THREE ESSAYS ON THE CAUSES AND CONSEQUENCES OF POOR HEALTH AND NUTRITION IN THE DEVELOPING WORLD

By

Kevin R. McGee

Submitted to the

Faculty of the College of Arts and Sciences

of American University

in Partial Fulfillment of

the Requirements for the Degree

of Doctor of Philosophy

In

Economics

Chair: Professor Paul Winters

Professor Maria S. Floro

Gbemisola Oseni (World Bank)

Dean of the College

April 23, 2014

Date

2014
American University
Washington, D.C. 20016

THREE ESSAYS ON THE CAUSES AND CONSEQUENCES OF POOR HEALTH AND NUTRITION IN THE DEVELOPING WORLD

by
Kevin R. McGee

ABSTRACT

This dissertation explores health and nutrition in the developing world as both a determinant of economic outcomes and the result of economic realities. Health and nutrition are critical components of economic and social well being and are therefore important factors of development. As such, much effort and resources have been devoted to improving health outcomes in the developing world. This dissertation (1) provides guidance on how policies can be best designed to improve health and (2) provides a better understanding of the linkages between poor health and economic outcomes. The three essays that comprise the dissertation investigate separate contexts and linkages involving health and nutrition in the developing world.

The first essay examines the importance of household infrastructure (water source, sanitation facilities, and flooring quality) for acute and chronic child diarrhea in Bolivia. It specifically focuses on the effect of combinations of improved infrastructure, a subject rarely discussed in existing research. The results from the essay suggest that improved sanitation facilities are effective at reducing acute diarrhea while improved flooring was effective at reducing chronic diarrhea. The results also suggest that having these two improved infrastructures in combination may be more effective than individually.

The second essay explores whether and how parents alter their work hours in response to a child becoming infected with malaria. How parents alter their work hours could have negative repercussions for the household as a whole either though less time devoted to child care or reduced income. Analyzing data from Malawi, it is found that there is no overall change in the work hours of parents. However, it does appear that both fathers and mothers engage in low-paid, part-time ganyu labor following child infection. Ganyu employment may help cover the costs of care, but could result in reduced care time or decreased time in other more lucrative forms of work.

The third essay investigates the linkages between agricultural production and household nutrition. It focuses on how the level and diversity of production translates into variability in household caloric intake and dietary diversity. These linkages are the underlying justification for many nutrition oriented agricultural policies, but has not been sufficiently addressed in the literature. Analyzing panel data from Nigeria, a strong positive relationship is found between agricultural output and both caloric intake and dietary diversity. In addition, a strong positive association was found between production diversity and dietary diversity. The results suggest that policies promoting expanded and more varied agricultural production may be effective at combating malnutrition in the developing world.

ACKNOWLEDGEMENTS

I want to express my eternal gratitude to my committee members without whose constant support and guidance I surely would never have finished this dissertation. I also want to thank the many American University faculty, fellow graduate students, and World Bank colleagues who provided me with invaluable suggestions and encouragement throughout the entire research process.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

HOUSEHOLD INFRASTRUCTURE AND DIARRHEAL DISEASE IN CHILDREN: EVIDENCE FROM BOLIVIA

1.1 Introduction

Much attention has been focused on child health as an important factor in development. The quality of a child's health is an important factor for biological development but has also been shown to influence school attendance and performance (Alderman et al., 2001, 2006; Maluccio et al., 2009), mortality risk, and labor market outcomes (Alderman et al., 2006). Improving child health and combating childhood illness should encourage both social and economic development. For this reason, a considerable amount of effort has been expended to combat poor child health in the developing world. Policy interventions have been multifarious reflecting the complex combination of factors that influence child health. One such factor is the quality of infrastructure in the child's household including the source of water, the sanitation facilities, and the type of flooring in the household. Improving the quality of these household infrastructures may result in better child health (Cattaneo et al., 2009; Günther and Fink, 2010). While improving each individual infrastructure may impact child health, the combined presence of multiple improved household infrastructures may have a greater impact. This paper seeks to determine whether *combinations* of improved drinking water source, sanitation facilities, and flooring result in lower incidence of diarrheal disease in children.

Diarrheal disease is one of the most prominent and devastating child health problems in the developing world. An estimated 2.5 billion cases of diarrhea occur every year amongst children under five years of age resulting in 1.5 million deaths (Wardlaw et al., 2010). Diarrheal diseases are the second most common cause of death among children accounting for nearly one in five child deaths (Wardlaw et al., 2010). Diarrhea is often the symptom of an intestinal infection caused by a virus, bacteria, or parasite. Most deaths are due to severe dehydration and fluid loss associated with the infection (Wardlaw et al., 2010). This leaves children who are undernourished and of poor health at significant risk of succumbing to the disease (Wardlaw et al., 2010).

How to combat such a far reaching affliction? As with most diseases, interventions can be implemented to (i) provide treatment after infection or (ii) prevent infection entirely. While diarrhea can be effectively treated with oral rehydration, the contagious nature of the infection places particular emphasis on infection prevention methods. Diarrhea inducing pathogens are transmitted from one person to another via ingestion of an infected individual's stool (Esrey et al., 1991). Once outside the body, the pathogens can be transmitted through surfaces, water, or food contaminated with fecal matter. Thus prevention can be achieved through the use of clean (noncontaminated) water, proper disposal of feces, and good hygienic practices. While there are many studies that examine the effectiveness of good hygiene in reducing diarrhea morbidity[1], this paper will focus on the effectiveness of clean water and proper disposal of feces through the household's source of water, quality of sanitation facilities, and type of flooring.

There exists an extensive literature relating household infrastructure to child health broadly and diarrheal diseases specifically. There is an exceptionally copious literature examining the child health impacts of improvements in household water and sanitation facilities. Two reviews of the literature by Esrey et al. (1991) and Hoddinott (1997) find considerable variation in findings. Their reviews highlight the complexity of the issue with some interventions being effective against certain parasites and health problems but ineffective against others. In a more recent synthetic review of impact evaluations of water and sanitation projects, Waddington et al. (2009) finds that sanitation interventions were more effective at reducing diarrhea morbidity than water supply interventions. While water and sanitation are the primary focus of a majority of the literature, there is a smaller literature that examines the impacts of flooring improvements on child health. Perhaps most notable, a study by Cattaneo et al. (2009) examines the impact of a program in Mexico to replace

[1] See for example Luby et al. (2004).

dirt floors with cement. The authors find that the program improved several important health factors in children, including parasitic infection and diarrhea morbidity.

Although the body of current research is expansive, a vast majority of studies focus on the health effects of improvements in *individual* household infrastructures with little discussion of the effect of *combinations* of improved infrastructure. Certain infrastructures may be complementary in that having both infrastructures in a household will result in an impact that is greater than sum of the individual impacts. The reverse may also be true: two infrastructures that are substitutes whereby the combined presence detracts from the sum of the individual impacts. Combinations of infrastructures are considered in two studies by Esrey (1996) and Khanna (2008). Esrey (1996) groups households based on which combinations are present to assess the impact of incremental changes in water and sanitation with no analysis of the complementarity or substitutability of these infrastructures. Khanna (2008) assess the joint impacts of water and sanitation improvements but it is not a major focus of his investigation. In contrast to these studies, this paper is to the best of this author's knowledge (i) the first systematic analysis of combinations of household infrastructure on child health and (ii) the first study to consider the joint impacts of water/sanitation and the type of flooring.

In order to determine if the combined presence of household infrastructures prevent diarrheal disease, data from four Bolivian Demographic and Health Survey (BDHS) are used. These data contain detailed information on child health and household characteristics including water source, sanitation facilities, and type of flooring. Using this information, several empirical specifications are implemented that include indicators for specific combinations of improved household infrastructures.

The results suggest that household infrastructure combinations are not of great importance for child health, contrary to the hypothesis of this paper. Although there was no consistent association between infrastructure combinations and both acute and chronic diarrhea, the results do indicate that some individual infrastructures are effective at preventing diarrhea. Improved sanitation facilities were found to prevent chronic diarrhea while nondirt flooring was found to prevent chronic diarrhea (as measured by height-for-age and weight-for-age). While there was little evidence of direct complementarity, the findings suggests that joint promotion of improved sanitation facilities and nondirt flooring will be effective at simultaneously preventing acute and chronic diarrhea.

The paper will proceed as follows. The next section outlines the conceptual approach and briefly reviews the literature on improved household infrastructure. Section 1.3 describes the data to be used in the analysis. Section 1.4 outlines the empirical method and Section 1.5 discusses the results. Section 1.6 concludes.

1.2 Conceptual Approach

The quality of childhood health and nutrition is of critical importance to the physical and mental development of children. Several studies have shown that children of poor health and nutrition have lower inherent cognitive ability relative to their healthier counterparts (Mendez and Adair, 1999; Berkman et al., 2002). Thus from the start, these children have an educational disadvantage. The negative education impacts of poor child health do not end there. Unhealthy children have lower attendance and enrollment rates (Alderman et al., 2001) and fewer years of schooling completed (Alderman et al., 2006; Maluccio et al., 2009). These negative impacts on education result in lower levels of human capital among children with poor health and translate into poorer labor market outcomes (Alderman et al., 2006). Thus poor childhood health and nutrition can have damaging and persistent impacts on individual economic outcomes.

Diarrheal disease can be a significant contributor to the health of children. The official definition of diarrhea is having loose or watery stools at least three times per day, or more frequently than normal for an individual (Wardlaw et al., 2010). Diarrhea itself is a symptom of an intestinal infection caused by a variety of pathogens. The detrimental and sometimes fatal impacts of diarrhea are due to severe dehydration and fluid loss that accompany the illness. Young children are especially at risk of dying as a result of diarrhea since (i) water constitutes a greater portion of their bodyweight (ii) they use more water over the course of a day, and (iii) their kidneys are less able to conserve water (Wardlaw et al., 2010). As a result, the diarrhea mortality rate is significantly higher for young children compared to the rest of the population.

In addition to dehydration, persistent diarrhea can result in malnutrition and poor child growth (Glewwe and Miguel, 2007). Malnutrition caused by persistent diarrhea can further worsen a child's health by making them more vulnerable to other infectious diseases (Zwane and Kremer, 2007). The malnutrition caused by chronic and persistent diarrhea would be reflected in anthropometric measures of children such as height-for-age, weight-for-age, and weight-for-height. Each measure captures slightly different information (see Section 1.3.1 for more details). Broadly, weight is considered a short-term measure of nutrition whereas height is more of a long-term measure. While persistent diarrhea can cause malnutrition in children, there are many other factors that contribute to malnutrition especially inadequate food intake and other infections that impair the body's ability to absorb food and nutrients (O'Donnell and Wagstaff, 2008). The latter category includes other parasites that may not cause diarrhea. Conclusions made regarding diarrhea through anthropometric measures must be tempered by the knowledge that other factors influence a child's anthropometrics.

Diarrhea is transmitted from one individual to another via the fecal-oral route (Wardlaw et al., 2010). The parasites responsible for diarrhea are secreted in the stools of the infected individual. Their stool is then ingested through water, food, or surfaces contaminated with stool. Given this transmission mechanism, diarrheal diseases can be prevented through use of uncontaminated water, proper disposal of feces, and good hygienic practices (Wardlaw et al., 2010). Water from less improved sources such as a river or lake are more likely to be contaminated than water piped into the household. Therefore, expanding access to piped water and other improved water sources may help to combat diarrhea infection. Proper disposal of feces is another potential method for preventing diarrhea. The sanitation facilities used by the household are particularly important. Especially poor facilities such as a tree or a bush do not dispose of stools and can encourage transmission whereas facilities that contain and dispose of feces such as flush toilets limit the potential for transmission. The type of flooring in the household can also contribute to disposal of feces. Dirt floors are more likely to contain feces because it is more difficult to keep clean and harder to identify fecal matter (Cattaneo et al., 2009). Therefore, households with improved flooring materials such as cement are less susceptible to diarrheal diseases than households with dirt floors.

Many researchers have examined the impact of water, sanitation, and flooring on diarrhea morbidity. The majority have focused on the effectiveness of water and sanitation improvements. The Millennium Development Goals, which call for halving the proportion of the global population with unsatisfactory access to water and sanitation, have spurred recent research on this subject. Access to clean drinking water and basic sanitation is broadly considered essential in preventing transmission of waterborne pathogens, especially diarrhea (Hoddinott, 1997; Zwane and Kremer, 2007). Despite the general consensus, the empirical results have not been entirely supportive. Lawson and Appleton (2007) did not find strong evidence that improved water and sanitation facilities had a positive impact on child health in Uganda. Moreover, they found that for anthropometric measures, seemingly less improved water infrastructure (rain water) improved nutrition whereas some more improved water sources (community and private piped water) *worsened* health. Hoddinott (1997) review investigations using similar anthropometric measures to Lawson and Appleton (2007) and find some additional conflicting results. Of the nine studies that they survey, seven found that safe water supplies (external of sanitation) improved health, two found no impact, and one found a *negative* impact.

In agreement with the majority of the studies examined by Hoddinott (1997), an expansive investigation by Günther and Fink (2010) found evidence that access to water and sanitation technology improved both child morbidity and mortality. In their examination of 172 Demographic and Health Surveys from 70 different countries, Günther and Fink (2010) determine that water and sanitation infrastructure lowered the probability of a child suffering from diarrhea by 7 to 17 percent on average. This represents a substantial decrease in the incidence of diarrhea. The authors also note that sanitation technology had a greater impact on health than water technology. A more focused study by Bose (2009) examines two rounds of the DHS survey in Nepal and matches and compares children with access to improved sanitation facilities to children without access to evaluate the impact of improved sanitation on diarrhea. He finds evidence that access to improved sanitation significantly decreases diarrhea incidence among children under 5 and that the effect is more pronounced for children under 2 years of age. This indicates that it may be advantageous to investigate the heterogeneity of impact amongst different age groups.

Clearly, the impact of improved water and sanitation facilities is not necessarily obvious and appears subject to considerable variation. The investigations discussed above cover a wide range of countries and regions. Differences in the disease environment, quality of health facilities, and governance across regions could account for variations in the effectiveness of water and sanitation improvements. Regional differences are only one potential explanation of the heterogeneity of impact. In a review of 144 studies, Esrey et al. (1991) found considerable differences in the impact of water and sanitation improvement methods on different waterborne illnesses. Among the six illnesses they examine, only diarrheal diseases were positively affected by all four interventions they specify (improved drinking water, water for domestic hygiene, water for personal hygiene, and human excreta disposal)[2]. Esrey et al. (1991) also found a highly variable effect of water and sanitation improvements on different diseases reported in the studies they reviewed. Among the "rigorous" studies examined, the median percent reduction in incidence ranged from 4 percent for hookworm up to 78 percent for the *dracunculiasis* parasitic infection (Esrey et al., 1991)[3].

Other elements may also need to be present for water and sanitation improvements to take effect. For instance, improved water and sanitation facilities may not be effective if hygiene practices within the household are poor. In evaluating a hygiene improvement project in Pakistan, Luby et al.

[2]See Table 2 on page 511 in Esrey et al. (1991).

[3]See Table 3 on page 511 of Esrey et al. (1991) for the full results.

(2004) find that children in households that received soap and hand-washing promotion had a 53 percent lower diarrhea incidence rate. In addition, the type of flooring in the household may mitigate the impact of water and sanitation improvements on child health. Most parasites are transmitted through ingestion of fecal matter. Dirt floors are more likely to contain fecal matter since it is harder to identify and dirt floors are more difficult to keep clean (Cattaneo et al., 2009). Studies such as Morales-Espinoza et al. (2003) in Mexico and Jacobsen et al. (2007) in Ecuador have found that children residing in impoverished households with dirt floors are more likely to be infected with intestinal parasites. This suggests that installing improved types of flooring may significantly improve child health. Cattaneo et al. (2009) evaluate a program in Mexico to replace dirt floors with cement and find that the improved flooring decreased the incidence of parasitic infestations, diarrhea, and anemia. They also observe that the improved flooring did not have a significant impact on anthropometric measures of child health. Cattano et al's results suggest that improved flooring might enhance the impact of improvements in water and sanitation.

Much of the literature is focused on the impact of individual household infrastructures while controlling for or omitting the combined impacts of the infrastructures. While each singular component may be important in preventing diarrheal diseases in children, the argument here is that the *combined* presence of these factors enhances child health to a much greater extent than on their own. For example, having improved sanitation facilities will likely decrease diarrhea infection risk on its own but the impact may be enhanced when improved facilities are combined with nondirt flooring. While the improved facilities will limit the potential for fecal matter contamination of household surfaces, nondirt flooring will make detection and cleanup of any contamination much easier. However, if improved facilities are combined with a dirt floor, then detection and cleanup of fecal matter is more difficult thus diminishing the overall benefit of having improved sanitation facilities. For water source combinations, using water less likely to be contaminated (piped) may enhance the overall benefit when combined with improved sanitation facilities or nondirt flooring. Using contaminated water in a flush toilet or to clean a nondirt floor may decrease the beneficial effects of those superior infrastructures. These scenarios illustrate the potential importance of infrastructure combinations. Despite this, the literature remains largely silent on the topic. The few studies that attempt to capture the combined impact of infrastructures (i.e. Esrey (1996) and Khanna (2008)) do not focus their analysis on these combinations and do not include the type of flooring in their analysis. To the best of the author's knowledge, this paper is the first systematic analysis of combinations of household infrastructure in the prevention of diarrheal disease.

The results of this study may also be of interest to policymakers. It will indicate whether household or village infrastructure improvement policies should focus on upgrading individual infrastructures to improve child diarrhea or if the focus should instead be on jointly upgrading infrastructures. For example, would upgrading household sanitation facilities result in a significant drop in diarrhea or would a program that upgrades sanitation facilities and improves the flooring type be more effective? If there is little evidence that combinations of infrastructures are important, then policymakers should focus on individual factors. If the opposite is true, the analysis below will inform policymakers which specific combinations are most effective at combating child diarrhea. Such information is essential in order to direct limited funds to the most efficacious actions or projects. To determine whether the combined presence of improved infrastructures prevents diarrheal disease, the analysis below will test if any combination of improved water access, sanitation facilities, and flooring material has a significant impact on child health *beyond the individual effect of each factor*.

1.3 Context and Data

The empirical analysis below investigates the potential importance of infrastructure combinations for child diarrhea in Bolivia. Child health is relatively poor in Bolivia which had an under-5 mortality rate of 54.2 per thousand in 2010 compared to an average of 23.3 per thousand among its Latin American and Caribbean neighbors[4]. Poor access to improved water sources and sanitation facilities has been cited as a cause for this high rate. Although access to an improved water source in Bolivia as a whole is relatively high at 86 percent in 2008, nearly a third of the rural population lacks access[5]. Access to improved sanitation facilities is much less common. In 2008, just 25 percent of the total and 9 percent of the rural population had access to improved sanitation facilities[6]. Clearly poor access to improved water and sanitation is a problem in Bolivia and may be harming the health of children through high diarrhea morbidity and mortality. Efforts have been made to combat this deficiency. Two joint projects between the World Bank and the government of Bolivia were implemented in the late 1990s which focused on improving water and sanitation access in rural Bolivia. The Second Social Investment Fund (SIF II) and the Rural Water and Sanitation Project (PROSABAR) were large interventions with an estimated 300,000 beneficiaries

[4]Source: World Bank, World Development Indicators

[5]Source: Ibid

[6]Source: Ibid

for each project (World Bank, 1993, 2002). In 2008, the government of Bolivia put forth a plan to improve access across the country. The plan aims to expand water access to 90 percent and sanitation access to 80 percent. The results of the study may provide an indication of the potential child health impacts of the government's efforts to improve water and sanitation access.

Data from four Bolivian Demographic and Health Survey (BDHS) conducted in 1994, 1998, 2003, and 2008 is utilized. The BDHS are cross-sectional surveys which will be pooled for the analysis. Each BDHS is a household level survey representative at the national, urban/rural, and Departmental levels[7]. All four surveys were conducted using a similar two-stage stratified sampling method with stratification first occurring at the department level and second within departments by place of residence (urban/rural). The primary sampling units were enumeration areas as defined in the most recent census. Each survey contains two separate questionnaires. The first is a household questionnaire that contains information on all individuals within sample households. The household questionnaire records individual (age, sex, education, etc) as well as household (facilities, assets, etc) characteristics. Especially relevant to this study, the household survey contains information on water source, sanitation, flooring, as well as anthropometrics for young children. The additional questionnaires were administered to women aged 15 to 49. The questionnaires ask detailed health questions including questions regarding the health and care of their children. For example, it asks if their children have suffered from diarrhea in the previous 2 weeks. This study is primarily concerned with children under 3 years of age and the set of BDHSs contain information on 16,177 children in this age range[8]. Table 1.1 presents summary statistics for the pooled sample and several samples.

1.3.1 Child Health

The BDHS contains four potential indicators of diarrheal disease that will be utilized in this study. The first is a binary response to a question that asks if the child has had diarrhea in last 2 weeks. This variable will serve as a measure of *acute* diarrhea morbidity. It therefore will provide an indication of the effectiveness of improved water, sanitation, or flooring on transmission of diarrhea but it will not necessarily capture the effect on the severity and persistence of diarrhea. As shown in the left column of Table 1.1, 29 percent of children in the pooled sample had diarrhea in the past two weeks.

Persistent episodes of diarrhea can result in malnutrition. Therefore, anthropometric

[7] Departments (Departamentos) are nine subnational divisions of Bolivia

[8] To arrive at the main sample, children with missing observations of regressor variables are dropped.

Table 1.1: Summary Statistcs

	Pooled	Acute Diarrhea		Stunted		Light		Thin	
		No	Yes	No	Yes	No	Yes	No	Yes
Child health:									
Had diarrhea recently	0.29	0.00	1.00	0.28	0.33	0.28	0.40	0.29	0.35
Ht/A Standard deviations	-1.08	-1.00	-1.26	-0.51	-2.83	-0.89	-2.77	-1.09	-0.54
Wt/A Standard deviations	-0.47	-0.38	-0.71	-0.11	-1.61	-0.24	-2.58	-0.43	-2.35
Wt/Ht Standard deviations	0.25	0.32	0.10	0.28	0.17	0.40	-1.11	0.33	-2.61
Household infrastructure:									
Piped water	0.68	0.68	0.67	0.71	0.57	0.70	0.54	0.68	0.57
Sanitation	0.61	0.62	0.58	0.66	0.43	0.63	0.43	0.61	0.53
Nondirt floor	0.59	0.60	0.56	0.64	0.43	0.61	0.39	0.59	0.45
Piped & Sanitation	0.49	0.50	0.47	0.55	0.32	0.51	0.30	0.50	0.36
Piped & nondirt	0.50	0.51	0.47	0.55	0.34	0.52	0.30	0.50	0.36
Sanitation & Nondirt	0.44	0.46	0.41	0.50	0.25	0.46	0.24	0.44	0.32
Piped & Sanitation & Nondirt	0.40	0.41	0.37	0.46	0.22	0.42	0.20	0.40	0.27
Child characteristics:									
Sex	0.51	0.50	0.53	0.51	0.53	0.51	0.53	0.51	0.62
Age (months)	17.7	17.7	17.7	16.6	21.1	17.5	19.8	17.7	16.7
Preceding birth interval (months)	31.5	31.6	31.2	32.0	29.7	31.7	29.5	31.5	29.4
Mother characteristics:									
Age mother	28.3	28.4	28.0	27.9	29.5	28.2	29.4	28.3	28.6
Age mother squared	849	857	832	825	924	842	920	849	871
Education in single years	6.58	6.75	6.17	7.19	4.71	6.82	4.42	6.61	5.52
Never Married	0.06	0.06	0.07	0.07	0.05	0.07	0.06	0.06	0.07
Married	0.88	0.89	0.88	0.88	0.90	0.88	0.89	0.88	0.88
Mother's relationsip to head:									
Head	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06
Spouse	0.73	0.74	0.73	0.72	0.77	0.73	0.77	0.73	0.73
Son or daughter	0.12	0.13	0.12	0.13	0.10	0.13	0.09	0.12	0.13
Son-in-law or daughter-in-law	0.04	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.04
Other relative	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.03	0.03
Other nonrelative	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 1.1: (continued)

	Pooled	Acute Diarrhea		Stunted		Light		Thin	
		No	Yes	No	Yes	No	Yes	No	Yes
Head characteristics:									
Head of household is male	0.88	0.88	0.88	0.87	0.89	0.88	0.89	0.88	0.89
Head age	36.8	36.9	36.6	36.9	36.6	36.8	36.7	36.8	36.6
Head age squared	1502	1507	1492	1512	1472	1505	1481	1503	1474
Household characteristics:									
Household members above 5 years old	4.05	4.04	4.09	4.01	4.19	4.03	4.30	4.05	4.22
Members under age 5	1.88	1.88	1.87	1.82	2.05	1.86	2.06	1.88	1.99
Owns TV	0.56	0.57	0.53	0.61	0.39	0.58	0.34	0.56	0.39
Owns radio	0.80	0.81	0.79	0.81	0.78	0.81	0.73	0.80	0.72
Owns refrigerator	0.23	0.25	0.20	0.28	0.09	0.25	0.08	0.23	0.18
Has electricity	0.64	0.65	0.62	0.69	0.49	0.66	0.45	0.65	0.49
# of rooms for sleeping per capita	0.28	0.28	0.27	0.29	0.24	0.28	0.24	0.28	0.26
Urban	0.53	0.54	0.50	0.58	0.39	0.55	0.37	0.53	0.42
Wealth quintile:									
Poorest	0.28	0.27	0.30	0.23	0.42	0.26	0.45	0.27	0.40
Poorer	0.22	0.22	0.23	0.21	0.26	0.22	0.26	0.22	0.24
Middle	0.21	0.21	0.22	0.22	0.18	0.22	0.16	0.22	0.12
Richer	0.17	0.17	0.17	0.20	0.10	0.18	0.09	0.17	0.14
Richest	0.11	0.13	0.08	0.14	0.03	0.12	0.04	0.11	0.10
Observations	16,177	11,470	4,707	12,214	3,963	14,571	1,606	15,783	394

measures of child nutrition will provide an indication (albeit imperfect) of *chronic and severe* diarrhea. To capture the impact of improved household infrastructure on chronic diarrhea, three anthropometric measures will be used in the analysis below: height-for-age, weight-for-age, and weight-for-height. Each child's height and weight were measured and compared with the international reference growth curves of the National Center for Health Statistics and the World Health Organization (WHO). The international reference growth curves are constructed based on data from an international reference population and are intended to represent the normal growth curve for any child[9]. The number of standard deviations from the mean of the growth curve is calculated based on each child's measurements.

Each measure imparts slightly different information. Child height is largely a function of the nutrition and health of a child throughout their life and is therefore considered to be a longer-term measure of health (Strauss and Thomas, 1998). Children which have had repeated episodes of diarrhea in previous years or received poor nutrition will be shorter or more stunted than if they had better health and nutrition. Since a direct measure of each child's "potential" height is not available, an approximate measure of a child's relative health can be obtained by comparing their height with the height of similarly aged children. For this reason, a child's height-for-age is an indicator of stunting. In contrast to height, weight is subject to greater fluctuation based on current nutrition and health and hence reflects a child's short-term health (Strauss and Thomas, 1998). Weight-for-age compares a child's weight with children of a similar age and weight-for-height compares weight with children of a similar stature. Weight-for-age captures the "lightness" of a child whereas weight-for-height measures "thinness" (O'Donnell and Wagstaff, 2008). Both of these indicators will reflect more recent persistent episodes of diarrhea.

Since anthropometric measures are being used as a proxy for chronic diarrhea, information on very young infants will not provide a long enough perspective for multiple episodes of diarrhea. Therefore, the sample will be limited to children who are 3 months or older for regressions with dependent anthropometric measures. There is one significant drawback to these measures: they do not reflect the most severe cases of diarrhea which prove fatal. Since we cannot observe the anthropometry of deceased children, the coefficient estimates for anthropometric regressions will likely be underestimates of the true impacts. According to Table 1.1, an average child in the pooled sample is relatively stunted (1.08 standard deviations (SD) below the WHO mean), underweight

---

[9]See http://www.who.int/nutgrowthdb/about/introduction/en/index3.html for further information.

for their age (0.47 SDs below the WHO mean), but relatively overweight for their height (0.25 SDs above the WHO mean).

The remaining columns of Table 1.1 present means for subsamples according to health (diarrhea) status. For acute diarrhea, the partition is simply between children that have had diarrhea in the past 2 weeks and those that haven't. For the anthropometric measures a standard cutoff of 2 standard deviations was used for stunting, lightness, and thinness. The top panel of the table shows a strong association between acute and chronic diarrhea. Children that suffer from acute diarrhea also have lower anthropometric measures. Likewise, children with lower anthropometric measures potentially caused by chronic diarrhea are much more likely to have suffered from a recent bout of diarrhea. For example stunted children were 5 percentage points more likely to have suffered recently from diarrhea than nonstunted children. This provides supporting evidence that anthropometric measures capture the effects of chronic diarrhea.

1.3.2 Household Infrastructure

This study focuses on the individual and combined impacts of three household infrastructures: drinking water source, sanitation facilities, and flooring type. Although the BDHS contains detailed information on each factor, the information is not consistent across the survey years. The infrastructures are partitioned into improved and unimproved types. Table B.1 in the Appendix contains the full frequency distributions for water source, sanitation facilities, and flooring type for each year of the BDHS.

The source of drinking water in the BDHS is aggregated into two water source categories for use in the analysis below: piped and non-piped. The piped category includes water piped into the dwelling, yard, or plot. Non-piped sources of water include wells, river/dam, lake/pond/stream, tanker truck, etc.. As Table 1.1 indicates, a majority of children in the pooled sample (68 percent) live in households that have piped water access. While there is little difference in piped water access between acute diarrhea status, there were larger differences between the three anthropometric measures. Children with better nutrition and less persistent episodes of diarrhea are more likely to have piped water access. While this is likely partially due to differences in wealth, it still provides some initial indication that piped water access could impact chronic diarrhea.

The BDHS also contains information on the type of sanitation facilities used by the household. Facilities will be grouped into improved sanitation and unimproved sanitation[10]. The 1994, 1998,

[10]Previous drafts of this essay had three sanitation categories: toilet, latrine, and other. However, there

and 2003 BDHSs ask respondents the type of facilities used by the household whereas the 2008 BDHS asks the main source of sanitation services (sewage/septic, open pit, etc). For the latter case, those households with sewage/septic services and that use an open pit will be categorized as having improved sanitation facilities while all others are grouped in the unimproved category. 61 percent of children in the pooled sample live in a household with improved infrastructure. Table 1.1 indicates that children with acute and chronic diarrhea are less likely to live in households with improved sanitation facilities.

The final key household environmental factor is the type of flooring in the household. Each BDHS records a variety of separate flooring types. These categories are dramatically simplified into mud/dirt floors and non mud/dirt floors. This grouping is justified since dirt or mud floors are generally considered greatly inferior to other types of flooring (in terms of preventing transmission of diarrheal parasites) while the other categories have only minor differences. Following this classification, 59 percent of children in the pooled sample reside in households with flooring other than dirt or mud. Similar to improved sanitation facilities, children with acute or chronic diarrhea are less likely to live in households with nondirt floors. In general, the descriptive analysis provides some indication of a link between household infrastructure quality and child diarrhea.

The hypothesis to be tested in this study is that certain combinations of household infrastructures have a greater impact on diarrheal diseases. While generally all improved combinations are expected to have a positive impact on child diarrhea, improved sanitation facilities and nondirt flooring are expected to have the greatest. These two infrastructures appear to have the greatest complementarity in disposal/identification of feces. To test whether combinations are effective, every interaction of the indicators described above are calculated. Their summary statistics are included in Table 1.1. The mean of the "Piped & Sanitation" variable indicates that 49 percent of children reside in households with piped water and improved sanitation facilities. Half of children live in households with piped water and nondirt flooring while 44 percent live in households with improved sanitation facilities and nondirt flooring. Only 40 percent of children live in households with all three types of improved household infrastructure. In accordance with the distribution of individual infrastructures, children not suffering from acute diarrhea or poor anthropometric measures are more likely to live in households with all improved combinations.

---

was strong collinearity between having a flush toilet and both piped water access and nondirt flooring. Since the justification for this partition was relatively weak and in order to better capture the effect of combinations of improved infrastructures, the improved/unimproved was adopted in this draft.

1.3.3 Additional Controls

Controls for child, mother, head, and household characteristics will also be included in the the analysis. Summary statistics of these variables are also reported in Table 1.1. The average age of a child in the pooled sample is about 18 months and about 51 percent of children in the pooled sample are male. The child's preceding birth interval is also included with an average of 31.4 months. Mother's age, years of education, marital status, and relationship to the household head are included. On average, mothers are about 28 years of age and have attended 6.6 years of school. Nearly 90 percent of mothers are married with only 6 percent that have never been married. The majority of mothers are the spouse of the household head while only 7 percent are heads themselves and 12 percent are the son or daughter of the head. Most children (88 percent) live in households with a male head with an average age of 37. The average household of sample children has 4 persons 5 years or older, 2 persons under 5, and 0.28 rooms for sleeping per capita. Approximately 64 percent live in households with electricity while just over half of live in urban areas (defined as communities with 2,000 or more inhabitants). Table 1.1 also includes sample means for wealth quintiles (as calculated within the BDHS). As expected, there appears to be a close association between wealth and incidence of acute and chronic diarrhea (and nutrition more broadly).

1.4 Empirical Methodology

The focus of this study is on the differential impact of various combinations of improved household infrastructures on acute and chronic diarrhea. In order to test whether this is the case, each improved infrastructure indicator (piped water, improved sanitation facilities, and non-dirt floors) as well as every possible combination of these improved factors will be included as regressors in all regressions. The basic regression to be run for all instances will be similar to the following:

$$\begin{aligned} H_{ihpt} &= \beta_0 + \beta_1 P_{hpt} + \beta_2 S_{hpt} + \beta_3 N_{hpt} \\ &\quad + \beta_4 (P_{hpt} \times S_{hpt}) + \beta_5 (P_{hpt} \times N_{hpt}) + \beta_6 (S_{hpt} \times N_{hpt}) \\ &\quad + \beta_7 (P_{hpt} \times S_{hpt} \times N_{hpt}) \\ &\quad + \Phi X_{ihpt} + \lambda Z_{hpt} + \gamma_{pt} + \varepsilon_{ihpt} \end{aligned}$$

Here, H_{ihpt} is the health indicator (diarrhea or anthropometric) of child i in household h in Province p at time t, P_{hpt} is the piped water indicator, S_{hpt} is the improved sanitation facility indicator, N_{hpt} is the non-dirt floor indicator, X_{ihpt} is a vector of child characteristics, Z_{hpt} is a vector of mother, head, and household characteristics, γ_{pt} are Province-year fixed effects, and ε_{ihpt} is the idiosyncratic error term. In the context of the binary diarrhea indicator, a negative coefficient implies a positive relationship between the regressor and child health (lower diarrhea occurrence). If as expected, each individual improved factor leads to better child health, then β_1,β_2, and β_3 would be negative and significant. However, the primary assertion made in this study is that combinations of improved factors have the greatest impact on health. Thus the effects of the combination of any of the improved infrastructures $(\beta_4, \beta_5, \beta_6, \beta_7)$ are expected to be negative and significant. For anthropometric measures, the signs of the coefficients should be reversed since a higher values of these measures implies improved health.

Province-year fixed effects (γ_{pt}) will control for observed and unobserved characteristics of Provinces and of each year of the BDHS[11]. These will include many local characteristics such as availability and quality of local health facilities, effectiveness of local government, etc. Bolivia is partitioned into 112 Provinces.

