ESSAYS IN DEVELOPMENT ECONOMICS: IMPROVING CHILD HEALTH, HOUSEHOLD NUTRITION, AND EMPLOYMENT OUTCOMES

by

YAWOTSE DZIDULA-ENYO NOUVE

(Under the Direction of Ellen McCullough)

ABSTRACT

Children's under-nutrition and poor health conditions can have severe consequences for household welfare, especially in developing countries. In Chapter 2, I estimate the effects of child health conditions on maternal farm employment (family farm and paid farm labor) and non-farm employment (self-employment and salary jobs) in Malawi. Chapter 3 explores ways to improve household nutrition. I investigate a long-standing debate in development economics, the policy choice between using agriculture as a leverage to improve nutrition by raising income and making healthy food affordable (market-based solutions), and using agriculture to improve nutrition by fostering the productivity of crops with desirable nutritional attributes (nutrition sensitive agriculture solution). I formalize this comparison between strategies as a test of agricultural household separability hypothesis using Nigerian farming households as the basis of empirical evidence.

INDEX WORDS: Development economics, Child health, Mother's employment, Instrumental variables, Food demand modeling, Agricultural household, Separability hypothesis, Market, Africa

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DEDICATION

I dedicate this dissertation to the Almighty God for His guidance and protection; to the memory of my father, Atitso Kudzo Nouve; to my mother, Elom Beatrice Agbotsu, for her prayers and constant support; to my beautiful daughters, Afi Gloria Nouve, Victoria Eyram Nouve, and Gabriella Etonam Nouve; to my loving wife, Jeanne Ikpindi Dare, for her unconditional support and love; and to my entire family.

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CHAPTER 1

INTRODUCTION

This dissertation deals with questions at the intersection of agriculture, nutrition, health, and employment in Africa. Specifically, I explore the linkages between child nutrition and health and mother's labor force participation, and the role of agriculture and food markets in improving farming households' nutritional outcomes.

Food insecurity and child undernourishment in particular remain unabated in developing countries albeit diverse efforts to address it. In the most recent State of Food Security and Nutrition in the World report (WFP, UNICEF, et al., 2022), it is estimated that about 11.7% of the global population are severely food-insecure. The report also indicates that globally, about 22% of children under the age of five are stunted and 6.7% are wasted. This global picture is even more severe in Africa where about 20.2% of the population are undernourished. The importance of improving child nutrition and health in developing countries is well documented in the literature (Hoddinott et al., 2013). Early childhood health issues can impede the child's educational, economic outcomes, and well-being at adult age (Smith, 2009; Black et al., 2022). However, little is known about the benefits of children's health improvement for mothers' economic outcomes.

The essay in Chapter 2, titled *The Impacts of Child Health Conditions on Maternal Employment Outcomes*, contributes to fill this gap in the literature. I use three waves of nationally representative panel household data from Malawi and instrumental variables estimations to investigate the effects of poor child health on maternal employment, looking at the effects on both farm employment and non-farm employment. I provide the first set of evidence in developing countries that shows that enhancing child health matters not only for the child but also for the mother, and indirectly for the household welfare. Although some of the estimated effects are not statistically significant, I find negative relationships between child health and maternal employment in most cases. My findings complement a body of literature on the role of child health for maternal employment in developed countries (Salkever, 1982; Kuhlthau & Perrin, 2001; Gould, 2004; Frijters et al., 2009; Wasi et al., 2012; Gallen, 2018; Fleche et al., 2019; Eriksen et al., 2021) and indicate the need for interventions to tackle poor child health in Africa, and in developing countries in general.

One possible way of improving children's health is by reducing the prevalence of stunting and wasting by making healthy diet more affordable, especially for poor households (WFP, UNICEF, et al., 2022). However, for this policy to be fully effective, especially in rural agricultural contexts, it implies that food markets are functioning well. In the case of incomplete food markets, other policies such as promoting nutrition sensitive agriculture might be more effective. Whether policy makers should trust markets to improve diet of poor households has been a long-standing debate in the development literature. Answering this question is equivalent to testing the Singh et al. (1986) agricultural household separability hypothesis, which postulates that households make decisions about their crop production to maximize their profits and then use the residual profits from farming to maximize their utility.

In the essay in Chapter 3, titled *Consumption-side Separability Test of Agricultural Households*, I test this hypothesis by structurally modelling household food preferences and investigating its relationship with household land allocation to food crops using 6-wave nationally representative panel data of farming households from Nigeria. I find that Nigerian farming households prefer to consume what they grow, which suggests that an effective diet improvement strategy would be to enhance the productivity of nutritionally desirable crops. This research provides one of the first few evidence of separability hypothesis from a consumption side approach and adds to the existence literature on this question that has long focused on the production side approach (Lopez, 1984; Pitt & Rosenzweig, 1986; Delforce, 1994; Behrman et al., 1997; Bowlus & Sicular, 2003; Le, 2010; LaFave & Thomas, 2016; Dillon & Barrett, 2017; Dillon et al., 2019).

Chapter 2

The Impacts of Child Health Conditions on Maternal Employment Outcomes

2.1 Introduction

Understanding the short-term and long-term consequences of early child health and nutrition is important for many reasons. Early child health and nutrition issues negatively affect a child's educational and economic outcomes as an adult (Hoddinott et al., 2013; Smith, 2009; Black et al., 2022; Currie & Goodman, 2020; Mwene-Batu et al., 2021). Severe malnutrition especially in impoverished conditions is a significant risk factor of child mortality globally (Pelletier & Frongillo, 2003; Black et al., 2008; Guerrant et al., 2013). Poor childhood health conditions may also affect a mother's labor supply (Gould, 2004; Corcnan et al., 2005).

