presented below and summarized in Table 7.1. School feeding was found to be associated with all four outcomes; deworming with attendance; school facilities and school quality with enrollment, girl-to-boy enrollment ratios and retention; water and sanitation facilities with enrollment, attendance, and girl-to-boy enrollment ratios; and distances to school with enrollment and attendance.

The review was limited to studies of primary school-age children from lower income countries with quasi-experimental or randomized controlled trial designs published since 1995.

Table 7.1 Summary of the evidence on the relationships between school environment variables and school participation outcomes

	Enrollment	Attendance	Girl-to-boy enrollment ratio	Retention
School feeding	++	++++	++	++
Deworming	—	+++	—	—
School facilities and school quality	++	—	+	+
Water and sanitation facilities	+++	+++	+++	—
Distance to school	++	+	—	—

— = no significant positive effects reported
+ = significant positive effect reported in at least one quasi-experimental evaluation
++ = significant positive effect reported in more than one quasi-experimental evaluation
+++ = significant positive effect reported in at least one randomized controlled trial
++++ = significant positive effect reported in more than one randomized controlled trial

7.1.3.1 School feeding

School feeding has been found to increase enrollment, attendance, girl-to-boy enrollment ratios, and retention, the evidence for which has been reviewed in Bundy *et al.* (2009).

To summarize, an evaluation of school feeding in Bangladesh observed a 14.2% increase in gross enrollment rates (9.6% increase in net enrollment rates), a 1.3 days per month increase in attendance, as well as a 7.5% reduction in the probability of dropping out (Ahmed 2004).

The Cochrane review on the effects of school feeding found that, based on results from two RCTs in lower income countries (Jacoby, Cueto, and Pollitt 1996; Powell *et al.* 1998), school attendance per year was on average 4 to 6 days greater in treatment than in control groups (Kristjansson *et al.* 2007).

As regards gender effects, a meta-analysis of data from 32 sub-Saharan African countries reported a 46% increase per year in girls' absolute enrollment in the highest primary grade in schools that combined on-site feeding with take-home rations, more than twice the increase than was observed in schools with on-site feeding alone (Gelli, Meir, and Espejo 2007). The authors argue that this also suggests a reduction in the dropout rate of girls in the higher primary grades. Similarly, in India, girls' enrollment was approximately 15% higher if the mid-day meal program was offered in the local school compared to if it was not, while no effect was detected for boys' enrollment (Drèze and Kingdon 2001).

7.1.3.2 Deworming

Three trials (Simeon *et al*. 1995; Watkins, Cruz, and Pollitt 1996; Miguel and Kremer 2004) were included in the Cochrane review analysis on the impact of deworming on school attendance (Taylor-Robinson *et al*. 2012). The Cochrane authors reported no effect from any of the trials in their analysis of the data. In examining the individual studies, Watkins, Cruz, and Pollitt (1996) found no effect of deworming on attendance even when baseline worm burden was adjusted for. However, Simeon *et al*. (1995) observed a significant improvement in attendance among the sub-group of children who were stunted. Miguel and Kremer (2004), in their study on deworming in Kenya, reported a significant reduction in absenteeism, particularly among younger pupils, which may be due in part to their higher infection rates than older students.[i]

7.1.3.3 School facilities and school quality

In terms of student-to-classroom as well as teacher-to-student ratios, an analysis of nationally-representative survey data from Kenya examined the impact of improving school quantity versus quality on primary school enrollment (Deolalikar 1998). The study found that the impact varied by the expenditure quintile of the child's household. Increasing the number of schools per 1,000 children of primary school age improved enrollment rates of children from the lowest quintiles while no effect was observed in children from the top quintiles. Conversely, as the number of teachers to students increased, enrollment rates expanded in the top quintiles but actually decreased in the lower quintiles, which may be due to reduction in funds targeted at improving the enrollment of the poorest to finance increased teacher salaries.

A study of the impact of student-to-teacher ratios on school enrollment and attainment in South Africa estimated that if student-to-teacher ratios were cut from 40 to 20, a year and a half of additional education would be attained over the school life of a student by age 15 (Case and Deaton 1999). Significant increases in the probability of enrollment were also estimated with reductions in the student-to-teacher ratio.

In a study of data from over 220,000 primary school-age children in 30 developing countries, with more teachers per 1,000 students and with smaller student-to-teacher ratios, children were found to be more likely to go to school (Huisman and Smits 2009). Additionally, with a higher percentage of female teachers (measured at the district level), girls were more likely to be enrolled.

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[i] Taylor-Robinson *et al*. (2012) contend that since baseline attendance rates were not given, there is no way of knowing whether the differences observed were due to the treatment or to random variations in attendance between the treatment groups.

7.1.3.4 Water and sanitation

In a recent cross-sectional analysis of school and household water and sanitation conditions in Western Kenya, the only school-level variable found to be associated with a reduction in the absenteeism outcome variable was latrine cleanliness (Dreibelbis *et al*. 2013). Water and sanitation quality seemed to be more important than quantity as the number of students per latrine was not associated with reduced absenteeism. The authors report this quality over quantity finding as being consistent with other studies that have found improvements in school attendance through water and sanitation interventions.

A randomized controlled trial in Western Kenya analyzed the effect of water, sanitation, and hygiene interventions on primary school attendance (Freeman *et al*. 2012). Hand washing, drinking water, and pupil-to-latrine improvements resulted in drops in absences among girls but not among boys, in areas unaffected by post-election violence.

In areas that experienced water shortages during the dry season, the trial also reported increased enrollment from the interventions (an average of 26 more students per school per year) as well as a 4% increase in the proportion of girls who were enrolled (Garn *et al*. 2013). No effects on enrollment were reported in areas with better access to water during the dry season.

7.1.3.5 Distance to school

Studies have also found small magnitude associations between distance to school and enrollment. In an analysis of 24 datasets from 21 low-income countries, Filmer (2007) reported that when the mean distance to primary school is relatively high, there is a significant negative effect on enrollment, but when the distances to school are relatively low, there is much greater variation in the association, which he states as being broadly consistent with the existing literature.

In more recent findings, the Huisman and Smits (2009) study mentioned above also found that with longer distances to travel to school, children were less likely to be enrolled in primary school. Longer distances to school were also found to be associated with lower attendance in Nigeria (Kazeem, Jensen, and Stokes 2010) and with lower enrollment in Ghana (Vuri 2010).

7.1.3.6 Variables beyond the scope of this study

Other variables beyond the scope of this study that have been found to influence the school participation outcomes measured include additional school-level factors as well as child- and household-level characteristics.

At the child-level, poorer educational outcomes have been associated with a number of health and nutrition issues, including undernutrition, micronutrient deficiencies, worm infections, malaria, and disabilities and impairments (Leslie and Jamison 1990). Building on these and other findings, a longitudinal study in Pakistan found child nutritional status to substantially affect primary school enrollment, with effects greater for girls than boys (Alderman *et al*. 2001). Also at the child-level, age and gender have been found to influence primary school participation as well (Buchmann 2000; Mugisha 2006).

At the household level, parental education and occupation, gender of the household head, birth orders, and household income and standard of living have all been associated with school participation outcomes (Lloyd and Blanc 1996; Baschieri and Falkingham 2009; Kazeem, Jensen, and Stokes 2010). Huisman and Smits (2009) found that parental education and wealth were particularly important in educational enrollment. With fathers who had more than secondary levels of education, the probability of child enrollment increased by 300%, and with mothers who had completed at least some primary education, the probability of child enrollment more than doubled. Similar effect sizes were observed for household wealth.[i] In a study of school participation determinants in Guinea, Glick and Sahn (2000) found that increases in parental education and household income were associated with greater gains in schooling for girls than for boys. Additionally, Behrman and Knowles (1999) note in their study of schooling and household income in Vietnam that higher-income households obtained higher-quality schooling, suggesting an interaction between household- and school-level factors.

An additional school-level variable not measured that has been found to be associated with student attendance is teacher absence. In northern Ghana, Ampiah and Adu-Yeboah (2009) reported that children were more likely not go to school on days when teachers were more likely to be absent.

7.1.3.7 Relative size of effects of determinants of school participation outcomes

Some studies have been able to assess a range of determinants of school participation outcomes and report on the relative effects sizes of each. Of the household-level (socio-economic and family structure) and district-level (educational and labor market structure) variables that Huisman and Smits (2009) assessed, they report parental education and wealth as being among the most important for primary school enrollment. Kabubo-Mariara and Mwabu (2007) conducted a similar analysis of household- and community-level indicators, finding that parental education and wealth were important along with maternal occupation, family structure, and child characteristics.

[i] Huisman and Smits (2009) detail some of the potential reasons why wealthier households exhibit higher school participation, including direct costs (e.g. fees, books, uniforms) being less of a barrier, opportunity costs (e.g. of children not laboring on the farm, not helping with household chores, not earning income [Basu 1999]) being less significant, and access to credit (which has been found to hinder the educational participation of poorer families [Edmonds 2006]) being less of a constraint.

7.2 Methodology

This section provides an overview of the study area and socio-economic, health, and education characteristics of the study population. Information on the school-level and district-level data collection tools and data entry is then provided, along with details on how variables were measured and constructed. Lastly, the data analysis methods are detailed, including for the summary statistics, bivariate regressions, and the multiple regression model building.

7.2.1 Study area and population

This survey was undertaken in 101 government primary schools in four divisions (Diani, Kubo, Lunga Lunga, and Msambweni)[i] on the south Kenyan coast. The main ethnic groups in the area belong to the Bantu Mijikenda; Digo and Duruma were found to be major dialects in a related study of the survey population (Dubeck, Jukes, and Okello 2012). Much of the area is rural and many households are engaged in subsistence farming, with maize, cassava, beans, and cowpeas as important crops (Klaver and Mwadime 2000; Halliday *et al*. 2014). The time that generally requires the most intensive agricultural labor is March to July/August, with the long rains occurring in May/June and the short rains in November/December (Klaver and Mwadime 2000). In terms of poverty, the area ranks among the poorest in Kenya (RTI International 2008).

Examining health and nutrition indicators of school-age children, of the class 1 and class 5 students surveyed in the wider HALI study, around one-quarter were found to be stunted, one-quarter underweight, and one-fifth thin (Halliday *et al*. 2014). Additionally, at the HALI baseline, the overall prevalence of *Plasmodium falciparum* among the children surveyed was found to be 13.0%, with the school-level prevalence ranging from 0.0% to 75.0% (Halliday *et al*. 2012). The authors also reported that 45.5% of children were anemic, with the school-level prevalence again ranging widely, from 26.3% to 80.0%. They also found that in schools nearest the coast (areas that exhibit low soil fertility), having a school feeding program at school was associated with a 50% reduction in a child's odds of anemia. In an analysis that used soil-transmitted helminth prevalence survey data in Kenya from 1974 to 2009 in developing geostatistical models to estimate prevalence for control purposes, the study area was estimated to be amongst the highest prevalence areas in the country, and once-yearly mass deworming was recommended for all school-age children in the area (Pullan *et al*. 2011).

For education, the Ministry of Education has reported poor performance on the primary school leaving exam (the Kenyan Certificate of Primary Education [KCPE]) in the study area

[i] With the shifting administrative layout of Kenya under the new constitution, these divisions are now all part of Kwale County, which is sub-divided differently from the old division system. For the purposes of analysis, the old division system is retained as it was the administrative structure at the time of the survey and allows for comparison across geographic areas.

(Dubeck, Jukes, and Okello 2012). Additionally, the authors of the sub-study found that only a few of the schools surveyed were located on a paved road while the majority were either 1 to 10 kilometers or more than 10 kilometers away from a paved road. In terms of girl-to-boy enrollment ratios in the area, of the class 1 and class 5 students surveyed by HALI, just under 50% were male (49.8% in the control schools and 48.7% in the intervention schools) (Halliday *et al*. 2014). The authors also reported household characteristics from the study population, which indicate that around 85% of parents had not progressed beyond primary school.

7.2.2 Study tools, variable measurements, and data entry

The school-level school feeding questionnaire was piloted in July 2011. At that time, interviews with district officers in charge of school feeding were also undertaken to gather information on the different government programs being implemented in their respective areas. After the piloting, the school-level questionnaire was shortened and simplified. The programmatic elements of the questionnaire were also restructured to address the dynamic nature of school feeding, covering multiple past, current, and future school feeding programs as well as the different implementers and types of programs involved. The final questionnaires were administered to head teachers in each of the schools in February 2012 as part of the HALI endline survey and examined school information and demographics; the school environment; past, present, and future school feeding programs; and food preparation and cooking.[i] Information on the ethical approval and informed consent obtained by the wider HALI study is detailed in Brooker *et al*. (2010).

As part of data collection on school information and demographics, enrollment, attendance, girl-to-boy enrollment ratio, retention, and the percentage of students who go home for lunch were assessed. Enrollment was measured by the number of boys and girls enrolled in each class from the Early Child Development (ECD) class and from primary classes 1 (P1)[ii] to 8 (P8), which was subsequently summed to determine the total enrollment of the school. Attendance was measured for classes 3 (P3) and 7 (P7) by recording the number of students in each class present in the school on the day of interview; the number attending were divided by the number of children enrolled for P3 and for P7 to determine the rate. The girl-to-boy enrollment ratio was calculated by dividing the total number of girls enrolled in the school by the total number of boys. Retention was determined by dividing the number of P6 students enrolled by the number of P1 students enrolled.[iii] For the percentage of students who go home for lunch, the number of students who go home at lunchtime

[i] The survey was conducted towards the beginning of the school year in Kenya, which runs from January to November with vacations in April, August, and December.
[ii] Students are generally 6 or 7 years of age at primary class 1.
[iii] Enrollment in P6 was used to calculate retention rather than in P7 or P8 as a few schools did not report enrollment data for these two upper grades. Multiple regression for retention (described below) was also run for a P8-to-P1 enrollment ratio with the schools with missing P8 data omitted. No substantive differences from the P6-to-P1 regressions were observed.

was recorded for P3 and for P7. These numbers were divided by the total number of children enrolled in the classes to determine the percentage for P3 and P7.

Total enrollment was used instead of gross or net enrollment rates because of the lack of information on the school catchment areas. This should be borne in mind when comparing with findings from other studies as some were able to calculate enrollment rates using data from household surveys, such as Deolalikar (1998). Implications for interpretation are further elaborated in the discussion.

Additionally, findings related to attendance may need to be interpreted with caution as it was measured at the school-level on only one day. Comparing it with methods employed by other school feeding studies that have assessed attendance, the three relevant studies from the literature review above all used school-level data as well (mainly from school registers) but used attendance information from a month or longer to determine average rates (Ahmed 2004; Jacoby, Cueto, and Pollitt 1996; Powell *et al.* 1998). Similarly, for deworming Miguel and Kremer (2004) used attendance rate information over a month from school registers, even while noting registers are not generally thought to be reliable in Kenya. Rather than school-level data, Dreibelbis *et al.* (2013) assessed absence over a two-week period through household surveys in a water and sanitation study, stating that they had found teacher-reported absences to be a problematic approach (Freeman *et al.* 2012). While a household survey was beyond the scope of this study, the inclusion of school attendance registers was considered. However, similar to what Miguel and Kremer (2004) noted, the registers of the schools in the area were deemed to be less reliable than determining attendance on the day of interview.

Also, as with all measures of retention that are not longitudinal, it is important to consider that the use of P6-to-P1 enrollment ratio as an approximation for retention could be an over- or an underestimation as children of various ages could be transferring in and out of the school and as children could be repeating grades. Examining the studies reviewed above that assessed retention, Ahmed (2004) used enrollment, transfer, and grade repeat information collected from school records to calculate school dropout rates, while Gelli, Meir, and Espejo (2007) drew on information on girls' absolute enrollment according to grade to approximate dropout. Due to the unreliability of school register data in the area (mentioned above), a cross-sectional approach similar to Gelli, Meir, and Espejo (2007) is employed here as the alterative.

Data from paper questionnaires were double-entered by a data entry company and verified using consistency checks.

7.2.3 Data analysis

Statistical analyses were performed at the school-level with 101 observations using Stata version 11.2 (Stata Corporation, College Station, TX, USA). Descriptive statistics were calculated, and independent two-sample t-tests were performed to compare means between two groups, and one-way ANOVA with Bonferroni adjustment was performed to compare means between several groups. The results from the district-level interviews are presented with the descriptive statistics as well.

Inferential statistics were also performed, aimed at testing whether independent variables observed are related to the outcome variables of total enrollment of the school, attendance for P3 and P7, girl-to-boy enrollment ratio, P6-to-P1 enrollment ratio (retention), and percentage of P3 and P7 students who go home for lunch.

Bivariate regressions were run with each of the independent variables on each of the outcome variables, and coefficients, 95% Confidence Intervals (C.I.), and significant p-values are reported. For the type of sanitary facility variable (the only independent variable with more than two categories), instead of regression, one-way ANOVA was used to test the difference in means of the categories. If significant differences were detected, the Tukey-Kramer method was used for pairwise comparisons between each of the groups.

To better account for the range and degree of influence the various independent variables may have on these outcomes, multiple regression models were fit for each outcome variable. Regression (ordinary least squares), regression with robust standard errors, robust regression, backward selection (p-value set at 0.1), and forward selection (p-value set at 0.1) methods were used to develop the preferred model, using root mean squared error (RMSE) and adjusted R^2 comparisons.

For regression, regression with robust standard errors, and robust regression, the independent variables found to have an association with the respective outcome variable of p-value ≤ 0.10 in the bivariate regressions were included in the multiple regression for the outcome variable. For the backward selection and forward selection models (both with robust standard errors), all of the independent variables were offered for initial inclusion in the models.

In the model building process, tests of assumptions were undertaken for normality of residuals, heteroscedasticity, multicollinearity, non-linearity, and model specification. Additionally, DFFITS values were examined to see if any exceeded the cut-off point of one for small data sets,[i] and if so, these outliers were examined in greater depth. If the assumptions were not met, Tukey's

[i] Wiesner, A. J., "Statistics 501: Chapter 10," Pennsylvania State University, http://stat.psu.edu/~ajw13/stat501/lectures/Chapter_10.doc.

ladder of powers was used to determine if a transformation was suitable for the outcome variable.[i] If so, the model was refit with the transformed variable and assumptions were retested. If assumptions were still not met, the non-normal independent variables were transformed, the model refit, and the results compared to previous models to determine which was preferred. Interpretation of the coefficients in models with transformed variables involved percentage changes for linear-log, log-linear, and log-log models (Benoit 2011). For transformations that did not involve logs, differentiation with respect to the independent variables as well as examination of trends in the predicted value of the dependent variable for different values of the independent variable were utilized (Emigh 2001).

7.3 Results

This section begins with the descriptive summary statistics for both the outcome and the independent variables. Results from the bivariate regressions are then presented, followed by the findings from the multiple regression models for each of the outcome variables.

7.3.1 Descriptive statistics

Table 7.2 presents the outcome and independent variables and their type (quantitative or categorical), a description of their distribution, the number of observations, mean, standard deviation, and minimum and maximum values.