Initially, the above equation will be estimated using the full pooled sample of BDHSs. While a probit or logit would be the optimal estimation method for diarrhea infection, a linear probability model will be estimated here. This was chosen to allow inclusion of Province-year fixed effects without the loss of a significant portion of the sample where there was no variation in diarrhea incidence[12]. Therefore both the diarrhea and anthropometric specifications will be estimated using ordinary least squares (OLS).

Diarrhea morbidity and especially anthropometric measures are influenced by factors other than household infrastructure such as family income, quality of health care, and number of siblings. The influence of these factors on child health may be captured in the coefficient estimates for household infrastructures. If this were true, these estimates would be biased and not accurately reflect the true impact of household infrastructures. Including these alternative determinants as

---

[11]While it was possible to include lower level fixed effects, some of the infrastructures considered in this study are community based and therefore the fixed effect would strip any effect from improved community infrastructures on child diarrhea.

[12]Estimating a probit/logit would necessitate dropping 1,666 observations (10% of the sample) due to no within Province-year variation in acute diarrhea). Estimations were performed using the logit fixed effect estimator with the Province-year fixed effects with results that were very consistent with the main linear probability model presented below.

controls will partially disentangle their specific influence and thereby limit the bias in the household infrastructure estimates. A series of child, mother, household head, and household level controls will be included in the regressions below to attempt to correct for this bias. In addition to continuous variables presented in Table 1.1, dummy variables are included in each regression for the month of interview to capture any seasonal variation in diarrhea incidence. Province-year fixed effects will also attenuate any omitted variable bias by capturing the effects of observable and unobservable local characteristics.

While including additional controls will limit the potential omitted variable bias, there are still other unobservables whose impacts may be captured in the coefficients on household infrastructures. An alternative method to correct for omitted variable bias is to instrument for these the household infrastructure variables. Instruments would have to be correlated with the relevant infrastructure variable but not correlated with the health outcome other than through infrastructure. In other words, an instrument would capture an *exogenous* variation in infrastructure. Some potential candidates for instruments would be data on exposure to the two government interventions mentioned above: the SIF II and PROSABAR. However, all attempts to acquire the data have been unsuccessful thus far. The Appendix outlines how the instrumental variable method could be implemented should the project data become available. Unfortunately, no other potential instruments were identified. However, it is argued here that omitted variable bias will be greatly mitigated by the inclusion of Province-time fixed effects.

Children within a community are exposed to a very similar environment in addition to having very similar background characteristics. For this reason, it is expected that errors are correlated within communities. This correlation will lead to an underestimate of standard errors in the estimations. Therefore, clustering within enumeration areas shall be accounted for in all standard error estimates below.

1.5 Results

Tables 1.2 and 1.3 presents the results for all four health measures. Columns 1, 3, 5, and 7 present results from specifications without the combinations. Columns 1, 2, 5, and 6 contain estimates for simple specifications that only include Province-year fixed effects. For acute diarrhea, improved sanitation facilities were the only improved infrastructure that had a significant impact. The estimate in column 1 indicates that children residing in households with improved sanitation facilities were 3.4 percent less likely to suffer from acute diarrhea. This result remains when additional controls are added.

The results for the impacts of individual infrastructures on chronic diarrhea (the anthropometric measures) are mixed. For the simple specifications without controls, all three improved infrastructures where associated with higher height-for-age and weight-for-age while only nondirt flooring was associated with higher weight-for-height. However, including additional controls weakens these associations. The results indicate that piped water was not effective at reducing chronic diarrhea, a result that seems to agree with the findings of Lawson and Appleton (2007). Improved sanitation facilities also appeared to have little to no effect when controlling for additional variables. The surprisingly weak results for sanitation is contrary to Günther and Fink (2010) who found a strong beneficial effect of improved sanitation facilities. However, the results indicate that having nondirt floors has a strong impact on height-for-age and weight-for-age. This may indicate that nondirt floors decrease chronic diarrhea but this also may be capturing the impact of nondirt floors on other health factors that contribute to a child's anthropometrics. Curiously, the strength of the flooring results here is opposite to that of Cattaneo et al. (2009). The authors find that improved flooring resulted in lower diarrhea incidence but had no effect on anthropometrics. Overall, the results for the individual impacts of improved infrastructures is surprisingly weak though improved flooring appears to have the most consistent benefits for health.

In regressions without the interaction terms, any effects of the combined presence of household infrastructures will be captured by the coefficients on the individual infrastructures. Including the interactions in the second set of regressions will strip their effects from the linear infrastructure coefficients. Therefore, one indication that infrastructure combinations have a distinct effect is whether the individual infrastructure coefficients change after including the interaction terms. A decrease in the individual coefficient after including combinations suggests that the combinations have a distinct and positive effect on the dependent health measure. However, this change cannot be statistically tested. A significant coefficient on an interaction term would provide stronger evidence that the combination of infrastructures has an effect on child diarrhea beyond the individual impacts of the infrastructures. The hypothesis is that the combinations of improved household infrastructures has a beneficial effect beyond the contribution of each infrastructure individually.

Columns 2, 4, 6, and 8 in Tables 1.2 and 1.3 present results for estimations that include the interactions of the various improved infrastructures. Looking across all four health measures, there are only two combinations that have a significant effect. The combination of improved sanitation facilities and nondirt flooring was weakly effective at reducing stunting by 0.17 standard deviations.

Table 1.2: Diarrhea & Height-for-Age Results

	Diarrhea				Height-for-age			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Household Infrastructure:								
Piped water	-0.004	-0.015	0.004	-0.010	0.147***	0.119**	0.039	0.054
	(0.010)	(0.017)	(0.011)	(0.017)	(0.032)	(0.055)	(0.032)	(0.053)
Sanitation	-0.034***	-0.045**	-0.021**	-0.041**	0.193***	0.072	0.056*	0.010
	(0.010)	(0.019)	(0.010)	(0.019)	(0.031)	(0.061)	(0.030)	(0.059)
Nondirt floor	-0.015	0.000	0.001	0.005	0.374***	0.254***	0.177***	0.156***
	(0.010)	(0.021)	(0.011)	(0.021)	(0.030)	(0.061)	(0.032)	(0.060)
Infrastructure interactions:								
Piped & Sanitation		0.042		0.040		0.029		0.023
		(0.026)		(0.026)		(0.080)		(0.076)
Piped & nondirt		-0.001		0.002		0.033		-0.018
		(0.027)		(0.027)		(0.079)		(0.076)
Sanitation & Nondirt		-0.003		0.008		0.174*		0.120
		(0.031)		(0.031)		(0.095)		(0.091)
Piped & Sanitation & Nondirt		-0.034		-0.024		0.008		-0.078
		(0.038)		(0.038)		(0.116)		(0.111)
Additional Controls	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.052	0.053	0.061	0.061	0.157	0.158	0.238	0.238

Note: Coefficient estimates presented with robust standard errors clustered at the enumeration area in parentheses. All regressions include province-year fixed effects. Additional controls whose results are omitted from the table include child, mother, head, and household characteristics and month of interview. See Appendix Table D.1 for full results. Significance denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.3: Weight-for-Age & Weight-for-Height Results

	Weight-for-Age				Weight-for-Height			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Household Infrastructure:								
Piped water	0.098***	0.084*	0.009	0.024	-0.011	-0.014	-0.046*	-0.046
	(0.029)	(0.047)	(0.029)	(0.046)	(0.027)	(0.042)	(0.028)	(0.042)
Sanitation	0.138***	0.098*	0.036	0.046	0.039	0.072	0.011	0.050
	(0.028)	(0.055)	(0.027)	(0.053)	(0.025)	(0.050)	(0.026)	(0.050)
Nondirt floor	0.278***	0.260***	0.119***	0.168***	0.064**	0.120**	0.006	0.074
	(0.027)	(0.053)	(0.029)	(0.052)	(0.025)	(0.050)	(0.027)	(0.050)
Infrastructure interactions:								
Piped & Sanitation		0.012		0.012		-0.007		-0.000
		(0.074)		(0.071)		(0.068)		(0.067)
Piped & nondirt		-0.015		-0.051		-0.038		-0.043
		(0.071)		(0.069)		(0.066)		(0.065)
Sanitation & Nondirt		0.001		-0.034		-0.131		-0.134*
		(0.084)		(0.081)		(0.080)		(0.079)
Piped & Sanitation & Nondirt		0.070		0.005		0.099		0.080
		(0.104)		(0.101)		(0.098)		(0.097)
Additional Controls	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.131	0.131	0.196	0.196	0.080	0.080	0.096	0.097

Note: Coefficient estimates presented with robust standard errors clustered at the enumeration area in parentheses. All regressions include province-year fixed effects. Additional controls whose results are omitted from the table include child, mother, head, and household characteristics and month of interview. See Appendix Table D.2 for full results. Significance denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

This is the combination that is expected to have the greatest degree of complementarity in reducing diarrhea. However, this result becomes insignificant when including additional controls. The same combination weakly detracts from the individual effects of improved sanitation and nondirt flooring on weight-for-height. We can see this in the individual infrastructure coefficient changes from column 7 to column 8 in Table 1.3: the individual coefficients on improved sanitation facilities and nondirt flooring increase when accounting for their combination.

Overall the results have indicated that combinations have a very small or poorly measured effect on acute and chronic diarrhea. Therefore, the hypothesis posed in this paper cannot be confirmed. However, there are some results for individual infrastructures that are of note. Improved sanitation appears to be effective at reducing acute bouts of diarrhea in children while nondirt flooring appears most effective at reducing chronic diarrhea (or other factors that influence anthropometrics).

The estimates on the controls are variable, but some effects are of note (see Tables D.1 and D.2 in the Appendix). All specifications indicate that chronic and acute diarrhea are more prevalent among boys than girls. Likewise, children with more educated mothers are at lower risk of diarrhea and lower rates of stunting and lightness. Children of mothers who are not related to the head of the household are at higher risk of diarrhea and have poorer anthropometric measures when compared to children whose mother is the head. Interestingly, asset ownership (refrigerator, TV, and radio) appears to generally be associated with better health, but the estimates may be capturing the impact of higher wealth on diarrhea. These results suggest that there may be significant heterogeneity in the impact of combinations of infrastructure on health.

1.5.1 Heterogeneity of Impact

To asses the potential for heterogeneity in the impact of combinations of infrastructures, the empirical method used above is applied to subsamples based on urban/rural residence and the sex of the child. Tables 1.4 through 1.7 present the infrastructure estimates for each sample (full, urban, rural, male, female).

Table 1.4 contains the estimates for acute diarrhea. Comparing the results for the urban and rural samples, there are some differences in the importance of combinations of infrastructure. In a rural setting, it appears that piped water access combined with sanitation detracts from the individual impacts of each infrastructure. When accounting for the combination, the impact of improved sanitation becomes positive and significant. One possible explanation for this result is that piped water in rural areas is likely of lower quality than urban areas. In addition, the individual impact of improved sanitation facilities was larger and significant in rural areas but small and insignificant in urban.

There are also some differences in the importance of household infrastructure for acute diarrhea of male and female children. Female acute diarrhea appears to be lessened by improved sanitation facilities but this does no appear to be the case for male children (although the point estimates are negative). The explanation for this difference is unclear, but it could be the case that girls are generally cleaner than boys and thus may be better able to benefit from more sanitary facilities. One other minor difference is that the combination of piped water access and sanitation facilities detracted from the individual impacts for boys but not significantly for girls.

Tables 1.5 through 1.7 present equivalent results for the anthropometric measures. Comparing the results for the urban and rural sample, there are some important differences. Combinations appear to play a larger role in stunting in rural areas. Having improved sanitation facilities and nondirt flooring appears to be largely beneficial in rural areas with a 0.2 standard deviation increase in height-for-age over the individual impacts. Surprisingly however, the combination of all three improved infrastructures detracted from the individual impacts overall in rural areas. This again could reflect relatively poor quality piped water available to rural households. This could also explain the negative association between piped water and weight-for-height in rural areas shown in Table 1.7.

As for acute diarrhea, there are a few differences in the importance of household infrastructure between male and female children. While the individual infrastructure effects are similar, there are some differences in the importance of combinations of infrastructures. The combination of improved sanitation and nondirt flooring again appears to be beneficial for male stunting and chronic diarrhea. However, the effect for female children was insignificant and close to zero. This combination also detracts from the individual impacts for male weight-for-height although this is offset by the large positive effect of having all three improved infrastructures for male children. No combination appears especially relevant for preventing the chronic diarrhea of female children.

While the results of this study have a mixed record of consistency with the findings of the literature, they do not provide unequivocal support for the hypothesis posed above. The impact of combinations of improved water, sanitation, and flooring had a minimal impact on diarrhea incidence and anthropometric measures of health. However, the results do provide some indication that combinations may matter more for children in rural areas. This is likely due to generally poorer

Table 1.4: Subsample Results - Diarrhea

	Full		Urban		Rural		Male		Female	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Piped water	0.004	-0.010	-0.001	-0.005	0.011	-0.006	-0.007	-0.033	0.017	0.010
	(0.011)	(0.017)	(0.018)	(0.046)	(0.015)	(0.020)	(0.016)	(0.025)	(0.015)	(0.025)
Sanitation	-0.021**	-0.041**	-0.016	-0.005	-0.027*	-0.065***	-0.011	-0.039	-0.035**	-0.051*
	(0.010)	(0.019)	(0.016)	(0.047)	(0.015)	(0.023)	(0.015)	(0.027)	(0.015)	(0.028)
Nondirt floor	0.001	0.005	0.021	0.056	-0.011	-0.017	0.007	0.021	-0.003	-0.019
	(0.011)	(0.021)	(0.016)	(0.046)	(0.015)	(0.026)	(0.015)	(0.030)	(0.016)	(0.030)
Interactions										
Piped & Sanitation		0.040		0.026		0.059*		0.063*		0.024
		(0.026)		(0.058)		(0.032)		(0.037)		(0.037)
Piped & nondirt		0.002		-0.014		-0.003		-0.001		0.020
		(0.027)		(0.056)		(0.036)		(0.039)		(0.038)
Sanitation & Nondirt		0.008		-0.037		0.033		-0.015		0.046
		(0.031)		(0.057)		(0.041)		(0.043)		(0.043)
Piped & Sanitation & Nondirt		-0.024		-0.005		-0.024		-0.013		-0.058
		(0.038)		(0.069)		(0.054)		(0.054)		(0.054)
Observations	16,177	16,177	8,601	8,601	7,576	7,576	8,276	8,276	7,901	7,901
R-squared	0.061	0.061	0.066	0.066	0.091	0.092	0.079	0.079	0.093	0.093

Note: Coefficient estimates presented with robust standard errors clustered at the enumeration area in parentheses. All regressions include Province-year fixed effects. Additional controls whose results are omitted from the table include child, mother, head, and household characteristics and month of interview. Significance denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.5: Subsample Results - Height-for-Age

	Full		Urban		Rural		Male		Female	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Piped water	0.039	0.054	0.063	0.084	0.050	0.047	0.034	-0.022	0.035	0.133*
	(0.032)	(0.053)	(0.052)	(0.132)	(0.042)	(0.060)	(0.044)	(0.071)	(0.044)	(0.073)
Sanitation	0.056*	0.010	0.081*	0.009	0.019	-0.017	0.048	-0.060	0.075*	0.117
	(0.030)	(0.059)	(0.045)	(0.143)	(0.043)	(0.069)	(0.041)	(0.081)	(0.042)	(0.080)
Nondirt floor	0.177***	0.156***	0.164***	0.216	0.169***	0.112	0.194***	0.104	0.152***	0.201**
	(0.032)	(0.060)	(0.048)	(0.132)	(0.043)	(0.077)	(0.043)	(0.082)	(0.044)	(0.088)
Interactions										
Piped & Sanitation		0.023		0.059		0.055		0.142		-0.129
		(0.076)		(0.166)		(0.096)		(0.105)		(0.105)
Piped & nondirt		-0.018		-0.105		0.079		0.109		-0.139
		(0.076)		(0.156)		(0.099)		(0.104)		(0.111)
Sanitation & Nondirt		0.120		0.014		0.204*		0.219*		0.015
		(0.091)		(0.168)		(0.120)		(0.125)		(0.126)
Piped & Sanitation & Nondirt		-0.078		0.030		-0.280*		-0.244		0.090
		(0.111)		(0.197)		(0.153)		(0.152)		(0.155)
Observations	15,192	15,192	8,071	8,071	7,121	7,121	7,759	7,759	7,433	7,433
R-squared	0.238	0.238	0.212	0.212	0.243	0.243	0.249	0.249	0.275	0.275

Note: Coefficient estimates presented with robust standard errors clustered at the enumeration area in parentheses. All regressions include Province-year fixed effects. Additional controls whose results are omitted from the table include child, mother, head, and household characteristics and month of interview. Significance denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.6: Subsample Results - Weight-for-Age

	Full		Urban		Rural		Male		Female	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Piped water	0.009	0.024	0.060	0.107	-0.015	-0.029	-0.016	-0.022	0.033	0.091
	(0.029)	(0.046)	(0.049)	(0.114)	(0.039)	(0.052)	(0.041)	(0.062)	(0.041)	(0.065)
Sanitation	0.036	0.046	0.034	0.062	0.026	0.018	0.036	0.050	0.045	0.085
	(0.027)	(0.053)	(0.042)	(0.127)	(0.038)	(0.063)	(0.038)	(0.075)	(0.038)	(0.074)
Nondirt floor	0.119***	0.168***	0.081*	0.206*	0.149***	0.160**	0.115***	0.188**	0.108***	0.136*
	(0.029)	(0.052)	(0.045)	(0.108)	(0.039)	(0.067)	(0.039)	(0.074)	(0.041)	(0.076)
Interactions										
Piped & Sanitation		0.012		-0.017		0.074		0.018		-0.046
		(0.071)		(0.153)		(0.088)		(0.098)		(0.096)
Piped & nondirt		-0.051		-0.150		0.046		-0.069		-0.037
		(0.069)		(0.136)		(0.089)		(0.097)		(0.097)
Sanitation & Nondirt		-0.034		-0.161		0.048		-0.143		0.062
		(0.081)		(0.147)		(0.109)		(0.114)		(0.116)
Piped & Sanitation & Nondirt		0.005		0.173		-0.207		0.123		-0.094
		(0.101)		(0.178)		(0.136)		(0.140)		(0.141)
Observations	15,192	15,192	8,071	8,071	7,121	7,121	7,759	7,759	7,433	7,433
R-squared	0.196	0.196	0.171	0.171	0.216	0.216	0.212	0.213	0.226	0.226

Note: Coefficient estimates presented with robust standard errors clustered at the enumeration area in parentheses. All regressions include Province-year fixed effects. Additional controls whose results are omitted from the table include child, mother, head, and household characteristics and month of interview. Significance denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 1.7: Subsample Results - Weight-for-Height

	Full		Urban		Rural		Male		Female	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Piped water	-0.046*	-0.046	-0.001	0.028	-0.087**	-0.104**	-0.066*	-0.044	-0.021	-0.028
	(0.028)	(0.042)	(0.046)	(0.112)	(0.036)	(0.047)	(0.039)	(0.059)	(0.040)	(0.061)
Sanitation	0.011	0.050	-0.011	0.065	0.029	0.043	0.006	0.098	0.017	0.028
	(0.026)	(0.050)	(0.040)	(0.110)	(0.035)	(0.060)	(0.036)	(0.068)	(0.037)	(0.072)
Nondirt floor	0.006	0.074	-0.028	0.065	0.045	0.104*	-0.000	0.134*	0.003	0.006
	(0.027)	(0.050)	(0.043)	(0.103)	(0.037)	(0.063)	(0.038)	(0.070)	(0.039)	(0.073)
Interactions										
Piped & Sanitation		-0.000		-0.060		0.049		-0.083		0.050
		(0.067)		(0.142)		(0.084)		(0.094)		(0.093)
Piped & nondirt		-0.043		-0.085		-0.012		-0.137		0.051
		(0.065)		(0.131)		(0.084)		(0.092)		(0.092)
Sanitation & Nondirt		-0.134*		-0.191		-0.113		-0.329***		0.053
		(0.079)		(0.139)		(0.107)		(0.109)		(0.114)
Piped & Sanitation & Nondirt		0.080		0.179		-0.001		0.332**		-0.167
		(0.097)		(0.171)		(0.133)		(0.136)		(0.137)
Observations	15,192	15,192	8,071	8,071	7,121	7,121	7,759	7,759	7,433	7,433
R-squared	0.096	0.097	0.096	0.096	0.131	0.131	0.120	0.122	0.125	0.125

Note: Coefficient estimates presented with robust standard errors clustered at the enumeration area in parentheses. All regressions include Province-year fixed effects. Additional controls whose results are omitted from the table include child, mother, head, and household characteristics and month of interview. Significance denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

quality of household infrastructure in rural areas of Bolivia compared to urban. Combinations also appeared more important for male children than female children. As noted above, these results could suffer from considerable omitted variable bias and therefore the estimates may not be reliable. More detailed study of this issue including an attempt to overcome omitted variable bias is warranted.

1.6 Conclusion

This paper has attempted to ascertain whether combinations of improved household infrastructures combat child diarrhea in Bolivia beyond the individual impacts of the each infrastructure. The results of the analysis have not provided conclusive evidence for this hypothesis. In the full sample analysis, only the combination of improved sanitation facilities and nondirt flooring had a significant effect on chronic diarrhea measured by height-for-age. The results suggest that this combination was especially beneficial for chronic diarrhea in rural areas and for male children. The remainder of combinations are nearly aways insignificant or exhibit no robust pattern. Nonetheless, there is some indication that combinations do matter but their effect is poorly estimated. When the effect of combinations is accounted for, the coefficient estimates on individual infrastructures quite often change substantially. If combinations did not matter at all, the coefficients would change little. However, this effect cannot be rigorously measured or tested.

Despite weak evidence for infrastructure combinations, there were some robust findings regarding the effect of individual infrastructures. Improved sanitation facilities were consistently found to be effective at preventing acute diarrhea. This finding is in concurrence with Günther and Fink (2010) who find that sanitation improvements were more effective at improving health than water improvements. However, flooring quality was found to be more important for preventing chronic diarrhea as measured by anthropometrics. The results here contrast somewhat with Cattaneo et al. (2009) who found that improved flooring was effective for acute diarrhea but not anthropometrics. Unlike improved sanitation facilities and flooring, piped water access was not consistently associated with either improvements in acute or chronic diarrhea. In fact, the results may point to a negative effect of piped water access in rural areas. While this is unexpected, it is not unfathomable as there could be significant variation in the quality of piped water especially in rural areas.

The results have important implications for health policy. In the realm of health economics, the results suggest that improved sanitation facilities and flooring are effective at preventing child diarrhea. Programs that support sanitation facility upgrades (e.g. improved latrine or flush toilets, installation of sewage systems) or household flooring improvements (e.g. from dirt to cement) should be encouraged in order to combat child diarrhea. Since improved sanitation facilities were found to be effective at combating *acute* diarrhea and nondirt flooring effective at preventing *chronic* diarrhea, the results also suggest policies that jointly promote both improved infrastructures may be most effective at broadly preventing child diarrhea morbidity and mortality.

Although the results from this study were not conclusive regarding combined infrastructural improvements, there were some indications that they may be important. Additional research that examines this relationship is warranted. One potential and rigorous way to better examine the effect of combinations is through a randomized control trial with randomized assignment of different combinations of infrastructural improvements. Additional research that is able to look at specific combinations would be informative for health policymakers.

CHAPTER 2

CHILD MALARIA AND PARENTAL WORKING HOURS IN SUB-SAHARAN AFRICA: EVIDENCE FROM MALAWI

2.1 Introduction

Malaria has long devastated sub-Saharan Africa and has an especially pernicious impact on young children in impoverished families. The extra care an infected child requires to recover from the disease in addition to the cost of any medication or treatment imposes a considerable burden on poverty stricken families. Parents from such families may alter their work hours in order to adequately cover the increased time and money required to care for infected children. Work hour alterations can have a further deleterious impact on family welfare. Households may decrease their work hours to provide the child with the proper care, but this may result in lower family income and enhanced poverty. Alternatively, households may increase their work hours to cover the direct costs of caring for the infected child. The increased work hours could cause a harmful reduction in the time devoted to caring for the infected child or other family children and family members. There could also be a variable effect across individual adults in the household. For instance, fathers of infected children may increase their work hours while mothers may decrease theirs. This paper investigates how households alter their work hours in response to a child becoming infected with malaria. A better understanding of household work hour response to child malaria will enable policy makers to intervene and prevent any detrimental poverty repercussions that may result from changes in work hours. Prevention of deepening poverty will by extension avoid the devastating health consequences associated with extreme poverty.

Labor supply response to poor child health has been a topic of interest to many economic and health researchers in the developed world. A series of developed country research has been conducted with the aim of assessing the effectiveness of social programs in preventing a downward spiral into poverty. In general, researchers have found the work hours of wives are negatively affected by child illness (Kuhlthau and Perrin, 2001; Noonan et al., 2005; Powers, 2003; Porterfield, 2002) but with less conclusive evidence regarding female heads of households (Gould, 2004). In the developing world, researchers are primarily concerned with the impact of parental work hours on child health (Blau et al., 1996; Glick and Sahn, 1998). Most development studies place little emphasis on the reverse causal link examined here. The few investigations of labor supply changes due to malaria generally find a decrease in adult work hours (Chima et al., 2003; Shepard et al., 1991; Nur and Mahran, 1988; Attanayake et al., 2000). However, the majority of these studies do not focus on the impact of child infection and all use data from small-scale surveys with limited geographic coverage.

Despite the copious amount of research already performed, there has been limited discussion of how the labor supply decisions of parents are altered when having an ill child *in the developing world*. This paper will attempt to fill this gap in the literature through a comprehensive analysis of parental work hour decision-making following child malaria infection. The analysis will provide policy makers and researchers with important information on the labor supply response of parents to child illness and the potential poverty and health implications of their work hour adjustments. Furthermore, it will enable proper design and targeting of policies aimed at curbing the harmful effects of child illness.

In order to investigate the impact of child infection on the work hours of parents, data from Malawi will be utilized. Malawi is a suitable country to focus the analysis on since it has a very high child malaria infection rate and widespread poverty. The under 5 malaria infection rate was 900 per thousand children in 2008 (WHO 2009) while just over half of the population was below the national poverty line in 2010 according to the World Bank. The Malawian data set that is used in the analysis is the Third Integrated Household Survey (IHS3). The IHS3 was administered to 12,288 households in Malawi between 2010 and 2011. A unique feature of the IHS3 is it contains information on work hours in a variety of tasks *and* whether each individual has experienced symptoms of malaria.

The IHS3 will be used to estimate the effect of child malaria infection on parental work participation and work hours. In addition to examining total work hours, the richness of the IHS3 allows further examination of the effect of participation and work hours in four separate work activities: household agriculture, household nonagriculture, wage employment, as well as casual, part-time, or ganyu labor[1]. This analysis will indicate whether there is a differential effect across work types and whether there are any shifts between work types.

The results of the analysis suggest that parents do not increase or decrease their overall work hours in response to child malaria infection. However, the main finding is that parents of malaria infected children work more hours in casual, part-time, or ganyu labor than similar parents whose children are not infected. This indicates that parents turn to ganyu labor for supplemental income to cover the additional care costs associated with child infection. This finding is complementary to Dimowa et al. (2010) who find that Malawian households use ganyu labor as an ex-post coping strategy following a household shock. The analysis also suggests that parents may shift work hours from household agricultural work to ganyu work. This shift could have significant implications for the longterm income of the households since ganyu wages are generally low. These results point to significant costs associated with child malaria infection that induce parents (especially mothers) to spend more time working in ganyu than they otherwise would have. This could have ramifications for household and child wellbeing. In light of the deleterious effects of malaria on child health and the longer term consequences in terms of increased household vulnerability to poverty, the results provide further support for policies aimed at the eradication of malaria.

The paper will proceed as follows. Section 2.2 details the conceptual framework that informs the analysis including a review of the current literature. Section 2.3 describes the IHS3 and the context in Malawi. The empirical approach is discussed in Section 2.4 followed by a presentation and discussion of the results in Section 2.5. Section 2.6 concludes.

2.2 Conceptual Framework

Malaria is a serious disease that affects hundreds of thousands of people each year. According to the World Health Organization (WHO), there were 219 million cases of malaria in 2010 resulting in around 660,000 deaths (WHO 2013). The majority of these deaths occurred among African children (WHO 2013). Malaria is caused by *Plasmodium* parasites that are transmitted exclusively through the bites of infected *Anopheles* mosquitoes (WHO 2013). Transmission rates are largely

[1] Ganyu labor is off-farm, informal labor that is usually performed on another person's farm (Dimowa et al., 2010)

dependent on the population of *Anopheles* mosquitoes which is subject to considerable seasonal variations in precipitation, temperature, and humidity (WHO 2012, WHO 2013). Immunity plays an important role in transmission and severity of the disease. For this reason, the young are especially in danger of succumbing to malaria since they have not had time to build up immunity (WHO 2012).

In nonimmune individuals, initial symptoms of “uncomplicated” malaria include fever, headache, chills, and vomiting. These symptoms usually arise within days or more after infection (WHO 2012). At this stage, rapid recovery can be achieved with prompt and effective treatment (WHO 2010). If not properly treated, severe malaria could ensue resulting in severe anemia, respiratory distress, coma (cerebral malaria), or acute renal (kidney) failure (WHO 2010). When left untreated, severe malaria is fatal in the majority of cases whereas treatment reduces mortality risk to between 10 and 20 percent (WHO 2010). Given the mortality risk associated with untreated malaria, parents have a strong incentive to seek treatment for their infected children.

Treatment of malaria is largely medication based. For uncomplicated malaria, the most effective means of treatment is artemisinin-based combination therapy, or ACT (WHO 2010). This involves simultaneous use of two or more combinations of medications containing artemisinin or one of its derivatives (WHO 2010). The use of these combinations is (1) often more effective than use of a single medication, and (2) provides two lines of defense when the strand of the parasite is resistant to one of the medications (WHO 2010). The treatment regimen for uncomplicated malaria typically lasts from 3 to 7 days (WHO 2010). Severe malaria is treated with either quinine or artemisinin derivatives taken intravenously for 24 hours followed by a full course of ACT (WHO 2010). A course of ACT costs around $1.40 though the cost borne by the household varies considerably (WHO 2011). Some governments provide ACT medications free of charge to children at public hospitals, though distribution and availability of the medication is sometimes inadequate.

In addition to being curable, malaria is also preventable. The two most prominent and effective means to prevent infection is through use of insecticide treated bed nets (ITNs) and indoor residual spraying (IRS). ITNs prevent sleeping occupants from being bitten by infected *Anopheles* mosquitoes which primarily bite between dusk and dawn (WHO 2013). IRS involves spraying insecticides on interior surfaces of dwellings where mosquitoes tend to rest after biting (WHO 2012). In addition to reducing the chance of individuals becoming infected, both these methods also reduce the intensity of community transmission (WHO 2012). Ownership of ITNs is relatively widespread covering an estimated 53 percent of sub-Saharan African households but only 33 percent of the population slept under ITNs in 2011 (WHO 2012). IRS was less common with only 11 percent of the African population at risk of malaria being protected by IRS. While prevention is an important front on the war against malaria, this paper is primarily concerned with the labor supply response of parents who have a child already infected with malaria.

The potential response to having a child infected with malaria is not necessarily monotonic. Parents may decrease their work hours to provide the necessary care for the infected child. However, parents may also increase the amount they work in order to cover any expenses associated with caring for the child or to compensate for the decreased working hours of caretakers. Both of these outcomes may have negative consequences for the wellbeing of the entire household. A decrease in work hours could lead to lower family income and further constrain the ability of families to cover the needs of its members. In addition, children may be sent to work to compensate for the loss of income. This will keep these children out of school resulting in lower human capital and poorer adult outcomes. In contrast, an increase in work hours may result in poor care for the infected child as well as other children and family members. The decrease in care time due to increased work hours can result in poor health and nutrition of children in the household (Glick and Sahn, 1998). Clearly, the work hour response of parents can have important implications for the overall wellbeing of the family and could result in deepening poverty.

Economists and health researchers have long been concerned with the relationship between child illness and parental labor supply. However, in contrast to the focus of this paper, the majority of past research has centered on either (1) developed countries, (2) how the labor supply decisions of parents affect child health or illness, or (3) the labor supply effects of 'economically active' household members (excluding children) infected with malaria. In the research investigating the impact of adolescent infection, the analysis of child infection is often ancillary to some other research component or conducted on a small scale.

A considerable amount of research on child illness and parental work hours has been conducted in the developed world, especially in the United States. A common focus among the literature is on disadvantaged families such as single or unwed parent families (Corman et al., 2005; Gould, 2004; Noonan et al., 2005; Powers, 2003) or low income families (Loprest and Davidoff, 2004). Malaria is not a concern in most developed countries, but the literature examines child 'illness' from a variety of perspectives including disability (Powers, 2003; Porterfield, 2002), special health care needs (Loprest and Davidoff, 2004), and overall health and illness (Corman et al., 2005; Gould, 2004; Kuhlthau and Perrin, 2001; Noonan et al., 2005). Despite the array of subgroups and 'illnesses' examined in the literature, the findings from most studies are in agreement: having a child with an illness or disability decreases the probability of parental employment and/or decreases parental work hours.

Although a majority of the literature find evidence of a negative relationship between child illness and the labor supply of parents, many studies stress that there is substantial heterogeneity of impact based on different household, parent, or child characteristics. Corman et al. (2005) found that the presence of a child in poor health reduces the probability that an unwed mother is working by eight percentage points and decreases her work hours by three hours per week on average. The results of Noonan et al. (2005) indicate a stronger effect on fathers of young children in poor health who work five hours less and have a probability of working eight percentage points lower than equivalent fathers without sick children. Contrary to the majority of studies, Loprest and Davidoff (2004) find no significant effect of having a child with special health care needs on both the probability of employment and hours worked of low-income single parents[2]. Their results may be sensitive to their definition of special health care needs. In her study, Gould (2004) emphasizes the importance of the type of illness a child has. She finds that single mothers work fewer hours if their child has a 'time intensive' illness but no significant impact on employment or work hours of single mothers whose children have an illness imposing a large financial burden. Her results suggest the time component of child illness for single mothers requires altering their labor supply but the financial component is dealt with through other coping mechanisms.

While the literature in the developed world has examined the direction of causation central to this paper, the literature in the developing world is primarily concerned with the reverse: the effect of parental labor supply on child health and illness. Studies examining the impact of parental labor supply on child illness often come out of the voluminous literature on maternal time use and child health but are themselves rather sparse. One study by Blau et al. (1996) finds little evidence of a direct causal effect of maternal labor supply on infant health. Perhaps more interestingly, their results suggest higher maternal wages improve infant health even though mothers of ill children are more likely to work and devote less time to child care. Glick and Sahn (1998) verified this result for anthropometric measures of child nutrition. According to their results, increased maternal labor income improves child nutrition. However, their results also showed an increase in maternal work hours was associated with a reduction in height-for-age of children under five years of age. While the existent development literature is different from the direction of causation addressed in this

[2]Loprest and Davidoff (2004) do find that parents of children with activity limitations are less likely to be working and have lower work hours.

paper, it does frame the trade-offs parents take into consideration when determining how many hours to work when their child is ill. Working more will increase income and could improve the health of the ill child (and other family members) but will also result in less time devoted to caring for the child and may in fact worsen health.