Maternal labor supply disruptions could be particularly relevant in rural agricultural contexts in Africa where there is a discrepancy between men and women in the access to and allocation of agricultural factors, including labor, land, farm inputs, and technologies and where gender roles are prevalent (Udry, 1996; Palacios-López & López, 2015). Because women are also more likely to dedicate a considerable time share to household work, such as caring for children, an expansion of household labor requirements due to child illness could curtail women's participation in the labor force and their labor productivity (Aguilar et al., 2014; Backiny-Yetna & McGee, 2015; Kilic et al., 2015; Ali et al., 2016; Doss, 2018). Besides the labor force participation effect, poor child health could also influence the mother's occupational choice and the mother's efficiency in the allocation of time across productive activities (Brummund & Merfeld, 2021), which has implications for household welfare. So, we ask the following questions: does a mother's labor supply change when her child is sicker? does a mother allocate her time to less efficient and sub-optimal activities when her child is sicker?

While the effect of child sickness on maternal labor supply has been extensively explored in developed countries, the evidence in developing countries is scarce. Also, most of the existing literature that addresses this relationship in the developing world has been largely investigating how maternal labor outcomes affect child nutrition and health. Looking at the question from a different angle and exploring whether child health affects maternal employment is also important.

Using three waves of nationally representative panel household data from the Malawi Integrated Household Surveys (IHS), this paper therefore provides new evidence on the impacts of child health status on mothers' employment. Malawi serves as the basis of empirical analysis because it has one of the highest prevalences of child stunting under 5 in sub-Saharan Africa (Akombi et al., 2017), and hence offers the opportunity to explore the nexus of child nutrition and health, and mother's employment. We retain households that include a mother and a child under the age of 3. The child health variable is the child stunting severity, based on the child's Height-for-Age z-score (HAZ). The use of stunting severity as a measure of child health health is supported by a vast literature in the fields of nutrition and health, documenting the association between child stunting and frequent child sickness, especially in developing countries (Black et al., 2008). Our maternal employment outcomes include labor supply to four separate economic activities – farm self-employment (family plots), seasonal farm wage (called ganyu in Malawi), non-farm self-employment (off-farm business), and non-farm wage (salary job). We estimate both the extensive margin of labor supply (participation) and the intensive margin of labor supply (average labor days per week).

To address the endogeneity issue caused by the reverse causality and simultaneity of child health and mother's employment outcomes, we use a novel instrument, the child's gender, to generate exogenous variation in child stunting severity, because boys are more likely to be stunted than girls (Elsmén et al., 2004; Wamani et al., 2007; Townsel et al., 2017; Thurstans et al., 2020; Thurstans et al., 2022). The exclusion restriction relies on the assumption that we do not expect child gender to affect maternal labor supply except through the child stunting severity channel. Our approach is similar to that of Frijters et al. (2009) who relied on the Instrumental Variables (IV) approach to address the econometric challenge of studying the child health-mother labor supply relationship. We address potential threats to the validity of this method and provide appropriate robustness checks that rule out these threats.

Our main findings reveal no statistically significant effects of child health on maternal employment. Although we find that the effect of child stunting severity on the mother's labor participation appears to be negative across estimations, most of the estimated effects are not statistically significant. The non-statistically significant reduction in labor supply is observed across all four types of labor — farm self-employment, farm wage employment, non-farm self-employment, and non-farm wage employment. More specifically, our findings show that a one unit increase in child stunting severity reduces mother's time allocated to family farms by about 0.3 labor days per week, to agricultural wage employment by 0.03 labor days per week, to non-farm self-employment by 0.2 labor days per week, and to non-farm wage employment by 0.3 labor days per week. Though we do not find enough statistical evidence to support this claim, findings suggest that agricultural wage labor and non-agricultural self-employment appear to be the least affected by poor child health, which can be explained by the fact that these activities might have low barriers to entry and might be more appealing to mothers with sick children from a revenue perspective, even though they might not necessarily be the most efficient (McCullough, 2017).

These findings hold after correcting for bias from the mother's self-selection into the labor market, using the Heckman two-step sample selection method (Heckman, 1976, 1979). We further explore the possible heterogeneity in the findings. The results indicate that the negative child health effects are larger among the age group 1 to 2 years old. Moreover, the effects of poor child health are larger in patrilineal communities where individuals trace their descent through their father as opposed to through their mother, which could be explained to some extent by the potential difference in women empowerment between communities. Overall, these findings reflect the fact that although child health might be an impediment to maternal employment, it does not appear to significantly affect the employment outcomes of mothers. Even when a child is sick, mothers might still be able to participate for instance in self-employment, either farm or non-farm, which is usually an informal and flexible economic activity with low entry requirements in developing countries. The results also do not show robust evidence of inefficient time allocation between economic activities.

In contrast, we find that unlike child health, mother's education and household landholdings have statistically significant impacts on the maternal labor supply. Results reveal that mothers with no education have a higher chance of participating in farm activities (paid labor to other farms or farm self-employment) while mothers with some education are more likely to participate in non-agricultural activities. Similarly, we find that the probability of mothers participating in farm labor augments with household landholdings. At the same time, an increase in household landholdings decreases the probability of mothers engaging in non-farm labor.

The findings are robust to using different child's age cutoffs and various measures of child stunting, including using different height-for-age thresholds, and different child growth references. The results albeit not statistically significant provide insights on the importance of child health for mother's participation in the labor force. For instance, in sub-Saharan Africa, women provide about half the agricultural labor (Palacios-Lopez et al., 2017). Poor child health could therefore reduce this contribution to the labor force. In addition, because different activities are associated with different returns to participation (McCullough, 2017), time allocation across different activities could have important implications for overall labor productivity (Brummund & Merfeld, 2021). Besides contributing to explain the link between education and household wealth, and women's occupational choice, these findings support the rationale behind designing interventions that reduce early childhood stunting and poor health conditions, thereby enhancing children's human capital in developing countries.