7.3.1.1 Outcome variables

Exploring the outcome variables, total enrollments of the schools range from 152 to 1,496 students, with a mean of around 616 students. Reported attendance rates for P3 and P7 students both exceed 100% in some schools and both average around 85%. The girl-to-boy enrollment ratio ranges from 0.73 to 1.25, with an overall mean of 0.96 girls for every boy. The average P6-to-P1 enrollment ratio (the proxy for retention) is 0.92, with a maximum value of 2.24, indicative of the number of P6 students being more than double than number of P1 students in some schools. Some schools also reported more children going home for lunch than were enrolled, as shown by the 179% and 256% maximum values for the percentage of P3 and P7 students who go home for lunch, respectively.

7.3.1.2 Independent variables

Summary statistics for the independent variables, categorized into school feeding, deworming, school facilities and school quality, water and sanitation, and distance to school, are presented below.

[i] For any transformations, logs were preferred (if suitable) for ease of interpretation.

Table 7.2 Outcome and independent variables with type and distribution

	Type	Description of distribution	Number of observations	Mean	Standard deviation	Minimum	Maximum
Outcome variables							
total enrollment of the school	quantitative	right-skewed	101	615.703	295.032	152	1496
attendance rate for P3	quantitative	left-skewed	97	0.850	0.192	0.333	1.242
attendance rate for P7	quantitative	left-skewed	95	0.845	0.184	0.333	1.073
girl-to-boy enrollment ratio of the school	quantitative	normal	101	0.957	0.105	0.728	1.253
P6-to-P1 enrollment ratio of the school (retention)	quantitative	right-skewed	101	0.922	0.371	0.217	2.238
percent of P3 students who go home for lunch	quantitative	left-skewed	78	0.827	0.274	0	1.786
percent of P7 students who go home for lunch	quantitative	left-skewed	90	0.732	0.379	0	2.564
Independent variables							
current school feeding program (1 = yes and 0 = no)	categorical		101	0.228	0.421	0	1
past or current school feeding program (1 = yes and 0 = no)	categorical		101	0.634	0.484	0	1
mass albendazole/mebendazole treatment in the last twelve months at school (1 = yes and 0 = no)	categorical		101	0.921	0.271	0	1
mass praziquantel treatment in the last twelve months at school (1 = yes and 0 = no)	categorical		101	0.663	0.475	0	1
snack selling at school (1 = yes and 0 = no)	categorical		101	0.604	0.492	0	1
electricity at school (1 = yes and 0 = no)	categorical		101	0.277	0.450	0	1
student-to-teacher ratio	quantitative	right-skewed	97	54.509	25.447	15.200	150.833
student-to-classroom ratio	quantitative	right-skewed	101	52.822	19.066	16.889	158.333
desk-to-student ratio in P3	quantitative	normal	95	0.381	0.152	0	0.821
desk-to-student ratio in P7	quantitative	right-skewed	94	0.475	0.172	0.216	1.167
type of sanitary facilities (1 = water borne, 2 = VIP latrine, 3 = ordinary latrine, and 4 = other)	categorical		101	2.970	0.359	2	4
student-to-sanitary-facilities ratio	quantitative	right-skewed	101	63.020	41.064	13.222	231.500
source of drinking water at school (1 = yes and 0 = no)	categorical		101	0.733	0.445	0	1
hand washing facilities at school (1 = yes and 0 = no)	categorical		101	0.267	0.445	0	1
distance to walk (in minutes) from school to nearest town center	quantitative	right-skewed	101	22.475	22.912	2	120
distance to walk (in minutes) to the school from farthest point in school's catchment area	quantitative	right-skewed	101	67.228	30.253	15	240
percentage of pupils who walk more than 30 minutes to get to the school	quantitative	normal	101	49.198	23.153	1	90

School feeding

First for school feeding, as reported in more detail in Appendix C, 63 schools have had school feeding in the past, 25 had a current program, and 16 had a program planned for the future (Table C-5). Implementers included WFP, the Government, parents, NGOs, and individuals (Table C-6), who delivered a range of program types (e.g. regular school feeding, expanded school feeding, emergency school feeding, HGSM; Table C-7) and meals/snacks/rations (e.g. breakfast, snack, lunch, take-home ration; Table C-8). Information gathered at the district level on the different types of government school feeding in the area is presented in Table 7.3.

Table 7.3 District-level information on the types of school feeding programs implemented in the area

Program type	Partners	Time period	Target coverage	Transfer	Serving sizes
Regular	MoE and WFP	since around 2006	lunch for all children with breakfast for ECD as well	food delivered by WFP	150g maize / bulgur wheat 40g beans / peas 5g vegetable oil 3g salt
Expanded	MoE and WFP	begun in 2009 as response to drought, phased out end of 2010 as production seemed to increase	lunch for all children	food delivered by WFP	150g maize / bulgur wheat 40g beans / peas 5g vegetable oil 3g salt
Emergency	MoE	begun in 2011 as response to severe drought, intended to last for a month	lunch for all children	cash transfer to schools, who then purchase food (encouraged to procure locally)	150g cereals 40g pulses 5g vegetable oil 3g salt

For the type of transfer received, around 60% of programs received food, 35% cash, and 5% both (Table C-9). Cash transfer school feeding programs reported funding shortfalls, which occurred due to a variety of factors, including the actual enrollment being greater than the enrollment the transfer was intended to cover, increased food prices, as well as unexpected losses (Table C-11). District-level data also indicated that there were difficulties initially in accessing funds transferred to schools' accounts as in some cases the money was sent to accounts without check-writing capabilities. Approximately 67% of cash transfer programs procured their food directly from wholesale traders, 24% from local retailers, and 9% from individual farmers (Table C-13). Respondents reported the origin of this food as being primarily from Mombasa, with some coming from the local market (Table C-14). This was in line with district-level findings as respondents reported that due to the drought, it was difficult to buy from local producers, but food was still being procured locally from suppliers who were sourcing from traders in Mombasa.[i] Additionally, programs more often had rules on which types of food could be procured (90%) than

[i] District officers also cited food transport as a cost challenge as schools were responsible for paying for the price of transport from the traders (often in Mombasa) to the schools.

on from whom it could be procured (57%), and less than two-thirds of programs involved advertizing of tenders (Table C-15). One challenge reported in district interviews was that food procured was required to meet MoE and Ministry of Health (MoH) standards and be tested for aflatoxin and other quality and safety issues. This was considered to be preventing local producers from participating as their food did not meet the standards. Additionally, large quantities of food are necessary for testing, quantities which local producers were unable to supply; thus, the food for programs was being sourced from traders.

For food transfer programs, the majority received deliveries either once a month or once a term rather than once a week or once every two weeks (Table C-17). Some food transfer programs were unable to reach all of the intended beneficiaries due to increased enrollment over time, less food being delivered than expected, and late delivery (Table C-18).

Examining the foods served by all types of school feeding programs, the foods that were most often reported as being frequently served were oil (82% of programs), maize (80%), beans (65%), salt (40%), pulses (33%), rice (20%), and uji[i] (18%), while among the least often frequently served were greens (3%) and fruit (1%) (Table C-19). For cash transfer programs, district-level information indicated that schools were preferring to buy rice and beans over maize and pulses as the former are cheaper and require far less cooking time and fuel. Over 30% of school feeding programs reported serving fortified food (Table C-21).

In terms of food preparation and cooking, the majority of schools only had a temporary school kitchen (70%) as opposed to a permanent one (25%) (Table C-22). District officers reported food storage as a challenge, as in some schools, which lack permanent storage areas, food has been rained on and spoiled. Additionally, the majority of schools sought to source the utensils and bowls, cooking fuel, water for cooking, and payment for cooks from parents or children (Table C-22). Information from district-level data indicated that water for cooking was a significant constraint in some areas where boreholes were salty and schools were unable to supply the water. In some instances, children were to bring 3 liters of water to school, the origin of which was varied, including from stagnant pools. Most schools had cooks that were hired to prepare the food (94%), some had parents (8%), and only a few had teachers involved (2%) (Table C-22). In instances where parents were responsible for paying the cook (who held a medical certificate), district-level information indicates that they may have been reluctant to cover this cost. Additionally, there were reports that some head teachers preferred food over cash transfers as the latter was requiring significant organization and coordination with suppliers and contract tendering and as funding shortfalls were being experienced.

[i] A porridge.

Other district-level findings related to school feeding included reports of enrollment dropping in schools that did not offer school feeding as students shifted enrollment to schools that did. Additionally, with delays in delivery of food, sizeable drops in attendance were reported.

Deworming

For deworming, over 90% of schools reported receiving mass albendazole/mebendazole treatment by the MoE/MoH in the last 12 months, and approximately two-thirds reported receiving mass praziquantel treatment. The percentage of schools with snacks being sold on the school compound was 60.4%, while 27.7% reported having electricity anywhere on the school compound.

School facilities and school quality

The mean student-to-teacher ratio overall was 54.5, with the maximum reported value being over 150 students per teacher in one school. The mean female-to-male teacher ratio was also found to be 1.09, with a range from 0 to 6. For student-to-classroom ratios, the maximum value was also over 150 students per classroom, with 52.8 as the mean. On average, there was around one desk for every three P3 students and one desk for every two P7 students.

Water and sanitation

For types of sanitary facilities, 87.1% of schools reported having an ordinary latrine, 7.9% reported having a ventilated improved pit (VIP) latrine, and 5.0% reported have another type of latrine. On average, there were more than 63 students for each functional sanitary facility. Nearly three-quarters of schools reported having a source of drinking water within the school compound, and around one-quarter reported having hand washing facilities.

Distance to school

The mean amount of time to walk from the school to the nearest town center was over 20 minutes, and the mean amount of time to walk to the school from the farthest point in the school's catchment area was over an hour. On average, nearly half of pupils walk more than 30 minutes to get to the school every day.

Additional summary statistics are reported in Appendix C, including comparisons in means of school participation and environment variables among the four geographic divisions; for school feeding programs, the type of meal/snack/ration provided and the type of transfer the schools received (food or cash); the quality of school feeding service delivery; the types of school feeding foods served; and information on food preparation and cooking.

7.3.2 Bivariate regressions

Bivariate regressions between outcome and independent variables were run to determine any significant associations for the 101 schools sampled (coefficients, 95% C.I., and significance levels reported in Table 7.4). No significant associations with any of the outcome variables were found for past or current school feeding program, student-to-sanitary-facilities ratio, distance to walk from school to the nearest town center, or distance to walk to the school from the farthest point in school's catchment area.

7.3.2.1 Enrollment

For total enrollment, strong evidence of association was found with snack selling at school (202.63, 95% C.I.: 89.95, 315.30), electricity at school (211.06 [87.23, 334.89]), the student-to-teacher ratio (6.21 [4.32, 8.11]), the student-to-classroom ratio (8.93 [6.41, 11.45]), the desk-to-student ratio in P3 (-622.52 [-980.25, -264.79]), and type of sanitary facility ($F[2,98] = 5.03$, p-value ≤ 0.01); moderate evidence of association with the desk-to-student ratio in P7 (-379.18 [-704.90, -53.45]) and source of drinking water (131.99 [2.35, 261.62]); and weak evidence of an association with hand washing facilities (127.74 [-2.06, 257.55]).

Examining the coefficients, schools with snack selling and schools with electricity had about 200 more students on average than schools without. Additionally, schools with drinking water and schools with hand washing facilities both had about 130 more students on average than schools without. For each additional student per teacher, there were approximately six more students enrolled in total, and for each additional student in the classroom, there were nearly nine more total students enrolled. In an inverse correlation, for each additional desk per student in P3, total enrollment was approximately 600 students lower on average. Similarly, for each additional desk per student in P7, total enrollment was an average nearly 400 students lower. Findings from the Tukey-Kramer test on type of sanitary facilities indicated the only significant difference between groups as schools with VIP latrines compared with schools with ordinary latrines (those with VIP latrines had approximately 275 more students enrolled on average).

7.3.2.2 Attendance

There was strong evidence of an association between P3 attendance and the desk-to-student ratio in P3 (0.469 [0.226, 0.711]). As indicated by the coefficient, for each additional desk per student, attendance increased by nearly 50% on average. Weak evidence of an association was also found between P3 attendance and hand washing facilities (-0.073 [-0.161, 0.014]). Schools with hand washing facilities had an approximate 7.3% lower attendance rate in P3 than schools without.

Table 7.4 Bivariate regressions of independent and outcome variables for the 101 schools sampled (coefficient and 95% C.I.)

	total enrollment	P3 attendance	P7 attendance	girl-to-boy enrollment ratio	P6-to-P1 enrollment ratio	percentage P3 who go home for lunch	percentage P7 who go home for lunch
current school feeding program	8.66	-0.015	-0.021	0.012	0.060	-0.151*	-0.212**
	(-130.93, 148.25)	(-0.106, 0.076)	(-0.109, 0.067)	(-0.037, 0.062)	(-0.115, 0.235)	(-0.305, 0.003)	(-0.402, -0.021)
past or current school feeding program	-14.84	-0.026	0.011	-0.018	-0.082	-0.055	-0.122
	(-136.32, 106.63)	(-0.107, 0.054)	(-0.068, 0.090)	(-0.061, 0.025)	(-0.234, 0.070)	(-0.181, 0.072)	(-0.284, 0.041)
mass albendazole/mebendazole treatment in the last twelve months at school	29.00	-0.030	0.061	-0.022	-0.085	0.168	0.379***
	(-187.70, 245.70)	(-0.171, 0.111)	(-0.074, 0.197)	(-0.099, 0.055)	(-0.357, 0.188)	(-0.084, 0.419)	(0.110, 0.647)
mass praziquantel treatment in the last twelve months at school	70.54	-0.003	0.029	-0.040*	-0.076	-0.008	0.152*
	(-52.55, 193.62)	(-0.086, 0.079)	(-0.050, 0.109)	(-0.083, 0.003)	(-0.231, 0.079)	(-0.149, 0.132)	(-0.015, 0.318)
snack selling at school	202.63***	-0.001	-0.008	-0.015	0.082	0.102	0.154*
	(89.95, 315.30)	(-0.081, 0.078)	(-0.085, 0.070)	(-0.057, 0.028)	(-0.067, 0.232)	(-0.022, 0.227)	(-0.007, 0.314)
electricity at school	211.06***	-0.038	-0.080*	0.009	0.176**	-0.107	0.016
	(87.23, 334.89)	(-0.125, 0.050)	(-0.164, 0.003)	(-0.038, 0.055)	(0.015, 0.336)	(-0.243, 0.030)	(-0.162, 0.194)
student-to-teacher ratio	6.21***	-0.001*	-0.002**	0.000	-0.003**	0.000	0.001
	(4.32, 8.11)	(-0.003, 0.000)	(-0.004, 0.000)	(-0.001, 0.001)	(-0.006, 0.000)	(-0.003, 0.003)	(-0.002, 0.004)
student-to-classroom ratio	8.93***	-0.001	-0.002	-0.001	-0.004*	0.000	0.002
	(6.41, 11.45)	(-0.004, 0.001)	(-0.004, 0.000)	(-0.002, 0.001)	(-0.007, 0.000)	(-0.003, 0.004)	(-0.002, 0.006)
desk-to-student ratio in P3	-622.52***	0.469***	0.336***	0.040	0.440*	0.438**	0.391
	(-980.25, -264.79)	(0.226, 0.711)	(0.094, 0.579)	(-0.104, 0.184)	(-0.050, 0.929)	(0.018, 0.858)	(-0.132, 0.913)
desk-to-student ratio in P7	-379.18**	0.155	0.351***	-0.029	-0.016	0.226	0.112
	(-704.90, -53.45)	(-0.076, 0.387)	(0.141, 0.562)	(-0.156, 0.098)	(-0.459, 0.426)	(-0.119, 0.572)	(-0.350, 0.573)
type of sanitary facilities	$F(2,98) = 5.03$***	$F(2,94) = 0.31$	$F(2,92) = 1.73$	$F(2,98) = 1.48$	$F(2,98) = 1.54$	$F(2,75) = 0.35$	$F(2,87) = 1.58$
student-to-sanitary-facilities ratio	0.85	-0.000	0.000	0.000	-0.001	-0.001	0.001
	(-0.58, 2.27)	(-0.001, 0.001)	(-0.001, 0.001)	(0.000, 0.001)	(-0.003, 0.001)	(-0.002, -0.001)	(-0.001, 0.002)
source of drinking water at school	131.99**	-0.024	0.017	-0.009	0.031	0.027	0.056
	(2.35, 261.62)	(-0.111, 0.064)	(-0.069, 0.103)	(-0.056, 0.038)	(-0.136, 0.197)	(-0.111, 0.166)	(-0.126, 0.239)
hand washing facilities at school	127.74*	-0.073*	-0.039	0.004	0.073	-0.057	0.069
	(-2.06, 257.55)	(-0.161, 0.014)	(-0.124, 0.047)	(-0.043, 0.051)	(-0.092, 0.239)	(-0.197, 0.083)	(-0.116, 0.254)
distance to walk (in minutes) from school to nearest town center	-1.76	-0.001	0.000	0.000	0.000	0.000	-0.001
	(-4.30, 0.78)	(-0.003, 0.001)	(-0.002, 0.001)	(-0.001, 0.001)	(-0.003, 0.003)	(-0.003, 0.003)	(-0.004, 0.003)
distance to walk (in minutes) to the school from farthest point in school's catchment area	-1.09	-0.001	0.000	0.000	-0.001	0.000	0.001
	(-3.02, 0.84)	(-0.002, 0.001)	(-0.001, 0.002)	(0.000, 0.001)	(-0.003, 0.002)	(-0.002, 0.002)	(-0.001, 0.004)
percentage of pupils who walk more than 30 minutes to get to the school	-1.64	0.001	0.001*	-0.001	-0.002	0.003	0.002
	(-4.17, 0.87)	(0.000, 0.003)	(0.000, 0.003)	(-0.002, 0.000)	(-0.005, 0.001)	(0.000, 0.006)	(-0.002, 0.005)
number of observations	101	97	95	101	101	78	90

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

For P7 attendance, strong evidence of an association was found with desk-to-student ratios in both P3 and P7 (0.336 [0.094, 0.579] and 0.351 [0.141, 0.562], respectively). P7 attendance was found to be an average of 33.6% higher for each additional desk per student in P3 and 35.1% higher for each additional desk in P7. Moderate evidence of an association was found between P7 attendance and student-to-teacher ratio (-0.002 [-0.004, 0.000]). For each additional student per teacher, P7 attendance decreased by 0.2% on average. Electricity and percentage of pupils who walk more than 30 minutes to get to the school were both found to have weak evidence of association with P7 attendance (-0.080 [-0.164, 0.003] and 0.001 [0.000, 0.003], respectively). Schools with electricity had an approximate 8.0% lower P7 attendance rate than schools without. Additionally, for every 1% increase in the percentage of pupils who walk more than 30 minutes to school, there was found to be about a 0.1% increase in the P7 attendance rate.

7.3.2.3 Girl-to-boy enrollment ratio

The only independent variable found to be associated with the girl-to-boy enrollment ratio was mass praziquantel treatment (weak evidence, -0.040 [-0.083, 0.003]). Schools that had experienced praziquantel treatment in the past twelve months had a 0.040 lower girl-to-boy enrollment ratio on average than those that had not.

In an additional girl-to-boy enrollment ratio regression run not presented in Table 7.4, no association was found with the female-to-male teacher ratio.