Very few studies directly examine the effect of child malaria infection on the labor supply decisions of parents. However, studies breaching the subject are frequently concerned with the costs of malaria infection and often focus on the infection of 'economically active' members. Economically active household members are often assumed to be persons older than ten or fifteen and exclude most children (Chima et al., 2003). In the literature, the labor supply response of parents falls under the umbrella of 'coping strategies' or strategies that households utilize to cope with the illness of a family member. In their review of the literature Chima et al. (2003) find that the time lost by adults caring for sick children was between one and five days on average. They cite a study by Shepard et al. (1991) which suggested total adult work time lost was around thirty percent of the duration of a child's illness. Some studies discuss labor substitution within a household containing an infected individual. Although studies predominately exclude infected children from their analysis, their examination of intra household labor substitution is directly related to the research of labor substitution between parents of infected children and other household members. Nur and Mahran (1988) found that in Sudan sixty-two percent of lost work hours due to malaria were compensated by a family member. However, they found that in Kenyan focus groups, less than half of small-scale farmers had their labor covered by another person when they were sick with malaria. Their results indicate there may exist a differential impact on parents in different forms of employment. In a study conducted in Sri Lanka, Attanayake et al. (2000) found that less than nineteen percent of economically active infected persons' work hours were covered by other household members. Attanayake et al.'s (2000) results suggest that the extent of labor substitution may be limited.

The existent literature is lacking a study which combines (1) an examination of the impact of child illness on parental work hours and (2) a developing world prospective. The analysis below will attempt to determine if there is a predominant labor supply response of parents in Malawi who have a child infected with malaria. To the best of the author's knowledge, this paper represents the first systematic analysis of the parental labor supply *response* to *child* illness in a *developing* country context using nationally representative data.

2.3 Context and Data

In order to asses the labor supply response of parents to having a child infected with malaria, data from Malawi will be utilized. Malaria infection is widespread in Malawi with an annual infection rate of 300 per thousand persons in 2008 (WHO 2009). Infection is especially endemic amongst children under five with an annual infection rate of nearly 900 per 1,000 children under five in 2008 (WHO 2009). Starting in 2007, a concerted effort was made by the Malawi government in conjuction with the United States President's Malaria Initiative (PMI) and other organizations to improve prevention and treatment of malaria. With significant funding from the PMI, there has been a large expansion in ITNs, IRS, and ACT treatment in Malawi (PMI 2011). ITNs were provided free of charge and distributed via health clinics (PMI 2011). According to the National Malaria Indicator Survey (MIS) conducted in 2010, 55 percent of children under 5 slept under an ITN the previous night (MoH 2010).

Starting in 2007, ACT treatment was provided free of charge at public hospitals for patients younger than 5 years (WHO 2009). However, according to the MIS only about 30 percent of children under 5 with symptoms of malaria took an antimalarial drug (MoH 2010). In addition, 63 percent of antimalarial drugs given to children under 5 came from government health facilities with 17 percent coming from private health facilities (MoH 2010). The MIS also collected information on the direct costs[3] incurred by the household for treatment of children under 5. Amongst the 38 percent of children that sought treatment and reported expenditures, the average direct cost of treatment was approximately US $1.83 (MoH 2010). Treatment costs were more likely to be incurred for treatment at nonpublic facilities (MoH 2010). These costs are significant, especially for impoverished households.

In addition to widespread malaria infection, Malawi also suffers from crippling poverty. According to World Bank estimates of the headcount ratio at the national poverty line, 50.7 percent of Malawians were poor in 2010. Given the developing country status and endemic malaria infection among children, Malawi is an ideal country to analyze the parental labor supply response to child malaria infection.

The data to be used in the analysis below is from the Malawi Third Integrated Household Survey (IHS3). The IHS3 is a household survey administered by the National Statistics Office of Malawi with assistance from the World Bank. It contains information on over 56,000 individuals

[3]Direct costs are defined in the MIS as spending on consultation, drugs, tests, transport, and food.

in 12,271 households from 768 enumeration areas. The IHS3 sample was selected from the 2008 Malawi Population and Housing Census using a stratified two-stage design. In the first stage, census enumeration areas (EAs) were selected with probability proportional to size within each district (Malawi is comprised of 31 districts). In the second stage, 16 households were selected within each sample EA using random systematic sampling. The final sample is representative at the national, regional, district and urban/rural levels in Malawi.

Enumeration areas were also separated into two subsamples across which the questionnaire implementation schedule varied. For the first subsample, households were interviewed once and all questionnaire components were administered at that time. This subsample consisted of 564 EAs and 9,024 households. Households in the second subsample were interviewed twice: once during the post planting period and once during the post harvest period with respect to the 2009/2010 rainy agricultural season. Households within the two visit sample were further split into two equally sized groups. For the first half of households, the household module of the questionnaire was administered in the post planting visit and for the second half it was administered in the post harvest visit. As a result of this design, there is at least one household interviewed in each calendar month within 64 EAs. Therefore, household module information spans the entire 12 month period for these 64 EAs (though not for the individual households themselves).

Since the focus of this paper is on *parental* labor supply, the sample is limited to mothers and fathers of children under 5 in the IHS3. The resultant sample contains 11,529 individuals: 5,225 fathers and 6,304 mothers. All estimations are performed on the full parent sample to capure any overall effects and then performed separately on mothers and fathers to capture any differential effects[4]. The IHS3 covers a broad range of topics including those most relevant to this paper: health and labor. Table 2.1 presents sample means for most variables incorporated into the empirical analysis. Column 1 contains sample means for the full parent sample with columns 2 and 3 containing sample means for fathers and mothers respectively. The variables included in Table 2.1 draw heavily on both the health and labor modules of the IHS3 though information on other controls will be gathered from additional modules.

[4]The analysis was also performed on additional male and female adults in households with at least one child under 5. These results were omitted from this paper for the sake of brevity but are available on request.

2.3.1 Labor

The labor module of the IHS3 contains information on all persons aged 5 years and older. It asks of these persons how many hours in the last seven days they had spent doing four types of "work": (1) work for which they were paid a wage or salary, (2) household agricultural activities for sale or for household food, (3) work for the household's nonagricultural business, and (4) casual, part-time, or ganyu labor[5]. Ganyu labor is off-farm, informal labor that is usually performed on another person's farm (Dimowa et al., 2010). Henceforth, this category of work will be referred to simply as "ganyu" although it does include other part-time or casual labor. These four variables (and their sum) make up the list of dependent variables to be to be used in the empirical analysis.

Summing up the four work variables will approximate the total "work hours" of an individual. However, these four categories do not necessarily capture all work activities. If a full diary (24 hours) of activities were recorded, a more rigorous measure of work hours could be determined. In addition, a full diary would allow an assessment of how time spent on childcare is adjusted when a child becomes infected with malaria. However, such detailed information was not collected as a part of the IHS3. Therefore, the implicit assumption in this paper is that time is substituted between work and childcare: that a decrease (increase) in work time is associated with an increase (decrease) in time devoted to childcare.

As shown in Table 2.1, there is considerable variation in work participation and hours between fathers and mothers. In the table, the first set of means is for participation rates in each type of work (defined as work hours above zero), the second set are for work hours conditional on participation, and the third set are for unconditional work hours. Fathers are more likely to work in income generating activities than mothers. While mothers are more likely to work in household agriculture, fathers are more likely work in all other activities. Unsurprisingly, agriculture is by far the most common work activity with over half of mothers and fathers participating.

Among those that work in these income generating activities, fathers generally worked more hours than mothers though the difference was small for household agriculture. The time gap is further emphasized when looking at unconditional work hours. Fathers consistently work more

[5]Ganyu labor consists of a variety of short-term work arrangements commonly agricultural in nature and concentrated in rural areas. The most common form of ganyu labor is weeding or ridging the fields of other smallholders or larger agricultural estates (Kerr, 2005). However, there are also nonagricultural forms of ganyu such as making bricks, building houses, and digging wells (Whiteside, 2000). The term of ganyu contracts is short, typically less than a week (Takane, 2008). Payment for ganyu labor can be in cash, in kind (often food or seed), or in combination (Whiteside, 2000). In general, women are paid less for ganyu employment than men (Whiteside, 2000). Ganyu labor is often characterized as a coping strategy for poor households to fulfill short-term needs between agricultural seasons or resulting from households shocks (Whiteside, 2000; Dimowa et al., 2010).

Table 2.1: Summary Statistcs

	Parents (1)	Fathers (2)	Mothers (3)	t-test (4)
Work participation				
Participated in any paid work	0.792	0.878	0.721	***
Participated in household agricultural work	0.596	0.586	0.604	*
Participated in households nonagricultural work	0.138	0.167	0.115	***
Participated in wage work	0.096	0.181	0.026	***
Participated in ganyu work	0.158	0.197	0.126	***
Conditional work hours				
Total paid work hours	24.60	29.14	20.03	***
Household agricultural work hours	17.03	17.84	16.38	***
Household nonagricultural work hours	23.46	27.11	19.06	***
Wage work hours	39.76	40.67	34.52	***
Ganyu work hours	14.12	16.15	11.48	***
Unconditional work hours				
Total work time	19.494	25.594	14.439	***
Household agriculture hours	10.144	10.453	9.888	**
Household nonagriculture hours	3.246	4.529	2.183	***
Wage labor hours	3.818	7.347	0.892	***
Ganyu labor hours	2.233	3.184	1.445	***
Health				
At least on child with malaria in HH	0.204	0.206	0.203	
Ill	0.142	0.133	0.151	***
Has malaria	0.057	0.053	0.059	
Household labor				
# of household ag workers in HH	2.435	2.430	2.439	
# of household nonag workers in HH	1.617	1.590	1.639	***
# of wage workers in HH	1.548	1.469	1.614	***
# of ganyu workers in HH	1.714	1.773	1.666	***
# of child household ag workers	0.243	0.235	0.249	
# of child household nonag workers	0.033	0.032	0.034	
# of child wage workers	0.012	0.013	0.012	
# of child Ganyu workers	0.026	0.024	0.028	
Household characteristics				
# of own children under 15	2.757	2.798	2.723	***
# of own children under 5	1.369	1.384	1.356	***
# of household memebers	5.417	5.407	5.426	
# of children ($<$ 15) in household	2.974	2.960	2.986	
# of adults ($>$ 14) in household	2.443	2.447	2.44	
Own house	0.810	0.804	0.815	
Electricity	0.065	0.068	0.063	
Household owns bednet	0.741	0.748	0.735	
Household owns a clock	0.12	0.12	0.12	
Individual characteristics				
Age (years)	31.0	34.1	28.5	***
Age (years) squared	1,036	1,241	867	***
Self reported time	0.617	0.563	0.663	***
Spouse lives in household	0.946	0.913	0.974	***
Mother is in household	0.046	0.023	0.066	***
Father is in household	0.025	0.012	0.036	***

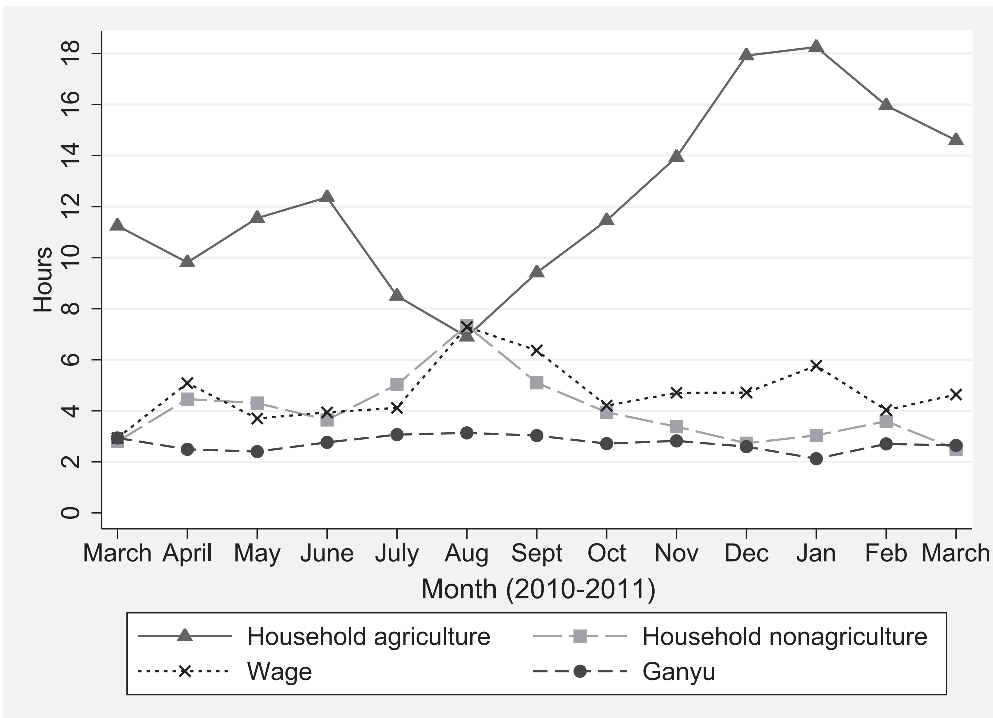
Table 2.1: (continued)

	Parents (1)	Fathers (2)	Mothers (3)	t-test (4)
Education				
Can write in Chichewa	0.687	0.771	0.618	***
Can write in English	0.358	0.451	0.282	***
Primary school	0.606	0.577	0.629	***
Secondary school	0.208	0.274	0.153	***
Post secondary	0.187	0.149	0.218	***
Relationship to householder				
Householder	0.504	0.966	0.120	***
Wife/husband of householder	0.452	0.024	0.807	***
Child of householder	0.038	0.007	0.064	***
Other relative of householder	0.004	0.001	0.007	***
In-law of householder	0.002	0.002	0.002	
Ethnicity				
Chewa	0.559	0.563	0.556	
Nyanja	0.045	0.043	0.047	
Yao	0.090	0.086	0.094	
Tumbuka	0.115	0.119	0.111	
Lomwe	0.040	0.039	0.041	
Sena	0.036	0.037	0.036	
Tonga	0.022	0.022	0.023	
Religion				
No religion	0.024	0.033	0.017	***
Traditional	0.009	0.009	0.009	
Christian	0.836	0.830	0.840	
Islam	0.124	0.121	0.127	
Marital status				
Married - monogamous	0.847	0.894	0.807	***
Married - polygamous	0.076	0.102	0.054	***
Formerly married	0.055	0.002	0.100	***
Observations	11,529	5,225	6,304	

than mothers suggesting that mothers devote more of their time to non-business related household activities including child care. This is especially true for wage employment with fathers working over 7 hours per week and mothers less than 1 hour per week on average. In contrast, time spent on household agricultural activities is more evenly distributed between fathers and mothers on average.

The amount of time spent in each activity varies substantially over time, mostly in line with the agricultural season. Figure 2.1 plots unconditional work time averages across the sample period in the four activities. The effect of the agricultural season on agriculture work hours is plain. Agriculture work hours appear to increase from August to January and then begin to decrease. Also apparent in Figure 2.1 is the rise in household nonagriculture and wage work the mirrors the dip in agriculture in August. In comparison to the other categories, time spent in ganyu work is relatively stable throughout the year. Figure 2.2 plots average work time conditional on participation. It shows that the amount of time spent in each activity is relatively consistent throughout the year. Work hours are highest for wage employment followed by a household nonagricultural business.

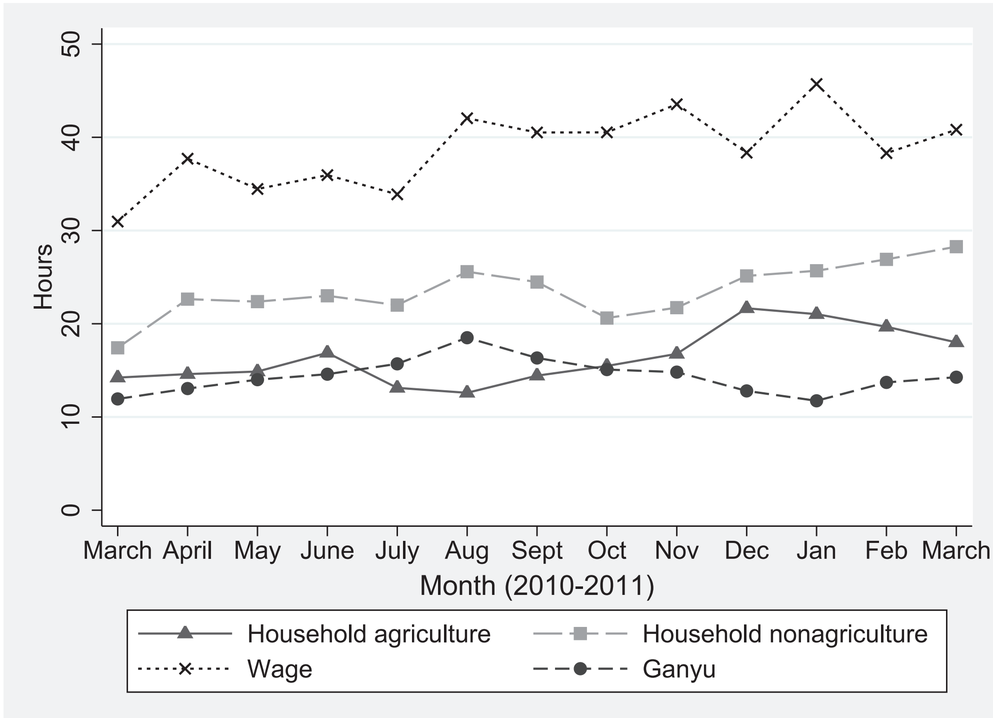
Figure 2.1. Adult Work Hours (Unconditional)



One potential concern is that the ‘work’ variables only take into account work for pay and subsistence production work; they do not capture time spent in household or domestic work and care work. Hence, the variables do not accurately reflect the trade-off between work and care that is central to the analysis. The wording of the questions in the IHS3 appears to counteract this possibility by emphasizing that household “work” only includes business related activities (agricultural and nonagricultural) or activities related to household food supply.

Another potential concern is regarding the reliability of reported work hours. There are two specific issues that could impact how reliable time estimates are: (1) if the individual is reporting their own work hours or if another household member is reporting for them and (2) whether the

Figure 2.2. Adult Work Hours (Conditional)



respondent can accurately estimate hours spent on a particular activity. Work hours reported by another household member are much more likely to suffer from measurement error. The percent of persons that are responding for themselves is shown in Table 2.1. A significant portion of individuals are not reporting for themselves (43 percent of fathers and 34 percent of mothers). To attenuate any bias caused by measurement error, a self reported time indicator will be included in all regressions. The second issue would potentially affect all individuals whether own reported or not. Due to the largely informal nature of work in the developing world, individuals may not have as clear a concept of the length of an hour as a person in the more formal employment. If this is the case, their estimates of "hours" may be unreliable. One potential indicator for whether a household has a good grasp of time is whether they own a clock. However, only 13 percent of IHS3 households report owning a clock. While this is an imperfect measure, it suggests that caution should be used when interpreting reported hours worked. Including clock ownership as a control variable will attempt to capture differences between respondents who may have a more accurate idea of their work hours.

Table 2.1 also contains information on the makeup of household workers. Agriculture has the highest number of average household workers with the number of workers in the other categories relatively consistent. This also true for child labor, though child workers are far fewer in number.

2.3.2 Health and Malaria

The health module of the IHS3 asks of *all household members* if they have suffered from an illness or injury in the past two weeks. Respondents were further asked what the illness or injury was. The most common response was "Fever, Malaria" reflecting the high prevalence of malaria in Malawi. Although this variable does not perfectly identify whether an individual actually has malaria, it will identify those that have malaria-like symptoms which is of more importance for this study.

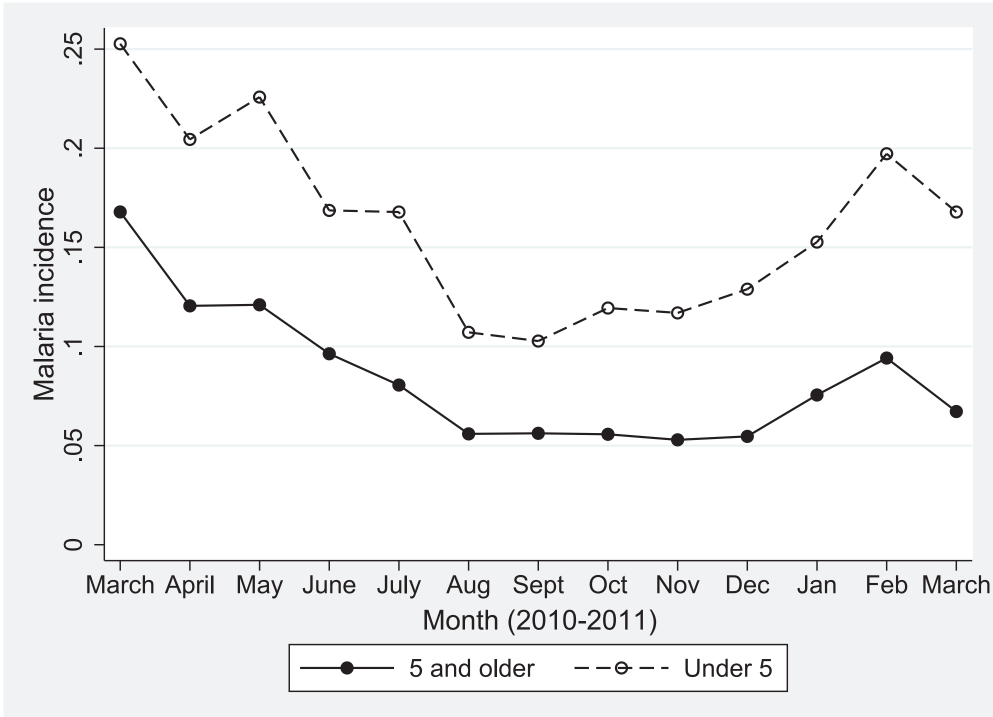
The primary independent variable in the analysis below will be a dummy variable indicating whether there is at least one young child (under 5 years of age) in the household with symptoms of malaria in last two weeks[6]. According to Table 2.1, approximately 20 percent of parents have at least one child infected with malaria. Amongst all children under 5 in the full sample, just under 16 percent have had symptoms of malaria in last two weeks.

The IHS3 also has additional follow up information on how individuals respond to their child's malaria infection. Over 60 percent of children that reported having a fever/malaria were diagnosed by a medical worker at a hospital or other health facility. Almost 70 percent of children with malaria sought care at a government health care facility whereas 12 percent went to a local grocery for medicine. This suggests that many households incur some time cost regarding both diagnosis and treatment. As further indication of the time cost, the IHS3 specifically asks how many days in the past two weeks other household members had to stop their normal activities to care for the ill person. A little under half of children reported that others had to stop their normal activities to care for them for a period of 4 days on average. This is a significant amount though a majority of children reported that no one changed their activities to care for them.

Also presented in Table 2.1 are indicators for individual illness and malaria infection. Overall, 14 percent of parents were ill in the past two weeks. Fathers were less likely to report illness than mothers. In contrast to children, only 6 percent of parents were infected with malaria. Malaria infection rates are also subject to considerable variation throughout the year. This is largely due to seasonal changes in the climate (e.g. rainfall, temperature, humidity, etc.) that affect the

[6]There were few households with more than one child infected with malaria. Estimations were performed using the number of children infected instead of the indicator. This yielded similar results.

Figure 2.3. Malaria Incidence Rates



propagation of mosquitoes. Figure 2.3 plots the monthly infection rates across the IHS3 survey period for both children under 5 and all other persons 5 or older. The cycle closely matches that of the agricultural season and, by extension, agricultural work hours (as shown in Figure 2.1) though with a slight lag. Also apparent from the figure is the large difference in infection rates between young children and all other persons throughout the year.

2.3.3 Other Controls

In addition to health and labor variables, a variety other controls are drawn from the IHS3. These include standard socioeconomic characteristics that could influence work hours such as age, education, religion, ethnicity, and marriage status. The average age of fathers in the sample is 34 and the average for mothers is 28. 58 percent of fathers have not progressed past primary school compared to 63 percent of mothers. Additional variables are included to capture household composition such household size, number of adults, and number of children. The average household is rather large at around 5.5 persons but this is partly because all samples are limited to households with children. Cohabitation with a child's grandparent could alter the care constraint considerably.

Grandparents are likely not employed and thus may have time to take infected children for care preventing parents from having to take off time from work. About 5 percent of parents live with their mother and 2.5 percent with their father. Mothers are much more likely to live with their parents than men. The next section will outline the empirical method to be used in the analysis.

2.4 Empirical Method

The ultimate aim of this paper is to determine whether and how parents alter their work hours in response to a child becoming infected with malaria. Ideally, this would be analyzed using panel data and would investigate how adult work hours changed after a child became infected. However, the IHS3 is only a cross-sectional survey (at present). As such, the empirical strategy used here will attempt to determine whether parents in households with an infected child work more or less than parents in households without infected children (controlling for other observable factors). A more thorough assessment of the "impact" of child infection will be possible with the release of the second wave of the IHS3 in the coming months.

2.4.1 Total Work

The first stage of the analysis will investigate the effect of child infection on total work hours and participation. This will indicate whether parents in child malaria households are (1) more or less likely to work and (2) work more or fewer hours overall. This suggests an empirical specification with dependent work hours and an indicator for a child under 5 with malaria as the primary regressor. The basic equation to be estimated will be similar to the following:

$$H_{ihd} = \beta_0 + \beta_1 M_{hd} + \alpha X_{ihd} + \gamma Z_{hd} + \lambda_d + \varepsilon_{ihd} \tag{2.1}$$

where H_{ihd} is either labor force participation or total work hours (wage work, household agriculture, household nonfarm enterprise, and ganyu labor) of person i in household h in district d, M_{hd} is an indicator for at least one child infected with malaria in household h, X_{ihd} is a vector of individual adult characteristics, Z_{hd} is a vector of household characteristics, λ_d controls for district level fixed effects, and ε_{ihd} is the error term. Given this specification, a positive and significant coefficient on β_1 would indicate the parents of children infected with malaria work more than those parents without infected children *ceteris paribus*. A variety of controls will be included in all regressions. Those controls not included in the results tables include the number of children in the household (aged from 0 to 14) as well as indicators for the education level of the parent, the agro-ecological zone, and the month and year of interview. The latter variables will control for seasonal variations in malaria infection rates.

As always, the optimal method to estimate the specification is dependent on the data. For the participation regression, a logit model will be used to predict participation. In the work hour specification, the dependent variable, working hours, is censored at zero. That is, supplied work hours are only observable for those individuals that choose to work. Any persons who do not work will have zero work hours and therefore the work hour distribution will be censored at zero. Since work hours are censored, OLS estimates of the above specification will be biased. The tobit model devised by James Tobin corrects for this bias by differentiating between noncensored and censored observations in the likelihood function. While the likelihood for noncensored observations remains standard, the likelihood for censored observations is specified as the probability of observing a value above the censored value (zero in this case). Since the tobit method corrects for this bias, it will be used to estimate the total work hour specification.

Parents are expected to be similar within each community since they face a very similar societal and economic environment and are more likely to have similar backgrounds. These within group similarities could imply that standard errors are correlated within communities leading to underestimation of standard errors in the model. Allowing for clustering of errors within enumeration areas will attempt to correct for the underestimation of standard errors below.

2.4.2 Work Activities

In addition to determining an overall effect on work hours, this paper seeks to assess whether there is a differential effect across types of work. Again, both participation and work hours will be analyzed separately. The participation specifications will assess the effect of child malaria infection on the extensive margin of parents in child malaria households—whether these individuals start or stop work in a particular activity. This will simply involve estimation of four logit models similar to Equation 2.1 for each of the four categories of work.

Estimation of the differential effect on the intensive margin (i.e. work hours in each activity) is more complex. One potential method to estimate this effect is to simply estimate equation 2.1 for the time spent on the four separate types of work. However, this would fail to account for the relationship between hours spent on the other three types of work since time is a fixed resource. For example, the amount of time spent on household agriculture is dependent on the time spent doing wage work, work for a household nonfarm enterprise, and ganyu work. Including time spent in the other activities as controls would help account for their interdependency. But this formulation assumes that time spent in the other three work activities is exogenous and fixed. While this may be true for some activities (e.g. formal wage employment) it seems unlikely in the majority of cases in Malawi. A more reasonable assumption is that work time is allocated between the four activities *simultaneously*. Proceeding under this assumption, a simultaneous equations model (SEM) will be used to estimate the differential impacts. This involves estimating a system of four equations of the following form:

$$H_{ihdk} = \beta_0 + \beta_1 M_{hd} + \sum_{j \neq k}^{j} \phi_j H_{ihdj} + \alpha X_{ihd} + \gamma Z_{hd} + \lambda_d + \varepsilon_{ihd} \tag{2.2}$$

where H_{ihdk} is hours spent doing activity $k = \{1, 2, 3, 4\}$ and H_{ihdj} is time spend doing activity $j = \{1, 2, 3, 4\}$ with $j \neq k$. As for total work time, time spent in the four activities will be censored at zero. Therefore, tobit estimations methods will be used within the simultaneous equations framework to account for the censored dependent variables.

There is potential for endogeneity bias in this formulation. Omitted variable bias could be present but will be attenuated by inclusion of the control variables in regressions. One additional method to limit any omitted variable bias is to include the lowest level of fixed effects possible in the estimating equations. The fixed effects will capture any observed or unobserved characteristics at the level of the fixed effects. While household fixed effects would be best, the primary dependent variable, child malaria infection, is at the household level. The next conceivable level of fixed effects is the enumeration area (EA). Ideally, EA level fixed effects would be included in the SEM model, but the censoring of the dependent variables proves problematic. In order to take into account the censor and include EA fixed effects, there would need to be variation in censored versus noncensored observations within the EA across the four work categories. This is a strong restriction that would necessitate excluding most EAs. Therefore, the SEM will additionally be estimated using EA fixed effects but without accounting for the censor. This will provide some indication of the presence of omitted variable bias, but will not adequately account for the censored nature of the data.

There would appear to be the greatest potential for bias due to reverse causality. The work hours of parents could influence the probability that a child becomes infected with malaria. For instance, parents who work more may be able to afford bed nets for the children and antimalarial medication to prevent infection and suppress symptoms. One method to correct for this bias is to use the instrumental variable technique. There are several potential instruments that could be utilized in the analysis. Climatological characteristics such as rainfall, temperature, and humidity are potential instruments closely associated with malaria due to their importance in the population of mosquitoes. However, these variables are also closely associated with agricultural production and thus time spent doing household agriculture. This would violate the exogeneity requirement for instrumental variables. No other suitable instruments were identified[7]. Therefore, any reverse causal effect will remain in the estimates. For this reason, the results may not reflect the *causal* effect of child malaria on adult working hours, but instead the *correlation* between child malaria and adult working hours.

2.4.3 Additional Regressions

While estimating the effect of child malaria on adult work hours will measure the overall increase or decrease in time spent in each type of work, it may not adequately capture shifts in work hours between types of work. To better measure any shifts, the effect on the share of total work hours devoted to each activity will be estimated. Another benefit of this analysis is that two relatively clear constraints can be imposed on the estimation: (1) the sum of shares must equal one and (2) the total change in shares must equal zero[8]. The implicit assumption behind these constraints is that the four activities account for total work time. One limitation when examining work hour shares is that those persons that do not report any work must be dropped (12 and 28 percent of the father and mother samples respectively). This could introduce some selection bias into the share results.

Two estimation methods will be used to assess the effect of child malaria on work shares. The first is identical to the SEM method with censoring used for work hours in each activity with the addition of the two constraints. The second method involves estimation of a fractional response model (FRM). The FRM, devised by Papke and Wooldridge (2000), is a quasi-likelihood method that accounts for the fact that the dependent variables ranges between zero and one and can take on either extreme value. Papke and Wooldridge (2000) demonstrate the superiority of their method over linear methods. The FRM results shall serve as a robustness check on the SEM share estimation.

[7] Data on local annual child malaria infection rates from the Malaria Atlas Project (MAP) was also considered. However, local rates were highly correlated with agricultural and wage work hours. This close association with work hours (external of child infection) makes this a problematic instrument.

[8] If the data contained a complete calendar of time allocation, similar constraints could be imposed on work hour estimations. This limitation could lead to unreasonable point estimates for the effect on work hours.

There is potential for considerably heterogeneity in how parents alter their work hours in response to child malaria infection. Three are considered here. The first level of heterogeneity is between urban and rural areas. Given the very different labor markets in urban and rural areas, there are expected to be some large differences between activities, particularly agriculture and wage employment. The second level of heterogeneity is whether the sex of the infected child causes a differential effect. It may be the case that parents respond differently when a male child becomes infected than when a female child becomes infected. For instance, it may be the case that parents are more concerned with the health of male children since they may have greater earning potential either as household labor or in external employment. To assess whether this is the case, Equation 2.2 will be estimated with separate indicators for male and female child infection within the household.

Lastly, there may be season variation in the work hour adjustments of parents. It has been shown in Figure 2.1 that work hours fluctuate throughout the year, largely in accordance with the agricultural season. In the height of the harvest season, parents may have no choice but to continue working the household farm normally whereas at other periods they may be able to delay some agricultural work. As mentioned previously, the IHS3 has observations that span the entire year (March 2010 - March 2011). Therefore, Equation 2.2 will be estimated for four periods that roughly correspond to the agricultural season: (1) March to June 2010, (2) July to October 2010, (3) November 2010 to January 2011, and (4) February to March 2011. The main planting season runs from November to January and the harvest season from March to June. Therefore periods 1 and 4 fall into the harvest season, period 2 is between harvest and the start of the next season, and period 3 covers the main planting period.

2.5 Results

2.5.1 Total Work

Table 2.2 contains the results for overall work participation and total work hours. Columns 1, 3, and 5 present the work participation results while columns 2, 4, and 6 contain the total work hours results. In all cases, having a child infected with malaria in the household does not have a significant relationship with labor force participation or total work hours. This suggests that parents of children infected with malaria are not more likely to work and do not work more hours than similar parents of children who are not infected with malaria. While not significant, the point estimate for total work hours is negative for fathers and positive for mothers. This is counter to the expectation that mothers would work less and increase care time while fathers would work more to make up for the lost work time. Another curious result here is that fathers' work participation and hours are more sensitive to own illness than mothers'. On average, fathers who reported being ill in the last 2 weeks worked almost 4 hours less than they otherwise would have. The estimate for mothers is very close to zero. Although the results in Table 2.2 suggest that there is no significant effect on overall work participation and hours, it does not exclude the possibility that there are differential effects on separate work activities.

2.5.2 Work Activities

Tables 2.3, 2.4, and 2.5 present the disaggregated results for parents, fathers, and mothers respectively. In each table, the first four columns contain logit marginal effect estimates for individual participation regressions. The four columns to the right contain the work hour SEM results (accounting for censoring). The results for parents overall suggest that parents with a malaria infected child were 4.2 percent more likely to have performed casual, part-time or ganyu work in the last 7 days than parents without a child infected with malaria. Furthermore, child malaria parents worked an additional 2.7 hours of casual, part-time, or ganyu work in the last 7 days. These results suggest that parents may take up and/or intensify employment in ganyu in order to cover increased medical costs associated with their child's infection. This result meshes well with those of Dimowa et al. (2010) who found evidence that Malawian households use ganyu as an ex-post coping strategy following a shock. In fact, Dimowa et al. (2010) find a surprisingly similar magnitude of effect on ganyu work hours following a household personal shock defined as an accident, illness, or death of a working-age household member. The results here suggest that their findings may extend to illness of nonworking-age household members.