Enhancing a child's human capital often refers to improving his educational outcomes. However, improving a child's health is also an important aspect of fostering his human capital (Currie, 2009, 2020). There is a vast literature that has showed that various investments in early childhood including parental investments have positive effects on the child's human capital development (Heckman et al., 2013; Attanasio, Meghir, et al., 2020; Attanasio, Cattan, et al., 2020). Evidence has also showed that early childcare has benefits for the child's development (Araujo et al., 2019) and the mother's employment outcomes (Connelly et al., 1996; Kimmel, 1998; Clark et al., 2019; Dang et al., 2022). In a context of rural agricultural contexts where there might be a competition in the allocation of resources between parents' investments on children and investments on household's needs such as farm or off-farm businesses, early childhood interventions aiming at improving child health and the child's human capital will particularly be beneficial for both the child's development and the mother's employment outcomes. However, as noted by Bernal and Ramırez (2019) and Blimpo et al. (2022), these interventions should include nutrition and health components to be fully effective.

Our paper contributes to the literature in two major ways. First, to the best of our knowledge, there is little to no evidence in developing countries that explains the links between child health and nutrition, and parents' labor supply. There is an extensive body of literature on the relationship between child health and maternal employment from developed countries. Most of these studies address the impact of child illness on maternal labor participation and earnings in a non-agricultural setting (Salkever, 1982; Kuhlthau & Perrin, 2001; Gould, 2004; Frijters et al., 2009; Wasi et al., 2012; Gallen, 2018; Fleche et al., 2019; Eriksen et al., 2021). The study most similar to ours is that of Frijters et al. (2009), which finds that poor child development decreases maternal labor force participation, using a sample of non-agricultural households from Australia. In addition, our paper contrasts the effects on farm employment outcomes with non-farm employment outcomes, hence offering a complete picture of the relationship between child health and mother's labor market.

Second, unlike many studies that consider child health as an outcome of interest, our study considers child health as the determinant of labor supply. We show that child health is also an important driver of household welfare through its impact on mothers' labor allocation. Most of the interventions to improve child nutrition usually target improvements in women's health or economic empowerment (Allendorf, 2007; Duflo, 2012; Komatsu et al., 2018; Heckert et al., 2019; Santoso et al., 2019; Essilfie et al., 2020; Abreha & Zereyesus, 2021; Chilinda et al., 2021; Melesse, 2021). Our findings suggest that interventions that target child nutrition and health might also improve women's economic empowerment and overall welfare, by raising their labor productivity.

The remainder of the paper is structured as follows. After describing our data and variable construction in section 2.2, we explain the empirical strategy in section 2.3. Section

2.4 describes the results, followed by heterogeneity analysis and robustness checks. Finally, the conclusion and the policy implications are presented in section 2.5.

2.2 Data

We use three waves of nationally representative household panel data, the 2010/11 Integrated Household Survey (IHS3), the 2013 Integrated Household Panel Survey (IHPS) 2013, and the 2016 IHPS.[1] Our dataset is part of the World Bank Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA). We test our hypothesis in Malawi because it has one of the highest prevalences of child stunting under 5 (Akombi et al., 2017). Our primary sample is composed of households that include at least one mother-child pair with the child between 6 months and 3 years of age. We restrict our sample of study to these households so that we can compute the child anthropometric indicator height-for-age Z score (HAZ). Our sample is also about 82% rural, and the labor market in rural Malawi is often characterized by seasonal employments (Guiteras & Jack, 2018).

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[1] The data collection for the first wave was conducted between March 2010 and March 2011, for the second wave between April and December 2013, and for the third wave between April 2016 and April 2017

Table 2.1: Summary statistics of regression variables

	Obs.	Mean	Std. dev.	Min	Max
Labor participation					
Labor participation=1	5108	0.86	0.34	0	1
Family farm labor=1	5108	0.75	0.43	0	1
Farm wage labor=1	5108	0.30	0.46	0	1
Non-farm wage labor=1	5108	0.04	0.19	0	1
Non-farm self-employment=1	5108	0.14	0.35	0	1
Number of labor days					
Family farm labor per week (days)	5108	2.02	1.97	0	7
Farm wage labor per week (days)	5108	0.25	0.64	0	6.46
Non-farm wage labor per week (days)	5108	0.14	0.88	0	7
Non-farm self-employment per week (days)	5108	0.55	1.62	0	7
Child health					
Height-for-age	5108	-1.12	1.86	-5	5
Height-for-age<-2.0	5108	0.29	0.45	0	1
Stunting severity	5108	0.36	0.78	0	3
Stunting severity>0	5108	0.29	0.45	0	1
Demographics					
Male child=1	5108	0.50	0.50	0	1
Child has siblings under five=1	5108	0.40	0.49	0	1
Mother's age in years	5108	27.88	6.51	15	49
Mother has some education=1	5108	0.21	0.41	0	1
Mother has a chronic disease=1	5104	0.05	0.21	0	1
Father's age in years	5108	33.47	8.04	15	68
Father labor participation=1	5108	0.95	0.22	0	1
Ratio dependent to active	5108	1.31	0.70	0	6
Household landholdings (ha)	5108	1.06	18.36	0	909.49

Notes: This table reports the summary statistics of regression variables. The number of labor days are not conditional on labor participation.

Our final sample of study has a total of 4758 households with 3303 households in wave 1, 954 households in wave 2, and 501 households in wave 3. As shown in tables A.1 and A.2 in appendix, for all three waves, we have a total of 4796 mothers, of which 2303 have boys only, 2341 have girls only and 152 have both boys and girls aged 0 - 3. The sample has 5108 children, of which 28% is stunted, with a height-for-age below -2 standard deviations. The sample is also balanced in terms of child gender, with 49.5% male. Table 2.1 shows the descriptive statistics of the sample and as illustrated in the table, the average height-for-age is -1.12. Table 2.1 also shows that the average age of mothers is 28 while the average age of fathers is 33. On average, households have 1.06 hectares of land. In table 2.2, we compare the variables for the sample of women with male vs female children. As illustrated in the table, male children are more likely to be stunted. We also note in this table that demographic variables do not differ significantly between the sample with male children and with female children, except for father's age.