7.3.2.4 Retention

Moderate evidence of an association with P6-to-P1 enrollment ratio was found with electricity and student-to-teacher ratio (0.176 [0.015, 0.336] and -0.003 [-0.006, 0.000], respectively). Schools with electricity had an approximately 0.176 higher P6-to-P1 enrollment ratio than schools without, and for each additional student per teacher, the P6-to-P1 enrollment ratio decreased by 0.003 on average. Weak evidence was found for associations with the student-to-classroom ratio and the desk-to-student ratio in P3 (-0.004 [-0.007, 0.000] and 0.440 [-0.050, 0.929], respectively). For each additional student per classroom, the P6-to-P1 ratio was found to decrease by 0.004, and for each additional desk per student in P3, the P6-to-P1 ratio was found to increase by 0.44.

7.3.2.5 Students who go home for lunch

For the percentage of P3 students who go home for lunch, moderate evidence of an association was found with the desk-to-student ratio in P3 (0.438 [0.018, 0.858]) and weak evidence with a current school feeding program (-0.151 [-0.305, 0.003]). For each additional desk per student in P3, the percentage of P3 students going home for lunch increased by over 40% on average, and schools with a school feeding program had about 15% fewer P3 students going home for lunch than schools without school feeding.

For the percentage of P7 students who go home for lunch, strong evidence of an association was found with mass albendazole/mebendazole treatment (0.379 [0.110, 0.647]) and weak evidence with mass praziquantel treatment (0.152 [-0.015, 0.318]). Schools that had received mass albendazole/mebendazole treatment in the past year had 37.9% more P7 students going home for lunch on average than those that had not and schools that received praziquantel had 15.2% more. Moderate evidence of an association was also found with a current school feeding program (-0.212 [-0.402, -0.021]). Schools with a school feeding program had about 21% fewer P7 students going home for lunch than schools without school feeding. Additionally, weak evidence of an association was found with snack selling (0.154 [-0.007, 0.314]). Schools with snack selling had approximately 15% more P7 students going home at lunch on average.

7.3.3 Multiple regressions

This section details the results from the multiple regression model building process for enrollment, attendance, girl-to-boy enrollment ratio, retention, and students who go home for lunch, each in turn.[i]

7.3.3.1 Enrollment

Taking all of the findings from Appendix D into account, the model presented in Table 7.5 is the preferred model for total enrollment. Interpreting the coefficients while considering the log transformations for total enrollment and student-to-classroom ratio, a 30% increase in the geometric mean of enrollment is expected when schools have electricity compared with when they do not. Additionally, with a 10% increase in the student-to-classroom ratio, an 11% increase in total enrollment is expected. When hand washing is available at school, a 14% increase in the geometric mean of enrollment is expected, and for each percentage increase in the pupils who walk more than 30 minutes to get to the school, a 0.3% decrease in the geometric mean of total enrollment is expected.

[i] Full details on the model building processes are reported in Appendix D.

Table 7.5 Forward selection regression model for the log of total enrollment, with non-normal independent variables transformed (coefficient and 95% C.I.)

	Forward selection
electricity at school	0.2651*** (0.1183, 0.4119)
log of student-to-classroom ratio	1.0543*** (0.8570, 1.2515)
hand washing facilities at school	0.1316** (0.0015, 0.2618)
percentage of pupils who walk more than 30 minutes to get to the school	-0.0025* (-0.0051, 0.0002)
Number of observations	90
RMSE	0.2675
Adjusted R^2	0.681

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

7.3.3.2 Attendance

For P3 attendance, the preferred model was forward selection regression for attendance rate for P3 cubed, with non-normal independent variables transformed (see Table 7.6). Given the cubed transformation of the outcome variable and the logged transformation of one of the independent variables, interpretation of the coefficients is complex. Desk-to-student ratio and percentage of pupils who walk more than 30 minutes to get to school both had a positive association with P3 attendance, with diminishing returns for each as they increased. Distance to walk to the school from the farthest point in the school's catchment area had a negative association, with the size of the effect decreasing as the distance increased. In terms of the overall model, these variables account for less than 20% of the variation observed in attendance rate for P3 (adjusted R^2: 0.171).

Table 7.6 Forward selection regression model for attendance rate for P3 cubed, with non-normal independent variables transformed (coefficient and 95% C.I.)

	Forward selection
desk-to-student ratio in P3	0.872*** (0.361, 1.384)
log of distance to walk (in minutes) to the school from farthest point in school's catchment area	-0.164** (-0.323, -0.006)
percentage of pupils who walk more than 30 minutes to get to the school	0.004*** (0.001, 0.007)
Number of observations	90
RMSE	0.3140
Adjusted R^2	0.171

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

The preferred model for attendance rate for P7 also involved forward selection regression with the outcome variable cubed and with non-normal independent variables transformed (see Table 7.7). As with P3 attendance, the nature of the transformations complicates the interpretation of the coefficients. Having electricity, having ordinary latrines compared to VIP latrines, and the distance to walk from school to the nearest town center all had negative associations with P7 attendance, while desk-to-student ratio and the percentage of pupils who walk more than 30 minutes to get to the school had positive associations. Diminishing returns were observed for each of the quantitative variables. The five variables in this model account for around 30% of the variation observed in attendance rate for P7 (adjusted R^2: 0.297).

Table 7.7 Forward selection regression model for attendance rate for P7 cubed, with non-normal independent variables transformed (coefficient and 95% C.I.)

	Forward selection
electricity	-0.189*** (-0.331, -0.047)
log of desk-to-student ratio in P7	0.413*** (0.209, 618)
type of sanitary facilities dummy_variable_3	-0.242*** (-0.410, -0.073)
log of distance to walk (in minutes) from school to nearest town center	-0.053* (-0.112, 0.005)
percentage of pupils who walk more than 30 minutes to get to the school	0.002* (0.000, 0.005)
Number of observations	90
RMSE	0.2691
Adjusted R^2	0.297

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

7.3.3.3 Girl-to-boy enrollment ratio

During the model building process, the only variable in any of the models found to have an association with girl-to-boy enrollment ratio was mass praziquantel treatment in the last twelve months at school, though the evidence of association was weak. Interpreting the coefficients from the forward selection model presented in Table 7.8, schools that had received praziquantel treatment had a mean girl-to-boy enrollment ratio approximately 0.04 lower than schools that had not. This variable only accounts for 2% of the total variance observed in girl-to-boy enrollment ratio (adjusted R^2: 0.022).[i]

[i] Another forw1ard selection regression model for girl-to-boy enrollment ratio run not presented here included female-to-male teacher ratio as one of the independent variables offered for inclusion. It was not selected by the model.

Table 7.8 Forward selection regression model for girl-to-boy enrollment ratio (coefficient and 95% C.I.)

	Forward selection
mass praziquantel treatment in the last twelve months at school	-0.041* (-0.088, 0.007)
Number of observations	90
RMSE	0.1060
Adjusted R^2	0.022

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

7.3.3.4 Retention

The backward selection regression for the log of retention, the preferred model for retention, is presented in Table 7.9. The independent variables selected by the model were electricity and the percentage of pupils who walk more than 30 minutes to get to the school. Interpreting the coefficients while considering the log transformation for retention, for each additional desk per student in P3, a 47% increase in the geometric mean of retention is expected. Conversely, for each percentage increase in the pupils who walk more than 30 minutes to get to the school, a 0.3% decrease in the geometric mean of retention is expected. The two independent variables only account for 7% of the variation observed in retention (adjusted R^2: 0.065).

Table 7.9 Backward selection regression model for the log of retention (coefficient and 95% C.I.)

	Backward selection
desk-to-student ratio in P3	0.472** (0.000, 0.944)
percentage of pupils who walk more than 30 minutes to get to the school	-0.003** (-0.006, 0.000)
Number of observations	90
RMSE	0.3615
Adjusted R^2	0.065

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

7.3.3.5 Students who go home for lunch

The preferred model for percent of P3 students who go home for lunch is the forward selection regression model, which selects snack selling, desk-to-student ratio in P3, and percentage of pupils who walk more than 30 minutes to get to the school as the independent variables (see Table 7.10). Interpreting the coefficients, the expected mean percentage of P3 students who go home for lunch is around 13% higher in schools with snack selling than schools without (albeit the evidence of association is weak). Additionally, for each additional desk per student in P3, the expected mean percentage who go home for lunch increases by around 50%. In terms of distance, for each additional percentage point increase in pupils who walk more than 30 minutes to get to the school, there is a half a percent increase in the percent of pupils who go home for lunch. These three variables account for less than 20% of the variation observed in the outcome variable (adjusted R^2: 0.193).

Table 7.10 Forward selection regression model for percent of P3 students who go home for lunch (coefficient and 95% C.I.)

	Forward selection
snack selling at school	0.128* (-0.016, 0.273)
desk-to-student ratio in P3	0.503** (0.103, 0.903)
percentage of pupils who walk more than 30 minutes to get to the school	0.005*** (0.002, 0.008)
Number of observations	74
RMSE	0.2488
Adjusted R^2	0.193

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

The preferred model for percent of P7 students who go home for lunch included transformation of the non-normal independent variables as well as exclusion of a school with an extreme DFFITS score. This backward selection regression model selected current school feeding, mass albendazole/mebendazole treatment, log of student-to-classroom ratio, desk-to-student ratio in P3, and one of the dummy variables for the type of sanitary facilities (see Table 7.11). Examining the coefficients, having a current school feeding program is associated with an approximate 36% reduction in the percentage of P7 students who go home for lunch. Additionally, having ordinary latrines as compared to VIP latrines is associated with a near 20% reduction in P7 students who go home for lunch. Mass albendazole and mebendazole treatment as well as desk-to-student ratio in P3 is associated with an increase in the percentage of P7 students who go home for lunch. The log of the student-to-classroom ratio is also associated with an increase; with a 10% increase in the student-to-classroom ratio, a 2% increase in the mean of the percent of P7 students who go home for lunch is expected. These independent variables account for nearly 40% of the variation observed in the percent of P7 students who go home for lunch (adjusted R^2: 0.371).

Table 7.11 Backward selection regression model for percent of P7 students who go home for lunch, with non-normal independent variables transformed and with extreme DFFITS value school dropped (coefficient and 95% C.I.)

	Backward selection
current school feeding program	-0.363*** (-0.545, -0.181)
mass albendazole / mebendazole treatment in the last twelve months at school	0.251*** (0.100, 0.402)
log of student-to-classroom ratio	0.210* (-0.014, 0.434)
desk-to-student ratio in P3	0.478** (0.005, 0.950)
type of sanitary facilities dummy_variable_3	-0.198** (-0.358, -0.038)
Number of observations	86
RMSE	0.2531
Adjusted R^2	0.371

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

7.4 Discussion

This section begins with a discussion on the school feeding findings, followed by discussion of the other school environment findings (deworming, school facilities and school quality, water and sanitation, and distance to school).

7.4.1 School feeding

No significant associations were found between school feeding and enrollment, attendance, girl-to-boy enrollment ratio, and retention in 101 schools on the Kenyan coast (though, unsurprisingly, school feeding was found to be associated with a reduction in the percentage of P7 students who go home for lunch). The lack of associations with the observed outcomes could be due in part to the dynamic nature of school feeding in the area. As seen in the past, present, and future program school-level findings and as reported in the district-level interviews, school feeding can vary year on year and even month on month by implementer (e.g. government, external partner, community) and by type of meal/snack/ration, amongst other variables.

Responses to school feeding over time could be contributing variability. For instance, Gelli, Meir, and Espejo (2007) observed in their meta-analysis that for schools that were to receive school feeding within a year, the average yearly rate of absolute enrollment increased by 14% for girls and boys. In the first year of school feeding, girls' absolute enrollment increased by 28% and boys' by 22%. However, after the first year, absolute enrollment rate increases returned to near their values in the year before school feeding was begun. To highlight the programmatic variability over time observed in this survey, the past programs averaged around 1.5 years of implementation (ranging from less than one month to nearly 15 years). Similarly, the present programs also had been running for an average of 1.5 years (ranging from less than one month to nearly 6 years).

Fluctuations in enrollment may be following introduction of programs, trends that cannot be captured from one time point. Furthermore, for attendance, even though district-level information suggested that drops in attendance occurred with delays in food delivery, school-level data were unable to capture whether this was happening as attendance rates over time and dates of food delivery were not measured.

Additionally, quality of school feeding delivery may influence the ability of programs to effect change in the outcomes observed. The funding and food shortfalls reported in cash transfer and food transfer school feeding programs, respectively, may result in fewer target beneficiaries being reached. Delivery may also be hampered by lack of infrastructure; for example, the majority of schools only had a temporary school kitchen as opposed to a permanent one. Inputs required of parents and children may hinder access as well, as they may be unable to provide the utensils and bowls, cooking fuel, water for cooking, and payment for cooks that the majority of school feeding programs seek to source from them. However, school feeding does not seem to be affecting teacher time (which could in turn influence the outcomes observed); most schools had cooks that were hired to prepare the food, some had parents, and only a few had teachers involved.

Another theory for why the presence of school feeding could be unrelated to higher school participation is because participation in the study areas may have already been high (Alderman and Bundy 2012). However, education data compiled by the Education Policy and Data Center (EPDC) (2007) suggest that the primary net enrollment rate in the study area is just under 80%, lagging a few percentage points behind the national average and indicating that there may well be opportunities for school feeding and other education interventions to boost enrollment rates in the area.

Information gathered at the district level indicates opportunities for strengthening of cash transfer programs and involvement of local producers specifically. In helping to address the quality and safety constraints highlighted in the district interviews, initiatives are underway that are focused on supporting smallholder farmers to access markets, improve production, and meet quality and safety standards. For example, the International Institute of Tropical Agriculture (IITA), with support from the Bill & Melinda Gates Foundation and others, has developed the bio-competitive product aflasafe™, which replaces toxic-producing strains of aflatoxin with atoxigenic strains and protects crops like maize along the entire value chain (Bandyopadhyay, Cotty, and Mutegi 2013). A country-specific composition of aflasafe™ is currently being field tested in Kenya on smallholder maize farms, which, if successful, could aid these farmers in accessing local structured demand markets, like school feeding.

In addition to assisting smallholder farmers in meeting quality standards, procurement procedures could be revised to better enable those farmers to access the school feeding market. A partner project led by SNV Netherland Development Organisation is seeking to improve procurement opportunities for smallholder farmers in reaching HGSF program markets in Ghana, Kenya, and Mali, including training of public officials on pro-smallholder procurement practices as well as development of community-based governance mechanisms to ensure stakeholder accountability along the procurement process (SNV 2012). The findings here have been discussed with SNV, including the large quantities of food needed for testing constraint, as part of the ongoing process to improve smallholder farmer market access. Another aim of improved procurement practices could be to ease burdens on teachers, who reported significant time being devoted to coordination of supplies and tendering of contracts in cash transfer programs.

In terms of the food basket, flexibility in the types of food that can be purchased has led to savings in cooking time and fuel. To ensure nutritional quality is not compromised with increased flexibility, food basket standards could be formulated with respect to macro- and micronutrients delivered rather than specific foods delivered, as is sometimes the case (Galloway 2010). Tools are being developed to help food basket planners at the national as well as local levels in planning menus that are nutritionally-balanced as well as cost-effective. Following piloting of a simple menu planning software application in Ghana at both the national and the school caterer level (PCD 2013), roll-out of the application with other government-led HGSF programs, including Kenya, is underway, in continued efforts to enable flexible food baskets that meet nutritional standards.

7.4.2 Deworming

The only variable found to be associated with the girl-to-boy enrollment ratio in multiple regressions was whether mass praziquantel treatment had been administered in the last twelve months at school. There was weak evidence that schools that had received praziquantel treatment had a mean girl-to-boy enrollment ratio approximately 0.04 lower than schools that had not. As schistosomiasis is highly focal, Sturrock *et al*. (2013) suggest that treatment should be targeted on a school-by-school basis. If the presence of treatment is taken as a proxy for a high prevalence of infection of schistosomiasis in the area of the school, the results here may suggest some gender effect of schistosomiasis on enrollment, with girls potentially more greatly affected than boys. However, a parasitological survey of primary schoolchildren conducted in Tanzania that reported gender effects found that in Tanga region (a region of the country that borders the study area in Kenya), schistosomiasis prevalence was higher in boys (varying from around 15% to 20% over age groups that ranged from 7 to 14 years of age) than in girls (generally less than 10% across the same age range),[i] the reverse of what is suggested by the results here[ii] (Clements *et al*. 2008).

Of course, the use of treatment as a proxy for prevalence may not be appropriate as schools that require mass treatment based on prevalence may not have received it as no systematic schistosomiasis treatment has yet been administered in the area (Halliday *et al*. 2012). As Sturrock *et al*. (2013) collected schistosomiasis prevalence data in 33 schools in Kenya's Coast Province (where the study area here is located), one opportunity for future research may be to examine whether a sufficient number of those schools were also part of this study and, if so, to analyze girl-to-boy enrollment ratios in relation to prevalence data specifically.

None of the deworming studies reviewed above examined associations with girl-to-boy enrollment ratios, but some did report improvements in attendance. The lack of association with deworming for schistosomiasis found here is similar to the Watkins, Cruz, and Pollitt (1996) findings but it could also be due to the one-day method of measuring attendance discussed above, which could be over- or underestimating attendance.

Similarly, for deworming for soil-transmitted helminths, no association was found with attendance, but strong evidence of a positive association was observed with the percent of P7 students who go home for lunch. This finding is more difficult to interpret. As mentioned above, all 101 schools studied here are recommended to receive once-yearly mass deworming for soil-transmitted helminths as they are located in a high prevalence area. In the schools that did not receive mass albendazole/mebendazole treatment, children may be more greatly infected than schools that did receive treatment. As infection can cause lethargy and reduction in physical fitness and activity (Stephenson, Latham, and Ottesen 2000), these children may be less likely to undertake the journey home in the middle of the school day, one potential explanation for the association observed. Another factor that should be borne in mind when examining the percentage of P7 students who go home for lunch is that even with the best fit model, some of the model assumptions were violated, as discussed in Appendix D.

7.4.3 School facilities and school quality

From the summary statistics, the mean student-to-teacher ratio (55:1) exceeds the MoE's recommendation of 40:1 (Kiumi, Kibe, and Nganga 2013). The mean student-to-classroom ratio (53:1) also surpasses the national benchmark of 45:1 (SACMEQ 2011), both further indications of the education input constraints in the area.

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[i] Similar gender effect patterns were observed in the other areas of Tanzania where parasitological surveys were undertaken.

[ii] Though another theory could be that there is a disconnect between the gender differences in prevalence and the gender differences in the effects of prevalence (i.e. school attendance).

A number of associations were observed between the outcome variables and school facilities and school quality. Electricity and the student-to-classroom ratio were associated with higher enrollment, desk-to-student ratio in P3 with higher P3 attendance, electricity with lower P7 attendance and desk-to-student ratio in P7 with higher P7 attendance, desk-to-student ratio in P3 with increased retention, snack selling and desk-to-student ratio in P3 with increased percentage of P3 students who go home for lunch, and student-to-classroom ratio and desk-to-student ratio in P3 with increased percentage of P7 students who go home for lunch.