In comparison to ganyu, all other categories of work did not have a significant relationship with child malaria. This suggests there is no consistent change in work hours in these activities following child infection. However, the overall result for pooled parents could mask important differences in the work hour response of fathers and mothers. Tables 2.4 and 2.5 present separate results for fathers and mothers using the same methodology as in Table 2.3. For fathers, there appears to be no relationship between participation in any activity and child malaria. In fact, the marginal effect estimates are very close to zero. However, the work hour results indicate that fathers in child malaria households work 2.3 hours more in casual, part-time, or ganyu labor than fathers of children who are not infected. For mothers (in Table 2.5), child malaria is associated with an increased probability of working in ganyu as well as working more hours in ganyu. This

Table 2.2: Total Work Results

	Parents		Fathers		Mothers	
	Y/N	Hours	Y/N	Hours	Y/N	Hours
	(1)	(2)	(3)	(4)	(5)	(6)
Child malaria status						
At least on child with malaria in HH	0.013	0.112	0.005	-0.604	0.014	0.591
	(0.010)	(0.563)	(0.023)	(0.783)	(0.013)	(0.594)
Individual characteristics						
Ill in last 2 weeks (excl. malaria)	-0.028	-1.630**	-0.118***	-3.762***	-0.013	-0.275
	(0.019)	(0.808)	(0.042)	(1.338)	(0.014)	(0.952)
Age (years)	0.009*	1.144***	0.008	0.881***	0.008	1.081***
	(0.005)	(0.146)	(0.007)	(0.235)	(0.006)	(0.204)
Householder	0.120*	12.36***	0.113**	4.443**	0.060	8.468***
	(0.070)	(0.535)	(0.054)	(1.945)	(0.049)	(0.922)
Married - polygamous	0.005	-3.208***	0.031	-4.240**	0.010	-2.033*
	(0.012)	(1.109)	(0.054)	(2.136)	(0.015)	(1.188)
Islam	-0.027	-0.509	-0.013	0.726	-0.032	-1.821*
	(0.018)	(0.870)	(0.034)	(1.224)	(0.027)	(1.016)
Self reported time	-0.000	-1.143***	0.115***	1.186*	-0.001	0.682
	(0.005)	(0.432)	(0.036)	(0.661)	(0.006)	(0.594)
Mother is in household	0.021	0.454	0.050	1.669	0.015	0.766
	(0.019)	(1.307)	(0.074)	(2.351)	(0.019)	(1.392)
Father is in household	0.008	0.030	0.116	4.632	-0.001	-1.020
	(0.021)	(1.735)	(0.106)	(3.293)	(0.019)	(1.853)
Observations	11,529	11,529	5,225	5,225	6,304	6,304
Pseudo R-squared	0.106	0.036	0.084	0.031	0.090	0.036

Note: "Y/N" columns contain marginal effect estimates from logit fixed effect estimations. "Hours" columns contain coefficient estimates from tobit estimations. Standard errors clustered at the enumeration area are in parentheses. All regressions include district fixed effects. Additional controls whose results are not presented include individual, household, and community characterisitcs. See Table D.3 in the Appendix for the full set of results. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 2.3: Parents – SEM Accounting for Censor

	Participation				Hours			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Child malaria status								
At least on child with malaria in HH	0.004	-0.002	-0.006	0.042***	0.023	-1.315	-0.757	2.657***
	(0.004)	(0.010)	(0.016)	(0.014)	(0.459)	(1.442)	(2.473)	(0.946)
Individual characteristics								
Ill in last 2 weeks (excl. malaria)	-0.016*	-0.005	-0.022	-0.028	-1.360**	0.789	-2.855	-1.762
	(0.009)	(0.015)	(0.024)	(0.021)	(0.633)	(2.162)	(3.652)	(1.348)
Age (years)	0.002	0.015*	0.025***	0.000	0.296***	2.869***	3.765***	0.011
	(0.001)	(0.009)	(0.007)	(0.005)	(0.114)	(0.540)	(0.785)	(0.267)
Householder	0.003	0.074	0.303***	0.215***	2.688***	10.47***	28.14***	10.82***
	(0.004)	(0.049)	(0.052)	(0.017)	(0.609)	(2.511)	(5.502)	(1.403)
Married - polygamous	-0.005	0.210	-0.053	-0.007	-2.158***	6.616***	-6.349	0.081
	(0.008)	(0.135)	(0.033)	(0.029)	(0.809)	(2.480)	(5.591)	(2.065)
Islam	-0.017*	0.018	-0.019	-0.049**	-0.494	2.200	-0.695	-2.494*
	(0.010)	(0.018)	(0.022)	(0.022)	(0.771)	(2.087)	(3.590)	(1.399)
Self reported time	0.026**	0.020	-0.122***	0.057***	2.532***	4.367***	-18.00***	2.975***
	(0.012)	(0.015)	(0.023)	(0.013)	(0.340)	(1.321)	(1.993)	(0.760)
Mother is in household	0.004	0.005	0.039	0.095**	-0.472	0.799	10.93*	5.541**
	(0.010)	(0.029)	(0.047)	(0.038)	(1.087)	(4.128)	(6.597)	(2.556)
Father is in household	0.015	-0.020	0.063	-0.052	0.132	-1.881	14.347	-2.865
	(0.015)	(0.041)	(0.058)	(0.055)	(1.470)	(5.842)	(8.979)	(3.420)

Note: Columns 1 through 4 contain marginal effect estimates from logit fixed effect estimations. Columns 5 through 8 contain coefficient estimates from SEM tobit esimations. Standard errors clustered at the enumeration area are in parentheses. All regressions include district fixed effects. Additional controls whose results are not presented include individual, household, and community characteristics. See Table D.4 for the full set of results. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

suggests that while increasing work in ganyu is common to both fathers and mothers, mothers start new ganyu employment while fathers simply increase the amount of ganyu they were already performing. This is not surprising given that mothers are generally less likely to be participating in ganyu employment. The results for all other forms of work remain insignificant for both mothers and fathers. Overall, the results do not suggest a large differential effect between mother and father work hours.

As mentioned previously, omitted variable bias could be a potential problem. Accounting for lower level fixed effects will help to diminish omitted variable bias. Tables 2.6 and 2.7 contain work hour results using the SEM with enumeration area fixed effects but not accounting for the censored data. Since the censor is not being taken into account, the estimated will be much smaller in magnitude. The parent results in Table 2.6 show a similar positive result for ganyu suggesting that omitted variable bias has a limited effect on the previous ganyu results. However, there is now a negative and significant correlation for household nonagricultural work. In the SEM with censor results, household nonagriculture was always negative but never significant. This provides some evidence that there are some omitted variables that that are causing bias in the household nonagricultural results. The negative effect for household nonagriculture suggests that parents decrease their hours in household nonfarm enterprises to care for ill children or work more hours in ganyu labor. Looking at the mother/father disaggregation in Table 2.7, the ganyu effect is not significant for either fathers or mothers but the negative household nonagriculture result is significant for mothers but not fathers.

The SEM with EA fixed effects results do appear to slightly differ from the results from the SEM with district fixed effects and accounting for the censor. The difference might indicate that omitted variable bias is present in the latter case, but the difference could also be a result of failing to account for the censor in the former. The positive correlation between child malaria and ganyu participation for parents overall and mothers specifically suggests that not accounting for the censor explains the ganyu difference. For household nonagricultural work, the estimates from the two estimation methods agree in direction but not in significance. It may be the case that omitted variable bias is preventing precise measurement of the child malaria effect on household nonagriculture in the SEM with censoring.

Table 2.4: Fathers – SEM Accounting for Censor

	Participation				Hours			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Child malaria status								
At least on child with malaria in HH	-0.000	-0.014	-0.003	0.009	-0.541	-1.742	-0.985	2.259*
	(0.003)	(0.023)	(0.008)	(0.012)	(0.600)	(2.282)	(2.860)	(1.286)
Individual characteristics								
Ill in last 2 weeks (excl. malaria)	-0.014	-0.049	-0.014	-0.011	-2.516**	-5.817	-5.485	-2.425
	(0.012)	(0.036)	(0.017)	(0.015)	(1.053)	(3.555)	(4.266)	(2.083)
Age (years)	0.001	0.010	0.007	-0.003	0.276	1.413*	2.518***	-0.626*
	(0.001)	(0.007)	(0.007)	(0.003)	(0.180)	(0.759)	(0.879)	(0.375)
Householder	0.016	0.012	-0.000	0.020	4.703***	2.346	-0.459	5.511
	(0.013)	(0.055)	(0.016)	(0.029)	(1.616)	(5.227)	(5.812)	(3.527)
Married - polygamous	0.003	0.440***	-0.043	-0.007	-0.818	2.409	-9.574	-1.671
	(0.007)	(0.058)	(0.038)	(0.016)	(1.586)	(4.194)	(7.452)	(3.792)
Islam	-0.008	0.073**	-0.011	-0.012	-0.313	7.074**	-2.174	-2.235
	(0.008)	(0.031)	(0.014)	(0.016)	(1.059)	(3.199)	(3.980)	(1.891)
Self reported time	0.031	0.037*	-0.047	0.020	5.192***	3.652*	-17.81***	3.809***
	(0.024)	(0.019)	(0.040)	(0.024)	(0.537)	(1.972)	(2.269)	(1.207)
Mother is in household	0.012	-0.027	-0.017	0.045	2.767	-2.239	-6.655	8.142*
	(0.014)	(0.093)	(0.031)	(0.056)	(2.210)	(8.867)	(9.171)	(4.768)
Father is in household	0.013	-0.111	0.044	-0.016	1.683	-10.100	22.79*	-1.134
	(0.017)	(0.135)	(0.049)	(0.033)	(2.837)	(13.196)	(12.172)	(6.698)

Note: Columns 1 through 4 contain marginal effect estimates from logit fixed effect estimations. Columns 5 through 8 contain coefficient estimates from SEM tobit esimations. Standard errors clustered at the enumeration area are in parentheses. All regressions include district fixed effects. Additional controls whose results are not presented include individual, households, and community characteristics. See Table D.5 for the full set of results. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 2.5: Mothers – SEM Accounting for Censor

	Participation				Hours			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Child malaria status								
At least on child with malaria in HH	0.008	0.002	-0.002	0.044*	0.424	-0.603	-1.872	2.707***
	(0.009)	(0.007)	(0.011)	(0.023)	(0.506)	(1.782)	(5.773)	(1.048)
Individual characteristics								
Ill in last 2 weeks (excl. malaria)	-0.016	0.006	0.001	-0.029	-0.784	4.393*	2.573	-1.962
	(0.014)	(0.012)	(0.010)	(0.028)	(0.737)	(2.414)	(7.441)	(1.450)
Age (years)	0.005	0.009	0.009	0.003	0.389**	3.277***	7.992***	0.230
	(0.003)	(0.012)	(0.029)	(0.007)	(0.162)	(0.851)	(2.183)	(0.378)
Householder	0.008	0.027	0.055	0.159***	2.634***	10.61***	57.87***	9.953***
	(0.011)	(0.040)	(0.187)	(0.061)	(0.742)	(2.525)	(7.165)	(1.449)
Married - polygamous	-0.015	0.087	0.002	0.044	-2.639***	7.739**	0.320	3.476*
	(0.015)	(0.127)	(0.016)	(0.037)	(0.843)	(3.067)	(11.268)	(2.027)
Islam	-0.024	-0.006	0.001	-0.053	-0.496	-2.796	6.415	-2.531
	(0.018)	(0.012)	(0.011)	(0.034)	(0.885)	(2.869)	(8.562)	(1.651)
Self reported time	-0.007	0.009	-0.014	0.080**	0.172	5.509***	-17.40***	3.713***
	(0.008)	(0.014)	(0.049)	(0.034)	(0.492)	(1.725)	(5.239)	(1.078)
Mother is in household	-0.004	0.000	0.029	0.074	-1.319	0.496	32.43***	4.607*
	(0.015)	(0.014)	(0.098)	(0.048)	(1.097)	(4.135)	(10.083)	(2.542)
Father is in household	0.015	-0.007	0.004	-0.057	-0.618	-1.000	6.801	-4.329
	(0.022)	(0.022)	(0.021)	(0.063)	(1.533)	(5.828)	(14.325)	(3.487)

Note: Columns 1 through 4 contain marginal effect estimates from logit fixed effect estimations. Columns 5 through 8 contain coefficient estimates from SEM tobit esimations. Standard errors clustered at the enumeration area are in parentheses. All regressions include district fixed effects. Additional controls whose results are not presented include individual, households, and community characteristics. See Table D.6 for the full set of results. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 2.6: Parents – SEM with EA Fixed Effects

	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)
Child malaria status				
At least on child with malaria in HH	0.152	-0.559**	-0.164	0.322*
	(0.250)	(0.253)	(0.283)	(0.166)
Individual characteristics				
Ill in last 2 weeks (excl. malaria)	-0.723**	0.198	-0.278	-0.290
	(0.342)	(0.346)	(0.388)	(0.228)
Age (years)	0.149**	0.274***	0.313***	0.061
	(0.066)	(0.067)	(0.075)	(0.044)
Age (years) squared	-0.001	-0.004***	-0.003***	-0.001**
	(0.001)	(0.001)	(0.001)	(0.001)
Householder	0.673***	2.011***	4.558***	2.318***
	(0.214)	(0.217)	(0.243)	(0.143)
Married - polygamous	-1.700***	-0.051	-0.724	-0.010
	(0.473)	(0.478)	(0.536)	(0.315)
Islam	0.087	-0.112	-0.027	-0.594**
	(0.437)	(0.442)	(0.496)	(0.291)
Self reported time	1.326***	0.238	-2.867***	0.107
	(0.193)	(0.195)	(0.219)	(0.129)
Can write in English	-0.660**	0.125	2.067***	-0.056
	(0.305)	(0.308)	(0.346)	(0.203)
Spouse lives in household	0.534	-0.606	-0.141	0.514
	(0.521)	(0.527)	(0.592)	(0.347)
Mother is in household	-0.258	-0.469	-0.279	0.464
	(0.625)	(0.632)	(0.709)	(0.416)
Father is in household	-0.210	-0.234	0.894	0.042
	(0.819)	(0.828)	(0.930)	(0.546)

Note: Coefficient estimates from SEM tobit esimations presented with standard errors in parentheses. All regressions include enumeration area fixed effects. Additional controls whose results are not presented include individual, household, and community characterisitcs. See Table D.7 in the Appendix for the full set of results. The month and year of interview were excluded due to almost no variation within EAs. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 2.7: Fathers & Mothers – SEM with EA Fixed Effects

	Fathers				Mothers			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Child malaria status								
At least on child with malaria in HH	-0.257	-0.521	-0.462	0.434	0.479	-0.513**	0.043	0.207
	(0.383)	(0.433)	(0.517)	(0.299)	(0.313)	(0.259)	(0.187)	(0.158)
Individual characteristics								
Ill in last 2 weeks (excl. malaria)	-1.236**	-0.303	-0.631	-0.476	-0.537	0.511	0.081	-0.214
	(0.562)	(0.635)	(0.757)	(0.439)	(0.430)	(0.356)	(0.257)	(0.216)
Age (years)	0.170	0.175	0.424***	-0.045	0.182*	0.196**	0.215***	0.053
	(0.110)	(0.124)	(0.148)	(0.086)	(0.095)	(0.078)	(0.056)	(0.048)
Householder	2.081**	0.556	-0.871	0.663	1.141**	1.168***	2.067***	1.473***
	(0.885)	(1.000)	(1.192)	(0.691)	(0.465)	(0.384)	(0.278)	(0.234)
Married - polygamous	-0.347	-1.926*	-0.429	0.056	-2.078***	-0.597	-0.067	0.364
	(0.939)	(1.061)	(1.265)	(0.733)	(0.586)	(0.485)	(0.350)	(0.295)
Islam	0.289	0.745	-0.435	-1.543***	-0.001	-0.905**	0.100	0.094
	(0.673)	(0.760)	(0.907)	(0.526)	(0.551)	(0.456)	(0.329)	(0.278)
Self reported time	2.333***	0.742**	-2.656***	0.478*	-0.094	0.580**	-0.509***	0.371***
	(0.324)	(0.366)	(0.437)	(0.253)	(0.280)	(0.231)	(0.167)	(0.141)
Mother lives in household	1.796	-0.660	-0.376	0.036	-1.049	-0.530	1.072***	0.804**
	(1.339)	(1.514)	(1.806)	(1.046)	(0.685)	(0.567)	(0.409)	(0.345)
Father lives in household	-0.578	0.002	3.668	1.400	-0.281	-0.054	0.395	-0.349
	(1.752)	(1.980)	(2.362)	(1.369)	(0.889)	(0.736)	(0.531)	(0.448)

Note: Coefficient estimates from SEM tobit esimations presented with standard errors in parentheses. All regressions include enumeration area fixed effects. Additional controls whose results are not presented include individual and household characterisitcs. See Table D.8 in the Appendix for the full set of results. The month and year of interview were excluded due to almost no variation within EAs. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

2.5.3 Additional Regressions

Estimating the effect of child malaria on the share of work time devoted to each activity may more accurately reflect shifts in work hours. The results from work share estimations are presented in Table 2.8. Only coefficient estimates for child malaria are shown with all other covariates omitted to save space. The results from SEM estimations (accounting for the censor) are in Panel A with the FRM results in Panel B. The results in Panel A for parents indicate that overall, parents increase their share of work time in ganyu by 8.4 percent. All other categories register a decrease in work share. While this doesn't necessarily suggest a decrease in work time in these activities, it emphasizes the increase in ganyu labor in relation to the remaining activities. The share of time in household agriculture is lower for parents that have a child infected with malaria compared to similar parents without infected children. This result may allay some endogeneity fears due to the concentration of malaria infection in areas with high agricultural intensity. If the results were being confounding by this relationship, the expectation would be that they would show a significant and positive association between child malaria and share of parental work time in agriculture.

The disaggregated SEM share results for mothers and fathers present a very similar story for both parents: a sizable increase in the share of ganyu labor with a decrease in the share of other work activities. However, the effects appear to be stronger for mothers of children infected with malaria whose share of ganyu labor was 10.4 percent higher compared to 6.9 percent higher for fathers. All other shares show a decrease with the exception of household nonagricultural work for mothers.

The FRM marginal effect results in Panel B are very similar to those for the SEM. However, the magnitudes of the ganyu effect are smaller since the FRM does not account for the censor. Also, there is no significant change in the share of ganyu hours for fathers in the FRM. Overall, the broad correspondence between the SEM and FRM results for work shares suggests that the positive ganyu effect is robust.

The heterogeneity of the results are examined in Tables 2.9, 2.10, and 2.11. In Table 2.9 the SEM is performed separately on the urban and rural samples. For parents in urban areas there is a large positive effect on hours spent on causal, part-time, or ganyu labor and a large negative effect on household agriculture hours associated with child malaria. The point estimates suggest that urban parents of infected children work 11 hours more ganyu per week and 5.5 hours less agriculture per week than similar urban parents whose children are not infected with malaria. For

Table 2.8: Share of Work Time

	Share of Total Work Time			
	(1)	(2)	(3)	(4)
Panel A: Simultaneous Equations with Censoring	*HH Ag*	*HH Nonag*	*Wage*	*Ganyu*
Parents	-0.021*	-0.027	-0.036	0.084***
	(0.013)	(0.034)	(0.036)	(0.032)
Fathers	-0.016	-0.034	-0.019	0.069*
	(0.019)	(0.048)	(0.049)	(0.039)
Mothers	-0.025*	0.009	-0.089*	0.104**
	(0.014)	(0.050)	(0.053)	(0.044)
Panel B: Fractional Response Model	*HH Ag*	*HH Nonag*	*Wage*	*Ganyu*
Parents	-0.022*	0.00	0.00	0.024***
	(0.012)	(0.009)	(0.005)	(0.008)
Fathers	-0.01	-0.01	0.00	0.02
	(0.019)	(0.014)	(0.015)	(0.013)
Mothers	-0.026*	0.01	0.00	0.018**
	(0.014)	(0.011)	(0.002)	(0.009)

Note: Panel A contains SEM tobit coefficient estimations. Panel B contains FRM marginal effect estimates. Standard errors clustered at the enumeration area are in parentheses. All regressions include district fixed effects. Additional controls are the same as those in the base regression. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

rural parents, only ganyu work hours are positively associated with child infection. The relationship is also much smaller in magnitude than for urban parents. This suggests that urban parents respond more strongly to child malaria infection than rural parents. However, both rural and urban parents appear to turn to ganyu labor in these situations. This could also highlight important differences in the type of work captured by “casual, part-time, or ganyu” labor in rural and urban areas. Since ganyu labor is predominantly concentrated in rural areas, this category may capture the effects of nonganyu casual or part-time employment in urban areas. If this is the case, then the results suggest that urban parents turn more strongly to casual and part-time labor. However, the data does not allow differentiation between casual, part-time, and ganyu work. When disaggregating, the ganyu effect disappears for both urban fathers and mothers but remains large in magnitude. In the rural sample, mothers appear to work more hours in ganyu when their child is infected with malaria but the effect was not significant for fathers.

Table 2.9: Urban versus Rural Results

	HH Ag	HH Nonag	Wage	Ganyu
	(1)	(2)	(3)	(4)
Urban				
Parents	-5.488*	-6.031	-1.508	11.131**
	(2.831)	(4.026)	(4.626)	(5.251)
Fathers	-9.468*	-7.658	-1.982	11.359*
	(5.024)	(5.846)	(5.495)	(6.291)
Mothers	-3.338	-5.838	1.364	8.589
	(3.368)	(5.484)	(12.322)	(6.584)
Rural				
Parents	0.148	-0.646	-1.178	1.818**
	(0.475)	(1.453)	(3.014)	(0.887)
Fathers	-0.263	-1.052	-1.658	1.157
	(0.604)	(2.402)	(3.421)	(1.194)
Mothers	0.456	0.109	-1.170	2.026**
	(0.517)	(1.715)	(6.316)	(1.002)

Note: SEM tobit coefficient estimations presented with standard erros clustered at the enumeration area in parentheses. All regressions include district fixed effects. Additional controls are the sameas those in the base regression. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 2.10 contains estimates from SEM regressions that have separate indicators for male and female infected children. Only the estimates for these two variables are included. The positive result for ganyu remains in the parent regression though it is significant and larger for male infection. This could suggest that parents increase their ganyu work hours more when male children become infected. Parents may be more sensitive to infection of male children because they have higher potential earnings or a greater contribution to household labor. There is also some indication that parents decrease work in a household nonagricultural business when a female child becomes infected but not for male children. The disaggregated results for mothers and fathers highlight some important differences. First, fathers appear to increase household agriculture and ganyu hours when a male child becomes infected, but not significantly when a female child is infected. In contrast, mothers appear to increase ganyu hours when either becomes infected, but the increase in ganyu was slightly larger for female child infection. This could suggest that fathers are more concerned about male child infection but mothers care about both children. However, fathers also appear to decrease hours spent working in a household nonagricultural business when a female child becomes infected. These results do suggests that there are some important differences in a parent's response to a male or a female child becoming infected. While further analysis of this differential is warranted, it could indicate that male child infection posses more of a burden on the household. However, it could also indicate that female children do not necessarily get the required medical care.

Seasonal variation in both malaria infection rates and work hours in each activity could result in heterogeneity throughout the year. Table 2.11 contains results from SEM regressions where the sample is segregated into four periods that correspond to the different phases of the agricultural season in Malawi. The results for parents overall show considerable variation across the periods. For ganyu, the effect is positive for throughout the survey period though only significant during the period between seasons. This time of year is the dry season when rainfall is nearly nonexistent. It does appear that at this time of year parents turn to casual, part-time, or ganyu labor when their child becomes infected with malaria. In addition, the results indicate that there is significant variation in adjustments to wage work. According to Table 2.11, parents of children infected with malaria work 10 fewer wage employment hours in the harvest season periods but 12 more hours between seasons. One potential explanation for this variation is that the harvest period is of critical

Table 2.10: Male vs. Female Child Infection

	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)
Parents				
Male child with malaria	1.007	2.241	-0.768	4.238**
	(0.715)	(2.492)	(4.803)	(1.734)
Female child with malaria	-0.320	-5.316*	3.436	2.925*
	(0.819)	(2.824)	(4.808)	(1.726)
Fathers				
Male child with malaria	1.877*	5.305	-0.916	4.503*
	(1.022)	(4.224)	(5.645)	(2.524)
Female child with malaria	-1.802	-7.421*	0.283	0.867
	(1.185)	(4.316)	(5.333)	(2.321)
Mothers				
Male child with malaria	0.336	-0.209	-5.496	3.398*
	(0.894)	(3.257)	(9.312)	(1.909)
Female child with malaria	0.926	-3.629	13.408	4.343**
	(0.962)	(3.558)	(10.355)	(1.814)

Note: SEM tobit coefficient estimations presented with standard errors clustered at the enumeration area in parentheses. All regressions include district fixed effects. Additional controls are the same as those in the base regression. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

importance for reaping the full benefits of agricultural production. Therefore, parents in agricultural households may need to maintain their on-farm work hours in the period, but will instead sacrifice some wage hours to care for the infected child. Between seasons however, agricultural income is scarce and thus parents may turn to wage employment to cover additional costs associated with care. In the planting season, parents appear to increase their work hours in household agriculture and a household nonagricultural business. However, there is some concern that these changes simply reflect seasonal variation in the work distribution of agricultural households which are more likely to have children infected with malaria. These variations are controlled for in all other specifications.

When looking separately at the seasonal variations for mothers and fathers, the coefficient estimates are quite similar though significance does vary. Changes in ganyu were strongest for mothers between seasons. Although not always significant, nearly all point estimates for ganyu were positive. For both parents, the point estimates for wage work are large but often insignificant. This could partially be a result of the relative infrequency of wage work and the smaller sample sizes. Overall, seasonal variation appears to be very similar between mothers and fathers.

Table 2.11: Seasonal Variation

	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)
Parents				
Mar–June 2010 (Harvest)	0.415	-0.325	-10.686**	1.052
	(0.894)	(2.652)	(5.076)	(1.700)
July–Oct 2010 (b/w Seasons)	-0.582	-3.852	12.952***	4.500**
	(0.980)	(2.653)	(4.211)	(2.034)
Nov 2010–Jan 2011 (Planting)	1.648**	6.181**	1.308	1.174
	(0.835)	(2.837)	(4.414)	(1.585)
Feb–Mar 2011 (Harvest)	-0.188	-3.084	-10.494*	1.939
	(1.107)	(4.430)	(6.164)	(2.171)
Fathers				
Mar–June 2010 (Harvest)	-0.106	-2.690	-12.150**	3.293
	(1.166)	(4.113)	(5.577)	(2.173)
July–Oct 2010 (b/w Seasons)	-0.476	-8.599**	13.187***	3.348
	(1.169)	(3.843)	(4.729)	(2.628)
Nov 2010–Jan 2011 (Planting)	1.029	7.642*	3.877	-0.536
	(1.073)	(4.257)	(5.030)	(2.269)
Feb–Mar 2011 (Harvest)	-1.933	3.004	-15.420*	1.446
	(1.306)	(6.437)	(8.243)	(3.605)
Mothers				
Mar–June 2010 (Harvest)	0.955	1.826	-11.920	0.306
	(1.015)	(3.310)	(9.641)	(1.824)
July–Oct 2010 (b/w Seasons)	0.175	-1.408	5.261	5.878**
	(1.192)	(3.304)	(11.263)	(2.336)
Nov 2010–Jan 2011 (Planting)	1.873**	5.258	-12.228	2.377
	(0.870)	(3.580)	(10.175)	(1.695)
Feb–Mar 2011 (Harvest)	0.286	-10.625*	17.280	2.355
	(1.247)	(6.182)	(14.577)	(2.474)

Note: SEM tobit coefficient estimations presented with standard errors clustered at the enumeration area in parentheses. All regressions include district fixed effects. Additional controls are the same as those in the base regression. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

2.6 Conclusion

This paper has attempted to determine whether parents adjust their work hours in response to having a child infected with malaria. To this end, data from the Malawi Third Integrated Household Survey was used to estimate the effect of child malaria infection on the total work hours and work hours in four major work activities of parents. Although data limitations prevent any definitive causal effect from being estimated, the results can be interpreted as correlations between child malaria and parental working hours. While there was no relationship between own child malaria and total work hours, the results broadly indicate that mothers and fathers of children infected with malaria spend more hours in casual, part-time, or ganyu employment than similar parents of children who are not infected with malaria. This may suggest that parents faced with increased costs associated with treatment or care for infected children turn to ganyu labor for supplemental income[9]. This assertion concurs with the findings of Dimowa et al. (2010) who find evidence that Malawian households use ganyu labor as an ex-post coping strategy following a household shock. This result was more robust for mothers through several subsample analyses.

The potential shift to increased casual, part-time, or ganyu work by parents when their child becomes infected with malaria could have larger implications for household wellbeing. Increasing work time could result in decreased time devoted to caring for the infected child and other members of the household. However, the total work time results suggest that parents may not be increasing or decreasing their total work time but instead shifting time from other activities to ganyu labor. Ganyu labor is generally considered to have low returns that are not adequate to sustain a household for a reasonable amount of time (Whiteside, 2000; Mkadawire and Ferguson, 1990). If households are indeed shifting their time away from other more productive activities, there could be long run ramifications for household wellbeing. The work share results provide some indication that parents of infected children may be shifting time from household agriculture to ganyu. Shifting time from household agriculture to ganyu could result in lower levels of own production and thus lower agricultural income that so many Malawians rely on. If this shift occurs at a critical point in the agricultural season, the effect on realized income could be significant. Additional research needs to be conducted to investigate the long term implications of this potential shift.

The results of this study have important implications for policy. The shift in the work hours of parents to ganyu could have adverse effects on the entire household. Policymakers should heed this potential problem and work to further defray costs associated with child malaria infection. Although malaria medication is theoretically free in Malawi, the cost of medical care is not necessarily free, especially if there are no nearby government health facilities. Perhaps an expansion of public health care would help lower costs associated with malaria. Of course, the best long term solution would be to eradicate malaria altogether.

There is still much potential for addiitonal research on this subject. The release of the second wave of the Malalwi IHS3 will allow a more rigorous analysis using panel methods. In future work, the analysis in this study will be extended using the second wave data.

[9]As mentioned above, ganyu employment is not necessarily paid in cash but instead may be paid in-kind. This could weaken the interpretation here and it is unclear to what extent payment for ganyu work is made in-kind in Malawi.

CHAPTER 3

AGRICULTURAL PRODUCTION AND HOUSEHOLD NUTRITION: EVIDENCE FROM NIGERIA

3.1 Introduction

The importance of agriculture in the lives and livelihoods of many sub-Saharan African households is undeniable. As such, many development policies are focused on agriculture with particular emphasis on improving agricultural production. The hypotheses underlying these interventions is that (1) increased agricultural production will increase both income and food availability in agricultural households and (2) higher income and food availability will result in improved nutritional outcomes. Current research examining the second link between agricultural production and nutrition is lacking. This shortcoming was highlighted at a conference on agriculture and nutrition held by International Food Policy Research Institute (IFPRI) in February 2011 (IFPRI, 2011). The conference called on researchers to "learn more about how different patterns of agricultural growth affect nutrition and health." This essay seeks to answer the call through an investigation of the relationship between agricultural production and nutrition using nationally representative panel data from Nigeria. Specifically, this essay examines how variation in agricultural production levels and diversity affect household caloric intake and dietary diversity.

There are several mechanisms through which agriculture and nutrition could be linked. Ruel et al. (2013) identify six separate pathways, two of which are particularly relevant in the context of this study: agricultural production as (1) a source of food and (2) a source of income. Agricultural households in the developing world often consume a portion of their production, especially when missing or imperfect product and input markets cause production and consumption decisions to be nonseparable (Singh et al., 1986). Under this pathway, expanded agricultural production increases availability and access to food from own production (Ruel et al., 2013). Agricultural production is also a major source of income for many agricultural households. Under the income pathway, expanded agricultural production increases marketing of output which increases income which in turn allows the household to purchase and consume greater quantities or varieties of food. While these two pathways are distinct, they are not necessarily mutually exclusive. Quite often households will consume a portion of own production and also market another portion (World Bank, 2007).

Many researchers have attempted to empirically establish the linkages between agriculture and nutrition. The vast majority of current research either (1) investigates very specific agricultural interventions or (2) has a narrow geographic focus (see Masset et al. (2011), Waage et al. (2013), and Girard et al. (2012) for systematic reviews). For example, many studies focus on the impact of increased production of specific nutritious foods to fulfill micronutrient needs (Hotz et al., 2012a,b; Hagenimana and Low, 2000) or promotion of homestead gardening (Olney et al., 2009; Marsh, 1998). However, there are surprisingly few studies that examine how broad variations in agricultural production impact nutrition. Studies that examined the nutrition pathway with agricultural production as a source of food generally find a positive association between agricultural production and nutrition (Muller, 2009, 1999; Olney et al., 2009; Zezza and Tasciotti, 2010). However, this strand of the empirical literature largely focuses either on production of certain crops (Muller, 2009, 1999; Olney et al., 2009) or participation in agriculture (Zezza and Tasciotti, 2010). Additional studies that examined the nutrition pathway with agricultural production as a source of income similarly find a positive effect of production on nutrition (Duflo and Udry, 2004; Villa et al., 2011).

In contrast to the majority of the literature, this study will investigate how broad, season-to-season changes in agricultural production affect household nutrition. To this end, two measures of production variability are examined: agricultural output and crop diversity. While the literature has primarily focused on the output of specific crops, overall output shall be the focus here. In addition, while most of the literature focuses solely on the effect of agricultural production levels, this study shall also examine the diversity of production. Consuming a variety of foods is thought to ensure an adequate intake of essential nutrients (Ruel, 2003). Therefore, in an environment where production and consumption decisions are linked, households that produce a wider variety of crops may have more diverse diets that better cover their nutritional needs. Despite this potential link, there has been little examination of production diversity the literature.

Several studies find that crop diversity is positively associated with dietary diversity (Jones et al., 2014; Bhagowalia et al., 2012; Keding et al., 2012). However, this finding was ancillary and not rigorously explored in most studies (Bhagowalia et al., 2012; Keding et al., 2012). Studies that focus specifically on the production diversity-consumption diversity link do not account for the possibility of endogenity bias and are unable to use panel methods (Jones et al., 2014). This study shall extend current understanding of this link by exploring and correcting for endogenous determination of crop diversification and utilizing panel methods on a nationally representative data set.

This study seeks to expand on the literature through joint examination of the effect of total agricultural production and production diversity on household caloric intake and dietary diversity. Recent nationally representative panel data from the Nigerian General Household Survey Panel (GHS-panel) is exploited in the analysis. Nigeria is an ideal case study for analyzing the linkages between agriculture and nutrition. It is one of the most important countries in Africa with the highest population and second largest economy. Agriculture remains an important sector to much of the population and malnutrition is relatively widespread.

Panel data analysis is a powerful tool that will limit the potential for omitted variable bias but has rarely been available to researchers investigating the production-nutrition relationship. The GHS-panel contains detailed information on household consumption, agricultural production, and geospatial variables. Missing or imperfect markets are likely a reality in rural Nigeria resulting in nonseparable production and consumption decisions by agricultural households. Simultaneous determination of production and consumption would introduce bias to the results. This problem is remedied using data on exogenous household level climate shocks to instrument for agricultural production. Use of panel data and exogenous climate shocks enables relatively strong conclusions to be drawn regarding agriculture and nutrition that have not been possible in other investigations.

The results suggest that there is a strong link between agricultural output and both household dietary diversity and caloric intake. Agricultural output elasticities of 0.14 and 0.53 are found for dietary diversity and caloric intake, respectively. While less than one, this suggests that a general expansion of agricultural production could be an effective means to improve nutrition. The results also indicate that production diversity is positively associated with dietary diversity. Although weak instruments prevent a definitive causal statement, the relationship is relatively strong with an elasticity of 0.8. While these positive links are largely in agreement with current research, it does indicate that a more general approach may also be effective at improving nutrition. Further research is needed to investigate the relative merits of these policies.