2.2.1 Construction of Labor Outcomes and Stunting Severity Variables

For each mother, we consider both farm labor supply and non-farm labor supply. For farm labor supply, we consider the mother's labor on all plots (family and own plots) during the agricultural seasons but also the mother's casual labor supplied to other farms for wage (ganyu). For non-farm labor, we consider salary employment but also self-employment in activities such as manufacturing, trade, restaurants, etc.

For both types of farm labor and non-farm labor, the data allow to calculate the total labor days over a period of 12 months. Respondents were asked the number of months of work in the 12 months prior to the data collection, the number of weeks per month during these months, and the number of days per week during these weeks. For non-farm labor, the

Table 2.2: Summary statistics by child gender

	Male			Female			
	N	Mean	SD	N	Mean	SD	Diff (male-female)
Labor participation							
Labor participation=1	2529	0.86	0.35	2579	0.86	0.34	-0.003
Family farm labor=1	2529	0.76	0.43	2579	0.75	0.43	-0.000
Farm wage labor=1	2529	0.30	0.46	2579	0.31	0.46	-0.037*
Non-farm wage labor=1	2529	0.03	0.17	2579	0.04	0.20	-0.005
Non-farm self-employment=1	2529	0.14	0.35	2579	0.14	0.35	0.001
Number of labor days							
Family farm labor per week (days)	2529	2.03	1.97	2579	2.01	1.97	-0.040
Farm wage labor per week (days)	2529	0.25	0.65	2579	0.25	0.64	-0.002
Non-farm wage labor per week (days)	2529	0.12	0.79	2579	0.17	0.97	-0.034
Non-farm self-employment per week (days)	2529	0.54	1.60	2579	0.55	1.64	-0.039
Child health							
Height-for-age	2529	-1.20	1.88	2579	-1.04	1.83	-0.183**
Height-for-age<-2.0	2529	0.30	0.46	2579	0.28	0.45	0.031*
Stunting severity	2529	0.40	0.82	2579	0.32	0.73	0.084***
Stunting severity>0	2529	0.30	0.46	2579	0.28	0.45	0.031*
Demographics							
Child has siblings under five=1	2529	0.40	0.49	2579	0.41	0.49	-0.002
Mother's age in years	2529	27.81	6.47	2579	27.95	6.54	-0.326
Mother has some education=1	2529	0.21	0.41	2579	0.21	0.40	-0.004
Mother has a chronic disease=1	2528	0.05	0.22	2576	0.04	0.20	0.006
Father's age in years	2529	33.41	8.02	2579	33.53	8.07	-0.555*
Father labor participation=1	2529	0.95	0.22	2579	0.95	0.21	-0.013
Ratio dependent to active	2529	1.32	0.71	2579	1.30	0.69	0.041
Household landholdings (ha)	2529	1.15	18.82	2579	0.96	17.91	0.215

Notes: This table shows the summary statistics of variables of interest by child gender. The table reports the statistics for the subsample of girls and the subsample of boys.

recall period is the last month of operation in the 12 months prior to the data collection, and respondents were asked about the number of days of work during this month.

We convert the total number of work days for each type of labor into a per-week measure, such that all types of labor are comparable. On average during a week, women in our sample spent about 2 labor days on family plots, 0.25 days of work on remunerated farm work, 0.55 days of work on self-employment activities, and 0.14 days on wage employment (Table 2.2)[2].

Table 2.1 shows that about 86% of mothers in the sample have participated in any form of labor in the 12 months prior to the data collection. The table corroborates that the sample is mainly rural agricultural given that 75% of mothers have worked on family plots while 30% have participated in paid agricultural labor during agricultural seasons. Also, about 14% of the mothers have run an off-farm self-business at least once in the last month prior to the survey but only about 4% have done a salary job.

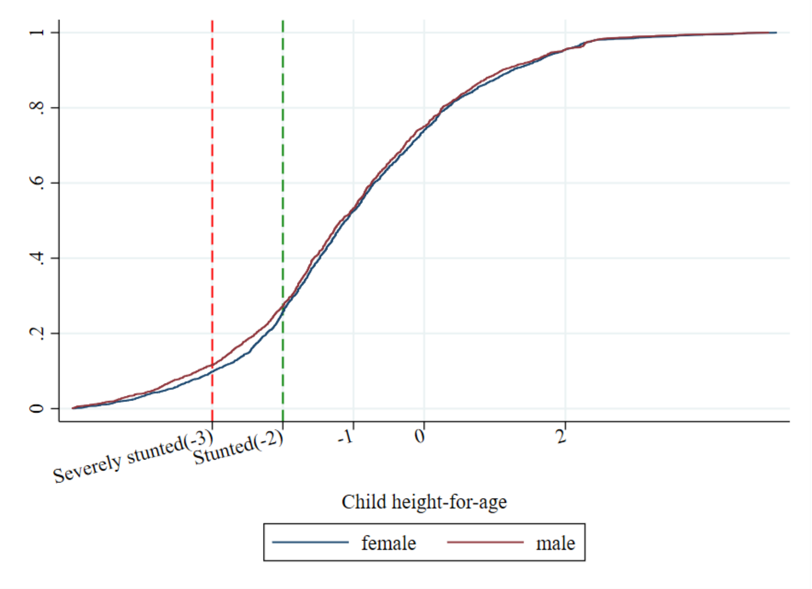

Figure 2.1: Height-for-age by child gender

Child stunting is when the value of the child's height-for-age (HAZ) is below -2 standard deviations (SD). To construct the treatment variable, the stunting severity, we redefine the

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[2] We consider in this study that a labor day is equivalent to 6 hours of work in a day.

initial height-for-age (HAZ) for children 0 - 3 such that children that have a positive HAZ are assigned a stunting severity value of 0 and those with a negative stunting severity centered at -2. We then multiply the new values by -1 such that the final treatment variable, which shows the severity of stunting among children with negative values of height-for-age, is positive. The mean stunting severity in our sample is 0.36, ranging from 0 to 3 (Table 2.1). An analysis by child gender shows that girls have on average a stunting severity of 0.32 while boys have on average a stunting severity of 0.40 (Table 2.2). The gender difference in child stunting is illustrated by the distribution of the height-for-age by child gender in figure 2.1. We further use the constructed stunting severity variable to create a dummy variable that equals 1 if the stunting severity is positive and 0 otherwise.