While none of the school facilities and school quality studies reviewed addressed electricity specifically, its association with increased total enrollment is not unexpected. More students-per-classroom with higher total enrollment is also not unexpected. While studies in the literature review reported an association between enrollment and student-to-teacher ratios (Deolalikar 1998; Huisman and Smits 2009), no association was found in this analysis. However, as the literature review studies examined enrollment rates rather than total enrollment, household-level data on enrollment or at least data on the number of primary school children within the school's catchment area would be required to calculate rates to allow for proper comparison.

For attendance, higher desk-to-student ratios being associated with higher attendance is not unexpected as well. While the studies reviewed did not examine desk-to-student ratios, the findings here suggest that they may be one dimension of school facilities and school quality important for education participation in the Kenyan context. The association between electricity and lower P7 attendance is more puzzling but could be due in part to the method of measurement for attendance discussed above.

Desk-to-student ratio was the only school facilities and quality variable to be associated with retention. Again, even as no studies reviewed assessed desk-to-student ratio, the positive association is not unexpected and suggests that this school facilities dimension may be important for keeping children progressing through school years in addition to keeping them attending school. The relationships could also be an indication of higher income of households in the area of the school, as higher household income is associated with higher-quality schooling (Behrman and Knowles 1999), one element of which here could be higher desk-to-student ratios, as well as increased school participation (Glick and Sahn 2000; Huisman and Smits 2009).

The unexpected associations and directions of associations between the school facilities and school quality variables and the percent of student who go home for lunch could be a product of the fit of the models, mentioned above.

No association was found between the female-to-male teacher ratio and girl-to-boy enrollment ratio, which differs from the significant positive association Huisman and Smits (2009) reported in their meta-analysis of data from 30 developing countries. One potential reason for the difference could be that Kenya may exhibit less of an association than the other countries examined. Another reason could be related to Huisman and Smits (2009) measuring enrollment at the household level. As the estimates here are from school survey data, information on out-of-school children are not included, which could be contributing to the lack of association observed.

7.4.4 Water and sanitation

As seen in the summary statistics, it seems the student-to-sanitary-facilities ratio in the schools surveyed was more than double the government standard. The ratio was around 62:1 for girls and 70:1 for boys, compared to the Government of Kenya ratio of 25:1 for girls and 30:1 for boys (Dreibelbis *et al*. 2013).

From the multiple regressions, it appears that having hand washing facilities at school is associated with increased enrollment and that the type of latrine is associated with attendance rate for P7 students as well as with the percentage of P7 students who go home for lunch. The direction of association between hand washing and enrollment is to be expected and is consistent with the results of the RCT in Western Kenya that involved a hand washing intervention mentioned above (Garn *et al*. 2013). For P7 attendance, the finding that schools with VIP latrines have higher attendance rates than schools with ordinary latrines is unexpected but could be partially attributable to the difficulties in measuring attendance mentioned above. In the other latrine type finding, one potential reason why schools with VIP as opposed to ordinary latrines have more P7 students going home for lunch may be related to girls experiencing puberty at that age (no associations with water and sanitation variables were found for P3 students going home for lunch).

7.4.5 Distance to school

For the distance variables, a summary of the direction of the relationships observed is presented in Table 7.12. The decrease in enrollment with increased percentage of pupils who walk more than 30 minutes to get to the school is consistent with other recent findings (Huisman and Smits 2009; Vuri 2010). The negative association of the variable with retention is also not unexpected, even though the studies reviewed did not examine retention specifically.

For P3 and P7 attendance, both positive and negative associations were observed with different distance variables. The negative associations with increased distance to walk from school to nearest town center (approximating how rural the school is) and with increased distance to walk to the school from the farthest point in the school’s catchment area (approximating how rural the school’s catchment area is) are consistent with findings from the studies mentioned above. While the positive association with percentage of pupils who walk more than 30 minutes to get to the school is unexpected, diminishing returns were observed for both P3 attendance and P7 attendance, suggesting that the increase in attendance becomes smaller as the percentages become larger. If long distances are driving the negative distance associations observed and smaller distances are driving the positive associations observed, the pattern for attendance could be similar to the significant negative effect with relatively long distances and much greater variation with relatively short distances reported by Filmer (2007) for enrollment. For the percent of P3 students who go home for lunch, the same model assumption reservations as discussed above should be borne in mind.

Table 7.12 Direction of associations observed between the distance variables and the outcome variables

	Enrollment	P3 attendance	P7 attendance	Retention	P3 home lunch
increased distance to walk (in minutes) from school to nearest town center	-	-	↓	-	-
increased distance to walk (in minutes) to the school from farthest point in school's catchment area	-	↓	-	-	-
increased percentage of pupils who walk more than 30 minutes to get to the school	↓	↑	↑	↓	↑

7.5 Conclusions

While no significant associations were found between school feeding and the education participation outcomes measured in this study, results from the school- and district-level data collection highlight the dynamic nature of school feeding programs in the study area. Variations in program duration, implementer, type of meal/snack/ration, and other variables could be contributing to the lack of associations observed. Strengthening national monitoring and evaluation of school feeding through the Education Management Information System (EMIS) may help track these changes and help coordinate program planning to ensure effective use of resources.

In addition to these results helping to inform the baseline of the HGSF impact evaluation in Kenya, the findings here have been discussed with the MoA and MoE, who are particularly interested in information on opportunities for further development of community-driven school feeding in Kenya. District-level data collected here provided indication of some opportunities for strengthening of cash transfer school feeding programs and sourcing from local producers specifically, including bio-control advances such as aflasafe™ for aflatoxin, revision of procurement procedures to be more smallholder farmer friendly, and utilization of menu planning tools under development to support food basket flexibility while maintaining nutritional quality.

For the other school environment variables observed, summary statistics findings on the education constraints in the study area were consistent with results from other analyses. From the multiple regressions, desk-to-student ratio was found to have a positive association with attendance and retention, suggesting that in the Kenyan context it may be one dimension of school facilities and school quality important for education participation. For water and sanitation, hand washing was found to have a positive association with enrollment. Additionally, the type of latrine may influence educational experience for girls; schools with VIP latrines were associated with more girls of pubertal age going home for lunch than schools with ordinary latrines. In terms of distance to school, findings of decreased education participation with increased distances, with potentially more variation at shorter distances, were consistent with results from other studies.

Of course, it is important to note that some of the most important determinants for child education participation outcomes (parental education and wealth [Huisman and Smits 2009]) and child-level characteristics [Kabubo-Mariara and Mwabu 2007]) are not captured in a school-level survey such as this. Household- and community-level surveys would be able to complement the school environment variables observed and provide a more complete analysis of determinants. This multi-level data collection approach has been undertaken in the HGSF impact evaluation baseline surveys in Mali and Ghana and is planned for the baseline in Kenya as well.

Chapter 8. Conclusions

This thesis identifies and details the potential for school-age children to benefit nutritionally from interventions through a complementary, life-cycle approach. In addressing the first main research question, evidence reviewed supports the hypotheses that height and weight at school age matter and that catch-up growth at school age is possible and has been achieved, to varying degrees, through interventions in school age and adolescence. For the second main research question, results from analyses on relationships between agricultural production and food consumption indicate that production variety is positively correlated with dietary diversity and food variety in the survey population, but no significant effects of household agriculture or food consumption measures on HAZ of children between the ages of 5 and 11 were found. Agriculture-nutrition frameworks provide a structure for discussing disconnects observed and how "leakages" may occur along various pathways in the framework. Among the principal findings for the third main research question was that no significant associations were found between school feeding and the education participation outcomes measured, which could be due in part to the dynamic nature of school feeding programs observed in the study area. From the data collected, some opportunities were highlighted for strengthening of cash transfer school feeding programs and sourcing from local producers specifically.

I conclude that opportunities for improving the nutrition of school-age children do exist and that understanding the potential for agriculture-nutrition disconnects and the dynamic nature of school feeding programs could help improve research and policy related to multi-sectoral, nutrition-sensitive interventions at school age, including Home Grown School Feeding. The main research and policy implications of my thesis are outlined in turn below, followed by a section on lessons learned throughout the PhD process.

8.1 Research implications

Three of the key implications for further research generated from these analyses are discussed below, including how the methods and results are being used to strengthen impact evaluations of HGSF in other countries, how analysis of existing and upcoming longitudinal data on school-age child growth could be enriched, and how potential age misreporting in growth studies can be addressed.

8.1.1 Strengthening analysis of the impact of home-grown school feeding programs on child growth

Methods and results from the school-age growth determinants and relationships between household food consumption and agricultural production analyses are being used to inform impact evaluations of HGSF in Ghana and Kenya. With the two-year follow-up planned for these studies, effects of the agriculture-related school feeding intervention on growth of school-age children will be able to be estimated, building on the agriculture and nutrition linkages elaborated here. Additionally, as catch-up to national and international standards has been reported by changes in environment studies as well as interventions addressing secondary stunting and underweight, greater understanding of how catch-up growth has been achieved in these settings may be able to strengthen the design of food and micronutrient interventions.

8.1.2 Examining existing and upcoming longitudinal data on school-age child growth

In addition to intervention studies, further analysis of existing data sets from birth cohort studies (for example, the COHORTS collaboration) could provide cross-country analysis of growth in school age and adolescence, while accounting for socio-economic, environment, human capital, behavioral, and chronic disease variables observed (Richter *et al*. 2011). Growth pattern analysis as presented in Stein *et al*. (2010) could be built upon to address sensitivities to using HAD as an outcome measure instead of HAZ (Leroy, Ruel, and Habicht 2013; Leroy *et al*. 2014) and to examining proportional deficits (Prentice *et al*. 2013b). Stein *et al*. (2010) concluded that as "there was little additional growth failure in the period from 24 mo through mid-childhood, our data further stress the criticality of interventions prior to age 24 mo." Using HAD instead of HAZ may alter that conclusion if the Leroy *et al*. 2014 finding of further growth faltering beyond the age of 2 using HAD and cross-sectional data is borne out in longitudinal data as well.[i]

As birth cohorts from the *Young Lives* studies in Ethiopia, India, Peru, and Vietnam are now coming into adolescence, similar approaches could be useful for assessment of growth and reckoning of catch-up. Additionally, *Young Lives* data includes measurement of household food consumption and agricultural production,[ii] information that few longitudinal studies have collected to date. These variables present an opportunity for examining the effects of household food

[i] Catch-up growth analysis using HAZ could also be built upon to address regression to the mean, expanding the initial calculations from COHORTS data presented by Cameron, Preece, and Cole (2006).

[ii] Of the questionnaires publicly available, household food consumption was surveyed in Rounds 2 and 3 but not in Round 1 (http://www.younglives.org.uk/what-we-do/household-and-child-survey/questionnaires-1). For agricultural production, amount of land used for agriculture was measured in Round 1, as was livestock ownership. More detailed information on agricultural production was collected in Rounds 2 and 3, including data on types of crops grown and quantities and values harvested.

consumption and agricultural production on child growth from infancy to adolescence, using approaches similar to Himaz (2009).

8.1.3 Addressing the reporting of age for nutrition status purposes

The preponderance of missing date of birth data and the inconsistencies between reported age and age calculated from available date of birth data (discussed in Section 3.3.4.1 and Section 4.1.5) underscores the difficulties of capturing accurate age data for anthropometric purposes in Mali, as experienced by others including Oshaug *et al*. (1994). While conclusions regarding the determinants estimates largely remained the same when sensitivity to different age calculations was tested, the potential over-reporting of ages may have led to an overestimation in the prevalences of undernutrition in the study population. In similar studies where age data is suspect, sensitivity analyses akin to those undertaken here are suggested to provide indication of the magnitude, direction, and effects of age misreporting.

8.2 Policy implications

Two of the chief policy implications arising from this work are detailed below, the first being the potential increased scope for nutrition interventions at school age and adolescence and the second discussing how access to nutrition interventions through schools could be improved, with reference to costs and multi-sectoral benefits.

8.2.1 Increased scope for nutrition interventions at school age and adolescence

Through these analyses, this thesis presents important policy considerations for the perception of school-age and adolescent growth.[i] While the potential of women of reproductive age and children under the age of two to benefit from nutrition-specific interventions is substantial (Bhutta *et al*. 2013), literature reviewed here counters the early stunting irreversibility claim with evidence that deficits can, at least to some extent, be made up in childhood and adolescence. These findings suggest that there may be greater scope for nutrition-sensitive interventions at school age,[ii] particularly with the increased interest of late in adolescence as an entry point for health interventions as women enter reproductive age (Viner *et al*. 2011; Bhutta *et al*. 2013). This potential for greater scope can be evaluated in light of recent findings on improvements in growth following early faltering benefitting schooling and cognitive achievement as well (Crookston *et al*. 2013).

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[i] The findings here have already contributed to high-level discussions on catch-up growth and will be published in part in *Disease Control Priorities, Third Edition* (DCP3).

[ii] Ruel, Alderman, and the Maternal and Child Nutrition Study Group (2013) define nutrition-specific interventions as those addressing immediate determinants of nutrition and nutrition-sensitive interventions as those addressing underlying causes of nutrition. They also highlight that the latter may serve as a delivery platform for the former.

8.2.2 Strengthening access to nutrition interventions through schools

In Kenya, with the variations observed in school feeding program duration, implementer, type of meal/snack/ration, and other variables, strengthening national monitoring and evaluation of school feeding (potentially through EMIS) may help track changes and coordinate program planning to ensure effective use of resources. In other policy implications, district-level data provided indication of some opportunities for strengthening of cash transfer school feeding programs and sourcing from local producers specifically, including bio-control advances such as aflasafe™ for aflatoxin, revision of procurement procedures to be more smallholder farmer friendly, and utilization of menu planning tools under development to support food basket flexibility while maintaining nutritional quality.

Of course, policy makers examining the suitability of school-based nutrition interventions would be assessing many more factors than are addressed here. For instance, decisions between using school- or household-based approaches (or a combination of the two) would want to take costs into account. Existing evidence on costs of school feeding that could help inform such decisions include Bundy *et al*. (2011), Gelli *et al*. (2011), and Gelli and Daryanani (2013).

Naturally, costs would be evaluated in light not only of nutrition benefits but also of the range of other multi-sectoral effects that interventions like HGSF may have, including on school participation and learning, community engagement, and smallholder farmer income (Masset and Gelli 2013), along with effects on other age groups. In building the multi-sectoral understanding in Mali, for example, the nutrition findings presented here are complemented by analyses on the status and determinants of primary education in the study population (Gelli *et al*. 2014)[i] as well as welfare effects of school feeding (Masset and Gelli 2014).[ii] In the planned two-year follow up of HGSF programs in Ghana and Kenya, effects on community participation and income for smallholder farmers will be examined as well. Potential spillover effects on the nutrition of younger siblings will also be assessed, as benefits for these preschoolers have been reported elsewhere (Buttenheim, Alderman, and Friedman 2011). In sum, discussion of nutrition effects for school-age children of interventions such as HGSF fits within a wider framework of potential benefits in other sectors and for other household members.

8.3 Lessons learned

Below are summary lists of recommendations for PhD work that I learned through the process, do’s and don’t’s that are particularly oriented toward future students.

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[i] One principle finding of the education determinants analysis was the association between school feeding and increased enrollment, attendance, and attainment (Gelli *et al*. 2014).

[ii] In the Mali study population, school feeding was found to have a sizeable effect on welfare (as measured by food shares); however, the effect was not statistically significant (Masset and Gelli 2014).

8.3.1 Recommended do's

- Do involve yourself in grant application processes whenever possible. This can afford insight into various donor mindsets and experience in identifying funding opportunities and developing grants, including formulation of key research questions relevant to policy making.
- Seek to gain knowledge and skills across the key elements of the research study process. Some of the areas I appreciated gaining experience in include: specifying evaluation questions and theories of change; constructing counterfactuals; selecting impact evaluation methods; undertaking ethics review processes at home and in study countries; establishing evaluation teams (developing and fostering relationships with study country researchers); establishing timeframes and budgets for the evaluations; choosing the sample; developing, translating, and field-testing the questionnaires; conducting the fieldwork; processing and validating the data; developing initial findings reports; decided how best to split out findings into distinct but complementary papers; and working with communications teams on wider dissemination strategies.
- Pursue EQ as well as IQ, especially in situations where your work may have policy change implications.
- Avail yourself of the many theoretical and practical statistics resources that are publicly available. I found myself referring to the excellent UCLA statistics website on numerous occasions.
- Everyone has different approaches to organization of PhD reading material, but one technique I found immensely useful was compiling all of the abstracts of publications I wanted to save for future reference into one Word document, which could be easily searched for keywords of interest later on. Additionally, as I entered the abstract, I also created a properly formatted bibliographic citation for the publication, which greatly streamlined referencing during the writing process.

8.3.2 Recommended don't's

- Don't expect that all will go as planned. For study country selection, I quickly learned the value of working on a multi-country study. When study development did not proceed at the pace planned for my initial focus country (due to efforts to ensure full governmental and partner buy-in), I was able to switch to working on another study country. When unrest prevented follow-up in that country, I also had to adjust from working on longitudinal data to examining cross-sectional data from the study baseline. The difficulty of completing impact studies in a PhD timeframe highlights the importance of formulating, as a back-up, interesting research questions that can be addressed with baseline, cross-sectional data if need be.

- As a technical point related to anthropometry data collection specifically, don't expect enumerators to automatically transfer over from the household roster all of the children eligible for the anthropometry module without specific data consistency checks. In anthropometric data analysis for Mali, I encountered the following issues: 1) ages from the household roster and anthropometry pages did not match up; 2) individuals' identification numbers from the two pages did not match up; and 3) some 2 to 15 year old children listed in the household roster were not then measured in anthropometry module. I was able to address the first two issues by flagging them with the data entry team, and we were able to resolve. For the third issue, I was able to ascertain some of the reasons for missingness based on other questions asked in the household module, but a more effective approach may have been to have the enumerators list out all of the 2 to 15 year olds from the household member module onto the anthropometry module and work in that same order. Additionally, for future studies, I would argue for that the addition of a question in the anthropometry module on whether or not the child was measured (and why) is worth the extra questionnaire space to avoid later issues during data analysis.