The remainder of this essay will proceed as follows. The conceptual framework and literature are reviewed in Section 3.2. Section 3.3 describes the data. The empirical methodology is laid out in Section 3.4 and the results are presented in Section 3.5. Section 3.6 concludes.

3.2 Conceptual Framework

Malnutrition remains a global problem but especially so in sub-Saharan Africa. Globaly, 26% of children were stunted, 16% were underweight, and 8% were suffering from wasting in 2011 (WHO, 2013). Poor nutrition is the underlying cause of more than a third of deaths in children under 5 (WHO, 2013). Nutrition has also been shown to be a key factor in several critical economically important outcomes such as the cognitive development of children (Mendez and Adair, 1999; Berkman et al., 2002), educational attendance and attainment (Alderman et al., 2001; Maluccio et al., 2009), labor productivity (Deolalikar, 1988), and agricultural productivity (Strauss, 1986). A variety of policies have been suggested and implemented to combat poor nutrition. Policies that promote improved agricultural production of households have been emphasized in countries where agriculture is the primary economic activity for many households. These policies presume that household agricultural production is closely associated with nutrition.

There are several potential linkages between agriculture and nutrition outcomes. Ruel et al. (2013) suggests six potential pathways through which agriculture can affect nutrition: (1) as a source of food, (2) as a source of income, (3) food price changes, (4) women's social status and empowerment, (5) women's time, (6) women's own health and nutritional status. Pathways 1 and 2 (discussed in the previous section) are perhaps the strongest linkages and are the main focus in this study. However, the other pathways may also be concomitant. Under pathway 3, agricultural policies and aggregate agricultural production could cause fluctuations in the price of non-food and food crops (Ruel et al., 2013). These fluctuations will affect both the price farmers receive for their commercialized output (and thus their income) as well as the purchase price for food.

The last three pathways identified by Ruel et al. (2013) highlight the potential nutrition effects of women's participation in agriculture. Women's participation could affect their control over household resources or decision making and thereby influence intra-household allocation of food, health, and care (Quisumbing et al., 2003). Their participation can also alter the time allocated to household management and care which are both critical elements of household nutrition outcomes especially for children. Lastly, participation can affect a woman's health through exposure to diseases associated with agriculture or affect her nutrition through added energy requirements (Ruel et al., 2013). As shown by Strauss (1986), health and nutrition can affect agricultural productivity and thus they can affect women's income from agriculture. While these gender effects are important, they are largely beyond the scope of this study.

In the context of this study, pathways 1 and 2 are expected to play a predominant role in the relationship between agricultural production and nutrition. Both pathways are likely present for the effect of agricultural output. Higher agricultural output could increase food availability from own production but may also increase commercialization of output and therefore household income. The ability to consume more or a wider variety of food from own production has obvious implications for household nutrition. Increased household income could result in the purchase of more or a wider variety of food. It is difficult to assess and measure the relative impacts of both these pathways and therefore the results below will only measure a general effect of variations in agricultural output on nutrition.

Pathway 1 is expected to dominate any link between production diversity and household nutrition. Production of a wider variety of food crops will increase the diversity of food available to the household. While diversification could also potentially have some implications for agricultural income, it is unlikely that this effect would be a strong determinant of nutrition.

Studies examining the direct link between agricultural production and nutrition are relatively sparse. The research in this area has largely focused on the link between the type of crop(s) produced and nutrition. Focusing on autarkic agricultural households in Rwanda, Muller (2009) found that production of certain crops such as beans and sweet potatoes improved nutrition whereas production of other crops such as traditional beer was associated with poorer nutrition (measured using body mass index). In a much more narrowly defined study, Hotz et al. (2012a) examined the impact of a large-scale intervention promoting production of a β-Carotene-rich orange sweet potato on vitamin A intake of children and women. Following a randomized control trial framework, the authors found that home production of the sweet potato increased vitamin A intake for both children and women. Although not looking at a specific type of crop, Zezza and Tasciotti (2010) looked at the effect of participation in agricultural production on nutrition amongst urban households in several developing countries. They found that participation in urban agriculture was associated with higher dietary diversity. While the literature has generally focused on specific crops, the proposed paper will investigate whether the number of crops produced by the household affects nutrition.

Household decisions regarding the number and type of crops to produce could be influenced by food prices, access to markets and credit. For example, smallholders are more likely to grow food crops than cash crops to ensure food self-sufficiency and thus staple food expenditures have a relatively low income elasticity (Fafchamps, 1992). Households may also choose to produce a wider variety of crops in order to manage risk. Producing multiple crops provides some insurance in case of shocks (weather, pest infestation, crop disease, etc) that would differentially effect certain crops. In the event one crop fails, farmers may rely on other crops that survive to fruition. Researches have demonstrated that producing a mixture of crop species leads to improved yields on average (Li et al., 2009; Kiær et al., 2009). Although this risk motivation is somewhat abstracted from household nutrition, it does have potential implications for nutrition. For example, more risk averse households may produce a wider variety of crops which may translate into improved household dietary diversity.

Despite the potential importance of crop diversity for household nutrition, few studies have examined this linkage. One study in India by Bhagowalia et al. (2012) examines the relationship between agricultural income and nutrition (measured using child anthropometric indicators) as well as between agricultural production and nutrition. They find a modest effect of income on nutritional status unless accompanied by improved health and education outcomes. However, they also find strong evidence that agricultural production conditions such as irrigation, crop diversity, and ownership of livestock substantially influence household dietary diversity. A more recent study by Jones et al. (2014) does perform a detailed analysis using nationally representative data from Malawi and finds a consistent positive relationship between crop diversity and nutrition. However, Jones et al. (2014) does not attempt to correct for endogeneity bias and was unable to use panel methods as will be done in this study.

There have been even fewer studies using data from Nigeria to examine the agriculture and nutrition linkage and the few papers that do exist are case studies or only use descriptive statistics (Babatunde et al., 2010; Okezie and Nwosu, 2007). Babatunde et al. (2010) examines the relationship between income and caloric intake for farm households in rural Nigeria using household data from 40 villages in Kwara state. Although, the authors find a significant positive relationship between income and caloric intake, the calorie-income elasticity was estimated as 0.181 suggesting that caloric intake does not increase substantially with income. They also find a positive relationship between farm size and calorie intake in Nigeria. Okezie and Nwosu (2007) examined the effect of agricultural commercialization on nutritional status of children in Abia state in Nigeria and found that children in households that are more commercialized recorded a higher prevalence of under-weight and stunting.

At present, the literature examining the direct link between agricultural production and nutrition is relatively sparse. Most studies have a narrow focus on specific crops or subnational regions. Furthermore, the importance of production diversity is rarely addressed. This study will contribute to the literature through a joint examination of the level and diversity of agricultural production and their effects on caloric intake and dietary diversity using nationally representative panel data. Focusing on overall production levels instead of production from specific crops will highlight any effect of agricultural income and food availability within the household on nutrition. A positive finding for agricultural output and nutrition would suggest that policies aimed at improving production are effective at improving household nutrition. The secondary focus on production diversity is more targeted. A positive relationship between production diversity and dietary diversity would indicate that policies which promote production of a wider variety of crops may result in improved nutrient intake.

3.3 Context and Data

This study utilizes detailed panel data from Nigeria to investigate the production-nutrition relationship. Nigeria is the most populous country in Africa and has the second largest economy on the continent. Agriculture remains a vital sector for the economy contributing an estimated 33 percent to GDP in 2012 according to the World Bank. Agricultural production is a vital source of income for many Nigerian households with nearly 60 of households employed in the sector (World Bank, 2014). Just under half (46%) of the population lives below the national poverty line. Malnutrition is also prevalent with 36 percent of child under 5 who are stunted. The importance of agriculture to many Nigerian households coupled with the relatively high rates of malnutrition makes Nigeria an ideal subject for this study.

The data is drawn from waves 1 and 2 of General Household Survey-Panel (GHS-Panel) conducted in 2010/11 and 2012/2013 by the Nigeria National Bureau of Statistics (NBS) in collaboration with the World Bank Living Standard Measurement Study - Integrated Surveys on Agriculture (LSMS-ISA) project. The GHS-Panel survey is modeled after the Living Standard Measurement Study (LSMS) surveys and is representative at the national, zonal, and rural/urban levels. The original sample consists of 5,000 households covering all 36 states in the country and the Federal Capital Territory, Abuja. One of the main objectives of the GHS-Panel is to improve agriculture data collection in Nigeria by collecting information at disaggregated levels (crop, plot, and household levels), and linking such data to non-agricultural aspects of livelihoods. All households were visited at two points in time: after planting (post-planting visit) and after harvest (post-harvest visit) and were administered multi-topic household, agriculture, and community questionnaires. Amongst a variety of topics, the household questionnaire gathered detailed information on food and non-food consumption and expenditure of households. The survey covers over 100 food items commonly consumed in Nigeria and collected information on household consumption (quantity consumed) of the items in the past seven days before the survey. The use of handheld GPS devices to record coordinates of household plots allows the linkage of the data with geospatial variables such as rainfall and temperature data from other sources. All estimates are weighted to obtain nationally representative estimates.

Of the original sample, around 3,000 households were agricultural households in rural and urban areas producing a wide variety of crops. This study shall focus on rural agricultural households. The final sample for each wave consists of 2,497 households in wave 1 and 2,470 in wave 2. However, in order to take full advantage of the panel, only households that report agricultural production in both waves are used in the analysis[1]. This yields a balanced panel of 2,171 rural agricultural households observed in both waves with full information on consumption, agricultural production, and other socioeconomic characteristics. Table 3.1 contains sample means for the main variables used in the analysis.

3.3.1 Nutrition

Two measures of household nutrition are used in the analysis: household calories per capita and dietary diversity. While related, each measure captures a slightly different dimension of nutrition. Calories per capita measures the amount of food (energy) consumed by the household. Dietary diversity measures how balanced the household diet is which is an indication of whether members are consuming essential nutrients. Both are calculated using consumption data collected in the post harvest visit of the GHS-Panel. Households were asked how much (by weight) of a variety of food items the household consumed in the past 7 days. The caloric value of consumed items was calculated using item-level conversions from the U.S. Department of Agriculture's National Nutrient Database for Standard Reference[2]. Calories consumed of each item were then aggregated

[1] In total, 625 households were dropped from the unbalanced panel: 321 households from wave 1 and 299 from wave 2. The vast majority of these were households which did not participate in agriculture in one wave or the other. Dropping these households implies that the results will only be valid for households who participated in agricultural production in both the 2010/2011 and 2012/2013 seasons. Of the 625 households, only 43 were true attritors in that they were interviewed in wave 1 but not wave 2. This suggests that attrition bias is not a serious issue. Some researchers have found that even in the presence of significant attrition, consistent coefficient estimates can still be obtained (Alderman et al 2001).

[2] Available at http://ndb.nal.usda.gov/index.html.

and divided by household size. As shown in Table 3.1, households consumed on average about 26,000 calories per member per week. This translates to 3,700 calories per person each day. This is above the 3,000 calorie requirement for an average (70kg) adult male as established by the FAO (FAO, 2004). Given that many members are children with lower requirements than, this average amount seems inflated. This is likely due to imprecise reporting on the part of respondents regarding the amounts of each food item consumed in the last 7 days.

While caloric intake captures how much food the household consumes, dietary diversity measures how balanced the household diet is. It has been shown that dietary diversity is closely associated with nutrition adequacy (Ruel 2003) as well as broader nutrition measures such as anthropometrics (Arimond and Ruel 2004). Dietary diversity is commonly measured as a simple count of the number of different food groups consumed. Food items in the consumption module of the GHS-Panel were collapsed into 12 distinct food groups that conform to guidelines from the Food and Agriculture Organization (Kennedy et al, 2011). The number of these food groups consumed by household was then counted. The average household in the panel consumed between 7 and 8 of the 12 food groups in the last 7 days. While there is no established minimum level of dietary diversity, this is lower than the average of 8.4 identically defined groups consumed in Malawi found by (Jones et al., 2014).

Both of these nutrition measures are at the household level. As such, they do not capture variations in the distribution of food within the household that could translate into different levels of *individual* nutrition. While no direct conclusions regarding individual nutrition can be drawn, researchers have documented a strong correspondence between household and individual nutrition measures (Hoddinott and Yohannes, 2002; Hatløy et al., 2000). Therefore, the measures used here may have implications for individual nutrition, but could also mask significant individual level variation. An additional analysis at the individual level would be ideal, but data limitations prevent such an analysis from being performed as a part of this study.

3.3.2 Agricultural Production

The level and diversity are the two measures of agricultural production used in the analysis. The level of production is an intensive measure of agricultural production while crop group diversity is an extensive measure of production. The level of production is measured using the total value of the harvest. Harvest value for each crop was calculated using the amount harvested (weight) multiplied by local farm gate prices which were calculated within the GHS-Panel. As a part of

Table 3.1: Summary Statistcs

	Pooled	Wave 1	Wave 2	Δ
Household Nutrition				
Dietary diversity food group count (12 groups)	7.61	7.44	7.78	***
Per capita household calories consumed (7 days)	26,566	25,108	28,025	***
Agricultural Production				
Total harvest value (Naira)	277,902	231,309	324,495	
Total harvest value (Naira) - Farmer estimate†	160,455	149,442	171,469	***
# of crop groups grown by the household (6 groups)	1.94	1.91	1.98	***
Climate Deviations (April-May)				
Rainfall (mm) - deviation from historical mean	-42.14	-47.70	-36.59	***
Degree days - deviation from historical mean	19.31	31.08	7.55	***
Other agricultural characteristics				
Value of household agricultural capital	9,762	4,858	14,665	
Total household land holdings (hectares)	1.18	1.27	1.09	***
Household owns livestock	0.74	0.76	0.73	**
HH received ag extension services	0.09	0.09	0.09	
Household characteristics				
Number of persons aged 15-65 in HH	3.44	3.19	3.68	***
Number of persons aged 0-14 in HH	3.06	3.06	3.06	
Number of persons aged 66 and over in HH	0.24	0.22	0.27	***
Maximum education in household	7.52	7.42	7.63	
Male Head of HH	0.90	0.91	0.88	***
Age of head	50.6	49.6	51.5	***
Head years of education	4.40	4.46	4.35	
Head is in monogamous marriage	0.60	0.63	0.58	***
Head is in polygamous marriage	0.27	0.25	0.28	**
Head is not married	0.13	0.12	0.14	**
Other income sources				
Any income from livestock production	0.28	0.32	0.24	***
Operated nonfarm enterprise	0.53	0.53	0.53	
Nonfarm wage employment	0.16	0.18	0.14	***
Other nonfarm income source	0.05	0.05	0.05	
Local market prices (Naira/kg)				
Rice - local	146.4	119.5	173.3	***
Rice - imported	211.2	170.6	251.8	***
Bread	256.7	227.1	286.4	***
Yam - roots	95.1	74.4	115.9	***
Gari - white	112.0	88.8	135.1	***
White beans	171.0	108.0	234.0	***
Palm oil	173.5	257.7	89.3	***
Groundnut oil	181.1	273.0	89.3	***
Tomatoes	117.9	88.3	147.6	***
Tomato puree (canned)	254.0	179.1	329.0	***
Onions	165.2	145.1	185.4	***
Okra - fresh	185.5	118.6	252.4	***
Beef	692.2	596.4	788.0	***
Fish - frozen	390.7	292.5	489.0	***
Observations	4342	2171	2171	

†There were 2,099 households with information on farmer esimtaed harvest value.

survey, farmers were asked how much of the harvest they sold and how much they received for the sale of the crop. Using these two values, farm gate prices were calculated for crop observations which report sales. The local[3] median price for each crop was calculated for observations where no sales were reported and multiplied by the amount harvested. According to this measure, the total harvest value for the average household in the panel was over 300,000 Naira. As a robustness check, the harvest value specifications will be estimated using an alternate measure: farmer estimates of harvest value[4].

Similar to dietary diversity, the primary measure of production diversity is a count of the number of crop groups harvested by the household. Food crops were separated in to 6 groups that correspond to 6 of the 12 dietary diversity groups. The grouping was used to create a measure that is directly comparable to dietary diversity. In order to solely capture the effect of *food* crop diversity, nonfood crops are excluded. As shown in Table 3.1, households grew crops from about 2 different food crop groups on average. One drawback of a simple count measure is that it does not account for how extensively each crop was grown. For example, a household that grows maize on 99% of their land and grows potatoes on the remaining 1% might be considered less diverse than a household that grows both crops on an equal share of land. Three additional diversity measures that account for the share of land devoted to each crop will be used as robustness checks: the inverse Simpson, Shannon, and Berger-Parker indices. See the appendix for a definition of these three indices.

3.3.3 Climate Shocks

A major factor that could influence agricultural production levels and diversity is climate variability. The extensive literature on climate variability and agricultural production has established a strong relationship between climate variability and crop yields (Rowhani et al., 2011; Porter and Semenov, 2005; Lobell and Field, 2007; Tao et al., 2008). On a global scale, Lobell and

[3]The lowest possible geographic level was used for "local" prices depending on the number of price observations within a locality. The geographic levels include enumeration area, local government area, state, and zone. Zone level prices were mostly restricted to rare crops.

[4]There are two main drawbacks to this measure. First, there are a fair number of households (72) where this variable was missing. Second, farmer estimates of value are often subjective and imprecise especially amongst farmers who do not sell any of their crop. Using local prices should provide a more accurate estimate of the true (sale) value of the harvest. Table 3.1 indicates that farmer estimates of value were considerably lower than value from farm gate prices. This suggests that on average farmers are underestimating the value of their harvest. For these two reasons, the simpler farmer estimated value is relegated to a robustness check and not used as the primary measure of production intensity.

Field (2007) find that seasonal temperature and precipitation explain roughly 30% of year-to-year variations in global yields of six widely grown crops. Rowhani et al. (2011) focus on Tanzania and examine the relationship between seasonal climate and crop yields and find that both intra and inter seasonal changes in temperature and precipitation influence cereal (maize, sorghum and rice) yields. The climate–yield relationship has also been identified in Nigerian agriculture (Adamgbe and Ujoh, 2012; Adejuwon, 2005; Ayinde and Muchie, 2011). Given this well established relationship, rainfall and degree day deviations from historical means are used as a source of exogenous variation in agricultural production.

While rainfall is a straightforward measure of precipitation, the number of degree days is a more nuanced measure of temperature. Degree days are a cumulative measure of optimal temperatures for plant growth. The number of degree days in a given day is roughly determine by the difference between the average temperature and some base temperature measure ($8°C$ here)[5]. Days with an extreme average temperature (below $8°C$ or $34°C$ and above) are excluded since extreme temperatures are harmful to plant health. In general degree days are expected to be positively associated with agricultural production as was found by Schlenker et al. (2006). However, one drawback is that the optimal temperature range (especially the maximum temperature) varies across crops. Therefore, the degree day measure may capture the effect of higher temperatures that may be harmful to some plants.

Daily rainfall data from 2000 and daily temperature data from 1981 was extrapolated from the Surface Meteorology and Solar Energy version 6.0 developed by the Atmospheric Sciences Data Center at NASA and geo-referenced to both waves of the GHS-Panel. Historical average rainfall and degree days during two critical months of planting season (April and May) were calculated for each household. The deviation from the average planting season rainfall and degree days were then calculated for the relevant planting season in each wave. According to Table 3.1, rainfall during the planting season was below average in both waves. There are also more degree days than average in both waves.

---

[5]The number of degree days on a given day is determined according to the following equation used by Ritchie and NeSmith (1991):

$$D = \begin{cases} 0 & \text{if} \quad (T_{max} + T_{min})/2 < 8 \quad \text{or} \quad (T_{max} + T_{min})/2 \geq 34 \\ (T_{max} + T_{min})/2 - T_{base} & \text{if} \quad 8 \leq (T_{max} + T_{min})/2 < 32 \\ 24 & \text{if} \quad 32 \leq (T_{max} + T_{min})/2 < 34 \end{cases}$$

where T_{max} is the maximum temperature in Celsius, T_{min} is the minimum temperature, and T_{base} is the base temperature ($8°C$ is used here).

3.3.4 Additional Controls

There are several additional controls that will be considered in the analysis and whose means are included in Table 3.1. Standard household characteristics are included in the analysis such as household head characteristics and household composition. Indicators for additional sources of income are also included. Having income from an additional source could potentially alter the nutrition-productivity relationship making households less reliant on own agricultural production. Household food purchase decisions will also be influenced by local market prices for food items. Local[6] prices were calculated from purchase information in the post harvest consumption data for 15 of the most commonly purchased food items.

3.4 Empirical Methodology

This paper seeks to explore the linkages between agricultural production and nutrition. Three specific linkages will be examined: (1) agricultural output and caloric intake, (2) agricultural output and dietary diversity, and (3) production diversity and dietary diversity. Each of the three will be examined individually but using the same methodology.

The most straightforward empirical strategy would simply involve OLS estimation of the follow basic equation:

$$\ln N_{hct} = \beta_0 + \beta_1 \ln Y_{hct} + \sum_{i=1}^{15} \theta_i \ln p_{ict} + \Phi X_{ht} + \mu_h + \varepsilon_{hct} \tag{3.1}$$

where N_{hct} is the nutrition (caloric intake or dietary diversity) of household h in community c at time t with $t = \{1, 2\}$, Y_{hct} is agricultural production (total harvest value or crop group diversity), p_{ict} are local market prices for the 15 most commonly purchased food items (i), X_{hct} is a vector of other household socioeconomic characteristics, μ_h are household fixed effects, and ε_{hct} is the idiosyncratic error term. Under this formulation, β_1 would represent the estimated production–nutrition elasticity. While this method is simple, it could suffer from endogeneity bias.

There are two main potential sources of endogeneity that are of concern in this framework: omitted variable and simultaneity bias. The effect of any unobserved or omitted variables that determine nutrition could bias the estimated effect of production. However, the ability to control for household fixed effects in the panel data setting should greatly limit the potential for omitted

[6] As for farm gate prices, the lowest possible geographic level was used for "local" market prices depending on the number of price observations within a locality.

variable bias. The household fixed effects will capture the effect of time invariant household observable and unobservable characteristics. The inclusion of additional control variables that vary over time will also help mitigate any omitted variable bias cause by time variant characteristics.

Perhaps the more concerning source of endogeneity is simultaneity bias. In the nonseparable household model of Singh et al. (1986), production and consumption decisions are made simultaneously. Missing and imperfect markets that could cause nonseparability of production and consumption are likely present in rural Nigeria. In a nonseparable context, estimation of the causal effect of agricultural production on nutrition would be confounded by simultaneity. One method to correct for simultaneity is through the use of instrumental variables (IV). This requires an exogenous source of variation in agricultural production. Planting season rainfall and degree day shocks are proposed here as one potential exogenous source of variation. The two stage least squares (2SLS) method is used to estimate the IV. This entails a first stage estimation of the following equation:

$$\ln Y_{hct} = \alpha_0 + \alpha_1 R_{hct} + \alpha_2 T_{hct} + \sum_{i=1}^{15} \lambda_i \ln p_{ict} + \Psi X_{hct} + \mu_h + \varepsilon_{hct} \tag{3.2}$$

where R_{hct} and T_{hct} are planting season rainfall and degree day deviations from historical means and all others are as defined above. Equation 3.2 is then used to obtain predictions of Y_{hct} which are then used in estimation of Equation 3.1.

Under this formulation, the causal effect (β_1) is not necessarily a mean effect for the entire population. Instead, β_1 captures a local average treatment effect for the subpopulation whose agricultural production is influenced by the instruments. In the context of this study, this subpopulation would be households whose agricultural output and crop diversity are most strongly influenced by rainfall and temperature variations. Therefore, β_1 is in essence capturing the causal effect of agricultural production on nutrition for households that are more susceptible to weather variations and shocks. This subpopulation is of particular interest since these households are likely at a greater risk of suffering from poor nutrition and food security.

When using instrumental variables, the primary concern is whether the instruments are valid. A valid instrument must satisfy both the relevance and exclusion restrictions. The well established link between weather variability and agricultural production in the literature suggests relevancy. The main concern is whether rainfall and degree day deviations satisfy the exclusion restriction. This condition would be violated if weather deviations were correlated with nutrition other than through agricultural production. The plausibility of the exclusion condition depends on the spatial intensity of rainfall shocks and market integration. While rainfall shocks could have an effect on nutrition via price variation, the econometric specification includes market prices in the second stage. Further, rural Nigerian markets seem to be sufficiently integrated such that any reduction in yields caused by local rainfall variability will have only a small effect on equilibrium prices.

Three important tests for endogeneity and instrument validity are performed for each 2SLS specification below. The first is the C-test which tests whether the instrumented variables are endogenous. The second is the Sargan and Bassman overidentification test. This tests whether the instruments are valid by testing the joint null hypothesis that the instruments are uncorrelated with the error term and they are correctly excluded from the estimated equation. Lastly, the Cragg-Donald Wald F-statistic tests the joint relevancy of the instruments with respect to the endogenous regressor.

3.5 Results

Tables 3.2 and 3.3 contain this study's primary results: Table 3.2 for agricultural output and Table 3.3 for production diversity (crop group count). In both tables the first three columns contain estimates for dietary diversity regressions and and the last two for household caloric intake. Both OLS and 2SLS estimates are presented for each nutrition measure although the first stage 2SLS results (the second column) are common to both specifications and therefore not repeated.

The OLS results in Table 3.2 indicate that total agricultural production is positively associated with both dietary diversity and caloric intake. However, these results could suffer from simultaneity bias if production and consumption decisions are nonseparable. The 2SLS results attempt to correct for this bias using planting season weather deviations to instrument for production. The first stage estimation results for Equation 3.2 in the second column show that above average rainfall has a positive effect on total harvest value but an above average number of degree days has a negative effect. Although it might be expected that degree days would positively affect harvests, the negative result here likely reflects the harmful effects of above average (though not extreme) temperatures. The second stage estimates for both dietary diversity and caloric intake indicate that higher agricultural production resulted in improved household nutrition susceptible to weather shocks.

For both specifications, the 2SLS coefficient estimates are considerably larger than the OLS estimates. There are two potential explanations for this difference. First, the OLS estimates may be biased downward and thereby represent an underestimate of the true relationship. This downward bias could be due to omitted variables whose negative effect on nutrition is being captured by the coefficient estimate on agricultural output. The downward bias could also be caused by the simultaneity of agricultural production and nutrition decisions. This would cause a downward bias if there is a negative reverse causal effect whereby households with better nutrition have lower agricultural output. Households with better nutrition may already have met much of their nutrition needs through other means and are less reliant on agricultural output. Both of these sources of negative bias could translate into OLS underestimates of the agricultural production effect on nutrition.

The second potential explanation for the difference between the OLS and 2SLS estimates is that the causal effect in the 2SLS is estimated for households susceptible to weather shocks. The linkage between agricultural production and nutrition might be strongest for these households. The true population average effect is likely lower than the local average treatment effect for these households. The true mean effect is expected to lie somewhere between the OLS and 2SLS estimates.

The link between total production and caloric intake appears much stronger than for dietary diversity. The estimates suggest that a 10 percent increase in the value of agricultural output will improve dietary diversity by 1.4 percent and caloric intake by 5.3 percent. The result for dietary diversity is stronger than the crop value-dietary diversity elasticity of 0.02 found by Villa et al. (2011). The estimated calorie-agricultural output elasticity is generally in line with calorie-income elasticities found in the literature, though there is significant variation (Skoufias, 2003; Bouis and Haddad, 1992; Behrman et al., 1997). Although the estimated elasticities are less than 1, they are still sizable suggesting that improving agricultural production could be an effective means to combat malnutrition and food insecurity.

The results from three important tests for endogeneity and instrument validity are presented at the bottom of Table 3.2. The concern about endogeneity seems to have been warranted. The C-test results strongly reject exogeneity of harvest value. The Sargan and Bassman overidentification test results support exogeneity of the instruments by failing to reject the null hypothesis that the instruments are valid. The Cragg-Donald Wald F-statistic tests the joint relevancy of the instruments with respect to total harvest value. With an F-statistic of 13, the test indicates that the set of instruments are strongly correlated with total harvest value. This value is above the F-statistic cutoff of 10 for weak instruments suggested by Staiger and Stock (1997). Overall, the results of these three tests strongly support the presence of endogeneity and the validity

Table 3.2: Value of Agricultural Ouput & Nutrition

	Log Dietary Diversity			Log Calories per capita	
	OLS	2SLS: 1st Stage	2SLS: 2nd Stage	OLS	2SLS: 2nd Stage
Log total harvest value (Naira)	0.012***		0.137***	0.023**	0.534***
	(0.004)		(0.047)	(0.010)	(0.133)
Rainfall (cm) deviation		0.020***			
		(0.005)			
Degree days deviation		-0.003***			
		(0.001)			
Number of persons aged 15-65 in HH	0.001	0.032	-0.004	-0.007	-0.026
	(0.009)	(0.040)	(0.010)	(0.021)	(0.029)
Number of persons aged 0-14 in HH	0.018**	0.031	0.013	0.057***	0.037
	(0.008)	(0.032)	(0.009)	(0.017)	(0.025)
Number of persons aged 66 and over in HH	0.011	0.053	0.002	-0.046	-0.083
	(0.020)	(0.111)	(0.025)	(0.046)	(0.071)
Male Head of HH	-0.062	-0.402	-0.011	0.023	0.234
	(0.049)	(0.261)	(0.063)	(0.126)	(0.181)
Head years of education	0.003	-0.015	0.004	0.007	0.014
	(0.003)	(0.012)	(0.003)	(0.006)	(0.009)
C-test for endogeneity (χ^2)			9.88***		32.96***
Sargan and Basmann overidentification χ^2			0.65		1.94
Cragg-Donald Wald F statistic (weak IV)		13.32***			

Note: Coefficient estimates presented with robust standard errors in parentheses. All regressions include household fixed effects. Additional controls whose results are omitted from the table include additional household characteristics as well as local market prices for 15 commonly purchased food items. See Table D.9 in the Appendix for the full set of results. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3.3: Production Diversity & Nutrition

	Log Dietary Diversity		
	OLS	2SLS: 1st Stage	2SLS: 2nd Stage
Log # of crop groups harvested	0.059***		0.838**
	(0.014)		(0.395)
Rainfall (cm) deviation		0.004**	
		(0.002)	
Degree days deviation		-0.000	
		(0.000)	
Number of persons aged 15-65 in HH	0.001	0.009	-0.007
	(0.009)	(0.013)	(0.014)
Number of persons aged 0-14 in HH	0.017**	0.011	0.008
	(0.008)	(0.010)	(0.012)
Number of persons aged 66 and over in HH	0.011	0.023	-0.009
	(0.020)	(0.029)	(0.034)
Maximum education in household	-0.001	0.006	-0.006
	(0.003)	(0.004)	(0.004)
Male Head of HH	-0.061	-0.113	0.026
	(0.049)	(0.085)	(0.091)
Age of head	0.001	0.002	-0.000
	(0.001)	(0.002)	(0.002)
Head years of education	0.002	-0.002	0.004
	(0.003)	(0.004)	(0.004)
Head is in monogamous marriage	0.033	0.008	0.024
	(0.043)	(0.085)	(0.061)
Head is in polygamous marriage	0.017	-0.005	0.015
	(0.050)	(0.095)	(0.070)
HH received ag extension services	0.029	0.024	0.013
	(0.023)	(0.031)	(0.035)
Household owns livestock	0.029*	0.003	0.029
	(0.017)	(0.024)	(0.024)
Any income from livestock production	0.058***	0.005	0.055***
	(0.015)	(0.019)	(0.021)
Operated nonfarm enterprise	0.023	0.004	0.022
	(0.019)	(0.030)	(0.027)
Nonfarm wage employment	0.048***	0.019	0.036
	(0.018)	(0.030)	(0.030)
C-test for endogeneity (χ^2)			9.48***
Sargan and Basmann overidentification χ^2			0.73
Cragg-Donald Wald F statistic (weak IV)		3.28**	

Note: Coefficient estimates presented with robust standard errors in parentheses. All regressions include household fixed effects. Additional controls whose results are omitted from the table include local market prices for 15 commonly purchased food items. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

of the instruments.

Table 3.3 contains the results for production diversity (crop group count) and nutrition. The OLS results indicate that greater production diversity is associated with a more diverse household diet. However, there is no significant correspondence for caloric intake. This result is not terribly surprising. Growing a wider variety of crops does not necessarily imply the household will consume more calories.

Similar to agricultural output, production diversity could be endogenous and therefore introduce some bias into the estimation. The results for the first stage of the 2SLS procedure show that above average planting season rainfall is positively associated with with the number of crop groups harvested. This could suggest that when there is more rainfall, more crops survive to harvest. However, there was no significant relationship between production diversity and degree days deviation. Overall, the correlation between weather deviations and crop diversity is much weaker than for total production with an F-statistic of 3. While this suggests that the joint effect of both instruments is different from zero, the F-statistic magnitude falls below the Staiger and Stock (1997) cutoff for weak instruments. Therefore, the second stage 2SLS results must be interpreted with caution.

The second stage results suggest a positive association between production diversity and nutrition. Again, the 2SLS estimates for crop diversity are considerably larger than the OLS. The estimates suggest that a 10 percent increase in production diversity is associated with an 8 percent increase in dietary diversity. The estimated crop diversity-dietary diversity elasticity is close to one suggesting that growing an additional crop group will result in one additional food group (similarly defined) being consumed by the household. If households are consuming their output, this would be expected. That the elasticity is slightly less than one also lends credibility since not all food groups that comprise dietary diversity are crops (e.g. meat and poultry). This result is consistent with the findings of Jones et al. (2014). They find a crop count-dietary diversity elasticity of 0.23. The lower magnitude is likely due to the different diversity measure (i.e. crop count instead of crop group count). Although the weakness of the instruments warrants some caution, this result does suggest that crop diversification results in improved dietary diversity and therefore a more balanced household diet. Despite the relatively weak instruments, the crop diversity specification passes both the endogeneity and overidentification tests.

Overall, the main results point to several strong links between agricultural production and nutrition. While increased agricultural output improves both household dietary diversity and caloric intake, increased crop diversification appears to be a more effective means to improve dietary diversity and thereby better ensure that household members have an adequate intake of essential nutrients. Since caloric intake and dietary diversity are both crucial elements of nutrition, the results of this study suggest that policymakers should jointly emphasize expanded agricultural production and crop diversification to better improve nutrition amongst agricultural households.

3.5.1 Differential Effects Across Food Groups

The results so far have shown that agricultural output is associated with higher caloric intake as well as consumption of a larger variety of foods. These generalized results however do not shed any light on how diet composition is affected by these changes. In order to investigate the effect of agricultural production on diet composition, two additional sets of 2SLS specifications shall be estimated using total harvest value and consumption information on 9 food groups. The first set shall examine the effect on the probability of consuming each food group using a linear probability model. The second shall estimate the effect on calories consumed from each food group. A third specification will examine the relationship between production of a food group and consumption of the same food group.

The 2SLS linear probability results are presented in Table 3.4. There is considerable variation in the effect of expanded agricultural output on consumption of the different food groups. An increase in agricultural output increase the probability that pulses, oils, fruits, and sweets were consumed by the household. The effect was largest for sweets but also sizable for the healthier pulses and fruits. The estimates indicate that a 10 percent increase in agricultural output increases the probability of consuming pulses by 2 percent and fruits by 1.2 percent. The relatively large effect on sweets indicates that households are using some additional income from expanded production to purchase food items.