2.2.2 Child Stunting and Health Conditions

As explained in the previous section, we use child stunting severity as a measure of child health conditions. We redefined the child height-for-age (HAZ) variable to create a positive stunting severity variable where the higher values are equivalent to a higher child stunting. In the absence of reliable health conditions variables in our data, we assume that a child stunting severity can reflect the child's health conditions as a whole. According to the Word Health Organization (Organization et al., 2012), stunting is part of the three impact indicators of child health. Moreover, several studies have used child anthropometric measures as child health variables. For example, Tanaka (2014) studied the child health effects of removing user fees in South Africa using primarily the child weight-for-age (WAZ) as the child health variable. The author also used the child weight-for-height (WHZ) and height-for-age (HAZ) as additional continuous measures of child health. The author suggests that while WAZ and WHZ are more likely to reflect short-term health effects, HAZ is more appropriate to capture the long-term cumulative effects. Since stunting is a good indicator of the child past nutrition status but also a predictor of the child future development, it is generally used as a long-term indicator of health conditions. Thus, stunting is a good proxy for the child overall health since it depicts the accumulated child nutrition and health capital from birth. Aslam and Kingdon (2012) also used child WAZ and HAZ as the child health variables to study the effects of parental education on child health in Pakistan while Ali and Elsayed (2018) used dichotomous measures of WHZ and HAZ as the child health variables to study the same causal relationship in Egypt. Moreover, Minoiu and Shemyakina (2012) used a difference-in-differences methodology to investigate the causal link between armed conflicts and child health, where the child health is evaluated using the child HAZ. Furthermore, Chen et al. (2017) used HAZ and WAZ as the child health indicator variables to explore whether an increase in family income will improve child health in China.

Earlier works such as Duflo (2000) also utilized the child anthropometric height-for-age z-score as an indicator of child health. In addition, Blau et al. (1996) investigated the relationship between child health and mother labor supply using direct measures of child height and weight (instead of height-for-age or weight-for age) as an indicator of long-term and short-term child health measures. The paper however acknowledged that while these variables may not comprehensively reflect the child health, they are commonly used in developing countries as health indicators given the correlation between the child nutrition and the child health in these countries. Even though most of the aforementioned studies used the child anthropometric measures as an outcome variable instead of as a treatment variable, we find enough support in the literature in using the child stunting severity as an indicator of child health.

Child stunting is often caused by undernutrition, infections, and diseases such as malaria and diarrhea, which results in an unhealthy growth (Guerrant et al., 2013; Checkley et al., 2008; Kang et al., 2013; Danaei et al., 2016; Gari et al., 2018; Keats et al., 2022). The reverse relationship is also possible; stunting can be a risk factor for diseases (Deen et al., 2002). In general, stunted children are likely to fall sick more frequently.

While stunting may be visible, it is difficult to distinguish the child nutrition and health conditions in the neighborhood of the HAZ threshold of -2 SD, or in the case of our main explanatory variable, the stunting severity threshold of 0. From a biological standpoint, a child with a HAZ below than -2 SD can be healthier than a child whom HAZ falls above that cut-off (Perumal et al., 2018). Using binary measures of stunting in our situation may therefore not capture the full impacts of restricted child growth. For that reason, we use the child's HAZ in its continuous form instead of its dichotomous form, in order to account for all of the variations in the children's stunting severity. The higher the stunting severity score, the more likely the child is to be unhealthy. One caveat about this approach is that we can have a non-linear relationship between the variables of interest. Nonetheless, we check the robustness of our estimates using also dichotomous measures of child stunting severity.

2.3 Empirical Strategy

This section explains the methods we use to analyze the relationship between child health and maternal labor outcomes. We investigate the impacts of child health on the supply of farm labor (paid and non-paid) and non-farm labor (salary and self-employment) separately. In each case, we investigate the effects of child health on maternal labor participation (extensive margin of labor supply) and on the number of days worked (intensive margin of labor supply).

For the intensive margin of labor supply, the four outcomes of interest are (i) the average weekly days of work in own and family farms, (ii) the average weekly days of ganyu work (casual farm wage labor), (iii) the average weekly days of non-farm employment, and (iv) the average weekly days of non-farm self-employment. We do not condition the intensive margin of labor supply estimations on labor participation. The corresponding extensive margin of labor of supply indicates whether the mother has participated in the employment.

2.3.1 Impacts of Child Health on Maternal Labor Supply

We face two major concerns in identifying the causal effects of child nutritional and health conditions on maternal labor supply outcomes. The first concern is the reverse causality or the simultaneity of the relationship. Maternal labor supply can affect child health. For instance, in the case of farm labor, an increase in the farm labor supply of mothers for instance could result in good agricultural yields which will increase the household food supply and will have nutritional benefits for children. On the other hand, a child who is often sick may prevent the mother from working on her plots or on her non-farm activities, and may prevent the mother from being fully effective in her work, which may lead to both a decrease in the time allocated to work by the mother or a decrease in the total productivity. In the case of seasonal paid farm labor (ganyu) and non-farm labor, a child with health issues could prevent the mother from working but at the same time, it could also make the mother prefer to work more for the purpose of getting cash more quickly to contribute to household food supply and improve the child nutritional and health conditions. We expect poor child health conditions to have negative effects on maternal farm labor outcomes, but in the presence of reverse causality, these negative effects could be underestimated due to the fact that mother's income from paid employment or mother's agricultural productivity are likely to have positive effects on child health, thereby leading to upward biased estimates.