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Appendix A. Mali household survey villages

Table A-1 The Mali household survey villages (including commune, cercle, and region) and the number of household members surveyed in each

Region	Cercle	Commune	Village	Number of household members surveyed
Kayes	Kayes	Séro Diamanou	Kougnandji	238
Kayes	Kayes	Séro Diamanou	Sitakounady	226
Kayes	Kayes	Djélébou	Nahaly	189
Kayes	Kayes	Djélébou	Sarayero	209
Kayes	Kayes	Karakoro	Teichibé	200
Kayes	Kayes	Karakoro	Boutinguisse	177
Kayes	Diéma	Gomitradougou	Nankoumana	151
Kayes	Diéma	Gomitradougou	Wattaye	152
Kayes	Diéma	Dioumara Koussata	Digui Tala	194
Kayes	Diéma	Dioumara Koussata	Sobougou	215
Kayes	Diéma	Grouméra	Groumera	201
Kayes	Diéma	Grouméra	Kassé - Kara	145
Kayes	Nioro du Sahel	Simbi	Lewa-Diarisso	199
Kayes	Nioro du Sahel	Simbi	Guemou	187
Kayes	Nioro du Sahel	Guétéma	Kolomina	139
Kayes	Nioro du Sahel	Guétéma	Guétema	168
Kayes	Nioro du Sahel	Nioro du Sahel	Madina Alahiry	148
Kayes	Nioro du Sahel	Nioro du Sahel	Kaomi	188
Kayes	Nioro du Sahel	Kadiaba Kadiel	Sambagori	183
Kayes	Nioro du Sahel	Kadiaba Kadiel	Fossi Karta	173
Kayes	Nioro du Sahel	Diaye Coura	Diaye Coura	190
Kayes	Nioro du Sahel	Diaye Coura	Siringo	207
Kayes	Nioro du Sahel	Nioro Tougouné Rangabé	Sioundi	166
Kayes	Nioro du Sahel	Nioro Tougouné Rangabé	Nioro Tougouné Rangabé	184
Kayes	Nioro du Sahel	Yéréré	Korokodio	171
Kayes	Nioro du Sahel	Yéréré	Yéréré	201
Kayes	Nioro du Sahel	Diarra	Niamy	164
Kayes	Nioro du Sahel	Diarra	Sigui	200
Kayes	Nioro du Sahel	Gogui	Tourourou	195
Kayes	Nioro du Sahel	Gogui	Diandjoumi	172
Koulikoro	Nara	Niamana	Danguiri	136
Koulikoro	Nara	Niamana	Kollah	177
Koulikoro	Nara	Fallou	Karfabougou	158
Koulikoro	Nara	Fallou	Toumboula	231
Koulikoro	Nara	Dilly	N'tomikoro	147
Koulikoro	Nara	Dilly	Kamatigui	192

Region	Cercle	Commune	Village	Number of household members surveyed
Koulikoro	Nara	Dabo	Tihfimbougou	155
Koulikoro	Nara	Dabo	Ouaourou	203
Koulikoro	Nara	Allahina	Goumango	163
Koulikoro	Nara	Allahina	Djiguibougou	176
Koulikoro	Nara	Dogofry	Birou Niakati	184
Mopti	Mopti	Sio	Soufouroulaye	138
Mopti	Mopti	Sio	Somabougou	188
Mopti	Bandiagara	Timniri	Tinimassogou	154
Mopti	Bandiagara	Timniri	Soh	144
Mopti	Bandiagara	Bara Sara	Mandoly	194
Mopti	Bandiagara	Bara Sara	Diallo	167
Mopti	Bandiagara	Pignari	Pâh	137
Mopti	Bandiagara	Pignari	Koko	163
Mopti	Bandiagara	Dourou	Golombo	171
Mopti	Bandiagara	Dourou	Dourou	189
Mopti	Bandiagara	Dandoli	Sinkarma	261
Mopti	Bandiagara	Dandoli	Dioubairou	214
Mopti	Bandiagara	Bandiagara	Ouro-gondo	91
Mopti	Bandiagara	Bandiagara	Ouro-gondo	197
Mopti	Bandiagara	Doucoumbo	Diombo-Djeneke	161
Mopti	Bandiagara	Doucoumbo	Bodio	164
Mopti	Bandiagara	Sangha	Sidiki Traori	200
Mopti	Bandiagara	Sangha	Bongo	199
Mopti	Bandiagara	Wadouba	Sol	197
Mopti	Bandiagara	Wadouba	Olguini	215
Mopti	Bandiagara	Ségué Iré	Niangari	233
Mopti	Bandiagara	Ségué Iré	Nangalaloumbo	221
Mopti	Bandiagara	Métoumou	Dourou	173
Mopti	Bandiagara	Métoumou	Sadegue	175
Mopti	Bandiagara	Diamnati	Kilegou	180
Mopti	Bandiagara	Diamnati	Dia	195
Mopti	Bandiagara	Kendé	Toupere	166
Mopti	Bandiagara	Kendé	Dani	178
Mopti	Bandiagara	Kendié	Tapou	158
Mopti	Bandiagara	Kendié	Kantaba Leye	195
Mopti	Bandiagara	Lowol-Guéou	Boui	179
Mopti	Bandiagara	Lowol-Guéou	Goumbo	172
Mopti	Bandiagara	Pignari Bana	Kakoli	117
Mopti	Bandiagara	Pignari Bana	Mackou	126
Mopti	Koro	Kassa	Kampoudie	207
Mopti	Koro	Kassa	Berdossou	204
Mopti	Koro	Bamba	Ogol Pepe	183
Mopti	Koro	Bamba	Koundianga	195
Mopti	Koro	Dioungani	Dana-Dogon	192
Mopti	Koro	Dioungani	Yorou-Na	171
Mopti	Koro	Yoro	Ganfani	159

Region	Cercle	Commune	Village	Number of household members surveyed
Mopti	Koro	Yoro	Kindi	166
Mopti	Koro	Dinangourou	Banagadie	155
Mopti	Koro	Dinangourou	Guimini	169
Mopti	Koro	Bondo	Domoni	195
Mopti	Koro	Bondo	Adounakanbe	216
Mopti	Koro	Youdiou	Patin	175
Mopti	Koro	Youdiou	Oropa	175
Mopti	Koro	Koporo Pen	Tinassassogou	166
Mopti	Koro	Koporo Pen	Oro	194
Mopti	Douentza	Haïré	Ouro N'Gerou	147
Mopti	Douentza	Haïré	Serma	153
Mopti	Douentza	Mondoro	Dougoussa	154
Mopti	Douentza	Mondoro	Toulewendou	172
Mopti	Douentza	Hombori	Ordiahitt	73
Mopti	Douentza	Hombori	Kissim	162
Mopti	Douentza	Dallah	Nani	136
Mopti	Douentza	Dallah	Toula	173
Mopti	Douentza	Douentza	Fombori	196
Mopti	Douentza	Douentza	Coumbena	192
Mopti	Douentza	Koubéwel Koundia	Kooraberi	208
Mopti	Douentza	Koubéwel Koundia	Tobaco	188
Mopti	Douentza	Tédjé	Panga-Nim	216
Mopti	Douentza	Tédjé	Obé	174
Mopti	Douentza	Gandamia	Bounty-Daka	156
Mopti	Douentza	Gandamia	Gana	148
Mopti	Douentza	Korarou	Ibrizaz	148
Mopti	Douentza	Korarou	Goui	143
Mopti	Douentza	Dangol-Boré	Hororo	140
Mopti	Douentza	Dangol-Boré	Songoli	69
Total	**8**	**56**	**111**	**19,536**

Appendix B. Mali supplementary tables

Figure B-1 Distribution of z-scores of school-age children

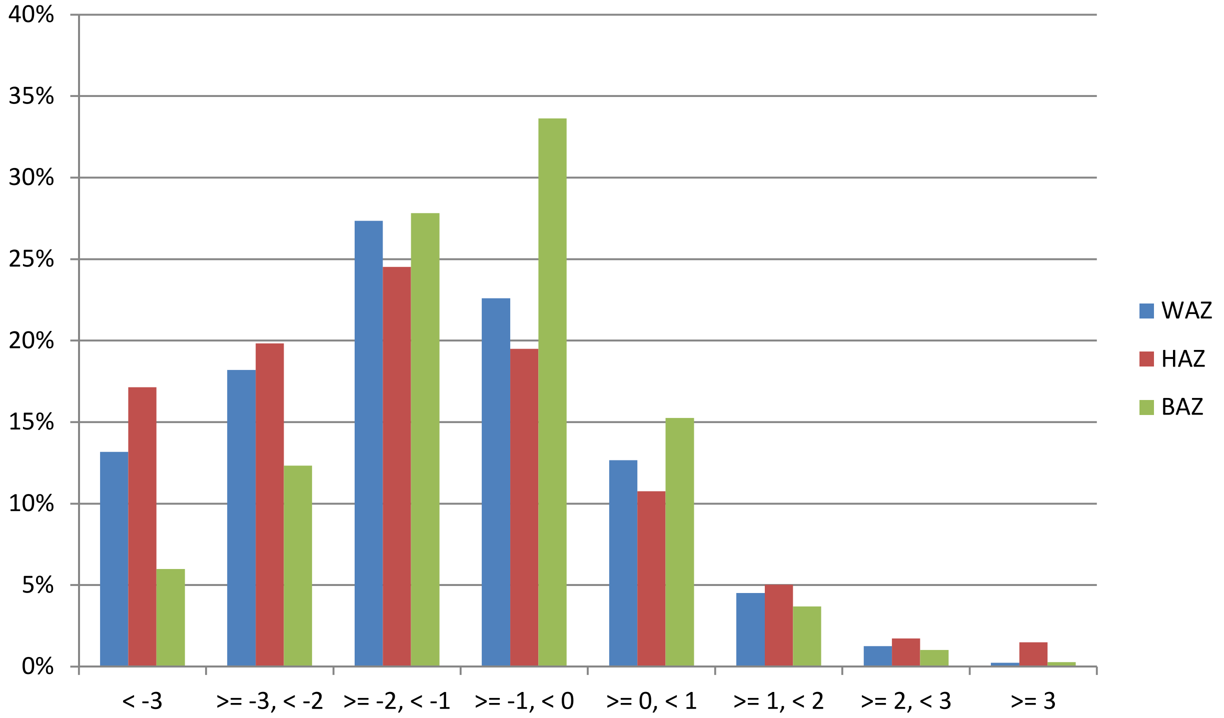

Table B-1 First stage regression in IV/2SLS estimation of child-, household-, and community-level determinants of height-for-age z-scores for children between 5 and 11 years of age

	Log per capita expenditure
Intercept	11.167 (0.245)***
Age	0.003 (0.038)
Age squared	0.001 (0.002)
Female	-0.016 (0.015)
Birth order	-0.066 (0.027)**
Birth order squared	0.004 (0.003)
Any schooling mother	0.155 (0.058)***
Any schooling household head	0.083 (0.048)*
Female household head	0.068 (0.081)
Mother's age	0.001 (0.002)
Household size	-0.023 (0.007)***
Dependency ratio	-0.044 (0.022)*
Number of children <2 years	-0.018 (0.028)
Polygamous	0.029 (0.037)
Urban	0.266 (0.108)**
Koulikoro	0.201 (0.083)**
Mopti	-0.459 (0.048)***
Log per capita wealth	0.096 (0.012)***
Unearned income	0.000 (0.000)***
Number	3,766
F-statistic	30.46
R-squared	0.27

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

Table B-2 Male to female ratios by age year for the children 2–15 years of age for whom anthropometric data were recorded

Age	Male	Female	Total	Male to female ratio
2	203	201	404	1.01
3	323	291	614	1.11
4	417	358	775	1.16
5	434	339	773	1.28
6	429	401	830	1.07
7	374	363	737	1.03
8	409	372	781	1.10
9	268	276	544	0.97
10	368	363	731	1.01
11	164	176	340	0.93
12	337	265	602	1.27
13	231	208	439	1.11
14	200	198	398	1.01
15	203	148	351	1.37
Total	3,417	3,109	6,526	1.10

Table B-3 Estimation of child-, household-, and community-level determinants of height-for-age z-scores for children between 5 and 11 years of age, with mother's and household head's education attainment and with any schooling any mother

	Height-for-age z-score	
	(A) OLS	(B) OLS
Intercept	-5.676 (1.011)***	-5.647 (1.015)***
Age	0.762 (0.152)***	0.758 (0.152)***
Age squared	-0.056 (0.010)***	-0.056 (0.010)***
Female	0.113 (0.052)**	0.112 (0.052)**
Birth order	0.416 (0.070)***	0.417 (0.069)***
Birth order squared	-0.007 (0.008)	-0.007 (0.008)
Log per capita expenditure [a]	0.061 (0.066)	0.062 (0.066)
Mother's education attainment	-0.083 (0.063)	
Any schooling any mother		-0.045 (0.128)
Household head's education attainment	-0.218 (0.027)***	-0.229 (0.032)***
Female household head	0.130 (0.356)	0.132 (0.355)
Mother's age	0.032 (0.005)***	0.032 (0.005)***
Household size	-0.035 (0.020)*	-0.036 (0.020)*
Dependency ratio	-0.204 (0.050)***	-0.204 (0.050)***
Number of children <2 years	-0.428 (0.065)***	-0.429 (0.065)***
Polygamous	-0.217 (0.107)**	-0.216 (0.108)**
Urban	0.048 (0.146)	0.032 (0.134)
Koulikoro	0.200 (0.189)	0.198 (0.189)
Mopti	-0.515 (0.105)***	-0.525 (0.105)***
Number	3,780	3,780
F-statistic	28.58	20.78
R-squared	0.10	0.10

[a] Potentially endogenous variable.
* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01
For all models, standard errors (in parentheses) are clustered at the village level.

Table B-4 First stage regression in IV/2SLS estimation of child-, household-, and community-level determinants of height-for-age z-scores for children between 5 and 11 years of age, including production diversity

	PDS
Intercept	1.951 (0.874)**
Age	0.146 (0.068)**
Age squared	-0.008 (0.004)*
Female	0.025 (0.030)
Birth order	-0.064 (0.045)
Birth order squared	0.004 (0.004)
Log per capita expenditure	0.010 (0.059)
Any schooling mother	-0.116 (0.108)
Any schooling household head	-0.020 (0.084)
Female household head	-0.174 (0.178)
Mother's age	-0.006 (0.003)*
Household size	0.036 (0.012)***
Dependency ratio	0.016 (0.036)
Number of children <2 years	-0.025 (0.044)
Polygamous	-0.023 (0.058)
Urban	-0.178 (0.214)
Koulikoro	0.146 (0.143)
Mopti	0.677 (0.136)***
Irrigation	0.754 (0.097)***
Land cultivated	0.030 (0.011)***
Number	3,780
F-statistic	13.35
R-squared	0.17

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

Table B-5 Estimation of child-, household-, and community-level determinants of height-for-age z-scores for children between 5 and 11 years of age, including production variety

	Height-for-age z-score	
	(C) OLS	(D) IV/2SLS
Intercept	-5.630	-5.493
	(1.010)***	(1.094)***
Age	0.757	0.747
	(0.151)***	(0.150)***
Age squared	-0.056	-0.055
	(0.010)***	(0.009)***
Female	0.112	0.111
	(0.051)**	(0.051)**
Birth order	0.418	0.419
	(0.070)***	(0.069)***
Birth order squared	-0.007	-0.007
	(0.008)	(0.008)
Log per capita expenditure [a]	0.060	0.042
	(0.066)	(0.084)
Any schooling mother	-0.031	-0.026
	(0.114)	(0.114)
Any schooling household head	-0.019	-0.009
	(0.103)	(0.109)
Female household head	0.139	0.162
	(0.357)	(0.362)
Mother's age	0.032	0.032
	(0.005)***	(0.005)***
Household size	-0.037	-0.042
	(0.019)*	(0.024)*
Dependency ratio	-0.205	-0.205
	(0.050)***	(0.049)***
Number of children <2 years	-0.429	-0.429
	(0.066)***	(0.066)***
Polygamous	-0.220	-0.217
	(0.108)**	(0.107)**
PVS [a]	0.007	0.040
	(0.019)	(0.079)
Urban	0.043	0.074
	(0.135)	(0.157)
Koulikoro	0.193	0.172
	(0.191)	(0.202)
Mopti	-0.539	-0.598
	(0.116)***	(0.185)***
Number	3,780	3,780
F-statistic	13.08	13.08
R-squared	0.10	0.10
Hansen J statistic		1.19
p-value of Hansen J statistic		0.274
LM test statistic for underidentification		34.75
p-value of underidentification LM statistic		0.000
F statistic for weak identification		17.63
p-value of Anderson-Rubin F-test		0.444
p-value of Anderson-Rubin chi-sq test		0.436

[a] Potentially endogenous variable.
* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01
For all models, standard errors (in parentheses) are clustered at the village level. For model D, only PVS is instrumented for, using household irrigation and household cultivated land.

Table B-6 First stage regression in IV/2SLS estimation of child-, household-, and community-level determinants of height-for-age z-scores for children between 5 and 11 years of age, including production variety

	PVS
Intercept	-2.801 (1.498)*
Age	0.333 (0.129)**
Age squared	-0.019 (0.008)**
Female	0.042 (0.061)
Birth order	-0.017 (0.082)
Birth order squared	-0.006 (0.007)
Log per capita expenditure	0.408 (0.103)***
Any schooling mother	-0.148 (0.214)
Any schooling household head	-0.337 (0.157)**
Female household head	-0.602 (0.297)**
Mother's age	-0.013 (0.006)**
Household size	0.123 (0.027)***
Dependency ratio	-0.000 (0.077)
Number of children <2 years	0.004 (0.106)
Polygamous	-0.064 (0.133)
Urban	-0.727 (0.339)**
Koulikoro	0.477 (0.283)*
Mopti	1.784 (0.235)***
Irrigation	1.157 (0.237)***
Land cultivated	0.078 (0.019)***
Number	3,780
F-statistic	16.85
R-squared	0.21

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

Table B-7 First stage regression in IV/2SLS estimation of child-, household-, and community-level determinants of height-for-age z-scores for children between 5 and 11 years of age, including dietary diversity

	DDS
Intercept	-6.695 (1.304)***
Age	-0.137 (0.097)
Age squared	0.009 (0.006)
Female	-0.026 (0.041)
Birth order	0.111 (0.057)*
Birth order squared	-0.014 (0.005)***
Log per capita expenditure	0.911 (0.096)***
Any schooling mother	0.153 (0.121)
Any schooling household head	0.083 (0.118)
Female household head	0.176 (0.251)
Mother's age	0.006 (0.004)
Household size	0.051 (0.017)***
Dependency ratio	-0.006 (0.054)
Number of children <2 years	0.189 (0.064)***
Polygamous	-0.003 (0.107)
Urban	0.622 (0.158)***
Koulikoro	0.101 (0.162)
Mopti	0.583 (0.153)***
Log per capita wealth	0.093 (0.029)***
Own poultry	0.428 (0.079)***
Number	3,766
F-statistic	11.90
R-squared	0.22

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

Table B-8 First stage regression in IV/2SLS estimation child-, household-, and community-level determinants of height-for-age z-scores calculated using reported age in years minus one year, for children with reported age in years minus one year of between 5 and 10 years of age

	Log per capita expenditure
Constant	11.007
	(0.277)***
Age	0.044
	(0.056)
Age squared	-0.002
	(0.004)
Female	-0.016
	(0.017)
Birth order	-0.065
	(0.028)**
Birth order squared	0.003
	(0.003)
Any schooling mother	0.144
	(0.060)**
Any schooling household head	0.085
	(0.047)*
Female household head	0.121
	(0.078)
Mother's age	0.001
	(0.002)
Household size	-0.018
	(0.007)**
Dependency ratio	-0.040
	(0.024)*
Number of children <2 years	-0.016
	(0.028)
Polygamous	0.028
	(0.040)
Urban	0.277
	(0.109)**
Koulikoro	0.214
	(0.087)**
Mopti	-0.461
	(0.049)***
Log per capita wealth	0.093
	(0.013)***
Unearned income	0.000
	(0.000)***
Number	3,148
F-statistic	26.52
R-squared	0.26

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

Appendix C. Kenya school feeding and the school environment descriptive statistics

Schools and teachers by division, and enrollment by division and by gender

Of the 101 schools, 35 were in Lunga Lunga, 27 in Diani, 20 in Kubo, and 19 in Msambweni (see Table C-1). The total enrollment reported in all the schools in ECD–P8 was 62,186 (31,864 boys and 30,322 girls), an average of 616 students enrolled per school. The total number of teachers was 1,145.