Table 3.5 presents the results for the total calories consumed from each food group. According to the results, increased agricultural output is associated with more consumption of many food groups on average. Only milk and meats were not significantly affected by changes in total harvest value. Again, the strongest effect is on calories consumed from sweets followed by pulses, oils, tubers, and fruits. Many of the agricultural output-consumption elasticities are greater than 1 suggesting that a 1 percent increase in agricultural output increases the calories consumed in those food groups by more than 1 percent. Livestock ownership (included as a control) was associated with a greater share of several food groups especially meat consumption but not a greater share of

Table 3.4. Production & Consumption of Food Groups (Indicators)

	Indicator for food group consumption								
	Grains	Tubers	Pulses	Oils	Fruits	Vegetables	Milk	Sweets	Meats
Log total harvest value (Naira)	0.022	0.095	0.195***	0.119***	0.125*	0.036	0.059	0.246***	0.030
	(0.023)	(0.061)	(0.076)	(0.043)	(0.070)	(0.033)	(0.062)	(0.086)	(0.051)
Number of persons aged 15-65 in HH	-0.008	-0.004	-0.002	-0.002	0.018	-0.002	-0.001	-0.006	0.002
	(0.005)	(0.013)	(0.017)	(0.009)	(0.015)	(0.007)	(0.013)	(0.019)	(0.011)
Number of persons aged 0-14 in HH	-0.003	0.012	0.004	-0.005	0.015	-0.005	0.018	-0.007	0.018*
	(0.004)	(0.011)	(0.014)	(0.008)	(0.013)	(0.006)	(0.012)	(0.016)	(0.009)
Number of persons aged 66 and over in HH	-0.014	0.033	-0.023	0.021	0.019	-0.011	0.022	-0.066	-0.007
	(0.012)	(0.032)	(0.040)	(0.023)	(0.037)	(0.017)	(0.033)	(0.046)	(0.027)
Maximum education in household	0.001	-0.002	0.000	-0.005**	0.002	0.000	-0.001	-0.003	-0.003
	(0.001)	(0.004)	(0.005)	(0.003)	(0.004)	(0.002)	(0.004)	(0.005)	(0.003)
Male Head of HH	-0.024	0.042	0.226**	0.082	-0.099	-0.062	0.085	0.075	-0.062
	(0.031)	(0.082)	(0.102)	(0.059)	(0.094)	(0.044)	(0.083)	(0.117)	(0.068)
Age of head	0.000	0.001	0.003	0.001	0.001	0.000	-0.001	0.002	-0.000
	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)
Head years of education	-0.001	0.006	0.001	0.004	0.004	0.004*	0.002	0.002	0.003
	(0.002)	(0.004)	(0.005)	(0.003)	(0.005)	(0.002)	(0.004)	(0.006)	(0.003)
HH received ag extension services	-0.017	0.052	0.012	-0.002	-0.009	-0.042**	0.069*	-0.029	0.012
	(0.013)	(0.035)	(0.043)	(0.025)	(0.040)	(0.019)	(0.035)	(0.049)	(0.029)
Household owns livestock	0.004	0.050**	0.043	-0.007	0.026	0.026**	0.017	0.065*	-0.015
	(0.009)	(0.024)	(0.030)	(0.017)	(0.027)	(0.013)	(0.024)	(0.034)	(0.020)

Note: 2SLS coefficient estimates presented with robust standard errors in parentheses. All regressions include household fixed effects. Additional controls whose results are omitted from the table include other income sources and local market prices for 15 commonly purchased food items. See Table D.10 in the Appendix for the full set of results. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3.5: Production & Consumption of Food Groups (Calories)

	Log Total Calories Consumed from Food Group								
	Grains	Tubers	Pulses	Oils	Fruits	Vegetables	Milk	Sweets	Meats
Log total harvest value (Naira)	0.456*	1.262**	1.917***	1.290***	0.969**	0.665**	0.712	1.990***	0.330
	(0.256)	(0.553)	(0.695)	(0.460)	(0.473)	(0.313)	(0.454)	(0.663)	(0.276)
Number of persons aged 15-65 in HH	-0.067	0.007	-0.057	-0.028	0.129	0.026	-0.007	-0.052	0.070
	(0.056)	(0.121)	(0.152)	(0.101)	(0.103)	(0.069)	(0.099)	(0.145)	(0.060)
Number of persons aged 0-14 in HH	0.014	0.130	0.085	-0.013	0.114	0.037	0.135	-0.043	0.033
	(0.048)	(0.103)	(0.130)	(0.086)	(0.088)	(0.059)	(0.085)	(0.124)	(0.052)
Number of persons aged 66 and over in HH	-0.154	0.280	-0.325	0.231	0.062	0.003	0.080	-0.388	0.092
	(0.137)	(0.295)	(0.370)	(0.245)	(0.252)	(0.167)	(0.242)	(0.353)	(0.147)
Maximum education in household	0.003	-0.019	0.013	-0.047	0.007	-0.001	-0.020	-0.024	-0.013
	(0.016)	(0.034)	(0.043)	(0.029)	(0.029)	(0.020)	(0.028)	(0.041)	(0.017)
Male Head of HH	-0.358	0.632	2.005**	0.852	-0.574	-0.527	0.588	0.605	0.561
	(0.347)	(0.750)	(0.942)	(0.624)	(0.641)	(0.425)	(0.616)	(0.898)	(0.374)
Age of head	0.007	0.010	0.037**	0.010	0.014	0.014*	0.001	0.017	0.001
	(0.007)	(0.015)	(0.018)	(0.012)	(0.012)	(0.008)	(0.012)	(0.017)	(0.007)
Head years of education	0.007	0.057	-0.001	0.030	0.040	0.026	0.032	0.015	0.000
	(0.017)	(0.036)	(0.046)	(0.030)	(0.031)	(0.021)	(0.030)	(0.043)	(0.018)
HH received ag extension services	-0.459***	0.225	-0.080	-0.210	-0.091	-0.430**	0.492*	-0.340	0.162
	(0.146)	(0.316)	(0.397)	(0.263)	(0.270)	(0.179)	(0.260)	(0.379)	(0.158)
Household owns livestock	0.099	0.415*	0.534*	-0.120	0.195	0.285**	0.086	0.496*	0.312***
	(0.101)	(0.219)	(0.274)	(0.182)	(0.187)	(0.124)	(0.180)	(0.262)	(0.109)

Note: 2SLS coefficient estimates presented with robust standard errors in parentheses. All regressions include household fixed effects. Additional controls whose results are omitted from the table include other income sources and local market prices for 15 commonly purchased food items. See Table D.11 in the Appendix for the full set of results. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

milk consumption.

Agricultural output appears to have the largest impact on consumption of sweets, pulses, oils, fruits, and tubers. This is a mixture of some calorie rich foods (sweets and oils) and some nutrient rich foods (pulses, fruits, and tubers). This mixture suggests that not all of the additional calories consumed by a household with increased agricultural output are coming from foods with low nutritional value but, in addition, the calories are not all coming from foods with high nutritional value.

In addition to the effect of the level of production on overall diet composition, it is also of interest whether households that produce a wide variety of food groups actually consume those same food groups. Table 3.6 contains linear probability estimates of specifications predicting consumption of food groups with indicators for production of the same food group on the right hand side. The coefficient estimates on these food group production indicators will demonstrate whether households that produce a certain food group are more likely to consume that food group. This provides a more detailed indication of the linkage between production diversity and dietary diversity. The results show that households that produce tubers, pulses, and fruits were more likely to consume the same food group, *ceteris paribus*. However, there was no significant relationship between production and consumption of grains, oils, and vegetables. This could suggest that diversification in tubers, pulses, and fruits are likely to improve the variety of foods consumed by the household.

3.5.2 Regional Differences

Nigeria is large and diverse country. The North-South divide is especially prevalent both culturally and climatically. The north is predominantly Muslim while the south is predominantly Christian. The climates are also distinct with the north being much warmer and drier than the cooler and wetter south. These differences could cause variations in the link between agricultural production and nutrition. The main specifications above are separately estimated on agricultural households in the North (n=1,469) and those in the South (n=702). The results are presented in Table 3.7.

The top panel of Table 3.7 contains estimates from the harvest value specifications. The OLS estimates highlight a stark difference between the north and the south. In the north, agricultural output is positively correlated with both dietary diversity and caloric intake while in the south no such correlation exists. Instrumenting for agricultural output using weather deviations, another difference is highlighted. Above average rainfall and degree days are important for agricultural

Table 3.6: Food Group Production & Consumption

	Indicator for food group consumption					
	Grains	Tubers	Pulses	Oils	Fruits	Vegetables
Grew grains or flours	-0.004					
	(0.011)					
Grew pulses/nuts/seeds		0.068**				
		(0.031)				
Grew starchy roots/tubers/plantains			0.064**			
			(0.027)			
Grew oil plants				-0.009		
				(0.028)		
Grew fruits					0.106**	
					(0.043)	
Grew vegetables						-0.006
						(0.014)
Number of persons aged 15-65 in HH	-0.007	-0.001	0.005	0.002	0.022	-0.000
	(0.005)	(0.013)	(0.014)	(0.008)	(0.014)	(0.007)
Number of persons aged 0-14 in HH	-0.002	0.015	0.011	-0.001	0.020*	-0.003
	(0.004)	(0.011)	(0.012)	(0.007)	(0.012)	(0.006)
Number of persons aged 66 and over in HH	-0.012	0.039	-0.010	0.030	0.026	-0.008
	(0.012)	(0.031)	(0.035)	(0.020)	(0.035)	(0.017)
Maximum education in household	0.001	-0.001	0.002	-0.004*	0.004	0.001
	(0.001)	(0.004)	(0.004)	(0.002)	(0.004)	(0.002)
Male Head of HH	-0.033	0.001	0.152*	0.033	-0.150*	-0.077*
	(0.030)	(0.076)	(0.086)	(0.049)	(0.085)	(0.042)

Note: 2SLS coefficient estimates presented with robust standard errors in parentheses. All regressions include household fixed effects. Additional controls whose results are omitted from the table include other income sources and local market prices for 15 commonly purchased food items. See Table D.12 in the Appendix for the full set of results. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3.7: North versus South

	Log Dietary Diversity			Log Calories per capita	
	OLS	2SLS: 1st Stage	2SLS: 2nd Stage	OLS	2SLS: 2nd Stage
Harvest Value:					
North					
Log total harvest value	0.017***		0.159**	0.039***	0.465***
	(0.006)		(0.069)	(0.014)	(0.159)
Rainfall (cm) deviation		0.022***			
		(0.006)			
Degree days deviation		-0.002**			
		(0.001)			
South					
Log total harvest value	0.004		0.082**	0.002	0.324***
	(0.005)		(0.037)	(0.014)	(0.125)
Rainfall (cm) deviation		0.017			
		(0.011)			
Degree days deviation		-0.027***			
		(0.007)			
Production Diversity:					
North					
Log # of crop groups	0.081***		2.714		
	(0.025)		(6.053)		
Rainfall (cm) deviation		0.000			
		(0.002)			
Degree days deviation		-0.000			
		(0.000)			
South					
Log # of crop groups	0.042***		0.225**		
	(0.016)		(0.092)		
Rainfall (cm) deviation		0.016***			
		(0.004)			
Degree days deviation		0.004			
		(0.003)			

Note: 2SLS coefficient estimates presented with robust standard errors in parentheses. All regressions include household fixed effects. Control variables are identical to those in the base regressions. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

output in the north, but in the south only degree day deviations are correlated. Furthermore, the point estimate for degree day deviations in the south is much larger (almost 15 times) than in the north. The second stage results show a significant and positive relationship between agricultural output and both nutrition measures in the north and the south. However, the point estimates in the south are about half those in the north.

The bottom panel of Table 3.7 contains estimates from production diversity specifications.

Unlike for agricultural output, production diversity is positively correlated with dietary diversity in both the north and the south. Again, the correlation is more prominent in the north. While above average rainfall was associated with greater harvested crop diversity in the south, neither form of weather deviation appeared to have an effect in the north. The nonrelationship in the north implies that the second stage results there cannot be trusted. However, the second stage results in the south do continue to indicate that harvesting more crop groups results in a wider array of food groups being consumed by the household.

Overall, these results suggest that the links between agricultural production and nutrition are stronger in northern Nigeria than in southern. This could reflect greater income diversification among households in the more economically developed south. Generating income from various sources could better allow households to separate post harvest consumption decisions from agricultural production outcomes.

3.5.3 Alternative Production Measures

As a robustness check on the main results, one alternative measure for agricultural output and three measures for production diversity are considered. For agricultural output, farmer estimated harvest value is used instead of harvest value determined from local farm gate prices. The results using this measure are presented in the top panel of Table 3.8. The results are very similar to those for the main harvest value measure. The agricultural output-nutrition elasticities are 0.3 for dietary diversity and 1.1 for caloric intake. These estimates are somewhat larger than those for harvest value from farm gate prices. This could indicate that the primary agricultural output results are underestimates of the true effects. In the end, these results lend support to the primary agricultural output estimates above.

The three production diversity measures considered here are the Simpson, Shannon, and Berger-Parker indices (see the appendix for definitions). These measures differ from the main diversity measure in that they take into account the share of land devoted to each crop group. The difference between the measures is largely due to differences in how shares are weighted. However, one important difference is the higher values of the Simpson index are associated with less diversity while the opposite is true for the other two inidces. The dietary diversity results for these three measures are somewhat different. In the OLS estimation, only the Berger-Parker index is correlated with improved dietary diversity. However, in the second stage results, both the Berger-Parker and Shannon indices have a positive and significant impact on dietary diversity. For the most part, these

Table 3.8: Alternative Production Measures

	Log Dietary Diversity			Log Calories per capita	
	OLS	2SLS: 1st Stage	2SLS: 2nd Stage	OLS	2SLS: 2nd Stage
Harvest Value					
Farmer estimate of value	0.022***		0.336***	0.058***	1.100***
	(0.006)		(0.121)	(0.015)	(0.355)
Rainfall (cm) deviation		0.010**			
		(0.004)			
Degree days deviation		-0.002***			
		(0.001)			
Simpson index					
Log of Simpson index	-0.014		-3.030		
	(0.010)		(4.401)		
Rainfall (cm) - deviation		-0.001			
		(0.002)			
Degree days deviation		0.000			
		(0.000)			
Shannon index					
Log of Shannon index	0.005		0.861*		
	(0.007)		(0.482)		
Rainfall (cm) - deviation		0.005*			
		(0.003)			
Degree days deviation		-0.000			
		(0.000)			
Berger-Parker index					
Log of Berger-Parker index	0.075***		1.051***		
	(0.021)		(0.341)		
Rainfall (cm) - deviation		0.004***			
		(0.001)			
Degree days deviation		-0.000***			
		(0.000)			

Note: 2SLS coefficient estimates presented with robust standard errors in parentheses. All regressions include household fixed effects. Control variables are identical to those in the base regressions. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

results are in agreement with the crop group count estimates above suggesting they are robust.

3.6 Conclusion

This essay has sought to explore the linkages between agricultural production and household nutrition. Policies promoting agricultural production with the aim of improving nutrition assume these linkages exist. However, the linkages have not been clearly established by researchers. The majority of current research focuses on specific and small scale agricultural interventions. In contrast to the majority of the literature, this study took a broader focus and was able to use panel data methods while also attempting to correct for endogeneity bias.

Three specific linkages were examined: (1) agricultural output and dietary diversity, (2) agricultural output and caloric intake, (3) production diversity and dietary diversity. Estimating two stage least squares models, positive associations are found in all three linkages. An output-dietary diversity elasticity of 0.14 is found while the estimated output-caloric intake elasticity was 0.53. The result for dietary diversity is stronger than other studies have found (Villa et al., 2011) but the caloric intake results are in the general range of many income-caloric intake elasticities found in the literature. While the elasticities are less than one, the results are still meaningful. This suggests that expanding agricultural output could result in both improved caloric intake and dietary diversity.

The results for production diversity and dietary diversity suggest that a 10 percent increase in the number of crop groups harvested by the household is associated with an 8.4 percent increase in household dietary diversity. However, this specification suffers from relatively weak instruments and its results should interpreted cautiously. These results are largely in agreement with a similar study by Jones et al. (2014) who found a strong positive association between production diversity and dietary diversity in Malawi.

Taken together, the results of this study suggest that there is significant potential for improving nutrition through enhanced agricultural production. This provides support for current interventions with such an aim. Furthermore, the results suggest that expanding agricultural output will result in improved caloric intake and dietary diversity, but the effect on dietary diversity appears stronger for crop diversification. This suggests that a mixed policy that promotes expanded production and more diversified production would be the most effective policy to broadly improve the nutrition of Nigerian agricultural households.

APPENDIX A

ENDOGENEITY IN CHAPTER 1

An alternative method to correct for omitted variable bias on household infrastructure coefficients is to instrument for these variables and implement a two-stage least squares (2SLS) model. Instruments would have to be correlated with the relevant infrastructure variable but not correlated with the health outcome other than through infrastructure. In other words, an instrument would capture an *exogenous* variation in infrastructure. One potential source of exogenous variation is whether the community of a household received treatment from the two water and sanitation projects mentioned in Section 3: the SIF II and PROSABAR. Clearly, having a SIF II or PROSABAR water or sanitation subproject implemented in the household's community would affect the infrastructure of the household. Therefore, the first condition of valid instruments is met. However, the second condition, no relationship between the instruments and the dependent variable other than through the endogenous regressors, could be a problem. This condition would be violated if treatment decisions were based on the health within a community. Given the design of the project, this could be a serious concern. This problem can be attenuated through community level controls which will capture observed and unobserved differences between treatment and control communities.

A 2SLS model could be estimated using water system, latrine, and sewer treatment under SIF II and PROSABAR as instruments for piped water, latrine, and flush toilet. The first stage regressions would consist of regressing these infrastructure variables against the interaction of treatment and post treatment (year=2003, 2008) dummies and all previous explanatory variables. Equation would then be implemented in the second stage using the predicted values for infrastructure variables. Identification will be an issue since all infrastructure variables (including interactions) would need to instrumented for (9 endogenous regressors) but only six instruments would be available. Additional instruments would need to be included. One set of additional instruments could be project participation interacted with an indicator for the political party in power within the community.

APPENDIX B

INFRASTRUCTURE CODES IN BOLIVIA DHS

Table B.1. Frequencies of Infrastructure Variables

1994		1998		2003		2008	
WATER ACCESS							
Piped	1,716	Piped within structure	1,840	Piped into dwelling	1,531	Piped into dwelling	1,429
Public tap	291	Piped outside structure	2,121	Piped into yard/spot	5,118	Piped into yard/spot	4,600
Piped neighbor	53	Piped outside lot	675	Piped outside dwelling	719	Public tab/standpipe	622
Neighbor	114	Well or water wheel	1,160	Well with elec pump	288	Protected well	192
Well	713	River, lake, roof, irrigation	1,271	Well without elec pump	1,142	Unprotected well	798
River, stream	673	Tanker truck	93	River/stream	1,034	River/damn	550
Tanker truck	69	Other	137	Pond/lake	117	Lake/pond/stream	65
Other	4			Water from neighbors	98	Tanker truck	133
				Tanker truck	165	Other	70
				Other	83		
SANITATION							
Own flush toilet	565	Private flush toilet	924	Flush toilet	2,400	Sewer	2,482
Toilet with septic tank	240	Shared flush toilet	342	Septic tank	690	Septic tank	669
Pit toilet	1,093	Toilet (private or shared)	7	Pit toilet	3,252	Open pit	2,510
No facility, bush	1,718	Private pit toilet latrine	1,824	No facility, bush	3,954	No facility, bush	73
		Shared pit toilet latrine	896				
		Latrine (private or shared)	16				
		No facility, bush	3,280				
FLOORING							
Earth, sand	1,785	Earth	3,280	Earth	4,118	Dirt	3,080
Wood planks	126	Wood	657	Wood planks	289	Wood	363
Polished wood	199	or tiles	446	Parquet	525	Parquet	475
Asphalt strip	152	Bricks	542	(missing name)	721	Carpet	15
Ceramic tiles	106	Cement	2,300	(missing name)	695	Cement	3,191
Cement	1,011	Other	64	(missing name)	3,877	Ceramic	866
Bricks	241			Carpet	36	Bricks	512
Other	10			Other	32	Other	22

APPENDIX C

ALTERNATIVE PRODUCTION DIVERSITY MEASURES

Three alternative production diversity measures are used as a robustness check. Unlike crop group count, all of these alternative measures take into account the share of land on which each crop group was harvested. First, the Simpson index measures the concentration of crops and is calculated according to the following formula:

$$S = \sum_{i=1}^{c} p_i^2$$

where S is the Simpson measure, p_i is the share of land on which crop i was harvested. In contrast to the other two measures, the Simpson index is decreasing in diversity.

The Shannon index in a measure of entropy. In the context of crop diversity, it measures the uncertainty of knowing what crop is grown on a randomly selected point of land. If there is one crop harvested on 99% of land and another harvested on the remaining 1%, then there is little uncertainty regarding which crop would be grown on a randomly chose point of harvested land. The Shannon index is calculated according to the following formula:

$$Sh = -\sum_{i=1}^{c} p_i \ln p_i$$

The Berger-Parker index is the most straightforward of the three. It is simply the inverse of the maximum p_i (i.e the portion of harvested land devoted to the most abundant crop).

APPENDIX D

TABLES

D.1 Chapter 1

Table D.1: Diarrhea & Height-for-Age Full Results

	Diarrhea				Height-for-age			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Household Infrastructure:								
Piped water	-0.004	-0.015	0.004	-0.010	0.147***	0.119**	0.039	0.054
	(0.010)	(0.017)	(0.011)	(0.017)	(0.032)	(0.055)	(0.032)	(0.053)
Sanitation	-0.034***	-0.045**	-0.021**	-0.041**	0.193***	0.072	0.056*	0.010
	(0.010)	(0.019)	(0.010)	(0.019)	(0.031)	(0.061)	(0.030)	(0.059)
Nondirt floor	-0.015	0.000	0.001	0.005	0.374***	0.254***	0.177***	0.156***
	(0.010)	(0.021)	(0.011)	(0.021)	(0.030)	(0.061)	(0.032)	(0.060)
Infrastructure interactions:								
Piped & Sanitation		0.042		0.040		0.029		0.023
		(0.026)		(0.026)		(0.080)		(0.076)
Piped & nondirt		-0.001		0.002		0.033		-0.018
		(0.027)		(0.027)		(0.079)		(0.076)

Table D.1: Diarrhea & Height-for-Age Results (cont.)

	Diarrhea				Height-for-age			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sanitation & Nondirt		-0.003		0.008		0.174*		0.120
		(0.031)		(0.031)		(0.095)		(0.091)
Piped & Sanitation & Nondirt		-0.034		-0.024		0.008		-0.078
		(0.038)		(0.038)		(0.116)		(0.111)
Child characteristics:								
Sex			0.020***	0.020***			-0.091***	-0.090***
			(0.007)	(0.007)			(0.020)	(0.020)
Age (months)			0.000	0.000			-0.031***	-0.031***
			(0.000)	(0.000)			(0.001)	(0.001)
Preceding birth interval (months)			0.000	0.000			0.002***	0.002***
			(0.000)	(0.000)			(0.000)	(0.000)
Mother characteristics:								
Age mother			-0.005	-0.005			0.021	0.021
			(0.004)	(0.004)			(0.013)	(0.013)
Age mother squared			0.000	0.000			-0.000*	-0.000*
			(0.000)	(0.000)			(0.000)	(0.000)
Education in single years			-0.004***	-0.004***			0.031***	0.031***
			(0.001)	(0.001)			(0.003)	(0.003)
Mother is working			0.038***	0.038***			-0.024	-0.024
			(0.008)	(0.008)			(0.023)	(0.023)
Never Married			-0.007	-0.007			-0.085	-0.085
			(0.022)	(0.022)			(0.061)	(0.061)
Married			-0.009	-0.010			0.044	0.045
			(0.020)	(0.020)			(0.058)	(0.058)
Spouse			-0.048*	-0.047*			0.033	0.033
			(0.025)	(0.025)			(0.075)	(0.075)
Son or daughter			-0.047*	-0.047*			0.105	0.107
			(0.028)	(0.028)			(0.082)	(0.082)
Mother's relationship to head (head omitted):								
Son-in-law or daughter-in-law			-0.011	-0.011			0.122	0.125
			(0.034)	(0.034)			(0.102)	(0.102)

Table D.1: Diarrhea & Height-for-Age Results (cont.)

	Diarrhea				Height-for-age			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Other relative			-0.005	-0.006			0.021	0.022
			(0.034)	(0.034)			(0.100)	(0.100)
Other nonrelative			0.072	0.073			-0.174	-0.173
			(0.051)	(0.051)			(0.132)	(0.132)
Head of household is male			0.041**	0.041**			0.011	0.011
			(0.018)	(0.018)			(0.054)	(0.054)
Head age			-0.000	-0.000			-0.002	-0.002
			(0.002)	(0.002)			(0.006)	(0.006)
Head characteristics:								
Head age squared			0.000	0.000			0.000	0.000
			(0.000)	(0.000)			(0.000)	(0.000)
Household members above 5 years old			0.003	0.003			-0.011	-0.010
			(0.003)	(0.003)			(0.008)	(0.008)
Members under age 5			-0.012**	-0.012**			-0.091***	-0.091***
			(0.005)	(0.005)			(0.015)	(0.015)
Household characteristics:								
Owns TV			-0.001	-0.001			0.085**	0.085**
			(0.013)	(0.013)			(0.036)	(0.036)
Owns radio			-0.003	-0.003			-0.006	-0.005
			(0.011)	(0.011)			(0.031)	(0.031)
Owns refrigerator			-0.033***	-0.033***			0.234***	0.231***
			(0.011)	(0.011)			(0.032)	(0.032)
Has electricity			0.007	0.007			0.045	0.046
			(0.013)	(0.013)			(0.038)	(0.038)
# of rooms for sleeping per capita			-0.126***	-0.126***			0.631***	0.630***
			(0.033)	(0.033)			(0.092)	(0.092)

Note: Coefficient estimates presented with robust standard errors clustered at the enumeration area in parentheses. All regressions include province-year fixed effects. Results for month of interview are omitted from the table. Significance denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.2: Weight-for-Age & Weight-for-Height Results

	Weight-for-Age				Weight-for-Height			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Household Infrastructure:								
Piped water	0.098***	0.084*	0.009	0.024	-0.011	-0.014	-0.046*	-0.046
	(0.029)	(0.047)	(0.029)	(0.046)	(0.027)	(0.042)	(0.028)	(0.042)
Sanitation	0.138***	0.098*	0.036	0.046	0.039	0.072	0.011	0.050
	(0.028)	(0.055)	(0.027)	(0.053)	(0.025)	(0.050)	(0.026)	(0.050)
Nondirt floor	0.278***	0.260***	0.119***	0.168***	0.064**	0.120**	0.006	0.074
	(0.027)	(0.053)	(0.029)	(0.052)	(0.025)	(0.050)	(0.027)	(0.050)
Infrastructure interactions:								
Piped & Sanitation		0.012		0.012		-0.007		-0.000
		(0.074)		(0.071)		(0.068)		(0.067)
Piped & nondirt		-0.015		-0.051		-0.038		-0.043
		(0.071)		(0.069)		(0.066)		(0.065)
Sanitation & Nondirt		0.001		-0.034		-0.131		-0.134*
		(0.084)		(0.081)		(0.080)		(0.079)
Piped & Sanitation & Nondirt		0.070		0.005		0.099		0.080
		(0.104)		(0.101)		(0.098)		(0.097)
Child characteristics:								
Sex			-0.114***	-0.114***			-0.106***	-0.106***
			(0.019)	(0.019)			(0.018)	(0.018)
Age (months)			-0.026***	-0.026***			-0.013***	-0.013***
			(0.001)	(0.001)			(0.001)	(0.001)
Preceding birth interval (months)			0.001***	0.001***			0.000	0.000
			(0.000)	(0.000)			(0.000)	(0.000)
Mother characteristics:								
Age mother			0.015	0.015			0.006	0.006
			(0.012)	(0.012)			(0.011)	(0.011)
Age mother squared			-0.000	-0.000			-0.000	-0.000
			(0.000)	(0.000)			(0.000)	(0.000)
Education in single years			0.019***	0.019***			0.002	0.002
			(0.003)	(0.003)			(0.003)	(0.003)

Table D.2: Weight-for-Age & Weight-for-Height Results (cont.)

	Weight-for-Age				Weight-for-Height			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mother is working			0.011	0.011			0.034*	0.034*
			(0.021)	(0.021)			(0.020)	(0.020)
Never Married			-0.099*	-0.101*			-0.047	-0.048
			(0.058)	(0.058)			(0.056)	(0.056)
Married			0.019	0.017			-0.017	-0.018
			(0.053)	(0.053)			(0.048)	(0.048)
Spouse			-0.055	-0.054			-0.110*	-0.110*
			(0.067)	(0.067)			(0.063)	(0.063)
Son or daughter			-0.005	-0.004			-0.108	-0.109
			(0.076)	(0.076)			(0.075)	(0.075)
Mother's relationship to head (head omitted):								
Son-in-law or daughter-in-law			-0.028	-0.027			-0.141	-0.143
			(0.092)	(0.092)			(0.088)	(0.088)
Other relative			-0.107	-0.106			-0.160*	-0.160*
			(0.087)	(0.087)			(0.087)	(0.087)
Other nonrelative			-0.295**	-0.294**			-0.261**	-**
			(0.127)	(0.128)			(0.132)	(0.131)
Head of household is male			0.066	0.066			0.084*	0.084*
			(0.049)	(0.049)			(0.047)	(0.047)
Head age			0.001	0.001			0.002	0.003
			(0.005)	(0.005)			(0.005)	(0.005)
Head characteristics:								
Head age squared			0.000	-0.000			-0.000	-0.000
			(0.000)	(0.000)			(0.000)	(0.000)
Household members above 5 years old			-0.009	-0.010			-0.004	-0.004
			(0.007)	(0.007)			(0.007)	(0.007)
Members under age 5			-0.044***	-0.044***			0.017	0.017
			(0.014)	(0.014)			(0.012)	(0.012)
Household characteristics:								
Owns TV			0.091***	0.091***			0.046	0.046
			(0.032)	(0.032)			(0.030)	(0.030)

Table D.2: Weight-for-Age & Weight-for-Height Results (cont.)

	Weight-for-Age				Weight-for-Height			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Owns radio			0.074***	0.073***			0.093***	0.092***
			(0.027)	(0.027)			(0.025)	(0.025)
Owns refrigerator			0.189***	0.193***			0.071**	0.076***
			(0.030)	(0.030)			(0.028)	(0.029)
Has electricity			0.053	0.052			0.045	0.043
			(0.035)	(0.035)			(0.034)	(0.034)
# of rooms for sleeping per capita			0.468***	0.471***			0.134	0.137*
			(0.086)	(0.087)			(0.083)	(0.083)
R-squared	0.131	0.131	0.196	0.196	0.080	0.080	0.096	0.097

Note: Coefficient estimates presented with robust standard errors clustered at the enumeration area in parentheses. All regressions include province-year fixed effects. Results for month of interview are omitted from the table. Significance denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

D.2 Chapter 2

Table D.3: Total Work Results

	Parents		Fathers		Mothers	
	Y/N	Hours	Y/N	Hours	Y/N	Hours
	(1)	(2)	(3)	(4)	(5)	(6)
Child malaria status						
At least on child with malaria in HH	0.013	0.112	0.005	-0.604	0.014	0.591
	(0.010)	(0.563)	(0.023)	(0.783)	(0.013)	(0.594)
Individual characteristics						
Ill in last 2 weeks (excl. malaria)	-0.028	-1.630**	-0.118***	-3.762***	-0.013	-0.275
	(0.019)	(0.808)	(0.042)	(1.338)	(0.014)	(0.952)
Age (years)	0.009*	1.144***	0.008	0.881***	0.008	1.081***
	(0.005)	(0.146)	(0.007)	(0.235)	(0.006)	(0.204)
Age (years) squared	-0.000*	-0.014***	-0.000	-0.010***	-0.000	-0.014***
	(0.000)	(0.002)	(0.000)	(0.003)	(0.000)	(0.003)
Householder	0.120*	12.36***	0.113**	4.443**	0.060	8.468***
	(0.070)	(0.535)	(0.054)	(1.945)	(0.049)	(0.922)
Married - polygamous	0.005	-3.208***	0.031	-4.240**	0.010	-2.033*
	(0.012)	(1.109)	(0.054)	(2.136)	(0.015)	(1.188)
Islam	-0.027	-0.509	-0.013	0.726	-0.032	-1.821*
	(0.018)	(0.870)	(0.034)	(1.224)	(0.027)	(1.016)
Self reported time	-0.000	-1.143***	0.115***	1.186*	-0.001	0.682
	(0.005)	(0.432)	(0.036)	(0.661)	(0.006)	(0.594)
Can write in English	-0.014	1.340**	0.002	2.070**	-0.019	0.284
	(0.011)	(0.654)	(0.029)	(0.938)	(0.017)	(0.855)
Spouse lives in household	0.039	-0.086	0.081	-1.364	-0.004	-2.263
	(0.024)	(1.143)	(0.062)	(2.104)	(0.018)	(1.722)
Mother is in household	0.021	0.454	0.050	1.669	0.015	0.766
	(0.019)	(1.307)	(0.074)	(2.351)	(0.019)	(1.392)
Father is in household	0.008	0.030	0.116	4.632	-0.001	-1.020
	(0.021)	(1.735)	(0.106)	(3.293)	(0.019)	(1.853)

Table D.3: Total Work Results (cont.)

	Parents		Fathers		Mothers	
	Y/N	Hours	Y/N	Hours	Y/N	Hours
	(1)	(2)	(3)	(4)	(5)	(6)
Household characteristics						
# of household memebers	-0.007	-0.974***	-0.012	-1.809***	-0.006	-1.253***
	(0.005)	(0.325)	(0.012)	(0.471)	(0.006)	(0.376)
Child dependency ratio	-0.019	-2.283***	0.018	-5.452***	-0.013	-1.951***
	(0.013)	(0.639)	(0.028)	(1.235)	(0.013)	(0.733)
Own house	0.050*	-1.538**	-0.037	-5.913***	0.066	3.078***
	(0.030)	(0.774)	(0.031)	(1.067)	(0.053)	(0.914)
Electricity	-0.003	4.043***	-0.003	1.625	0.006	7.115***
	(0.011)	(1.409)	(0.049)	(1.714)	(0.013)	(1.930)
Household owns a clock	0.019	4.421***	0.062	5.152***	0.014	3.834***
	(0.014)	(0.854)	(0.039)	(1.212)	(0.015)	(1.043)
# of wage workers per adult equivalent		-13.58***		1.893		-12.52***
		(1.782)		(3.063)		(1.732)
# of agricultureal workers per adult equivalent		12.52***		9.111***		13.65***
		(0.753)		(1.034)		(0.809)
# of nonagriculture workers per adult equivalent		8.578***		7.737***		6.598***
		(1.318)		(2.083)		(1.316)
Community characteristics						
KMs to place to purchase common medicines	0.000	0.012*	0.001	0.018*	-0.000	0.006
	(0.000)	(0.007)	(0.001)	(0.009)	(0.000)	(0.007)
KMs to health clinic (Chiptala)	-0.000	-0.067**	-0.002*	-0.115***	0.000	-0.024
	(0.000)	(0.029)	(0.001)	(0.039)	(0.000)	(0.031)
KMs to health facility with a doctor	-0.000	0.002	0.000	0.004	-0.000	0.000
	(0.000)	(0.008)	(0.000)	(0.010)	(0.000)	(0.009)
Household geographic characteristics						
Distance to nearest road (KMs)	0.000	-0.033	-0.001	-0.090*	0.001	0.018
	(0.000)	(0.038)	(0.001)	(0.050)	(0.001)	(0.038)
Distance to nearest population center (KMs)	0.000	0.016	0.000	0.029	0.000	0.002
	(0.000)	(0.024)	(0.001)	(0.029)	(0.000)	(0.025)

Table D.3: Total Work Results (cont.)