Second, we are concerned about the omitted variable bias issue due to the fact that unobserved factors such as genetic factors, mother's health conditions during pregnancy, that affect child health will also affect maternal health, and thereby affecting maternal labor supply outcomes. The omitted variable bias can also emanate from sample selection bias due to mothers' self-selection into labor force. In all cases, we would have in equation 2.2, the error term correlated with the treatment variable, the child stunting severity (SS), that is, $Cov(SS_{it}, \varepsilon_{it}) \neq 0$, and implementing the standard OLS will yield biased estimates.

To address these concerns, we employ an identification strategy using an Instrumental Variables (IV) method, where we use the gender of the child to instrument for child stunting severity. This IV will most likely satisfy the relevance condition because there is consistent evidence in the literature that boys are more likely to be stunted than girls (Elsmén et al., 2004; Wamani et al., 2007; Townsel et al., 2017; Thurstans et al., 2020; Thurstans et al., 2022). The validity condition is satisfied because we do not expect any other channel through which the gender of a young child affects maternal labor outcomes except through its effects on child stunting severity. In an experimental setting, our IV would work as an assignment variable, determined exogenously from potential outcomes, on which the treatment is assigned. Thus, our IV method will identify the Local Average Treatment Effects (LATE) among the compliers to the treatment, that is, the fraction of male children that react to the treatment. More specifically, given that our treatment variable is continuous, the IV will isolate the average causal effects of the child stunting severity on mother's labor supply outcomes (Angrist & Imbens, 1995).

For a mother i in survey wave t, the first stage equation of the IV estimation is:

$$SS_{it} = \alpha Male_i + \mathbf{X'_{it}}\gamma + \lambda_\mathbf{t} + \nu_\mathbf{it}, \tag{2.1}$$

where SS_{it} is the treatment variable, the severity of stunting for mother i child. We consider the intensity of the treatment instead of the binary treatment for the reasons mentioned in section 2.2.2. $Male_i$ captures the gender of the child subject to HAZ measurement and equals 1 if male child. $\mathbf{X'_{it}}$ is a matrix of controls that includes child siblings (whether the child has siblings under 5), mother's age, age squared, mother's education, mother's health (whether the mother has a chronic disease), father's age, father labor participation, ratio of household dependent (members older than 65 or younger than 15) to active members, and household landholdings. λ_t represents survey wave fixed-effects.

The second stage is specified as follows.

$$L_{it} = \beta \hat{SS}_{it} + \mathbf{X'_{it}}\delta + \mu_{\mathbf{t}} + \varepsilon_{\mathbf{it}}, \tag{2.2}$$

where L_{it} is the labor supply of interest for mother i. $\hat{SS}_{it}$ is the estimated severity of child stunting. $\mathbf{X'_{it}}$ is a matrix of control variables as in equation 2.1. We also include survey wave fixed-effects in the model, μ_t. ε_{it} is the idiosyncratic error term.

2.3.2 Child Gender as Instrument: Validity and Robustness

The first assumption about child gender as instrument is that a male child is more likely to be stunted, and thereby more subject to health problems than a female child. The relationship between the child gender and the child height-for-age is illustrated in figure 2.1. The most recent World Bank statistics show that in Malawi, the prevalence of stunting among girls under age 5 is 39% as compared to 41.4% among boys of the same age category.

This is a general picture in most developing countries as findings reveal in Senegal (Bork & Diallo, 2017), in Bangladesh (Sultana et al., 2019), in sub-Saharan Africa (Wamani et al., 2007), and in many developing countries (Thurstans et al., 2020; Thurstans et al., 2022). The statistics in our sample as explained in section 2.2.1 corroborate these trends and confirm that male children are more stunted in general. One possible explanation for this gender difference in child stunting is the fact that boys are more vulnerable to diseases and infections as evidenced by Muenchhoff and Goulder (2014) and discussed in Thurstans et al. (2022), which will increase their probability of being stunted. There is also a possibility that adverse clinical conditions such as preterm birth or low birthweight will negatively affect male children's health more than female children (Elsmén et al., 2004; Townsel et al., 2017; Thurstans et al., 2022), hence increasing their vulnerability to stunting.

Our second crucial assumption about the instrument is the fact that we do not expect the gender of a child under 3 years of age to determine or affect the labor supply outcomes of the parents. This is because at such young age, whether the child is a boy or girl won't matter for the mother's ability to do agricultural work or any other type of work. Our identification strategy is primarily based on this exogeneity assumption. Furthermore, we assume that a child health condition is the only channel through which his gender will affect mother's employment. A possible violation of this assumption is that a mother might have (or others in a household might have) child gender preferences, that is, a mother would react differently to a stunted boy than a stunted girl. Another possible violation is when the child gender determines the occupational choice of the mother. For instance, if the child is a boy, mothers might tend to work more to save money for the child's school and health expenses relative to a female child, thereby selecting into remunerated employment. We address these concerns with appropriate robustness checks. More specifically, we look at the relationship between the child gender and the household's spendings on the child's education and health. A resulting significant relationship would undermine our identifying assumptions.

2.4 Results

This section presents the results of poor child health effects on maternal employment. We first present the pooled IV estimation results of the impacts of child health on the mother's overall labor participation. We then show the effects separately for each type of labor, looking at the extensive margin of labor (labor participation) and the intensive margin of labor (average weekly labor days). The estimations show a strong correlation between the IV (gender of the child) and the treatment (the severity of the child stunting), with a first stage F-statistic of about 24. Overall, the findings reveal a consistent negative effect of poor child health on mother's labor supply across different types of employment, but these findings are not statistically significant. Instead, having some education appears to be a statistically significant predictor of the mother's labor supply.