Mean student-to-teacher ratio and mean student-to-classroom ratio, by division

The mean and 95% C.I. student-to-teacher ratio overall was 54.5 (49.4, 59.6), and the mean student-to-classroom ratio was 52.8 (49.1, 56.6) (see Table C-2). Lunga Lunga had a significantly higher student-to-teacher ratio and student-to-classroom than the other three divisions (p-values $\leq$ 0.01 and 0.05, respectively).

Mean attendance rate, mean percentage of children who go home for lunch, and mean desk-to-student ratio in P3 and P7, by division

For P3 and P7, the number of children present on the day, the number of children who go home for lunch, and the number of desks in the classroom were recorded (see Table C-3).

The overall mean attendance rates and 95% C.I. were 0.85 (0.81, 0.89) for P3 and 0.85 (0.81, 0.88) for P7, with significant differences observed between the divisions. For the percentage of children who go home for lunch, the mean was higher for P3 (83% [76%, 89%]) than for P7 (73% [65%, 81%]) (p-value $\leq$ 0.05). The desk-to-student ratio in P3 was 0.38 (0.35, 0.41), significantly lower than the 0.47 (0.44, 0.51) ratio in P7 (p-value $\leq$ 0.01). Significant differences were also observed between the divisions.

School environment, by division

In terms of deworming, 92.1% of schools reported receiving mass albendazole/mebendazole treatment by the MoE/MoH in the last 12 months, and 66.3% reported receiving mass praziquantel treatment.

Overall, 60.4% of schools reported snacks being sold on the school compound, and 27.7% reported having electricity anywhere on the school compound.

For types of sanitary facilities, 87.1% of schools reported having an ordinary latrine, 7.9% reported having a VIP latrine, and 5.0% reported have another type of latrine. The mean student-to-functional-sanitary-facility ratio was 70.4 (61.8, 79.1) for boys and 61.8 (53.0, 70.5) for girls, a borderline statistically significant difference (p-value ≤ 0.10).

Overall, 73.3% of schools reported having a source of drinking water within the school compound, and 26.7% reported having hand washing facilities.

The mean amount of time to walk from the school to the nearest town center was 22.5 (18.0, 27.0) minutes, and the mean amount of time to walk to the school from the farthest point in the school's catchment area was 67.2 (61.3, 73.2) minutes. The mean percentage of pupils who walk more than 30 minutes to get to the school every day was 49.2% (44.6%, 53.8%).

These school environment statistics, disaggregated by region, can be found in Table C-4.

Number of schools with school feeding and number of school feeding programs, by division

Thirty-five schools reported not having school feeding programs, and 66 schools reported having a past (since 2008) or present school feeding program or one planned for the future (next term) (see Table C-5). As alternatives to school feeding, 82% of schools reported that children go home for lunch, 12% reported that children carry their food with them, and 6% reported that parents bring in food.

As schools could have past, present, and future programs as well as multiples of each, 104 programs in total were reported (63 past programs, 25 present programs, and 16 future programs.

Program implementers and type of school feeding program, by division

In terms of program implementers (more than one implementer possible), 51.0% of programs reported the government as implementer, 34.6% reported WFP, 26.9% reported parents, 12.5% reported NGOs, and 1.9% reported individuals.

For the type of program, 33.7% of programs reported expanded school feeding as the type, 21.2% reported emergency school feeding, 13.5% reported regular school feeding, 2.9% reported HGSM, and 28.9% reported other.

These statistics, disaggregated by region, can be found in Table C-6 and Table C-7.

Type of meal/snack/ration and type of transfer, by division

For the type of meal/snack/ration served (more than one possible), 83.7% of programs reported serving lunch, 16.3% reported serving breakfast, and 5.8% reported breakfast and lunch for ECD. No programs reported serving snacks, fortified snacks, or take-home rations.

In terms of the type of transfer, 59.6% of programs reported receiving food, 35.6% reported receiving cash, and 4.8% reported receiving both.

These statistics, disaggregated by region, can be found in Table C-8 and Table C-9.

Cash transfer programs: frequency of transfer, funding shortfalls, food procurement and origin, and program management, by division

Of the cash transfer school feeding programs, 51.2% reported receiving funds once a term, 32.6% reported once a month, 4.7% reported once a week, 4.7% reported once every two weeks, 4.7% reported once a year, and 2.3% reported other (see Table C-10).

In terms of funding shortfalls, 51.4% of cash transfer programs reported shortfalls due to increased food prices, 25.7% due to the actual enrollment being greater than the enrollment the transfer was intended to cover, 2.9% due to unexpected losses, and 8.6% due to other reasons (see Table C-11).

For the frequency of food procurement, 41.9% of cash transfer school feeding programs reported procuring food once a term, 37.2% monthly, 14.0% weekly, and 7.0% other (see Table C-12).

In terms of from whom the food was procured directly, 66.7% of cash transfer school feeding programs reported procuring from wholesale traders, 23.8% from local retailers, and 9.5% from local retailers (see Table C-13). No program reported procuring from farmer groups.

Tracking back where the food procurer purchased the food, 61.9% of cash transfer school feeding programs reported that the food came from Mombasa, 33.3% reported it coming from the local market, and 5.3% reported other (see Table C-14).

For the food procurement processes, 90.5% of cash transfer school feeding programs reporting having rules on which types of food can be procured, 79.1% reported inspecting food upon delivery, 64.3% reporting advertizing tenders, and 57.1% reporting having rules on from whom food can be procured (see Table C-15).

In terms of program management structures, 46.5% of cash transfer school feeding programmers reported having the school management committee active in managing the program, 39.5% reported the school feeding management committee, and 14.0% reported the parent teacher association (see Table C-16).

Food transfer programs: frequency of delivery and gaps and shortfalls, by division

For food transfer school feeding programs, 52.9% of programs reported receiving food deliveries once a term, 29.4% once a month, 5.9% once every two weeks, 4.4% once a week, and 7.4% other (see Table C-17).

In terms of gaps and shortfalls, 20.6% of food transfer school feeding programs report being ever unable to reach intended beneficiaries. Of these programs, 50.0% cited less food being delivered than expected as the reason for the shortfall, 14.3% cited increased enrollment over time, and 35.7% cited another reason (see Table C-18). No programs cited food spoilage or late delivery as reasons for gaps or shortfalls.

Nutrition: types of food regularly served and food fortification, by division

Of the 104 school feeding programs, 98 reported information on the types and quantities of food and any fortification included in the program. The following is an analysis of the nutrition content of those 98 programs.

In terms of staples, 79.6% of programs reported regularly serving maize, 65.3% beans, 32.7% pulses, 20.4% rice, 18.4% uji (a type of porridge), 8.2% wheat, and 5.1% porridge. Additionally, 81.6% of programs reported regularly serving oil and 40.8% reported serving salt. Less than five percent of programs reported regularly serving ugali, greens, bread, fruit, meat, and chai. (See Table C-19, along with Table C-20, which reports mean serving sizes.)

For food fortification, 31.2% of school feeding programs reported having fortified food. Of these fortified programs, 44.8% reported having vitamin B12 fortification, 41.4% iron, 34.5% iodine, 31.0% vitamin B6, 20.7% vitamin A, and 17.2% other (see Table C-21).

Food preparation and cooking

For statistics on food preparation and cooking, see Table C-22.

Table C-1 Schools and teachers by division, and enrollment by division and by gender

	Number of schools	Number of boys enrolled ECD–P8	Number of girls enrolled ECD–P8	Total number enrolled ECD–P8*	Total number of teachers
Diani	27	8,608	8,166	16,774	327
Kubo	20	4,478	4,194	8,672	186
Lunga Lunga	35	13,221	12,575	25,796	378
Msambweni	19	5,557	5,387	10,944	254
Total	101	31,864	30,322	62,186	1,145

*There was 1 missing value for ECD, 1 for P7, and 4 for P8 for each the boys and the girls.

Table C-2 Mean student-to-teacher ratio and mean student-to-classroom ratio, by division (mean, followed by 95% C.I.)

	Student-to-teacher ratio	Student-to-classroom ratio
Diani	47.3[a]	49.4[d]
	(43.4, 51.2)	(45.5, 53.2)
Kubo	47.3[b]	45.3[e]
	(36.3, 58.4)	(35.0, 55.7)
Lunga Lunga	70.1[abc]	62.3[def]
	(58.8, 81.3)	(55.1, 69.6)
Msambweni	44.6[c]	48.1[f]
	(39.0, 50.2)	(42.8, 53.4)
Total	54.5	52.8
	(49.4, 59.6)	(49.1, 56.6)
Number of observations	97	101

[a] p-value ≤ 0.01
[b] p-value ≤ 0.01
[c] p-value ≤ 0.01
[d] p-value ≤ 0.05
[e] p-value ≤ 0.01
[f] p-value ≤ 0.05

Table C-3 Mean attendance rate, mean percentage of children who go home for lunch, and mean desk-to-student ratio in P3 and P7, by division (average, followed by 95% C.I.)

	Mean attendance rate		Mean percentage of children who go home for lunch		Mean desk-to-student ratio	
	P3	**P7**	**P3**	**P7**	**P3**	**P7**
Diani	0.90[a]	0.88	88%	85%	0.44[dg]	0.51[g]
	(0.85, 0.96)	(0.83, 0.94)	(81%, 95%)	(78%, 91%)	(0.39, 0.49)	(0.44, 0.57)
Kubo	0.95[b]	0.91[c]	79%	68%	0.40	0.46
	(0.90, 0.99)	(0.84, 0.97)	(63%, 96%)	(51%, 86%)	(0.35, 0.45)	(0.38, 0.54)
Lunga Lunga	0.75[ab]	0.78[c]	79%	64%	0.30[deh]	0.44[h]
	(0.68, 0.83)	(0.71, 0.85)	(63%, 94%)	(45%, 84%)	(0.25, 0.35)	(0.38, 0.49)
Msambweni	0.85	0.85	83%	76%	0.41[e]	0.50
	(0.76, 0.94)	(0.74, 0.95)	(73%, 94%)	(61%, 90%)	(0.35, 0.45)	(0.41, 0.60)
Total	0.85	0.85	83%[f]	73%[f]	0.38[i]	0.47[i]
	(0.81, 0.89)	(0.81, 0.88)	(76%, 89%)	(65%, 81%)	(0.35, 0.41)	(0.44, 0.51)
Number of observations	97	95	78	90	95	94

[a] p-value ≤ 0.05
[b] p-value ≤ 0.01
[c] p-value ≤ 0.10
[d] p-value ≤ 0.01
[e] p-value ≤ 0.10
[f] p-value ≤ 0.05
[g] p-value ≤ 0.05
[h] p-value ≤ 0.01
[i] p-value ≤ 0.01

Table C-4 School environment, by division (all variables had 101 observations)

	Diani	Kubo	Lunga Lunga	Msambweni	Total
% of schools with deworming					
albendazole/mebendazole	96.3%	85.0%	88.6%	100.0%	92.1%
praziquantel	74.1%	55.0%	71.4%	57.9%	66.3%
% of schools with snacks sold on school compound	92.6%[ab]	30.0%[ac]	48.6%[b]	68.4%[c]	60.4%
% of schools with electricity	37.0%	25.0%	17.1%	36.8%	27.7%
type of sanitary facilities					
water borne	0.0%	0.0%	0.0%	0.0%	0.0%
VIP latrine	18.5%	0.0%	2.9%	10.5%	7.9%
ordinary latrine	70.4%	100.0%	97.1%	79.0%	87.1%
other	11.1%	0.0%	0.0%	10.5%	5.0%
mean student-to-functional-sanitary-facility ratio					
boys	75.7 (55.7, 95.8)	61.5 (43.2, 79.9)	75.3 (60.7, 90.0)	63.3 (48.8, 77.8)	70.4[d] (61.8, 79.1)
girls	74.1 (52.2, 95.9)	46.4 (31.7, 61.0)	66.7 (52.2, 81.3)	51.3 (38.7, 64.0)	61.8[d] (53.0, 70.5)
% of schools with drinking water	81.5%	75.0%	68.6%	68.4%	73.3%
% of schools with hand washing facilities	18.5%	25.0%	37.1%	21.1%	26.7%
mean time (in minutes) to walk from the school to the nearest town center	22.3 (16.7, 27.9)	22.9 (8.8, 37.0)	25.5 (16.9, 34.2)	16.9 (10.0, 23.4)	22.5 (18.0, 27.0)
mean time (in minutes) to walk to the school from the farthest point in the school's catchment area	66.9 (50.5, 83.2)	66.8 (55.0, 78.5)	73.9 (65.2, 82.6)	56.1 (49.2, 62.9)	67.2 (61.3, 73.2)
mean percentage of pupils that walk more than 30 minutes to get to the school	43.5% (33.7%, 53.3%)	50.5% (40.1%, 60.3%	53.4% (47.0%, 59.8%)	48.2% (35.8%, 60.5%)	49.2% (44.6%, 53.8%)

[a] p-value ≤ 0.01
[b] p-value ≤ 0.01
[c] p-value ≤ 0.05
[d] p-value ≤ 0.10

Table C-5 Number of schools with school feeding and number of school feeding programs, by division

	Diani	Kubo	Lunga Lunga	Msambweni	Total
number of schools	6	19	28	13	66
number of programs	11	34	45	14	104
past	2	26	27	8	63
present	5	3	12	5	25
future	4	5	6	1	16

Table C-6 % of programs with [blank] as an implementer (more than one possible), by division

	Diani	Kubo	Lunga Lunga	Msambweni	Total
WFP	9.1%	44.1%	31.1%	42.9%	34.6%
Government	9.1%	73.5%	48.9%	35.7%	51.0%
parents	36.4%	2.9%	37.8%	42.9%	26.9%
community group	0.0%	0.0%	0.0%	0.0%	0.0%
NGO	36.4%	8.8%	11.1%	7.1%	12.5%
individual	18.2%	0.0%	0.0%	0.0%	1.9%

Table C-7 % of programs that are [blank] type of school feeding, by division (104 observations)

	Diani	Kubo	Lunga Lunga	Msambweni	Total
regular school feeding	27.3%	8.8%	11.1%	21.4%	13.5%
expanded school feeding	9.1%	47.1%	28.9%	35.7%	33.7%
emergency school feeding	0.0%	38.2%	17.8%	7.1%	21.2%
HGSM	0.0%	5.9%	2.2%	0.0%	2.9%
NMK	0.0%	0.0%	0.0%	0.0%	0.0%
other	64.6%	0.0%	40.0%	35.7%	28.9%

Table C-8 % of programs that provide [blank] as the type of meal/snack/ration (more than one possible), by division (104 observations)

	Diani	Kubo	Lunga Lunga	Msambweni	Total
breakfast	45.5%	2.9%	11.1%	42.9%	16.3%
snack	0.0%	0.0%	0.0%	0.0%	0.0%
breakfast and lunch for ECD	9.1%	5.9%	4.4%	7.1%	5.8%
lunch	54.5%	94.1%	91.1%	57.1%	83.7%
fortified snack	0.0%	0.0%	0.0%	0.0%	0.0%
take-home rations	0.0%	0.0%	0.0%	0.0%	0.0%

Table C-9 % of programs that receive [blank] as a transfer, by division (104 observations)

	Diani	Kubo	Lunga Lunga	Msambweni	Total
cash	36.4%	55.9%	24.4%	21.4%	35.6%
food	63.6%	44.1%	66.7%	71.4%	59.6%
both	0.0%	0.0%	8.9%	7.1%	4.8%

Table C-10 % of cash transfer school feeding programs that receive funds [blank] often, by division (43 observations)

	Diani	Kubo	Lunga Lunga	Msambweni	Total
once a week	0.0%	5.0%	6.7%	0.0%	4.7%
once every two weeks	0.0%	5.0%	0.0%	25.0%	4.7%
once a month	25.0%	25.0%	33.3%	75.0%	32.6%
once a term	75.0%	55.0%	53.3%	0%	51.2%
once a year	0.0%	5.0%	6.7%	0.0%	4.7%
other	0.0%	5.0%	0.0%	0.0%	2.3%

Table C-11 % of cash transfer school feeding programs with funding shortfalls due to [blank], by division (35 observations)

	Diani	Kubo	Lunga Lunga	Msambweni	Total
actual enrollment greater than enrollment the transfer was intended to cover	0.0%	26.7%	35.7%	0.0%	25.7%
increased food prices	25.0%	60.0%	50.0%	50.0%	51.4%
transport costs	0.0%	0.0%	0.0%	0.0%	0.0%
unexpected losses	25.0%	0.0%	0.0%	0.0%	2.9%
other	0.0%	6.7%	14.3%	0.0%	8.6%
N/A	50.0%	6.7%	0.0%	50.0%	11.4%

Table C-12 % of cash transfer school feeding programs that procure food [blank] often, by division (43 observations)

	Diani	Kubo	Lunga Lunga	Msambweni	Total
daily	0.0%	0.0%	0.0%	0.0%	0.0%
weekly	25.0%	0%	20.0%	50.0%	14.0%
monthly	75.0%	30.0%	33.3%	50.0%	37.2%
once a term	0.0%	60.0%	40.0%	0.0%	41.9%
other	0.0%	10.0%	6.7%	0.0%	7.0%

Table C-13 % of cash transfer school feeding programs that procure their food directly from [blank], by division (42 observations)

	Diani	Kubo	Lunga Lunga	Msambweni	Total
individual farmers	25.0%	10.5%	6.7%	0.0%	9.5%
farmer groups	0.0%	0.0%	0.0%	0.0%	0.0%
wholesale traders	75.0%	79.0%	66.7%	0.0%	66.7%
local retailers	0.0%	10.5%	26.7%	100%	23.8%

Table C-14 % of cash transfer school feeding programs where the origin of the food procured is [blank], by division (42 observations)

	Diani	Kubo	Lunga Lunga	Msambweni	Total
Mombasa	75.0%	52.6%	66.7%	75.0%	61.9%
Tanzania	0.0%	0.0%	0.0%	0.0%	0.0%
local market	25.0%	42.1%	26.7%	25.0%	33.3%
other	0.0%	5.3%	6.7%	0.0%	5.3%

Table C-15 % of cash transfer school feeding programs that have [blank], by division

	Diani	Kubo	Lunga Lunga	Msambweni	Total	Number of observations
rules on from whom food can be procured	25.0%	73.7%	60.0%	0.0%	57.1%	42
rules on which types of food can be procured	100.0%	89.5%	86.7%	100.0%	90.5%	42
advertized tenders	0.0%	94.7%	60.0%	0.0%	64.3%	42
food inspected on delivery	100.0%	73.7%	87.5%	50.0%	79.1%	43

Table C-16 % of cash transfer school feeding programs that have [blank] active in managing the program, by division (43 observations)

	Diani	Kubo	Lunga Lunga	Msambweni	Total
school management committee	0.0%	57.9%	37.5%	75.0%	46.5%
school feeding management committee	100.0%	42.1%	31.3%	0.0%	39.5%
parent teacher association	0.0%	0.0%	31.3%	25.0%	14.0%

Table C-17 % of food transfer school feeding programs that receive deliveries [blank] often, by division (68 observations)

	Diani	Kubo	Lunga Lunga	Msambweni	Total
once a week	28.6%	0.0%	2.9%	0.0%	4.4%
once every two weeks	14.3%	20.0%	0.0%	0.0%	5.9%
once a month	28.6%	6.7%	37.1%	36.4%	29.4%
once a term	28.6%	66.7%	48.6%	63.6%	52.9%
other	0.0%	6.7%	11.4%	0.0%	7.4%