	Parents		Fathers		Mothers	
	Y/N	Hours	Y/N	Hours	Y/N	Hours
	(1)	(2)	(3)	(4)	(5)	(6)
Distance to nearest ADMARC outlet (KMs)	0.000	-0.046	0.002	-0.067	0.000	-0.010
	(0.001)	(0.052)	(0.002)	(0.076)	(0.001)	(0.053)
Distance to district Boma (KMs)	0.000	-0.006	0.001	-0.000	0.000	-0.010
	(0.000)	(0.021)	(0.001)	(0.025)	(0.000)	(0.023)
Annual mean temperature (celcius)	-0.001	-0.073**	-0.003***	-0.100**	-0.000	-0.047
	(0.001)	(0.037)	(0.001)	(0.046)	(0.001)	(0.038)
Annual precipitation (mm)	0.000	0.005*	0.000	0.007**	0.000	0.003
	(0.000)	(0.003)	(0.000)	(0.003)	(0.000)	(0.003)
Observations	11,529	11,529	5,225	5,225	6,304	6,304
Pseudo R-squared	0.106	0.036	0.084	0.031	0.090	0.036

Note: "Y/N" columns contain marginal effect estimates from logit fixed effect estimations. "Hours" columns contain coefficient estimates from tobit estimations. Standard errors clusetered at the enumeration area are in parentheses. All regressions include district fixed effects. Additional controls whose results are not presented include individual age groups of household children, indicators for the education level of the parent, indicators for the month and year of interview, and indicators for the agro-ecological zone of the household. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.4: Parents – SEM Accounting for Censor

	Participation				Hours			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Child malaria status								
At least on child with malaria in HH	0.004	-0.002	-0.006	0.042***	0.023	-1.315	-0.757	2.657***
	(0.004)	(0.010)	(0.016)	(0.014)	(0.459)	(1.442)	(2.473)	(0.946)
Individual characteristics								
Ill in last 2 weeks (excl. malaria)	-0.016*	-0.005	-0.022	-0.028	-1.360**	0.789	-2.855	-1.762
	(0.009)	(0.015)	(0.024)	(0.021)	(0.633)	(2.162)	(3.652)	(1.348)
Age (years)	0.002	0.015*	0.025***	0.000	0.296***	2.869***	3.765***	0.011
	(0.001)	(0.009)	(0.007)	(0.005)	(0.114)	(0.540)	(0.785)	(0.267)
Age (years) squared	-0.000	-0.000*	-0.000***	-0.000	-0.003*	-0.042***	-0.038***	-0.005
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.008)	(0.010)	(0.004)
Householder	0.003	0.074	0.303***	0.215***	2.688***	10.47***	28.14***	10.82***
	(0.004)	(0.049)	(0.052)	(0.017)	(0.609)	(2.511)	(5.502)	(1.403)
Married - polygamous	-0.005	0.210	-0.053	-0.007	-2.158***	6.616***	-6.349	0.081
	(0.008)	(0.135)	(0.033)	(0.029)	(0.809)	(2.480)	(5.591)	(2.065)
Islam	-0.017*	0.018	-0.019	-0.049**	-0.494	2.200	-0.695	-2.494*
	(0.010)	(0.018)	(0.022)	(0.022)	(0.771)	(2.087)	(3.590)	(1.399)
Self reported time	0.026**	0.020	-0.122***	0.057***	2.532***	4.367***	-18.00***	2.975***
	(0.012)	(0.015)	(0.023)	(0.013)	(0.340)	(1.321)	(1.993)	(0.760)
Can write in English	-0.017*	0.003	0.136***	-0.011	-1.487***	1.127	18.71***	-0.624
	(0.009)	(0.013)	(0.029)	(0.019)	(0.571)	(1.836)	(3.001)	(1.240)
Spouse lives in household	0.020*	0.113	-0.061*	0.042	0.802	-1.945	-7.483	3.029
	(0.011)	(0.073)	(0.033)	(0.033)	(0.873)	(3.271)	(5.490)	(2.026)
Mother is in household	0.004	0.005	0.039	0.095**	-0.472	0.799	10.93*	5.541**
	(0.010)	(0.029)	(0.047)	(0.038)	(1.087)	(4.128)	(6.597)	(2.556)
Father is in household	0.015	-0.020	0.063	-0.052	0.132	-1.881	14.347	-2.865
	(0.015)	(0.041)	(0.058)	(0.055)	(1.470)	(5.842)	(8.979)	(3.420)
Household characteristics								
# of household memebers	-0.003	-0.007	-0.010	-0.011	-1.045***	-2.614***	-2.023	0.063
	(0.003)	(0.007)	(0.008)	(0.008)	(0.268)	(0.864)	(1.422)	(0.607)

Table D.4: Parents – SEM Accounting for Censor (cont.)

	Participation				Hours			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Child dependency ratio	-0.007	-0.010	-0.027*	0.023*	-0.796	-8.859***	-1.266	2.965***
	(0.005)	(0.012)	(0.016)	(0.013)	(0.542)	(1.948)	(3.520)	(1.117)
Own house	0.077**	0.007	-0.182***	0.024	6.171***	0.799	-25.69***	0.599
	(0.035)	(0.013)	(0.034)	(0.018)	(0.700)	(1.781)	(2.874)	(1.262)
Electricity	-0.074**	0.037	0.057**	-0.172***	-6.541***	6.871***	5.823*	-9.095***
	(0.035)	(0.029)	(0.023)	(0.043)	(1.552)	(2.558)	(3.346)	(3.078)
Household owns a clock	-0.010	0.043	0.098***	-0.092***	-0.394	6.711***	13.38***	-5.400***
	(0.007)	(0.030)	(0.023)	(0.026)	(0.777)	(1.774)	(2.606)	(1.767)
# of wage workers†					-5.622***	-26.58***	47.27***	-2.166
					(1.365)	(4.465)	(7.629)	(2.792)
# of agricultureal workers†					19.39***	-12.74***	-18.48***	0.082
					(0.775)	(1.939)	(3.499)	(1.415)
# of nonagriculture workers†					-4.792***	65.28***	-23.97***	-4.637**
					(0.979)	(3.556)	(5.665)	(2.209)
Community characteristics								
KMs to place to purchase medicines	-0.000	-0.000	0.000*	-0.000	0.009**	-0.010	0.071***	-0.020
	(0.000)	(0.000)	(0.000)	(0.000)	(0.005)	(0.017)	(0.017)	(0.017)
KMs to health clinic (Chiptala)	0.000	-0.001	-0.002*	0.000	-0.027	-0.053	-0.312*	0.017
	(0.000)	(0.001)	(0.001)	(0.001)	(0.024)	(0.061)	(0.163)	(0.047)
KMs to health facility with a doctor	-0.000	0.000	-0.000	0.000	-0.000	0.019	-0.008	0.020
	(0.000)	(0.000)	(0.000)	(0.000)	(0.007)	(0.019)	(0.025)	(0.013)
Household geographic characteristics								
Distance to road (KMs)	0.000	-0.001	-0.003***	0.000	0.015	-0.184*	-0.548***	0.003
	(0.000)	(0.001)	(0.001)	(0.001)	(0.035)	(0.109)	(0.190)	(0.071)
Distance to population center (KMs)	0.000	0.000	-0.001*	-0.001	0.023	0.018	-0.171*	-0.053
	(0.000)	(0.000)	(0.001)	(0.001)	(0.022)	(0.056)	(0.104)	(0.040)
Distance to ADMARC outlet (KMs)	0.000	0.000	0.002	-0.001	-0.038	-0.095	0.357	-0.042
	(0.000)	(0.001)	(0.002)	(0.001)	(0.047)	(0.154)	(0.268)	(0.097)
Distance to district Boma (KMs)	0.000	0.000	0.000	-0.001	-0.011	-0.004	0.014	-0.024
	(0.000)	(0.000)	(0.001)	(0.000)	(0.018)	(0.049)	(0.085)	(0.033)

Table D.4: Parents – SEM Accounting for Censor (cont.)

	Participation				Hours			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Annual mean temperature (celcius)	-0.000	-0.001	-0.002***	0.001	-0.019	-0.125	-0.379**	0.063
	(0.000)	(0.001)	(0.001)	(0.001)	(0.030)	(0.086)	(0.177)	(0.060)
Annual precipitation (mm)	0.000	0.000	0.000	-0.000**	0.001	0.011	0.017	-0.007
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.007)	(0.011)	(0.005)

†Per adult equivalent.

Note: Columns 1 through 4 contain marginal effect estimates from logit fixed effect estimations. Columns 5 through 8 contain coefficient estimates from SEM tobit esimations. Standard errors clustered at the enumeration area are in parentheses. All regressions include district fixed effects. Additional controls whose results are not presented include individual age groups of household children, indicators for the education level of the parent, indicators for the month and year of interview, and indicators for the agro-ecological zone of the household. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.5: Fathers – SEM Accounting for Censor

	Participation				Hours			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Child malaria status								
At least on child with malaria in HH	-0.000	-0.014	-0.003	0.009	-0.541	-1.742	-0.985	2.259*
	(0.003)	(0.023)	(0.008)	(0.012)	(0.600)	(2.282)	(2.860)	(1.286)
Individual characteristics								
Ill in last 2 weeks (excl. malaria)	-0.014	-0.049	-0.014	-0.011	-2.516**	-5.817	-5.485	-2.425
	(0.012)	(0.036)	(0.017)	(0.015)	(1.053)	(3.555)	(4.266)	(2.083)
Age (years)	0.001	0.010	0.007	-0.003	0.276	1.413*	2.518***	-0.626*
	(0.001)	(0.007)	(0.007)	(0.003)	(0.180)	(0.759)	(0.879)	(0.375)
Age (years) squared	-0.000	-0.000*	-0.000	0.000	-0.003	-0.023**	-0.023**	0.003
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.010)	(0.011)	(0.005)
Householder	0.016	0.012	-0.000	0.020	4.703***	2.346	-0.459	5.511
	(0.013)	(0.055)	(0.016)	(0.029)	(1.616)	(5.227)	(5.812)	(3.527)
Married - polygamous	0.003	0.440***	-0.043	-0.007	-0.818	2.409	-9.574	-1.671
	(0.007)	(0.058)	(0.038)	(0.016)	(1.586)	(4.194)	(7.452)	(3.792)
Islam	-0.008	0.073**	-0.011	-0.012	-0.313	7.074**	-2.174	-2.235
	(0.008)	(0.031)	(0.014)	(0.016)	(1.059)	(3.199)	(3.980)	(1.891)
Self reported time	0.031	0.037*	-0.047	0.020	5.192***	3.652*	-17.81***	3.809***
	(0.024)	(0.019)	(0.040)	(0.024)	(0.537)	(1.972)	(2.269)	(1.207)
Can write in English	-0.008	0.033	0.045	-0.004	-1.620**	5.096*	14.47***	-0.740
	(0.007)	(0.027)	(0.039)	(0.008)	(0.798)	(2.844)	(3.468)	(1.674)
Spouse lives in household	0.010	0.333***	-0.044	0.020	1.392	-4.785	-9.148	4.322
	(0.009)	(0.057)	(0.038)	(0.031)	(1.631)	(4.798)	(7.610)	(4.056)
Mother is in household	0.012	-0.027	-0.017	0.045	2.767	-2.239	-6.655	8.142*
	(0.014)	(0.093)	(0.031)	(0.056)	(2.210)	(8.867)	(9.171)	(4.768)
Father is in household	0.013	-0.111	0.044	-0.016	1.683	-10.100	22.79*	-1.134
	(0.017)	(0.135)	(0.049)	(0.033)	(2.837)	(13.196)	(12.172)	(6.698)
Household characteristics								
# of household memebers	-0.001	-0.014	-0.004	-0.004	-0.659	-4.799***	-2.514	-0.157
	(0.002)	(0.012)	(0.005)	(0.005)	(0.412)	(1.400)	(1.705)	(0.881)

Table D.5: Fathers – SEM Accounting for Censor (cont.)

	Participation				Hours			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Child dependency ratio	-0.003	0.012	-0.001	0.011	-0.939	-13.69***	-4.915	2.860
	(0.005)	(0.027)	(0.009)	(0.014)	(1.141)	(3.722)	(4.635)	(2.390)
Own house	0.041	-0.007	-0.085	0.007	6.959***	-0.177	-28.08***	0.466
	(0.031)	(0.025)	(0.072)	(0.011)	(0.973)	(2.816)	(3.170)	(1.794)
Electricity	-0.044	0.092**	0.011	-0.058	-7.967***	9.396**	-1.175	-13.06***
	(0.035)	(0.037)	(0.014)	(0.069)	(2.096)	(4.116)	(4.224)	(4.185)
Household owns a clock	-0.013	0.040	0.046	-0.025	-2.544***	4.084	14.69***	-6.163***
	(0.011)	(0.029)	(0.040)	(0.030)	(0.986)	(3.034)	(3.132)	(2.324)
# of wage workers†					-5.479*	-23.64***	56.22***	1.204
					(2.938)	(8.122)	(9.051)	(5.300)
# of agricultureal workers†					20.12***	-11.05***	-17.47***	1.043
					(0.960)	(3.213)	(3.613)	(1.933)
# of nonagriculture workers†					-5.656***	76.32***	-24.54***	-6.090*
					(1.732)	(4.910)	(6.392)	(3.228)
Community characteristics								
KMs to place to purchase medicines	-0.000	-0.000	0.000	-0.000	0.007	0.008	0.031	-0.033*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.008)	(0.021)	(0.023)	(0.020)
KMs to health clinic (Chiptala)	0.000	-0.002*	-0.001	0.000	-0.039	-0.149	-0.346*	0.033
	(0.000)	(0.001)	(0.001)	(0.000)	(0.030)	(0.097)	(0.183)	(0.063)
KMs to health facility with a doctor	-0.000	0.000	0.000	0.000	-0.001	0.036	-0.002	0.019
	(0.000)	(0.000)	(0.000)	(0.000)	(0.008)	(0.033)	(0.019)	(0.015)
Household geographic characteristics								
Distance to road (KMs)	0.000	-0.001	-0.002	-0.001	0.011	-0.132	-0.845***	-0.126
	(0.000)	(0.001)	(0.002)	(0.001)	(0.042)	(0.138)	(0.213)	(0.090)
Distance to population center (KMs)	0.000	0.002*	-0.000	-0.000	0.023	0.179**	-0.171	-0.069
	(0.000)	(0.001)	(0.001)	(0.000)	(0.027)	(0.082)	(0.109)	(0.050)
Distance to ADMARC outlet (KMs)	0.000	-0.002	0.001	-0.000	-0.037	-0.464**	0.372	-0.037
	(0.000)	(0.002)	(0.001)	(0.001)	(0.062)	(0.213)	(0.308)	(0.129)
Distance to district Boma (KMs)	0.000	0.001	0.000	-0.000	-0.003	0.060	-0.012	-0.016
	(0.000)	(0.001)	(0.000)	(0.000)	(0.022)	(0.073)	(0.093)	(0.042)

Table D.5: Fathers – SEM Accounting for Censor (cont.)

	Participation				Hours			
	HH Ag	HH Nonag	Wage	Ganyu	HH Ag	HH Nonag	Wage	Ganyu
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Annual mean temperature (celcius)	0.000	-0.002	-0.001*	-0.000	0.009	-0.197	-0.423**	-0.025
	(0.000)	(0.001)	(0.001)	(0.000)	(0.037)	(0.121)	(0.187)	(0.073)
Annual precipitation (mm)	0.000	0.000	0.000	-0.000	0.002	0.004	0.016	-0.002
	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)	(0.010)	(0.011)	(0.006)

†Per adult equivalent.

Note: Columns 1 through 4 contain marginal effect estimates from logit fixed effect estimations. Columns 5 through 8 contain coefficient estimates from SEM tobit esimations. Standard errors clustered at the enumeration area are in parentheses. All regressions include district fixed effects. Additional controls whose results are not presented include individual age groups of household children, indicators for the education level of the parent, indicators for the month and year of interview, and indicators for the agro-ecological zone of the household. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.6: Mothers – SEM Accounting for Censor

	Participation				Hours			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Child malaria status								
At least on child with malaria in HH	0.008	0.002	-0.002	0.044*	0.424	-0.603	-1.872	2.707***
	(0.009)	(0.007)	(0.011)	(0.023)	(0.506)	(1.782)	(5.773)	(1.048)
Individual characteristics								
Ill in last 2 weeks (excl. malaria)	-0.016	0.006	0.001	-0.029	-0.784	4.393*	2.573	-1.962
	(0.014)	(0.012)	(0.010)	(0.028)	(0.737)	(2.414)	(7.441)	(1.450)
Age (years)	0.005	0.009	0.009	0.003	0.389**	3.277***	7.992***	0.230
	(0.003)	(0.012)	(0.029)	(0.007)	(0.162)	(0.851)	(2.183)	(0.378)
Age (years) squared	-0.000	-0.000	-0.000	-0.000	-0.004*	-0.048***	-0.094***	-0.007
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.013)	(0.031)	(0.006)
Householder	0.008	0.027	0.055	0.159***	2.634***	10.61***	57.87***	9.953***
	(0.011)	(0.040)	(0.187)	(0.061)	(0.742)	(2.525)	(7.165)	(1.449)
Married - polygamous	-0.015	0.087	0.002	0.044	-2.639***	7.739**	0.320	3.476*
	(0.015)	(0.127)	(0.016)	(0.037)	(0.843)	(3.067)	(11.268)	(2.027)
Islam	-0.024	-0.006	0.001	-0.053	-0.496	-2.796	6.415	-2.531
	(0.018)	(0.012)	(0.011)	(0.034)	(0.885)	(2.869)	(8.562)	(1.651)
Self reported time	-0.007	0.009	-0.014	0.080**	0.172	5.509***	-17.40***	3.713***
	(0.008)	(0.014)	(0.049)	(0.034)	(0.492)	(1.725)	(5.239)	(1.078)
Can write in English	-0.022	-0.007	0.051	-0.012	-0.922	-2.857	39.03***	-0.680
	(0.016)	(0.013)	(0.174)	(0.028)	(0.710)	(2.352)	(7.228)	(1.568)
Spouse lives in household	0.020	0.015	0.017	-0.061	0.240	-0.108	16.190	-3.183
	(0.019)	(0.025)	(0.059)	(0.049)	(1.427)	(4.659)	(12.316)	(2.322)
Mother is in household	-0.004	0.000	0.029	0.074	-1.319	0.496	32.43***	4.607*
	(0.015)	(0.014)	(0.098)	(0.048)	(1.097)	(4.135)	(10.083)	(2.542)
Father is in household	0.015	-0.007	0.004	-0.057	-0.618	-1.000	6.801	-4.329
	(0.022)	(0.022)	(0.021)	(0.063)	(1.533)	(5.828)	(14.325)	(3.487)

Table D.6: Mothers – SEM Accounting for Censor (cont.)

	Participation				Hours			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Household characteristics								
# of household memebers	-0.007	-0.002	-0.003	-0.012	-1.374***	-1.492	-3.041	-0.035
	(0.006)	(0.005)	(0.012)	(0.011)	(0.300)	(1.084)	(2.728)	(0.631)
Child dependency ratio	-0.010	-0.006	-0.006	0.024	-0.661	-6.955***	-8.466*	2.028*
	(0.009)	(0.010)	(0.020)	(0.017)	(0.572)	(1.970)	(5.133)	(1.044)
Own house	0.100*	0.008	-0.030	0.019	5.250***	1.399	-21.40***	0.388
	(0.059)	(0.013)	(0.102)	(0.025)	(0.746)	(2.300)	(6.449)	(1.398)
Electricity	-0.086	0.002	0.034	-0.088	-5.430***	3.669	31.49***	-2.927
	(0.054)	(0.011)	(0.115)	(0.066)	(1.692)	(3.635)	(7.022)	(3.156)
Household owns a clock	-0.002	0.025	0.013	-0.089*	0.972	8.374***	5.205	-4.269**
	(0.011)	(0.038)	(0.044)	(0.049)	(0.846)	(2.424)	(5.822)	(2.087)
# of wage workers†					-6.057***	-26.93***	63.69***	-1.707
					(1.369)	(4.481)	(11.307)	(2.669)
# of agricultureal workers†					18.66***	-13.48***	-24.84***	-0.653
					(0.771)	(2.223)	(8.190)	(1.445)
# of nonagriculture workers†					-4.507***	57.94***	-26.30**	-3.967*
					(1.010)	(3.395)	(12.563)	(2.233)
Community characteristics								
KMs to place to purchase medicines	0.000	-0.000	0.000	-0.000	0.011**	-0.030	0.167***	-0.015
	(0.000)	(0.000)	(0.001)	(0.000)	(0.005)	(0.019)	(0.036)	(0.016)
KMs to health clinic (Chiptala)	0.000	-0.000	-0.000	0.000	-0.018	0.059	-0.062	0.017
	(0.000)	(0.000)	(0.001)	(0.001)	(0.026)	(0.085)	(0.331)	(0.056)
KMs to health facility with a doctor	-0.000	-0.000	-0.000	0.000				
	(0.000)	(0.000)	(0.000)	(0.000)	0.002	-0.001	-0.040	0.021
Household geographic characteristics					(0.008)	(0.019)	(0.081)	(0.013)
Distance to road (KMs)	0.000	-0.001	0.000	0.002	0.012	-0.269**	0.429	0.120*
	(0.000)	(0.001)	(0.001)	(0.001)	(0.037)	(0.123)	(0.345)	(0.071)
Distance to population center (KMs)	0.000	-0.000	-0.000	-0.001	0.020	-0.150**	-0.112	-0.029
	(0.000)	(0.001)	(0.000)	(0.001)	(0.023)	(0.069)	(0.221)	(0.041)

Table D.6: Mothers – SEM Accounting for Censor (cont.)

	Participation				Hours			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Distance to ADMARC outlet (KMs)	0.001	0.001	0.001	-0.001	-0.029	0.227	0.437	-0.057
	(0.001)	(0.001)	(0.002)	(0.002)	(0.051)	(0.179)	(0.513)	(0.107)
Distance to district Boma (KMs)	0.000	-0.000	0.000	-0.001	-0.017	-0.058	0.069	-0.027
	(0.000)	(0.000)	(0.000)	(0.001)	(0.019)	(0.059)	(0.174)	(0.037)
Annual mean temperature (celcius)	-0.000	-0.000	-0.000	0.003***	-0.036	-0.062	-0.164	0.125*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.032)	(0.108)	(0.336)	(0.066)
Annual precipitation (mm)	0.000	0.000	0.000	-0.000*	0.001	0.020**	0.034	-0.011**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)	(0.009)	(0.022)	(0.005)

†Per adult equivalent.

Note: Columns 1 through 4 contain marginal effect estimates from logit fixed effect estimations. Columns 5 through 8 contain coefficient estimates from SEM tobit esimations. Standard errors clustered at the enumeration area are in parentheses. All regressions include district fixed effects. Additional controls whose results are not presented include individual age groups of household children, indicators for the education level of the parent, indicators for the month and year of interview, and indicators for the agro-ecological zone of the household. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.7: Parents – SEM with EA Fixed Effects

	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)
Child malaria status				
At least on child with malaria in HH	0.152	-0.559**	-0.164	0.322*
	(0.250)	(0.253)	(0.283)	(0.166)
Individual characteristics				
Ill in last 2 weeks (excl. malaria)	-0.723**	0.198	-0.278	-0.290
	(0.342)	(0.346)	(0.388)	(0.228)
Age (years)	0.149**	0.274***	0.313***	0.061
	(0.066)	(0.067)	(0.075)	(0.044)
Age (years) squared	-0.001	-0.004***	-0.003***	-0.001**
	(0.001)	(0.001)	(0.001)	(0.001)
Householder	0.673***	2.011***	4.558***	2.318***
	(0.214)	(0.217)	(0.243)	(0.143)
Married - polygamous	-1.700***	-0.051	-0.724	-0.010
	(0.473)	(0.478)	(0.536)	(0.315)
Islam	0.087	-0.112	-0.027	-0.594**
	(0.437)	(0.442)	(0.496)	(0.291)
Self reported time	1.326***	0.238	-2.867***	0.107
	(0.193)	(0.195)	(0.219)	(0.129)
Can write in English	-0.660**	0.125	2.067***	-0.056
	(0.305)	(0.308)	(0.346)	(0.203)
Spouse lives in household	0.534	-0.606	-0.141	0.514
	(0.521)	(0.527)	(0.592)	(0.347)
Mother is in household	-0.258	-0.469	-0.279	0.464
	(0.625)	(0.632)	(0.709)	(0.416)
Father is in household	-0.210	-0.234	0.894	0.042
	(0.819)	(0.828)	(0.930)	(0.546)
Household characteristics				
# of household memebers	-0.351***	-0.337**	0.377**	0.061
	(0.134)	(0.135)	(0.152)	(0.089)
Child dependency ratio	-0.357	-1.742***	1.028***	0.093
	(0.282)	(0.285)	(0.320)	(0.188)
Own house	1.549***	0.285	-3.412***	-0.231
	(0.316)	(0.319)	(0.359)	(0.210)
Electricity	-0.551	1.221**	2.238***	-0.728**
	(0.515)	(0.521)	(0.584)	(0.343)
Household owns a clock	-0.031	1.522***	2.345***	-0.446*
	(0.354)	(0.358)	(0.402)	(0.236)
# of wage workers†	-1.985***	-4.460***	-5.291***	0.140
	(0.624)	(0.631)	(0.708)	(0.416)
# of agricultureal workers†	7.654***	-1.348***	0.019	-0.258
	(0.315)	(0.319)	(0.358)	(0.210)
# of nonagriculture workers†	-2.374***	9.567***	-0.074	-1.225***
	(0.492)	(0.498)	(0.558)	(0.328)
Household geographic characteristics				
Distance to road (KMs)	-0.043	0.007	0.011	0.044
	(0.125)	(0.126)	(0.142)	(0.083)
Distance to population center (KMs)	0.057	0.125	0.043	0.013

Table D.7: Parents – SEM with EA Fixed Effects (cont.)

	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)
	(0.096)	(0.097)	(0.109)	(0.064)
Distance to ADMARC outlet (KMs)	0.142	-0.051	0.038	-0.084
	(0.124)	(0.126)	(0.141)	(0.083)
Distance to district Boma (KMs)	0.041	-0.048	-0.103	0.159**
	(0.101)	(0.102)	(0.115)	(0.067)
Annual mean temperature (celcius)	-0.013	-0.114*	-0.055	-0.029
	(0.067)	(0.068)	(0.076)	(0.045)
Annual precipitation (mm)	-0.003	-0.011	-0.001	0.007
	(0.008)	(0.008)	(0.009)	(0.005)

†Per adult equivalent

Note: Coefficient estimates from SEM tobit esimations presented with standard errors in parentheses. All regressions include enumeration area fixed effects. Additional controls whose results are not presented include individual age groups of household children, indicators for the education level of the parent, and indicators for the agro-ecological zone of the household. The month and year of interview were excluded due to almost no variation within EAs. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.8: Fathers & Mothers – SEM with EA Fixed Effects

	Fathers				Mothers			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Child malaria status								
At least on child with malaria in HH	-0.257	-0.521	-0.462	0.434	0.479	-0.513**	0.043	0.207
	(0.383)	(0.433)	(0.517)	(0.299)	(0.313)	(0.259)	(0.187)	(0.158)
Individual characteristics								
Ill in last 2 weeks (excl. malaria)	-1.236**	-0.303	-0.631	-0.476	-0.537	0.511	0.081	-0.214
	(0.562)	(0.635)	(0.757)	(0.439)	(0.430)	(0.356)	(0.257)	(0.216)
Age (years)	0.170	0.175	0.424***	-0.045	0.182*	0.196**	0.215***	0.053
	(0.110)	(0.124)	(0.148)	(0.086)	(0.095)	(0.078)	(0.056)	(0.048)
Age (years) squared	-0.001	-0.003*	-0.004**	-0.000	-0.002	-0.003**	-0.003***	-0.001
	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Householder	2.081**	0.556	-0.871	0.663	1.141**	1.168***	2.067***	1.473***
	(0.885)	(1.000)	(1.192)	(0.691)	(0.465)	(0.384)	(0.278)	(0.234)
Married - polygamous	-0.347	-1.926*	-0.429	0.056	-2.078***	-0.597	-0.067	0.364
	(0.939)	(1.061)	(1.265)	(0.733)	(0.586)	(0.485)	(0.350)	(0.295)
Islam	0.289	0.745	-0.435	-1.543***	-0.001	-0.905**	0.100	0.094
	(0.673)	(0.760)	(0.907)	(0.526)	(0.551)	(0.456)	(0.329)	(0.278)
Self reported time	2.333***	0.742**	-2.656***	0.478*	-0.094	0.580**	-0.509***	0.371***
	(0.324)	(0.366)	(0.437)	(0.253)	(0.280)	(0.231)	(0.167)	(0.141)
Can write in English	-0.729	0.677	1.783***	0.101	-0.227	-0.415	1.603***	0.014
	(0.464)	(0.524)	(0.625)	(0.362)	(0.406)	(0.336)	(0.243)	(0.205)
Spouse lives in household	1.633	-2.640**	-0.218	0.803	0.484	-0.684	0.112	-0.468
	(0.996)	(1.125)	(1.342)	(0.778)	(0.792)	(0.656)	(0.473)	(0.399)
Mother lives in household	1.796	-0.660	-0.376	0.036	-1.049	-0.530	1.072***	0.804**
	(1.339)	(1.514)	(1.806)	(1.046)	(0.685)	(0.567)	(0.409)	(0.345)
Father lives in household	-0.578	0.002	3.668	1.400	-0.281	-0.054	0.395	-0.349
	(1.752)	(1.980)	(2.362)	(1.369)	(0.889)	(0.736)	(0.531)	(0.448)
Household characteristics								
# of household memebers	-0.296	-0.764***	-0.219	0.125	-0.499***	-0.234*	0.089	0.015
	(0.235)	(0.266)	(0.317)	(0.184)	(0.160)	(0.132)	(0.095)	(0.080)

Table D.8. Fathers & Mothers – SEM with EA Fixed Effects (cont.)

	Fathers				Mothers			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Child dependency ratio	-1.121*	-3.040***	-0.163	0.350	-0.232	-1.239***	0.036	0.300*
	(0.633)	(0.716)	(0.854)	(0.495)	(0.334)	(0.277)	(0.200)	(0.168)
Own house	1.603***	-0.045	-5.484***	-0.329	1.239***	0.424	-0.498**	-0.209
	(0.488)	(0.552)	(0.658)	(0.381)	(0.395)	(0.327)	(0.236)	(0.199)
Electricity	-0.853	1.138	1.598	-1.783***	-0.397	1.505***	2.953***	0.186
	(0.773)	(0.874)	(1.042)	(0.604)	(0.659)	(0.545)	(0.394)	(0.332)
Household owns a clock	-0.630	1.573***	4.126***	-0.826**	0.362	1.431***	0.849***	-0.165
	(0.539)	(0.609)	(0.726)	(0.421)	(0.449)	(0.371)	(0.268)	(0.226)
# of wage workers†	-0.909	-7.789***	9.055***	0.988	-3.305***	-4.822***	0.590	-0.363
	(1.401)	(1.583)	(1.888)	(1.094)	(0.701)	(0.580)	(0.419)	(0.353)
# of agricultureal workers†	8.676***	-1.840***	-1.402**	0.018	7.882***	-1.282***	-0.437*	-0.507**
	(0.503)	(0.568)	(0.678)	(0.393)	(0.394)	(0.326)	(0.236)	(0.199)
# of nonagriculture workers†	-3.100***	17.25***	-5.753***	-2.480***	-2.207***	8.475***	-1.193***	-0.801***
	(0.880)	(0.994)	(1.186)	(0.687)	(0.589)	(0.487)	(0.352)	(0.297)
Household geographic characteristics								
Distance to road (KMs)	-0.228	0.067	-0.031	-0.063	0.112	-0.021	0.040	0.127
	(0.190)	(0.215)	(0.256)	(0.148)	(0.158)	(0.130)	(0.094)	(0.079)
Distance to population center (KMs)	0.192	0.351**	0.093	0.124	-0.054	-0.071	0.017	-0.086
	(0.144)	(0.163)	(0.195)	(0.113)	(0.122)	(0.101)	(0.073)	(0.062)
Distance to ADMARC outlet (KMs)	0.150	-0.129	0.175	-0.146	0.133	-0.004	-0.110	-0.084
	(0.190)	(0.214)	(0.256)	(0.148)	(0.156)	(0.129)	(0.093)	(0.079)
Distance to district Boma (KMs)	0.222	-0.078	-0.128	0.283**	-0.092	-0.015	-0.055	0.061
	(0.152)	(0.172)	(0.205)	(0.119)	(0.129)	(0.106)	(0.077)	(0.065)

Table D.8. Fathers & Mothers – SEM with EA Fixed Effects (cont.)

	Fathers				Mothers			
	HH Ag (1)	HH Nonag (2)	Wage (3)	Ganyu (4)	HH Ag (5)	HH Nonag (6)	Wage (7)	Ganyu (8)
Annual mean temperature (celcius)	-0.044	-0.267**	-0.087	-0.044	-0.017	0.003	-0.025	-0.006
	(0.103)	(0.116)	(0.139)	(0.080)	(0.085)	(0.070)	(0.051)	(0.043)
Annual precipitation (mm)	-0.004	-0.023*	0.000	0.010	-0.002	0.001	0.001	0.005
	(0.011)	(0.013)	(0.015)	(0.009)	(0.010)	(0.008)	(0.006)	(0.005)

†Per adult equivalent.

Note: Coefficient estimates from SEM tobit esimations presented with standard errors in parentheses. All regressions include enumeration area fixed effects. Additional controls whose results are not presented include individual age groups of household children, indicators for the education level of the parent, and indicators for the agro-ecological zone of the household. The month and year of interview were excluded due to almost no variation within EAs. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

D.3 Chapter 3

Table D.9: Value of Agricultural Ouput & Nutrition

	Log Dietary Diversity			Log Calories per capita	
	OLS	2SLS: 1st Stage	2SLS: 2nd Stage	OLS	2SLS: 2nd Stage
Log total harvest value (Naira)	0.012***		0.137***	0.023**	0.534***
	(0.004)		(0.047)	(0.010)	(0.133)
Rainfall (cm) deviation		0.020***			
		(0.005)			
Degree days deviation		-0.003***			
		(0.001)			
Number of persons aged 15-65 in HH	0.001	0.032	-0.004	-0.007	-0.026
	(0.009)	(0.040)	(0.010)	(0.021)	(0.029)
Number of persons aged 0-14 in HH	0.018**	0.031	0.013	0.057***	0.037
	(0.008)	(0.032)	(0.009)	(0.017)	(0.025)
Number of persons aged 66 and over in HH	0.011	0.053	0.002	-0.046	-0.083
	(0.020)	(0.111)	(0.025)	(0.046)	(0.071)
Maximum education in household	-0.001	0.016	-0.002	0.002	-0.004
	(0.003)	(0.011)	(0.003)	(0.006)	(0.008)
Male Head of HH	-0.062	-0.402	-0.011	0.023	0.234
	(0.049)	(0.261)	(0.063)	(0.126)	(0.181)
Age of head	0.001	-0.006	0.002*	0.003	0.006*
	(0.001)	(0.005)	(0.001)	(0.002)	(0.004)
Head years of education	0.003	-0.015	0.004	0.007	0.014
	(0.003)	(0.012)	(0.003)	(0.006)	(0.009)
Head is in monogamous marriage	0.030	0.259	-0.006	0.100	-0.049
	(0.043)	(0.180)	(0.048)	(0.100)	(0.136)
Head is in polygamous marriage	0.010	0.538**	-0.063	0.062	-0.238
	(0.051)	(0.218)	(0.059)	(0.113)	(0.170)

Table D.9: Value of Agricultural Output & Nutrition (cont.)