2.4.1 Child Health Effects on Maternal Labor Force Participation

The first set of results, in table 2.3, shows the impacts of child health on the mother's participation in any form of employment. Both the IV and the OLS results indicate that severe child stunting negatively affects the mother's overall labor participation but only the result from the OLS specification is statistically significant. In other words, child sickness will decrease the likelihood of the mother's employment or increase the likelihood of the mother opting out of the labor market. Although our results are consistent with previous literature on the relationship between child health and mother's labor supply, the findings are not statistically significant.

2.4.1.1 Effects on Family Farm Labor

Table 2.4 reports the results of the pooled estimates of the impacts of child health on maternal time spent on household's plots. The IV second stage coefficients reported in column 5 of table 2.4 show that a one standard deviation (SD) increase in the child stunting severity decreases maternal farm labor supply by about 0.3 labor days per week. In other words, female farmers facing issues of poor child health are less likely to allocate their time to family farms. This result is different from the extensive margin of labor supply findings in column 3, where the linear probability model (LPM) estimate shows a positive child health effect. Nonetheless, the results indicate no statistical significance in neither cases. Results also reveal that education has a statistically negative effect on mother's farm labor supply while household landholdings is positively associated with mother's farm labor supply. Across all specifications, we also find that father's labor participation is a significant predictor of maternal farm labor supply.

Table 2.3: Labor Participation Estimates

		(Extensive margin)		
	1st Stage	Reduced Form	OLS	2nd Stage
	(1)	(2)	(3)	(4)
Stunting severity			-0.0178*	-0.0123
			(0.0092)	(0.1442)
Male child=1	0.0789***	-0.0010		
	(0.0273)	(0.0114)		
Mother's age in years	-0.0018	-0.0067	-0.0068	-0.0067
	(0.0168)	(0.0070)	(0.0070)	(0.0070)
Mother's age squared	0.0001	0.0001	0.0001	0.0001
	(0.0003)	(0.0001)	(0.0001)	(0.0001)
Mother has some education=1	-0.0265	-0.0927***	-0.0931***	-0.0930***
	(0.0344)	(0.0194)	(0.0193)	(0.0198)
Mother has a chronic disease=1	0.1134	-0.0427	-0.0407	-0.0413
	(0.0842)	(0.0325)	(0.0329)	(0.0360)
Father's age in years	-0.0001	-0.0014*	-0.0014*	-0.0014*
	(0.0022)	(0.0008)	(0.0008)	(0.0008)
Father labor participation=1	0.0087	0.1364***	0.1365***	0.1365***
	(0.0527)	(0.0332)	(0.0332)	(0.0331)
Child has siblings under five=1	0.0204	0.0222*	0.0225*	0.0224*
	(0.0289)	(0.0117)	(0.0117)	(0.0119)
Ratio dependent to active	0.0433**	0.0189**	0.0197**	0.0194*
	(0.0220)	(0.0082)	(0.0081)	(0.0109)
Household landholdings (ha)	0.0001	0.0002**	0.0002**	0.0002**
	(0.0008)	(0.0001)	(0.0001)	(0.0001)
Wave FE	Yes	Yes	Yes	Yes
R-squared	0.0448	0.0514	0.0531	0.0529
F-statistic	24.05	14.93	15.02	14.86
Observations	5104	5104	5104	5104

Notes: This table reports the iv estimates of child stunting severity on maternal labor participation The dependent variable in columns 2-4 is binary and equals 1 if positive number of labor days. The first column reports the first stage results. Reduced form estimates are shown in column 2, and iv estimates are shown in column 4 Robust standard errors in parentheses are clustered at the household level. *, **, *** indicate the statistical significance at the 10%, 5%, and 1% level, respectively.

Table 2.4: Farm Labor Estimates

		Labor participation (Extensive margin)			Nber of labor days (Intensive margin)		
	1st Stage (1)	Reduced Form (2)	OLS (3)	2nd Stage (4)	Reduced Form (5)	OLS (6)	2nd Stage (7)
Stunting severity			-0.0163	0.0424		0.0092	-0.3467
			(0.0110)	(0.2130)		(0.0543)	(0.9418)
Male child=1	0.0789***	0.0033			-0.0274		
	(0.0273)	(0.0168)			(0.0740)		
Mother's age in years	-0.0018	-0.0254***	-0.0254***	-0.0253***	-0.1153**	-0.1150**	-0.1159**
	(0.0168)	(0.0092)	(0.0092)	(0.0093)	(0.0490)	(0.0490)	(0.0490)
Mother's age squared	0.0001	0.0005***	0.0005***	0.0005***	0.0022***	0.0022***	0.0022***
	(0.0003)	(0.0001)	(0.0001)	(0.0001)	(0.0008)	(0.0008)	(0.0008)
Mother has some education=1	-0.0265	-0.1898***	-0.1903***	-0.1887***	-0.4852***	-0.4850***	-0.4944***
	(0.0344)	(0.0254)	(0.0254)	(0.0262)	(0.0972)	(0.0973)	(0.1017)
Mother has a chronic disease=1	0.1134	-0.1591***	-0.1571***	-0.1639***	-0.3650*	-0.3672*	-0.3257
	(0.0842)	(0.0533)	(0.0535)	(0.0590)	(0.1929)	(0.1935)	(0.2254)
Father's age in years	-0.0001	-0.0024*	-0.0024*	-0.0024*	0.0053	0.0054	0.0053
	(0.0022)	(0.0012)	(0.0012)	(0.0013)	(0.0060)	(0.0060)	(0.0060)
Father labor participation=1	0.0087	0.2780***	0.2778***	0.2776***	1.1791***	1.1811***	1.1821***
	(0.0527)	(0.0535)	(0.0537)	(0.0534)	(0.1061)	(0.1064)	(0.1101)
Child has siblings under five=1	0.0204	0.0336*	0.0339*	0.0327*	0.2023**	0.2024**	0.2094**
	(0.0289)	(0.0184)	(0.0184)	(0.0193)	(0.0843)	(0.0844)	(0.0882)
Ratio dependent to active	0.0433**	0.0240*	0.0249*	0.0222	0.1289**	0.1275**	0.1439*
	(0.0220)	(0.0133)	(0.0133)	(0.0166)	(0.0636)	(0.0640)	(0.0743)
Household landholdings (ha)	0.0001	0.0004**	0.0004**	0.0003**	0.0031***	0.0031***	0.0031***
	(0.0008)	(0.0002)	(0.0002)	(0.0002)	(0.0007)	(0.0007)	(0.0007)
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic	24.05	14.81	14.99	14.93	27.37	27.46	26.38
Observations	5104	5104	5104	5104	5104	5104	5104