Table C-18 % of food transfer school feeding programs that have any times when they are unable to reach the intended beneficiaries, what these gaps and shortfalls are due to, by division

	Diani	Kubo	Lunga Lunga	Msambweni	Total	Number of observations
% of food transfer school feeding programs ever unable to reach intended beneficiaries	14.3%	20.0%	17.1%	36.4%	20.6%	68
reasons for the gaps and shortfalls (% of food transfer school feeding programs ever unable to reach intended beneficiaries, more than one possible)						14
increased enrollment over time	0.0%	25.0%	0.0%	16.7%	14.3%	
less food delivered than expected	100.0%	50.0%	33.3%	50.0%	50.0%	
food spoilage after delivery	0.0%	0.0%	0.0%	0.0%	0.0%	
food spoilage before delivery	0.0%	0.0%	0.0%	0.0%	0.0%	
late delivery	0.0%	0.0%	66.7%	0.0%	0.0%	
other	0.0%	25.0%	33.3%	50.0%	35.7%	

Table C-19 % of school feeding programs that regularly serve [blank], by division (98 observations)

	Diani	Kubo	Lunga Lunga	Msambweni	Total
maize	64.6%	86.7%	83.7%	64.3%	79.6%
pulses	0.0%	36.7%	34.9%	42.9%	32.7%
oil	54.5%	100.0%	86.1%	50.0%	81.6%
wheat	0.0%	10.0%	11.6%	0.0%	8.2%
rice	36.4%	33.3%	14.0%	0.0%	20.4%
beans	63.6%	80.0%	69.8%	21.4%	65.3%
salt	45.5%	46.7%	39.5%	28.6%	40.8%
uji	27.3%	6.7%	16.3%	42.9%	18.4%
ugali	18.2%	0.0%	0.0%	7.1%	3.1%
greens	18.2%	0.0%	2.3%	0.0%	3.1%
fruit	9.1%	0.0%	0.0%	0.0%	1.0%
meat	9.1%	0.0%	0.0%	0.0%	1.0%
biscuits	0.0%	0.0%	0.0%	0.0%	0.0%
bread	9.1%	3.3%	0.0%	0.0%	2.0%
porridge	27.3%	0.0%	4.7%	0.0%	5.1%
chai	9.1%	0.0%	0.0%	0.0%	1.0%
other	0.0%	3.3%	2.3%	7.1%	3.1%

Table C-20 Mean serving size (in grams) for the programs that report quantities for these food types, by division

	Diani	Kubo	Lunga Lunga	Msambweni	Total	Number of observations
maize	102.5 (57.5, 147.5)	150.0 (–)	200.2 (140.3, 260.0)	132.9 (98.6, 167.1)	170.0 (141.0, 199.0)	62
pulses	–	40.0 (–)	51.3 (31.0, 71.6)	42.0 (37.9, 46.1)	45.9 (35.8, 56.1)	32
oil	0.4 (-0.1, 0.8)	8.8 (3.5, 14.1)	8.9 (2.2, 15.7)	5.0 (–)	8.3 (4.4, 12.2)	64
wheat	–	150.0 (–)	150.0 (–)	–	150.0 (–)	8
rice	80.0 (–)	150.0 (–)	278.4 (22.0, 534.8)	–	201.8 (87.9, 315.7)	16
beans	122.5 (117.5, 127.5)	38.8 (35.1, 42.4)	73.3 (42.1, 104.4)	50.0 (–)	58.5 (42.9, 74.1)	44
salt	<0.1 (–)	134.9 (-50.1, 319.9)	2.75 (2.1, 3.4)	3.0 (–)	66.6 (-24.7, 157.9)	31
uji	–	40.0 (–)	110.0 (-61.3, 281.3)	43.3 (35.2, 51.5)	71.4 (-1.5, 144.3)	7
ugali	165.0 (-915.0, 1,245.0)	–	–	–	165.0 (-915.0, 1,245.0)	2
greens	125.0 (-197.7, 447.7)	–	0.4 (–)	–	83.5 (-174.7, 341.6)	3
fruit	10.0 (–)	–	–	–	10.0 (–)	1
meat	1.0 (–)	–	–	–	1.0 (–)	1
biscuits	–	–	–	–	–	0
bread	–	–	–	–	–	0
porridge	250.0 (–)	–	40 (–)	–	197.5 (30.4, 364.6)	4
chai	–	–	–	–	–	0
other	NA	NA	NA	NA	NA	NA

Table C-21 % of school feeding programs that have fortified food, including which micronutrients, by division

	Diani	Kubo	Lunga Lunga	Msambweni	Total	Number of observations
% of school feeding programs that have fortified food	10.0%	30.0%	38.5%	28.6%	31.2%	93
% of fortified food school feeding programs that have [blank] micronutrient fortification						
iron	0.0%	66.7%	33.3%	25.0%	41.4%	12
iodine	0.0%	11.1%	53.3%	25.0%	34.5%	10
zinc	0.0%	0.0%	0.0%	0.0%	0.0%	0
vitamin B6	100%	44.4%	26.7%	0.0%	31.0%	9
vitamin B12	0.0%	55.6%	53.3%	0.0%	44.8%	13
vitamin A	0.0%	44.4%	6.7%	25.0%	20.7%	6
other	0.0%	11.1%	20.0%	25.0%	17.2%	5

Table C-22 Food preparation and cooking, by division

	Diani	Kubo	Lunga Lunga	Msambweni	Total	Number of observations
% of schools with a school garden						64
cultivated this year	33.3%	44.4%	48.2%	30.8%	42.2%	
not cultivated this year	50.0%	50.0%	40.7%	23.1%	40.6%	
% of schools with school kitchen						64
permanent	33.3%	44.4%	14.8%	15.4%	25.0%	
temporary	50.0%	55.6%	81.5%	76.9%	70.3%	
% of schools with a designated eating area						64
permanent	16.7%	0.0%	0.0%	7.7%	3.1%	
temporary	33.3%	33.3%	29.6%	23.1%	29.7%	
% of schools with a designated food storage room						64
permanent	50.0%	83.3%	29.6%	30.8%	46.9%	
temporary	16.7%	16.7%	48.2%	38.5%	34.4%	
average length of time (in months) food can be stored in the area without becoming spoiled	3.0 (0.8, 5.2)	6.4 (4.3, 8.5)	4.9 (2.5, 7.4)	2.9 (2.0, 3.8)	4.9 (3.6, 6.2)	55
% of schools where food is cooked within the school compound	100.0%	100.0%	100.0%	100.0%	100.0%	63
% of schools who have [blank] cooking/preparing the food (more than one answer possible)						64
hired cooks	83.3%	100.0%	96.3%	84.6%	93.8%	
pupils	0.0%	0.0%	0.0%	0.0%	0.0%	
teachers	0.0%	0.0%	0.0%	7.7%	1.6%	
parents	16.7%	0.0%	7.4%	15.4%	7.8%	
% of schools where [blank] pays for the cooks						60
parents	40.0%	100.0%	100.0%	100.0%	95.0%	
school	0.0%	0.0%	0.0%	0.0%	0.0%	
NGO	60.0%	0.0%	0.0%	0.0%	5.0%	
% of schools where [blank] amount of time is required for cooking each day						63
less than 1 hour	0.0%	0.0%	7.7%	30.7%	9.5%	
over 1 hour	33.3%	11.1%	23.1%	7.7%	17.5%	
over 2 hours	50.0%	50.0%	38.5%	61.5%	47.6%	
over 3 hours	16.7%	33.3%	26.9%	0.0%	22.2%	
over 4 hours	0.0%	5.6%	3.9%	0.0%	3.2%	

% of schools where [blank] amount of time is required for distributing the food each day						64
less than 30 minutes	0.0%	27.8%	18.5%	30.7%	21.9%	
30 minutes to 1 hour	100.0%	61.1%	63.0%	69.2%	67.2%	
over 1 hour	0.0%	11.1%	18.5%	0.0%	10.9%	
% of schools where [blank] provide(s) kitchen/storeroom infrastructure						63
WFP	0.0%	5.6%	0.0%	0.0%	1.6%	
Government	0.0%	0.0%	0.0%	0.0%	0.0%	
parents	83.3%	72.2%	88.5%	76.9%	81.0%	
children	0.0%	0.0%	0.0%	0.0%	0.0%	
NGO	16.7%	0.0%	0.0%	0.0%	1.6%	
other	0.0%	22.2%	11.5%	23.1%	15.9%	
% of schools where [blank] provide(s) utensils						64
WFP	0.0%	0.0%	14.8%	0.0%	6.3%	
Government	0.0%	11.1%	14.8%	0.0%	9.4%	
parents	50.0%	66.7%	40.7%	69.2%	54.7%	
children	0.0%	5.6%	14.8%	0.0%	7.8%	
NGO	33.3%	0.0%	3.7%	0.0%	4.7%	
other	16.7%	16.7%	11.1%	30.7%	17.2%	
% of schools where [blank] provide(s) payments of cooks						63%
WFP	0.0%	0.0%	0.0%	0.0%	0.0%	
Government	0.0%	0.0%	0.0%	0.0%	0.0%	
parents	50.0%	94.4%	96.2%	92.3%	90.5%	
children	0.0%	5.6%	3.9%	0%	3.2%	
NGO	50.0%	0.0%	0.0%	0.0%	4.8%	
other	0.0%	0.0%	0.0%	7.7%	1.6%	
% of schools where [blank] provide(s) cooking fuel						63
WFP	0.0%	0.0%	0.0%	0.0%	0.0%	
Government	0.0%	0.0%	0.0%	0.0%	0.0%	
parents	50.0%	50.0%	46.2%	46.2%	47.6%	
children	33.3%	44.4%	53.9%	38.5%	46.0%	
NGO	16.7%	0.0%	0.0%	0.0%	1.6%	
other	0.0%	5.6%	0.0%	15.4%	4.8%	
% of schools where [blank] provide(s) water for cooking						63
WFP	0.0%	0.0%	3.7%	0.0%	1.6%	
Government	0.0%	0.0%	0.0%	0.0%	0.0%	
parents	16.7%	23.5%	29.6%	53.9%	31.8%	
children	33.3%	29.4%	18.5%	15.4%	22.2%	
NGO	50.0%	5.9%	0.0%	0.0%	6.4%	
other	0.0%	41.2%	48.2%	30.8%	38.1%	
% of schools where [blank] provide(s) children's bowls						56
WFP	0.0%	0.0%	0.0%	0.0%	0.0%	
Government	0.0%	0.0%	0.0%	0.0%	0.0%	
parents	66.7%	64.3%	65.2%	76.9%	67.9%	
children	0.0%	35.7%	34.8%	23.1%	28.6%	
NGO	33.3%	0.0%	0.0%	0.0%	3.6%	
other	0.0%	0.0%	0.0%	0.0%	0.0%	
% of schools where children wash their hands before eating						64
yes, with water and soap	66.7%	44.4%	55.6%	46.2%	51.6%	
yes, with water only	16.7%	55.6%	40.7%	46.2%	43.8%	

Appendix D. Kenya school feeding and the school environment multiple regressions

D.1 Enrollment

The results from the five different regression models for total enrollment are reported in Table D-1, including coefficients, confidence intervals, and significant p-values for the independent variables and RMSE and adjusted R^2 for the models.

Comparing the regression results with and without robust standard errors, all of the coefficient values are the same; however, the confidence intervals and p-values differ. Much of the interpretation on the strength of the evidence of association between enrollment and electricity, student-to-classroom ratio, and hand washing facilities remains the same between the two models. However, with robust standard errors, there is slightly more evidence that the coefficient of student-to-teacher ratio is different from zero.

Comparing the regression with robust standard errors model with the robust regression model, the coefficients differ between the two but are fairly similar in magnitude. Additionally, the strength of evidence of association between enrollment and electricity, student-to-teacher ratios, student-to-classroom ratio, and hand washing facilities are nearly parallel.

In backward selection, electricity, student-to-classroom ratio and hand washing were selected by the model. However, dissimilar to the previous models discussed, student-to-teacher ratio was not selected while snack selling was. In the forward selection model, student-to-teacher ratio was selected but the p-value did not indicate statistical significance. In both of the selection models, all of the coefficients tended to be larger than in the robust regression model, except for hand washing (and student-to-teacher ratio for forward selection).

The RMSE and adjusted R^2 are very similar across the models. When consistency of variable significance is taken into account as well, the forward selection model seems to be the best fit. Snack selling electricity, student-to-teacher ratio, student-to-classroom ratio, and hand washing combined account for over half of the variation observed in total enrollment (adjusted R^2: 0.509).

However, when performing diagnostics to determine whether the data meets the assumptions of the model, results from the Shapiro-Wilk W test for normality indicate that the distribution of the residuals is not normal (p-value = 0.00005) while results from the White's test indicate that the variance of the residuals is homogenous (p-value = 0.2258). There is also no evidence of multicollinearity as the variance inflation factors for each of the variables is well less than ten.

Examining linearity in the relationship between enrollment and the independent variables, there seems to be some evidence of non-linearity, particularly for student-to-classroom ratio. Regarding model specification, results from the link test and from the regression specification error test (RESET) both indicate that the model has been specified correctly.

Table D-1 Multiple regression models for total enrollment (coefficient and 95% C.I.)

	Regression	**Regression with robust standard errors**	**Robust regression**	**Backward selection**	**Forward selection**
snack selling at school	82.32 (-9.02, 173.66)	82.32 (-2.88, 167.52)	47.00 (-23.09, 117.09)	95.66** (14.81, 176.51)	88.41** (5.89, 170.93)
electricity at school	195.23*** (90.64, 299.81)	195.23*** (72.98, 317.47)	134.88*** (54.63, 215.13)	217.05*** (112.88, 321.23)	214.66*** (109.28, 320.05)
student-to-teacher ratio	2.17* (-0.39, 4.72)	2.17** (-0.09, 4.25)	3.11*** (1.15, 5.08)		1.75 (-0.70, 4.19)
student-to-classroom ratio	5.31*** (1.94, 8.68)	5.31*** (1.30, 9.31)	3.84*** (1.25, 6.42)	8.15*** (4.89, 11.42)	6.62*** (2.63, 10.62)
desk-to-student ratio in P3	-176.61 (-531.00, 177.77)	-176.61 (-614.79, 261.57)	-226.57 (-498.50, 45.37)		
desk-to-student ratio in P7	-75.73 (-341.49, 190.03)	-75.73 (-294.23, 142.78)	-64.08 (-268.01, 139.85)		
type of sanitary facilities dummy_variable_3	-175.00** (-341.89, -8.12)	-175.00 (-454.03, 104.02)	-52.80 (-180.86, 75.26)		
type of sanitary facilities dummy_variable_4	-84.33 (-349.41, 180.74)	-84.33 (-490.62, 321.96)	-20.18 (-223.58, 183.23)		
source of drinking water at school	-15.37 (-115.03, 84.30)	-15.37 (-85.97, 55.24)	-48.44 (-124.91, 28.03)		
hand washing facilities at school	111.89** (12.19, 211.60)	111.89** (25.25, 198.54)	146.23*** (69.73, 222.74)	104.46** (14.60, 194.31)	108.04** (18.00, 198.09)
Number of observations	90	90	90	90	90
RMSE	196.9	196.9	196.9	198.58	197.36
Adjusted R^2	0.511	0.511	0.511	0.503	0.509

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

Note: By testing the two dummy variables for type of sanitary facilities together, the overall variable was found to be not statistically significant in the regression, regression with robust standard errors, and robust regression models.

To attempt to address the non-normality issue, the natural log of total enrollment was taken (the transformation with the smallest chi-square in a ladder test). The forward selection model was refit with the log transformed total enrollment outcome variable, and the results are reported in Table D-2. All of the same independent variables were selected by the forward selection model for the log of enrollment as those for enrollment, with the addition of desk-to-student ratio in P7. Similar strengths of evidence of association were also found. In testing assumptions, the model was found to have normally distributed residuals (Shapiro-Wilk W test: p-value = 0.1814), homoscedasticity (White's test: p-value = 0.3372), and no multicollinearity; however, there was evidence of non-linearity with the quantitative independent variables included and evidence of model misspecification (link test: p-value = 0.002; RESET test: p-value = 0.0006).

Table D-2 Forward selection regression model for the log of total enrollment (coefficient and 95% C.I.)

	Forward selection
snack selling at school	0.1684** (0.0312, 0.3056)
electricity at school	0.3335*** (0.1836, 0.4834)
student-to-teacher ratio	0.0026 (-0.0006, 0.0058)
student-to-classroom ratio	0.0117*** (0.0044, 0.0190)
desk-to-student ratio in P7	-0.3555** (-0.7052, -0.0059)
hand washing facilities at school	0.2271*** (0.0837, 0.3706)
Number of observations	90
RMSE	0.3023
Adjusted R^2	0.593

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

To address the issue of non-linearity, all of the non-normal independent variables offered for inclusion in the model were transformed[i] and the model was refit. The results are reported in Table 7.5. Comparing these findings with those from the untransformed independent variables used in the Table D-2 model, the variables snack selling, student-to-teacher ratio, and desk-to-student ratio are no longer selected and the variable percentage of pupils who walk more than 30 minutes to get to the school has been added. The strength of evidence of association for the three variables that were retained is fairly similar. Examining the model assumptions, the model was found to have normally distributed residuals (Shapiro-Wilk W test: p-value = 0.1814), homoscedasticity (White's test: p-value = 0.1312), no multicollinearity, no non-linearity, and no DFFITS values exceeding one. There was some evidence of model misspecification (link test: p-value = 0.052; RESET test: p-value = 0.041), but it was weaker than in tests of the previous model. As a further check, a backward selection process run on the same set of independent variables fit the same model, and these variables account for nearly 70% of the variation observed in total enrollment (adjusted R^2: 0.681).

D.2 Attendance

D.2.1 Attendance rate for P3

Results from five multiple regression models for attendance rate for P3 are presented in Table D-3. The backward selection and forward selection models both selected the same three variables

[i] Based on ladder test findings, the student-to-teacher ratio, the student-to-classroom ratio, the desk-to-student ratio in P7, the student-to-sanitary-facilities ratio, the distance to walk (in minutes) from school to nearest town center, and the distance to walk (in minutes) to the school from farthest point in school's catchment area were all logged.

and have the highest adjusted R^2 values of the models. In testing assumptions of the forward selection, the model was found to have non-normally distributed residuals (Shapiro-Wilk W test: p-value = 0.0025), heteroscedasticity (White's test: p-value = 0.0013), no multicollinearity, non-linearity, and no evidence of model misspecification (link test: p-value = 0.249; RESET test: p-value = 0.2286).

Table D-3 Multiple regression models for attendance rate for P3 (coefficient and 95% C.I.)