	Log Dietary Diversity			Log Calories per capita	
	OLS	2SLS: 1st Stage	2SLS: 2nd Stage	OLS	2SLS: 2nd Stage
HH received ag extension services	0.029	0.184	0.009	-0.163***	-0.241***
	(0.023)	(0.119)	(0.027)	(0.050)	(0.076)
Household owns livestock	0.030*	-0.085	0.042**	0.032	0.082
	(0.017)	(0.076)	(0.018)	(0.036)	(0.053)
Any income from livestock production	0.058***	0.063	0.050***	0.020	-0.012
	(0.015)	(0.062)	(0.016)	(0.030)	(0.046)
Operated nonfarm enterprise	0.023	-0.009	0.027	0.015	0.031
	(0.019)	(0.088)	(0.020)	(0.039)	(0.058)
Nonfarm wage employment	0.050***	-0.019	0.055**	0.044	0.065
	(0.018)	(0.098)	(0.022)	(0.044)	(0.063)
Other nonfarm income source	-0.028	0.349**	-0.074**	0.097*	-0.094
	(0.023)	(0.136)	(0.034)	(0.056)	(0.098)
C-test for endogeneity (χ^2)			9.88***		32.96***
Sargan and Basmann overidentification χ^2			0.65		1.94
Cragg-Donald Wald F statistic (weak IV)		13.32***			

Note: Coefficient estimates presented with robust standard errors in parentheses. All regressions include household fixed effects. Additional controls whose results are omitted from the table include local market prices for 15 commonly purchased food items. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.10: Production & Consumption of Food Groups

	Indicator for food group consumption								
	Grains	Tubers	Pulses	Oils	Fruits	Vegetables	Milk	Sweets	Meats
Log total harvest value (Naira)	0.022	0.095	0.195***	0.119***	0.125*	0.036	0.059	0.246***	0.030
	(0.023)	(0.061)	(0.076)	(0.043)	(0.070)	(0.033)	(0.062)	(0.086)	(0.051)
Number of persons aged 15-65 in HH	-0.008	-0.004	-0.002	-0.002	0.018	-0.002	-0.001	-0.006	0.002
	(0.005)	(0.013)	(0.017)	(0.009)	(0.015)	(0.007)	(0.013)	(0.019)	(0.011)
Number of persons aged 0-14 in HH	-0.003	0.012	0.004	-0.005	0.015	-0.005	0.018	-0.007	0.018*
	(0.004)	(0.011)	(0.014)	(0.008)	(0.013)	(0.006)	(0.012)	(0.016)	(0.009)
Number of persons aged 66 and over in HH	-0.014	0.033	-0.023	0.021	0.019	-0.011	0.022	-0.066	-0.007
	(0.012)	(0.032)	(0.040)	(0.023)	(0.037)	(0.017)	(0.033)	(0.046)	(0.027)
Maximum education in household	0.001	-0.002	0.000	-0.005**	0.002	0.000	-0.001	-0.003	-0.003
	(0.001)	(0.004)	(0.005)	(0.003)	(0.004)	(0.002)	(0.004)	(0.005)	(0.003)
Male Head of HH	-0.024	0.042	0.226**	0.082	-0.099	-0.062	0.085	0.075	-0.062
	(0.031)	(0.082)	(0.102)	(0.059)	(0.094)	(0.044)	(0.083)	(0.117)	(0.068)
Age of head	0.000	0.001	0.003	0.001	0.001	0.000	-0.001	0.002	-0.000
	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)
Head years of education	-0.001	0.006	0.001	0.004	0.004	0.004*	0.002	0.002	0.003
	(0.002)	(0.004)	(0.005)	(0.003)	(0.005)	(0.002)	(0.004)	(0.006)	(0.003)
Head is in monogamous marriage	-0.012	-0.037	-0.016	-0.116***	-0.117	0.072**	-0.104*	-0.087	0.054
	(0.023)	(0.062)	(0.077)	(0.044)	(0.071)	(0.033)	(0.063)	(0.088)	(0.052)
Head is in polygamous marriage	0.004	0.008	-0.088	-0.185***	-0.150*	0.057	-0.137*	-0.167	0.032
	(0.029)	(0.077)	(0.096)	(0.055)	(0.089)	(0.042)	(0.078)	(0.110)	(0.064)
HH received ag extension services	-0.017	0.052	0.012	-0.002	-0.009	-0.042**	0.069*	-0.029	0.012
	(0.013)	(0.035)	(0.043)	(0.025)	(0.040)	(0.019)	(0.035)	(0.049)	(0.029)
Household owns livestock	0.004	0.050**	0.043	-0.007	0.026	0.026**	0.017	0.065*	-0.015
	(0.009)	(0.024)	(0.030)	(0.017)	(0.027)	(0.013)	(0.024)	(0.034)	(0.020)

Table D.10: (continued)

	Indicator for food group consumption								
	Grains	Tubers	Pulses	Oils	Fruits	Vegetables	Milk	Sweets	Meats
Any income from livestock production	0.016**	0.050**	0.033	0.012	0.058**	-0.001	0.030	0.053*	0.044**
	(0.008)	(0.021)	(0.026)	(0.015)	(0.024)	(0.011)	(0.021)	(0.030)	(0.017)
Operated nonfarm enterprise	0.002	0.051*	0.028	0.004	-0.018	-0.001	-0.010	0.008	0.002
	(0.010)	(0.027)	(0.033)	(0.019)	(0.030)	(0.014)	(0.027)	(0.038)	(0.022)
Nonfarm wage employment	0.017	-0.003	0.018	0.028	0.071**	0.019	0.042	0.082**	0.023
	(0.011)	(0.029)	(0.035)	(0.020)	(0.033)	(0.015)	(0.029)	(0.041)	(0.024)
Other nonfarm income source	0.008	-0.042	-0.073	-0.059*	-0.072	-0.027	-0.055	-0.144**	-0.012
	(0.017)	(0.044)	(0.055)	(0.032)	(0.051)	(0.024)	(0.045)	(0.063)	(0.037)

Note: 2SLS coefficient estimates presented with robust standard errors in parentheses. All regressions include household fixed effects. Additional controls whose results are omitted from the table include local market prices for 15 commonly purchased food items. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.11. Production & Consumption of Food Groups (Calories)

	Log Total Calories Consumed from Food Group								
	Grains	Tubers	Pulses	Oils	Fruits	Vegetables	Milk	Sweets	Meats
Log total harvest value (Naira)	0.456*	1.262**	1.917***	1.290***	0.969**	0.665**	0.712	1.990***	0.330
	(0.256)	(0.553)	(0.695)	(0.460)	(0.473)	(0.313)	(0.454)	(0.663)	(0.276)
Number of persons aged 15-65 in HH	-0.067	0.007	-0.057	-0.028	0.129	0.026	-0.007	-0.052	0.070
	(0.056)	(0.121)	(0.152)	(0.101)	(0.103)	(0.069)	(0.099)	(0.145)	(0.060)
Number of persons aged 0-14 in HH	0.014	0.130	0.085	-0.013	0.114	0.037	0.135	-0.043	0.033
	(0.048)	(0.103)	(0.130)	(0.086)	(0.088)	(0.059)	(0.085)	(0.124)	(0.052)
Number of persons aged 66 and over in HH	-0.154	0.280	-0.325	0.231	0.062	0.003	0.080	-0.388	0.092
	(0.137)	(0.295)	(0.370)	(0.245)	(0.252)	(0.167)	(0.242)	(0.353)	(0.147)
Maximum education in household	0.003	-0.019	0.013	-0.047	0.007	-0.001	-0.020	-0.024	-0.013
	(0.016)	(0.034)	(0.043)	(0.029)	(0.029)	(0.020)	(0.028)	(0.041)	(0.017)
Male Head of HH	-0.358	0.632	2.005**	0.852	-0.574	-0.527	0.588	0.605	0.561
	(0.347)	(0.750)	(0.942)	(0.624)	(0.641)	(0.425)	(0.616)	(0.898)	(0.374)
Age of head	0.007	0.010	0.037**	0.010	0.014	0.014*	0.001	0.017	0.001
	(0.007)	(0.015)	(0.018)	(0.012)	(0.012)	(0.008)	(0.012)	(0.017)	(0.007)
Head years of education	0.007	0.057	-0.001	0.030	0.040	0.026	0.032	0.015	0.000
	(0.017)	(0.036)	(0.046)	(0.030)	(0.031)	(0.021)	(0.030)	(0.043)	(0.018)
Head is in monogamous marriage	-0.124	-0.532	-0.111	-0.948**	-0.918*	0.637**	-0.905*	-0.767	-0.653**
	(0.262)	(0.565)	(0.709)	(0.470)	(0.482)	(0.320)	(0.464)	(0.676)	(0.282)
Head is in polygamous marriage	-0.037	-0.378	-0.827	-1.737***	-1.191**	0.387	-1.251**	-1.367	-0.567
	(0.326)	(0.704)	(0.884)	(0.586)	(0.602)	(0.399)	(0.579)	(0.844)	(0.352)
HH received ag extension services	-0.459***	0.225	-0.080	-0.210	-0.091	-0.430**	0.492*	-0.340	0.162
	(0.146)	(0.316)	(0.397)	(0.263)	(0.270)	(0.179)	(0.260)	(0.379)	(0.158)
Household owns livestock	0.099	0.415*	0.534*	-0.120	0.195	0.285**	0.086	0.496*	0.312***
	(0.101)	(0.219)	(0.274)	(0.182)	(0.187)	(0.124)	(0.180)	(0.262)	(0.109)

Table D.11: (continued)

	Log Total Calories Consumed from Food Group								
	Grains	Tubers	Pulses	Oils	Fruits	Vegetables	Milk	Sweets	Meats
Any income from livestock production	0.165*	0.479**	0.298	0.025	0.372**	0.013	0.280*	0.344	-0.052
	(0.088)	(0.190)	(0.238)	(0.158)	(0.162)	(0.108)	(0.156)	(0.227)	(0.095)
Operated nonfarm enterprise	0.121	0.444*	0.184	-0.077	-0.170	0.069	-0.104	-0.048	0.343***
	(0.112)	(0.242)	(0.304)	(0.202)	(0.207)	(0.137)	(0.199)	(0.290)	(0.121)
Nonfarm wage employment	0.256**	0.024	0.138	0.280	0.383*	0.035	0.299	0.632**	0.029
	(0.120)	(0.260)	(0.327)	(0.216)	(0.222)	(0.147)	(0.214)	(0.312)	(0.130)
Other nonfarm income source	0.095	-0.503	-0.631	-0.537	-0.551	-0.031	-0.435	-1.216**	0.221
	(0.188)	(0.406)	(0.510)	(0.338)	(0.347)	(0.230)	(0.333)	(0.486)	(0.203)

Note: 2SLS coefficient estimates presented with robust standard errors in parentheses. All regressions include household fixed effects. Additional controls whose results are omitted from the table include local market prices for 15 commonly purchased food items. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.12: Food Group Production & Consumption)

	Indicator for food group consumption					
	Grains	Tubers	Pulses	Oils	Fruits	Vegetables
	(0.011)					
Grew pulses/nuts/seeds		0.068**				
		(0.031)				
Grew starchy roots/tubers/plantains			0.064**			
			(0.027)			
Grew oil plants				-0.009		
				(0.028)		
Grew fruits					0.106**	
					(0.043)	
Grew vegetables						-0.006
						(0.014)
Number of persons aged 15-65 in HH	-0.007	-0.001	0.005	0.002	0.022	-0.000
	(0.005)	(0.013)	(0.014)	(0.008)	(0.014)	(0.007)
Number of persons aged 0-14 in HH	-0.002	0.015	0.011	-0.001	0.020*	-0.003
	(0.004)	(0.011)	(0.012)	(0.007)	(0.012)	(0.006)
Number of persons aged 66 and over in HH	-0.012	0.039	-0.010	0.030	0.026	-0.008
	(0.012)	(0.031)	(0.035)	(0.020)	(0.035)	(0.017)
Maximum education in household	0.001	-0.001	0.002	-0.004*	0.004	0.001
	(0.001)	(0.004)	(0.004)	(0.002)	(0.004)	(0.002)
Male Head of HH	-0.033	0.001	0.152*	0.033	-0.150*	-0.077*
	(0.030)	(0.076)	(0.086)	(0.049)	(0.085)	(0.042)
Age of head	0.000	0.000	0.002	0.000	0.001	-0.000
	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)
Head years of education	-0.002	0.005	-0.002	0.003	0.003	0.003
	(0.001)	(0.004)	(0.004)	(0.002)	(0.004)	(0.002)
Head is in monogamous marriage	-0.005	-0.009	0.040	-0.082**	-0.082	0.082***
	(0.022)	(0.058)	(0.065)	(0.037)	(0.064)	(0.032)
Head is in polygamous marriage	0.017	0.061	0.022	-0.116***	-0.078	0.078**
	(0.026)	(0.067)	(0.075)	(0.043)	(0.074)	(0.037)

Table D.12: (continued)

	Indicator for food group consumption					
	Grains	Tubers	Pulses	Oils	Fruits	Vegetables
HH received ag extension services	-0.013	0.064**	0.042	0.016	0.012	-0.037**
	(0.013)	(0.033)	(0.037)	(0.021)	(0.036)	(0.018)
Household owns livestock	0.001	0.042*	0.022	-0.018	0.015	0.022*
	(0.009)	(0.023)	(0.026)	(0.014)	(0.025)	(0.012)
Any income from livestock production	0.017**	0.058***	0.044**	0.020	0.064***	0.001
	(0.008)	(0.020)	(0.023)	(0.013)	(0.022)	(0.011)
Operated nonfarm enterprise	0.001	0.047*	0.018	0.000	-0.022	-0.002
	(0.010)	(0.026)	(0.029)	(0.017)	(0.029)	(0.014)
Nonfarm wage employment	0.016	-0.010	0.009	0.023	0.066**	0.017
	(0.011)	(0.028)	(0.031)	(0.018)	(0.031)	(0.015)
Other nonfarm income source	0.016	-0.008	-0.003	-0.014	-0.028	-0.014
	(0.014)	(0.037)	(0.042)	(0.024)	(0.041)	(0.021)

Note: 2SLS coefficient estimates presented with robust standard errors in parentheses. All regressions include household fixed effects. Additional controls whose results are omitted from the table include local market prices for 15 commonly purchased food items. Significance is denoted: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

REFERENCES

Adamgbe, Emmanuel and Fanan Ujoh (2012) "Variations in Climatic Parameters and Food Crop Yields: Implications on Food Security in Benue State, Nigeria," *Confluence Journal of Environmental Studies*, Vol. 7, pp. 59–67.

Adejuwon, James O. (2005) "Food Crop Production in Nigeria. I. Present Effects of Climate Variability," *Climate Research*, Vol. 30, pp. 53–60.

Alderman, Harold, Jere R Behrman, Victor Lavy, and Rekha Menon (2001) "Child health and school enrollment: A longitudinal analysis," *Journal of Human Resources*, pp. 185–205.

Alderman, Harold, John Hoddinott, and Bill Kinsey (2006) "Long term consequences of early childhood malnutrition," *Oxford Economic Papers*, Vol. 58, pp. 450–474.

Attanayake, Nimal, Julia Fox-Rushby, and Anne Mills (2000) "Household Costs of "Malaria" Morbidity: a Study in Matale District, Sri Lanka," *Tropical Medicine & International Health*, Vol. 5, pp. 595–606.

Ayinde, Ope and Mammo Muchie (2011) "Effect of Climate Change on Agricultural Productivity in Nigeria: A Co-integration Model Approach," *Journal of Human Ecology*, Vol. 35.

Babatunde, Raphael Olanrewaju, Adedeji Olusayo Adejobi, and Segun Bamidele Fakayode (2010) "Income and Calorie Intake Among Farming Households in Rural Nigeria: Results of Parametric and Nonparametric Analysis," *Journal of Agricultural Science*, Vol. 2.

Behrman, Jere R and Anil B Deolalikar (1990) "The Intrahousehold Demand for Nutrients in Rural South India," *Journal of Human Resources*, pp. 665–696.

Behrman, Jere R, Andrew D Foster, and Mark R Rosenzweig (1997) "The Dynamics of Agricultural Production and the Calorie-Income Relationship: Evidence from Pakistan," *Journal of Econometrics*, Vol. 77, pp. 187–207.

Berkman, Douglas S, Andres G Lescano, Robert H Gilman, Sonia L Lopez, and Maureen M Black (2002) "Effects of stunting, diarrhoeal disease, and parasitic infection during infancy on cognition in late childhood: a follow-up study," *The Lancet*, Vol. 359, pp. 564–571.

Bhagowalia, Priya, Derek D Headey, and Suneetha Kadiyala (2012) "Agriculture, Income, and Nutrition Linkages in India: Insights from a Nationally Representative Survey,"Technical report, International Food Policy Research Institute (IFPRI).

Blau, David M, David K Guilkey, and Barry M Popkin (1996) "Infant Health and the Labor Supply of Mothers," *Journal of Human Resources*, pp. 90–139.

Bose, Ron (2009) "The impact of Water Supply and Sanitation interventions on child health: evidence from DHS surveys,"Technical report, Mimeo. New Delhi: International Initiative for Impact Evaluation.

Bouis, Howarth E (1994) "The Effect of Income on Demand for Food in Poor Countries: Are our Food Consumption Databases Giving us Reliable Estimates?" *Journal of Development Economics*, Vol. 44, pp. 199–226.

Bouis, Howarth E and Lawrence J Haddad (1992) "Are Estimates of Calorie-Income Elasticities Too High?: A Recalibration of the Plausible Range," *Journal of Development Economics*, Vol. 39, pp. 333–364.

Cattaneo, Matias D, Sebastian Galiani, Paul J Gertler, Sebastian Martinez, and Rocio Titiunik (2009) "Housing, health, and happiness," *American Economic Journal: Economic Policy*, pp. 75–105.

Chima, Reginald Ikechukwu, Catherine A Goodman, and Anne Mills (2003) "The Economic Impact of Malaria in Africa: A Critical Review of the Evidence," *Health Policy*, Vol. 63, pp. 17–36.

Corman, Hope, Kelly Noonan, and Nancy E Reichman (2005) "Mothers' Labor Supply in Fragile Families: The Role of Child Health," *Eastern Economic Journal*, Vol. 31, pp. 601–616.

Deolalikar, Anil B (1988) "Nutrition and Labor Productivity in Agriculture: Estimates for Rural South India," *The Review of Economics and Statistics*, Vol. 70, pp. 406–13.

Dimowa, Ralitza, Katharina Michaelowa, and Anke Weber (2010) "Ganyu Labour in Malawi: Understanding Rural Households Labour Supply Strategies."

Duflo, Esther and Christopher Udry (2004) "Intrahousehold Resource Allocation in Cote d'Ivoire: Social Norms, Separate Accounts and Consumption Choices,"Technical report, National Bureau of Economic Research.

Esrey, Steve A, James B Potash, Leslie Roberts, and Clive Shiff (1991) "Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma.," *Bulletin of the World Health organization*, Vol. 69, p. 609.

Esrey, Steven A (1996) "Water, waste, and well-being: a multicountry study," *American journal of epidemiology*, Vol. 143, pp. 608–623.

Fafchamps, Marcel (1992) "Cash Crop Production, Food Price Volatility, and Rural Market Integration in the Third World," *American Journal of Agricultural Economics*, Vol. 74, pp. 90–99.

FAO (2004) *Health Energy Requirements*, Rome, Italy: Food and Agriculture Organization.

Girard, Amy Webb, Julie L Self, Corey McAuliffe, and Olafunke Olude (2012) "The Effects of Household Food Production Strategies on the Health and Nutrition Outcomes of Women and Young Children: A Systematic Review," *Paediatric and Perinatal Epidemiology*, Vol. 26, pp. 205–222.

Glewwe, Paul and Edward A Miguel (2007) "The impact of child health and nutrition on education in less developed countries," *Handbook of development economics*, Vol. 4, pp. 3561–3606.

Glick, Peter and David E Sahn (1998) "Maternal Labour Supply and Child Nutrition in West Africa," *Oxford Bulletin of Economics and Statistics*, Vol. 60, pp. 325–355.

Gould, Elise (2004) "Decomposing the Effects of Children's Health on Mother's Labor Supply: Is it Time or Money?" *Health Economics*, Vol. 13, pp. 525–541.

Günther, Isabel and Gunther Fink (2010) "Water, sanitation and childrens health: evidence from 172 dhs surveys," Policy Research Working Paper 5275, Prospects Group, Development Economics Group, The World Bank, Washington D.C.

Haddad, Lawrence (2000) "A Conceptual Framework for Assessing Agriculture–Nutrition Linkages," *Food & Nutrition Bulletin*, Vol. 21, pp. 367–373.

Hagenimana, Vital and Jan Low (2000) "Potential of Orange-Fleshed Sweet Potatoes for Raising vVtamin A Intake in Africa," *Food & Nutrition Bulletin*, Vol. 21, pp. 414–418.

Hatløy, Anne, Jesper Hallund, Modibo M Diarra, and Arne Oshaug (2000) "Food Variety, Socioeconomic Status and Nutritional Status in Urban and Rural Areas in Koutiala (Mali)," *Public Health Nutrition*, Vol. 3, pp. 57–65.

Hoddinott, John (1997) "Water, health, and income: A review," Food Consumption and Nutrition Division Discussion Paper 25, International Food Policy Research Institute, Washington, D.C.

Hoddinott, John and Yisehac Yohannes (2002) "Dietary Diversity as a Food Security Indicator," *Food consumption and nutrition division discussion paper*, Vol. 136, p. 2002.

Hotz, Christine, Cornelia Loechl, Alan de Brauw, Patrick Eozenou, Daniel Gilligan, Mourad Moursi, Bernardino Munhaua, Paul van Jaarsveld, Alicia Carriquiry, and JV Meenakshi (2012a) "A Large-scale Intervention to Introduce Orange Sweet Potato in rural Mozambique Increases Vitamin A Intakes Among Children and Women," *British Journal of Nutrition*, Vol. 108, pp. 163–176.

Hotz, Christine, Cornelia Loechl, Abdelrahman Lubowa, James K Tumwine, Grace Ndeezi, Agnes Nandutu Masawi, Rhona Baingana, Alicia Carriquiry, Alan de Brauw, Jonnalagadda V Meenakshi et al. (2012b) "Introduction of β-Carotene–Rich Orange Sweet Potato in Rural Uganda Resulted in Increased Vitamin A Intakes Among Children and Women and Improved Vitamin A Status Among Children," *The Journal of Nutrition*, Vol. 142, pp. 1871–1880.

IFPRI (2011) *Leveraging Agriculture for Improving Nutrition and Health: Highlights from an International Conference*, Washington, DC: International Food Policy Research Institute.

Jacobsen, Kathryn H, Priscila S Ribeiro, Bradley K Quist, and Bruce V Rydbeck (2007) "Prevalence of intestinal parasites in young Quichua children in the highlands of rural Ecuador," *Journal of health, population, and nutrition*, Vol. 25, p. 399.

Jones, Andrew D, Aditya Shrinivas, and Rachel Bezner-Kerr (2014) "Farm Production Diversity is Associated with Greater Household Dietary Diversity in Malawi: Findings from Nationally Representative data," *Food Policy*, Vol. 46, pp. 1–12.

Keding, Gudrun B, John M Msuya, Brigitte L Maass, and Michael B Krawinkel (2012) "Relating Dietary diversity and Food Variety scores to Vegetable Production and Socio-economic Status of Women in Rural Tanzania," *Food Security*, Vol. 4, pp. 129–140.

Kerr, Rachel Bezner (2005) "Informal Labor and Social Relations in Northern Malawi: The Theoretical Challenges and Implications of Ganyu Labor for Food Security," *Rural sociology*, Vol. 70, pp. 167–187.

Khanna, Gauri (2008) "The impact on child health from access to water and sanitation and other socioeconomic factors," HEI Working Paper No. 02/2008.

Kiær, Lars P, Ib M Skovgaard, and Hanne Østergård (2009) "Grain Yield Increase in Cereal Variety Mixtures: A Meta-Analysis of Field Trials," *Field Crops Research*, Vol. 114, pp. 361–373.

Kuhlthau, Karen A and James M Perrin (2001) "Child Health Status and Parental Employment," *Archives of Pediatrics & Adolescent Medicine*, Vol. 155, p. 1346.

Lawson, David and Simon Appleton (2007) "Child health in Uganda: policy determinants and measurement," *The European Journal of Development Research*, Vol. 19, pp. 210–233.

Li, Chengyun, Xiahong He, Shusheng Zhu, Huiping Zhou, Yunyue Wang, Yan Li, Jing Yang, Jinxiang Fan, Jincheng Yang, Guibin Wang et al. (2009) "Crop Diversity for Yield Increase," *PLoS One*, Vol. 4, p. e8049.

Lobell, David B and Christopher B Field (2007) "Global Scale Climate–Crop Yield Relationships and the Impacts of Recent Warming," *Environmental Research Letters*, Vol. 2, p. 014002.

Loprest, Pamela and Amy Davidoff (2004) "How Children with Special Health Care Needs Affect the Employment Decisions of Low-income Parents," *Maternal and Child Health Journal*, Vol. 8, pp. 171–182.

Luby, Stephen P, Mubina Agboatwalla, John Painter, Arshad Altaf, Ward L Billhimer, and Robert M Hoekstra (2004) "Effect of intensive handwashing promotion on childhood diarrhea in high-risk communities in Pakistan," *JAMA: the journal of the American Medical Association*, Vol. 291, pp. 2547–2554.

Malawi Ministry of Health (2010) *Malawi National Malaria Indicator Survey 2010*.

Maluccio, John A, John Hoddinott, Jere R Behrman, Reynaldo Martorell, Agnes R Quisumbing, and Aryeh D Stein (2009) "The impact of improving nutrition during early childhood on education among guatemalan adults*," *The Economic Journal*, Vol. 119, pp. 734–763.

Marsh, Robin (1998) "Building on Traditional Gardening to Improve Household Food Security," *Food Nutrition and Agriculture*, pp. 4–14.

Masset, Edoardo, Lawrence Haddad, Alexander Cornelius, and Jairo Isaza-Castro (2011) "Effectiveness of Agricultural Interventions that Aim to Improve Nutritional Status of Children: Systematic Review," *BMJ (Clinical research ed.)*, Vol. 344, pp. d8222–d8222.

Mendez, Michelle A and Linda S Adair (1999) "Severity and timing of stunting in the first two years of life affect performance on cognitive tests in late childhood," *The Journal of nutrition*, Vol. 129, pp. 1555–1562.

Mkadawire, R and A Ferguson (1990) "Smallholder Agricultural Food Security and Estate Expansion in Malawi: A Case Study of Salima ADD."

Morales-Espinoza, Emma Marianela, Héctor Javier Sánchez-Pérez, María del Mar García-Gil, Guadalupe Vargas-Morales, José Domingo Méndez-Sánchez, and Margarita Pérez-Ramírez (2003) "Intestinal parasites in children, in highly deprived areas in the border region of Chiapas, Mexico," *salud pública de méxico*, Vol. 45, pp. 379–388.

Muller, Christophe (1999) "The Impact of the Production Composition on the Nutrition Status of Agricultural Households in Rwanda," *Applied Economics Letters*, Vol. 6, pp. 125–131.

——— (2009) "Do Agricultural Outputs of Partly Autarkic Peasants Affect their Health and Nutrition? Evidence from Rwanda," *Food policy*, Vol. 34, pp. 166–175.

Noonan, Kelly, Nancy E Reichman, and Hope Corman (2005) "New Fathers' Labor Supply: Does Child Health Matter?" *Social Science Quarterly*, Vol. 86, pp. 1399–1417.

Nur, El Tahir M and HA Mahran (1988) "The Effect of Health on Agricultural Labour Supply: A Theoretical and Empirical Investigation," in A.N. Herrin and P. Rosenfield eds. *Economics, Health and Tropical Diseases*, Manila, Philippines: University of the Philippines.

O'Donnell, Owen A and Adam Wagstaff (2008) *Analyzing health equity using household survey data: a guide to techniques and their implementation*: World Bank.

Okezie, CA and AZ Nwosu (2007) "The Effect Of Agricultural Commercialization On The Nutritional Status Of Cocoa Growing Households In Ikwuano lga Of Abia State Nigeria," *International Journal of Agriculture and Rural Development*, Vol. 9, pp. 12–15.

Olney, Deanna K, Aminuzzaman Talukder, Lora L Iannotti, Marie T Ruel, and Victoria Quinn (2009) "Assessing Impact and Impact Pathways of a Homestead Food Production Program on Household and Child Nutrition in Cambodia," *Food & Nutrition Bulletin*, Vol. 30.

Papke, Leslie E and Jeffrey M Wooldridge (2000) "Econometric Methods for Fractional Response Variables with an Application to 401 (K) Plan Participation Rates," *Journal of Applied Econometrics*, Vol. 11, pp. 619–32.

Pitt, Mark M (1983) "Food Preferences and Nutrition in Rural Bangladesh," *The Review of Economics and Statistics*, pp. 105–114.

Porter, John R and Mikhail A Semenov (2005) "Crop Responses to Climatic Variation," *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol. 360, pp. 2021–2035.

Porterfield, Shirley L (2002) "Work Choices of Mothers in Families with Children with Disabilities," *Journal of Marriage and Family*, Vol. 64, pp. 972–981.

Powers, Elizabeth T (2003) "Children's Health and Maternal Work Activity Estimates Under Alternative Disability Definitions," *Journal of Human Resources*, Vol. 38, pp. 522–556.

President's Malaria Initiative (2011) *Malaria Operational Plan: Malawi*.

Quisumbing, Agnes R et al. (2003) *Household Decisions, Gender, and Development: A Synthesis of Recent Research*: International Food Policy Research Institute.

Ritchie, JT and DS NeSmith (1991) "Temperature and Crop development," *Modeling Plant and Soil Systems*, pp. 5–29.

Rowhani, Pedram, David B Lobell, Marc Linderman, and Navin Ramankutty (2011) "Climate Variability and Crop Production in Tanzania," *Agricultural and Forest Meteorology*, Vol. 151, pp. 449–460.

Ruel, Marie T (2003) "Operationalizing Dietary Diversity: A Review of Measurement Issues and Research Priorities," *The Journal of Nutrition*, Vol. 133, pp. 3911S–3926S.

Ruel, Marie T, Harold Alderman, and the Maternal and Child Nutrition Study Group (2013) "Nutrition-Sensitive Interventions and Programmes: How Can They Help to Accelerate Progress in Improving Maternal and Child Nutrition?" *The Lancet*, Vol. 382, pp. 536–551.

Schlenker, Wolfram, W Michael Hanemann, and Anthony C Fisher (2006) "The Impact of Global Warming on US Agriculture: An Econometric Analysis of Optimal Growing Conditions," *Review of Economics and Statistics*, Vol. 88, pp. 113–125.

Shepard, Donald S, MB Ettling, U Brinkmann, R Sauerborn et al. (1991) "The Economic Cost of Malaria in Africa.," *Tropical Medicine and Parasitology*, Vol. 42, p. 199.

Singh, Inderjit, Lyn Squire, and John Strauss (1986) *Agricultural Household Models: Extensions, Applications, and Policy*: Johns Hopkins University Press.

Skoufias, Emmanuel (2003) "Is the Calorie–Income Elasticity Sensitive to Price Changes? Evidence from Indonesia," *World Development*, Vol. 31, pp. 1291–1307.

Staiger, Douglas and James H Stock (1997) "Instrumental Variables Regression with Weak Instruments," *Econometrica*, Vol. 65, pp. 557–586.

Strauss, John (1984) "Joint Determination of Food Consumption and Production in Rural Sierra Leone: Estimates of a Household-Firm Model," *Journal of Development Economics*, Vol. 14, pp. 77–103.

——— (1986) “Does Better Nutrition Raise Farm Productivity?” *The Journal of Political Economy*, pp. 297–320.

Strauss, John and Duncan Thomas (1998) “Health, nutrition, and economic development,” *Journal of economic literature*, Vol. 36, pp. 766–817.

Takane, Tsutomu (2008) “Labor Use in Smallholder Agriculture in Malawi: Six Village Case Studies,” *African Study Monographs*, Vol. 29, pp. 183–200.

Tao, Fulu, Masayuki Yokozawa, Jiyuan Liu, and Zhao Zhang (2008) “Climate-Crop Yield Relationships at Provincial Scales in China and the Impacts of Recent Climate Trends,” *Climate Research*, Vol. 38, pp. 83–94.

Villa, Kira M, Christopher B Barrett, and David R Just (2011) “Differential Nutritional Responses Across Various Income Sources Among East African Pastoralists: Intrahousehold Effects, Missing Markets and Mental Accounting,” *Journal of African Economies*, Vol. 20, pp. 341–375.

Waage, J, C Hawkes, R Turner, E Ferguson, D Johnston, B Shankar, G McNeill, J Hussein, H Homans, D Marais et al. (2013) “Current and Planned Research on Agriculture for Improved Nutrition: A Mapping and a Gap Analysis,” *Proceedings of the Nutrition Society*, Vol. 72, p. E316.

Waddington, Hugh, Birte Snilstveit, Howard White, and Lorna Fewtrell (2009) *Water, sanitation and hygiene interventions to combat childhood diarrhoea in developing countries*, Vol. 31: International Initiative for Impact Evaluation Delhi.

Wardlaw, Tessa, Peter Salama, Clarissa Brocklehurst, Mickey Chopra, and Elizabeth Mason (2010) “Diarrhoea: why children are still dying and what can be done,” *The Lancet*, Vol. 375, pp. 870–872.

Whiteside, Martin (2000) *Ganyu Labour in Malawi and its Implications for Livelihood Security Interventions: An Analysis of Recent Literature and Implications for Poverty Alleviation*: AgREN Network Paper 99, Overseas Development Institute.

WHO (2013) *Global Nutrition Policy Review: What Does it Take to Scale Up Nutrition Action?*, Geneva, Switzerland: World Health Organization.

World Bank (1993) “Staff Appraisal Report: Second Social Investment Fund,” Report No. 11927-BO.

——— (2002) “Implementation Completion Report: PPFI-P82 10; PPFI-P821 1; PPFI-P8212; IDA-28Q60; COFN-03770,” Report No. 23133.

——— (2007) “From Agriculture to Nutrition: Pathways, Synerfies and Outcomes,” Washington, DC: The International Bank for Reconstruction and Development, World Bank.

——— (2012) “Malawi: Country Brief.”

——— (2014) “Nigeria Agriulture and Rural Poverty,” Report No.: 78364 NG.

World Health Organization (2009) *World Malaria Report: 2009*, Geneva, Switzerland: WHO Press.

——— (2010) *Guidelines for the Treatment of Malaria*, Geneva, Switzerland: WHO Press.

——— (2011) *World Malaria Report: 2011*, Geneva, Switzerland: WHO Press.

——— (2012) *World Malaria Report: 2012*, Geneva, Switzerland: WHO Press.

——— (2013) *Malaria*: Fact Sheet No. 94.

Zezza, Alberto and Luca Tasciotti (2010) "Urban Agriculture, Poverty, and Food Security: Empirical Evidence from a Sample of Developing Countries," *Food Policy*, Vol. 35, pp. 265–273.

Zwane, Alix Peterson and Michael Kremer (2007) "What works in fighting diarrheal diseases in developing countries? A critical review," *The World Bank Research Observer*, Vol. 22, pp. 1–24.