	Regression	Regression with robust standard errors	Robust regression	Backward selection	Forward selection
student-to-teacher ratio	0.000 (-0.002, 0.001)	0.000 (-0.002, 0.002)	0.001 (-0.001, 0.002)		
desk-to-student ratio in P3	0.434*** (0.177, 0.691)	0.434*** (0.136, 0.732)	0.322** (0.070, 0.573)	0.524*** (0.252, 0.796)	0.524*** (0.252, 0.796)
hand washing facilities at school	-0.061 (-0.144, 0.022)	-0.061 (-0.157, 0.035)	-0.058 (-0.139, 0.024)		
distance to walk (in minutes) to the school from farthest point in school's catchment area				-0.001* (-0.002, 0.000)	-0.001* (-0.002, 0.000)
percentage of pupils who walk more than 30 minutes to get to the school				0.002** (0.000, 0.004)	0.002** (0.000, 0.004)
Number of observations	92	92	92	90	90
RMSE	0.1698	0.1698	0.1663	0.1646	0.1646
Adjusted R^2	0.141	0.141	0.068	0.207	0.207

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

To attempt to address the non-normality, the attendance rate for P3 was cubed (the transformation with the smallest chi-square in a ladder test). The forward selection model was refit with the log transformed attendance rate for P3 outcome variable, and the results are reported in Table D-4. All of the same independent variables were selected by the forward selection model for the attendance rate for P3 cubed as those for attendance rate for P3 without the transformation. In testing assumptions, the model was found to have normally distributed residuals (Shapiro-Wilk W test: p-value = 0.6272), homoscedasticity (White's test: p-value = 0.1128), no multicollinearity, non-linearity, and evidence of model misspecification (link test: p-value = 0.002; RESET test: p-value = 0.0006).

To attempt to address the non-linearity, all of the non-normal independent variables offered for inclusion in the model were transformed and the model was refit. The results are reported in Table 7.6. Comparing these findings with those from the untransformed independent variables used in the Table D-4 model, the same independent variables were selected by both models. Examining the model assumptions, the model was found to have normally distributed residuals (Shapiro-Wilk W test: p-value = 0.5818), homoscedasticity (White's test: p-value = 0.0832), no multicollinearity, no evidence of model misspecification (link test: p-value = 0.573; RESET test: p-value = 0.673), and no DFFITS values greater than one, but there was some evidence of non-linearity. This model is the preferred for attendance rate for P3. As a further check, a backward selection process run on the same set of independent variables fit the same model.

Table D-4 Forward selection regression model for attendance rate for P3 cubed (coefficient and 95% C.I.)

	Forward selection
desk-to-student ratio in P3	0.868*** (0.355, 1.381)
distance to walk (in minutes) to the school from farthest point in school's catchment area	-0.002** (-0.004, 0.000)
percentage of pupils who walk more than 30 minutes to get to the school	0.004** (0.001, 0.007)
Number of observations	90
RMSE	0.3133
Adjusted R^2	0.175

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

D.2.2 Attendance rate for P7

Results from five multiple regression models for attendance rate for P7 are presented in Table D-5. The backward selection and forward selection models both selected the same three variables and have the highest adjusted R^2 values of the models. In testing assumptions of the forward selection, the model was found to have non-normally distributed residuals (Shapiro-Wilk W test: p-value = 0.00003), heteroscedasticity (White's test: p-value = 0.0003), no multicollinearity, non-linearity, and evidence of model misspecification (link test: p-value = 0.038; RESET test: p-value = 0.0508).

To attempt to address the non-normality, the attendance rate for P7 was cubed (the transformation with the smallest chi-square in a ladder test). The forward selection model was refit with the log transformed attendance rate for P7 outcome variable, and the results are reported in Table D-6. The same independent variables were selected by the forward selection model for the attendance rate for P7 cubed as those for attendance rate for P7 without the transformation, with the addition of student-to-teacher ratio, distance to walk from school to nearest town center, and percentage of pupils who walk more than 30 minutes to get to the school. In testing assumptions, the model was found to have non-normally distributed residuals (Shapiro-Wilk W test: p-value = 0.0282), homoscedasticity (White's test: p-value = 0.0568), no multicollinearity, non-linearity, and no evidence of model misspecification (link test: p-value = 0.147; RESET test: p-value = 0.4161).

Table D-5 Multiple regression models for attendance rate for P7 (coefficient and 95% C.I.)

	Regression	Regression with robust standard errors	Robust regression	Backward selection	Forward selection
electricity	-0.066 (-0.154, 0.021)	-0.066 (-0.149, 0.016)	-0.064* (-0.140, 0.012)	-0.127*** (-0.221, -0.032)	-0.127*** (-0.221, -0.032)
student-to-teacher ratio	-0.001 (-0.003, 0.001)	-0.001 (-0.003, 0.001)	-0.001 (-0.002, 0.001)		
desk-to-student ratio in P3	0.232* (-0.030, 0.495)	0.232 (-0.075, 0.539)	0.147 (-0.081, 0.374)		
desk-to-student ratio in P7	0.260** (0.034, 0.486)	0.260* (-0.043, 0.563)	0.248** (0.051, 0.444)	0.341** (0.078, 0.603)	0.341** (0.078, 0.603)
type of sanitary facilities dummy_variable_3				-0.144*** (-0.227, -0.061)	-0.144*** (-0.227, -0.061)
percentage of pupils who walk more than 30 minutes to get to the school	0.001 (0.000, 0.003)	0.001* (0.000, 0.003)	0.001 (0.000, 0.003)		
Number of observations	90	90	90	90	90
RMSE	0.1712	0.1712	0.1486	0.1700	0.1700
Adjusted R^2	0.178	0.178	0.171	0.190	0.190

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

Table D-6 Forward selection regression model for attendance rate for P7 cubed (coefficient and 95% C.I.)

	Forward selection
electricity	-0.182** (-0.332, -0.033)
student-to-teacher ratio	-0.002 (-0.005, 0.001)
desk-to-student ratio in P7	0.487** (0.040, 0.935)
type of sanitary facilities dummy_variable_3	-0.244*** (-0.408, -0.080)
distance to walk (in minutes) from school to nearest town center	-0.002* (-0.005, 0.000)
percentage of pupils who walk more than 30 minutes to get to the school	0.003* (0.000, 0.005)
Number of observations	90
RMSE	0.2811
Adjusted R^2	0.233

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

To attempt to address the remaining non-normality and the non-linearity, all of the non-normal independent variables offered for inclusion in the model were transformed and the model was refit. The results are reported in Table 7.7. Comparing these findings with those from the untransformed independent variables used in the Table D-6 model, student-to-teacher ratio was no longer selected by the model. Examining the model assumptions, the model was found to have normally distributed residuals (Shapiro-Wilk W test: p-value = 0.1917), homoscedasticity (White's test: p-value = 0.0543), no multicollinearity, some evidence of non-linearity, no evidence of model misspecification (link test: p-value = 0.182; RESET test: p-value = 0.369), and no DFFITS values greater than one. This model is the preferred for P7 attendance. As a further check, a backward selection process fit the same model.

D.3 Girl-to-boy enrollment ratio

Results from five multiple regression models for the girl-to-boy enrollment ratio are presented in Table D-7. The backward selection and forward selection models both select the same variable as was significant in the bivariate regressions (mass praziquantel treatment in the last twelve months at school). All five regression models have adjusted R^2 values of 3% or less. In testing assumptions of the forward selection, the model was found to have normally distributed residuals (Shapiro-Wilk W test: p-value = 0.3382), homoscedasticity (White's test: p-value = 0.6776), no non-linearity, no evidence of model misspecification (link test: p-value = 0.087), and no DFFITS values greater than one.

Table D-7 Multiple regression models for girl-to-boy enrollment ratio (coefficient and 95% C.I.)

	Regression	Regression with robust standard errors	Robust regression	Backward selection	Forward selection
mass praziquantel treatment in the last twelve months at school	-0.040* (-0.083, 0.003)	-0.040* (-0.084, 0.004)	-0.044** (-0.087, -0.001)	-0.041* (-0.088, 0.007)	-0.041* (-0.088, 0.007)
Number of observations	101	101	101	90	90
RMSE	0.1036	0.1036	0.1029	0.1060	0.1060
Adjusted R^2	0.023	0.023	0.030	0.022	0.022

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

To examine the effect of transforming all of the non-normal independent variables, the forward selection model was refit with these transformed variables, and the results are reported in Table D-8. Again, the only variable selected by the forward selection model for inclusion was mass praziquantel treatment (backward selection regression also selected the identical sole variable). The same assumptions testing results from the model without transformed independent variables holds true. As the simplest model that meets the model assumptions, the untransformed forward selection is preferred.

Table D-8 Forward selection regression model for girl-to-boy enrollment ratio, with non-normal independent variables transformed (coefficient and 95% C.I.)

	Forward selection
mass praziquantel treatment in the last twelve months at school	-0.041* (-0.088, 0.007)
Number of observations	90
RMSE	0.1060
Adjusted R^2	0.022

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

D.4 Retention

Results from five multiple regression models for retention are presented in Table D-9. The backward selection model selected two of the four variables found to be significant in the bivariate regressions while the forward selected only selected one and added one of the dummies for type of sanitary facilities. Of the two selection models, backward had the higher adjusted R^2. In testing the backward selection assumptions, the model was found to have non-normally distributed residuals (Shapiro-Wilk W test: p-value = 0.00012), homoscedasticity (White's test: p-value = 0.6880), no multicollinearity, no non-linearity, and no evidence of model misspecification (link test: p-value = 0.821; RESET test: p-value = 0.9612).

Table D-9 Multiple regression models for retention (coefficient and 95% C.I.)

	Regression	**Regression with robust standard errors**	**Robust regression**	**Backward selection**	**Forward selection**
electricity	0.148* (-0.020, 0.317)	0.148** (0.003, 0.293)	0.207*** (0.054, 0.359)	0.127* (-0.020, 0.274)	
student-to-teacher ratio	-0.002 (-0.006, 0.002)	-0.002 (-0.006, 0.002)	-0.002 (-0.006, 0.002)		-0.002* (-0.004, 0.000)
student-to-classroom ratio	0.001 (-0.005, 0.007)	0.001 (-0.004, 0.005)	0.001 (-0.004, 0.007)		
desk-to-student ratio in P3	0.347 (-0.227, 0.921)	0.347 (-0.141, 0.835)	0.359 (-0.160, 0.878)	0.436** (0.032, 0.840)	
type of sanitary facilities dummy_variable_3					-0.155* (-0.324, 0.014)
Number of observations	92	92	92	90	90
RMSE	0.3600	0.3600	0.3257	0.3530	0.3563
Adjusted R^2	0.033	0.033	0.084	0.040	0.022

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

To attempt to address the non-normality, the outcome variable was logged. The backward selection model was refit with the transformed retention outcome variable, and the results are reported in Table 7.9. The two independent variables selected by the model were desk-to-student ratio in P3 and percentage of pupils who walk more than 30 minutes to get to the school. In testing assumptions, the model was found to have normally distributed residuals (Shapiro-Wilk W test: p-value = 0.5337), homoscedasticity (White's test: p-value = 0.4786), no multicollinearity, non-linearity, no evidence of model misspecification (link test: p-value = 0.895; RESET test: p-value = 0.9010), and no DFFITS values greater than one. Thus, this model is the preferred for retention.

D.5 Students who go home for lunch

D.5.1 Percent of P3 students who go home for lunch

Results from five multiple regression models for the percent of P3 students who go home for lunch are presented in Table D-10. The backward selection and forward selection models both selected the same three variables and have the highest adjusted R^2 values of the models. In testing assumptions of the forward selection, the model was found to have non-normally distributed residuals (Shapiro-Wilk W test: p-value = 0.0015), homoscedasticity (White's test: p-value = 0.1265), no multicollinearity, non-linearity, weak evidence of model misspecification (link test: p-value = 0.057; RESET test: p-value = 0.2923), and no DFFITS values exceeding one.

Table D-10 Multiple regression models for percent of P3 students who go home for lunch (coefficient and 95% C.I.)

	Regression	**Regression with robust standard errors**	**Robust regression**	**Backward selection**	**Forward selection**
current school feeding program	-0.188** (-0.344, -0.032)	-0.188 (-0.435, 0.059)	-0.112** (-0.206, -0.019)		
snack selling at school				0.128* (-0.016, 0.273)	0.128* (-0.016, 0.273)
desk-to-student ratio in P3	0.513** (0.100, 0.925)	0.513*** (0.144, 0.881)	0.424*** (0.177, 0.672)	0.503** (0.103, 0.903)	0.503** (0.103, 0.903)
percentage of pupils who walk more than 30 minutes to get to the school				0.005*** (0.002, 0.008)	0.005*** (0.002, 0.008)
Number of observations	77	77	77	74	74
RMSE	0.2622	0.2622	0.1574	0.2488	0.2488
Adjusted R^2	0.099	0.099	0.149	0.193	0.193

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

To attempt to address the non-normality, options for transforming the outcome variable were explored, but all of the options in the ladder test resulted in a less normally distributed variable. Examining the effects of transforming all of the non-normal independent variables, the same three variables are selected by the model with transformed independent variables as that without, and the same tests of assumptions results hold true.

As the backward selection model with transformed independent variables also selects the same three variables and the variables selected did not require transformation, the forward selection regression model without any transformations is preferred as the simplest, best fit model.

D.5.2 Percent of P7 students who go home for lunch

Results from five multiple regression models for percent of P7 students who go home for lunch are presented in Table D-11. Of the selection models, backward has a higher adjusted R^2 value and selected more variables that were found to have associations with the outcome in the bivariate regressions. In testing assumptions of the backward selection, the model was found to have non-normally distributed residuals (Shapiro-Wilk W test: p-value = 0.00000), heteroscedasticity (White's test: p-value = 0.0163), no multicollinearity, non-linearity, and evidence of model misspecification (link test: p-value = 0.023; RESET test: p-value = 0.0078).

Table D-11 Multiple regression models for percent of P7 students who go home for lunch (coefficient and 95% C.I.)

	Regression	**Regression with robust standard errors**	**Robust regression**	**Backward selection**	**Forward selection**
current school feeding program	-0.150 (-0.341, 0.042)	-0.150 (-0.415, 0.116)	-0.260*** (-0.415, -0.105)	-0.234* (-0.501, 0.033)	
mass albendazole / mebendazole treatment in the last twelve months at school	0.290** (0.005, 0.575)	0.290** (0.067, 0.513)	0.312*** (0.082, 0.542)	0.366*** (0.155, 0.577)	0.372*** (0.118, 0.627)
mass praziquantel treatment in the last twelve months at school	0.082 (-0.089, 0.252)	0.082 (-0.075, 0.239)	0.053 (-0.085, 0.191)		
snack selling at school	0.108 (-0.051, 0.267)	0.108 (-0.043, 0.259)	0.141** (0.012, 0.270)		
student-to-classroom ratio				0.005*** (0.002, 0.009)	
desk-to-student ratio in P3				0.727*** (0.252, 1.202)	
type of sanitary facilities dummy_variable_3					-0.160*** (-0.271, -0.049)
distance to walk (in minutes) to the school from farthest point in school's catchment area				0.002* (0.000, 0.005)	
Number of observations	90	90	90	87	87
RMSE	0.3579	0.3579	0.2892	0.3321	0.3556
Adjusted R^2	0.107	0.107	0.264	0.209	0.094

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

To attempt to address the non-normality, options for transforming the outcome variable were explored, but all of the options in the ladder test resulted in a less normally distributed variable. Examining the effects of transforming all of the non-normal independent variables, only mass albendazole/mebendazole treatment, the log of student-to-classroom ratio, and desk-to-student ratio in P3 were selected by the backward selection model (see Table D-12). Examining the model assumptions, the model was found to have non-normally distributed residuals (Shapiro-Wilk W test: p-value = 0.0000), homoscedasticity (White's test: p-value = 0.9992), no multicollinearity, some evidence of non-linearity, and no evidence of model misspecification (link test: p-value = 0.419; RESET test: p-value = 0.6220).

Table D-12 Backward selection regression model for percent of P7 students who go home for lunch, with non-normal independent variables transformed (coefficient and 95% C.I.)

	Backward selection
mass albendazole / mebendazole treatment in the last twelve months at school	0.363*** (0.137, 0.590)
log of student-to-classroom ratio	0.296*** (0.082, 0.509)
desk-to-student ratio in P3	0.642*** (0.186, 1.098)
Number of observations	87
RMSE	0.3462
Adjusted R^2	0.141

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01

In exploring outliers in the data that could contribute to violations in the assumptions, the DFFITS values were calculated for an untransformed backward selection model. One value exceeded the cut-off point of one for small data sets (DFFITS = 2.27). The reported percentage of P7 students who go home for lunch at this school was 256%, an observation that could merit exclusion.

When the model building process is begun again with the extreme DFFITS value school dropped, the results from the initial five multiple regression models are reported in Table D-13. The backward selection model had the highest adjusted R^2 value and selected current school feeding, mass albendazole/mebendazole treatment, student-to-classroom ratio, desk-to-student ratio in P3, and one of the dummies for type of sanitary facilities for inclusion. Assessing the assumptions of the model, it was found to have non-normally distributed residuals (Shapiro-Wilk W test: p-value = 0.0118), heteroscedasticity (White's test: p-value = 0.0051), no multicollinearity, some non-linearity, and evidence of model misspecification (link test: p-value = 0.020; RESET test: p-value = 0.0077).

To attempt to address the non-normality, options for transforming the outcome variable were explored, but all of the options in the ladder test resulted in a less normally distributed variable. Examining the effects of transforming all of the non-normal independent variables, the same five independent variables were selected as the untransformed backward selection model (see Table 7.11). Examining the model assumptions, the model was found to have some evidence of non-normally distributed residuals (Shapiro-Wilk W test: p-value = 0.0100), some evidence of heteroscedasticity (White's test: p-value = 0.0065), no multicollinearity, some evidence of non-linearity, evidence of model misspecification (link test: p-value = 0.018; RESET test: p-value = 0.0034), and no DFFITS values exceeding one. Of the models assessed, this model is preferred as meeting the most assumptions and having the highest adjusted R^2 value.

Table D-13 Multiple regression models for percent of P7 students who go home for lunch, with extreme DFFITS value school dropped (coefficient and 95% C.I.)

	Regression	Regression with robust standard errors	Robust regression	Backward selection	Forward selection
current school feeding program	-0.252*** (-0.407, -0.098)	-0.252*** (-0.435, -0.070)	-0.259*** (-0.415, -0.102)	-0.363*** (-0.544, -0.183)	-0.368*** (-0.559, -0.178)
mass albendazole / mebendazole treatment in the last twelve months at school	0.261** (0.035, 0.486)	0.261** (0.055, 0.466)	0.317*** (0.088, 0.545)	0.261*** (0.110, 0.412)	0.262*** (0.098, 0.427)
mass praziquantel treatment in the last twelve months at school	0.049 (-0.086, 0.185)	0.049 (-0.097, 0.196)	0.053 (-0.085, 0.190)		
snack selling at school	0.148** (0.021, 0.275)	0.148** (0.015, 0.281)	0.139** (0.011, 0.268)		
student-to-classroom ratio				0.004** (0.000, 0.007)	
desk-to-student ratio in P3				0.494** (0.009, 0.978)	
type of sanitary facilities dummy_variable_3				-0.203** (-0.357, -0.049)	-0.266*** (-0.400, -0.132)
Number of observations	89	89	89	86	86
RMSE	0.2837	0.2837	0.2874	0.2538	0.3570
Adjusted R^2	0.245	0.245	0.264	0.367	0.333

* p-value ≤ 0.10; ** p-value ≤ 0.05; *** p-value ≤ 0.01