Notes: This table reports the iv estimates of child stunting severity on maternal on-farm labor supply. The dependent variable in columns 2-4 is binary and equals 1 if positive number of labor days. The dependent variable in columns 5-7 is the weekly average number of labor days. The first column reports the first stage results. Reduced form estimates are shown in columns 2 and 5, and iv estimates are shown in columns 4 and 7. Robust standard errors in parentheses are clustered at the household level. *, **, *** indicate the statistical significance at the 10%, 5%, and 1% level, respectively.

2.4.1.2 Effects on Ganyu Labor

Table 2.5 shows the impacts of child health on maternal agricultural wage labor supply (ganyu). We find that an increase in the child stunting severity by a unit leads to a decreases in the mother's supply of casual agricultural labor by about 0.03 days of work per week on average. This implies that as the child becomes sicker, mothers are less likely to allocate their time to paid farm work. The extensive margin of labor estimate in column 3 of table 2.5 shows a decrease of about 0.51, and this latter result is statistically significant. Although women receive cash payments from ganyu labor, we find that they are less likely to allocate their time to paid agricultural labor when facing poor child health problems.

These results are similar to the child health effects on family plots' labor supply and could be explained by the fact that poor child health adds additional burdens to childcare that prevent mothers from working or from being fully efficient in farm work, given that farm work is physically demanding due to the limited use of agricultural technology. Similar to the farm labor supply, we find that women with some education are less likely to engage in paid agricultural labor and women in households with large landholdings are on the other hand more likely to do so.

2.4.1.3 Effects on Non-Agricultural Wage Employment

Table 2.6 reports the effects of child health on the mother's time allocation to salary jobs. We find a decrease of about 0.3 labor days for a standard deviation increase in the severity of child stunting. Similarly, the extensive margin of labor supply estimate in column 3 reveals a decrease in the likelihood of the mother working in non-agricultural wage jobs. Those jobs include paid labor from private or government employments in sectors such as education, health, Restaurants, sales, etc. Although these findings are not statistically significant, the direction of the relationship is consistent with the previous findings. The present results are most similar to the cases often observed in developed countries where mothers are more

Table 2.5: Ganyu Labor Estimates

		Labor participation (Extensive margin)			Nber of labor days (Intensive margin)		
	1st Stage (1)	Reduced Form (2)	OLS (3)	2nd Stage (4)	Reduced Form (5)	OLS (6)	2nd Stage (7)
Stunting severity			-0.0195	-0.5088*		-0.0179	-0.0272
			(0.0119)	(0.2994)		(0.0163)	(0.4055)
Male child=1	0.0789***	-0.0402**			-0.0021		
	(0.0273)	(0.0192)			(0.0321)		
Mother's age in years	-0.0018	0.0064	0.0067	0.0055	0.0353*	0.0353*	0.0353*
	(0.0168)	(0.0127)	(0.0127)	(0.0143)	(0.0190)	(0.0190)	(0.0189)
Mother's age squared	0.0001	-0.0001	-0.0001	-0.0001	-0.0005	-0.0005	-0.0005
	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0003)	(0.0003)
Mother has some education=1	-0.0265	-0.2059***	-0.2065***	-0.2194***	-0.2031***	-0.2036***	-0.2039***
	(0.0344)	(0.0231)	(0.0232)	(0.0300)	(0.0321)	(0.0322)	(0.0345)
Mother has a chronic disease=1	0.1134	0.1579***	0.1586***	0.2156***	0.1411	0.1431	0.1441
	(0.0842)	(0.0518)	(0.0527)	(0.0786)	(0.1096)	(0.1097)	(0.1298)
Father's age in years	-0.0001	-0.0043**	-0.0042**	-0.0044**	-0.0027	-0.0027	-0.0027
	(0.0022)	(0.0019)	(0.0018)	(0.0022)	(0.0034)	(0.0034)	(0.0034)
Father labor participation=1	0.0087	0.0696	0.0726	0.0740	0.0718	0.0720	0.0720
	(0.0527)	(0.0440)	(0.0446)	(0.0530)	(0.0586)	(0.0590)	(0.0591)
Child has siblings under five=1	0.0204	0.0190	0.0198	0.0294	-0.0014	-0.0010	-0.0008
	(0.0289)	(0.0221)	(0.0221)	(0.0272)	(0.0381)	(0.0381)	(0.0398)
Ratio dependent to active	0.0433**	0.0185	0.0180	0.0406*	0.0200	0.0208	0.0212
	(0.0220)	(0.0167)	(0.0167)	(0.0235)	(0.0261)	(0.0263)	(0.0302)
Household landholdings (ha)	0.0001	0.0008***	0.0008***	0.0009*	0.0025***	0.0025***	0.0025***
	(0.0008)	(0.0001)	(0.0001)	(0.0005)	(0.0002)	(0.0001)	(0.0001)
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic	24.05	15.77	15.16	7.644	31.48	36.24	39.34
Observations	5104	5104	5104	5104	5104	5104	5104

Notes: This table reports the iv estimates of child stunting severity on maternal ganyu labor supply. The dependent variable in columns 2-4 is binary and equals 1 if positive number of labor days. The dependent variable in columns 5-7 is the weekly average number of casual paid farm labor days. The first column reports the first stage results. Reduced form estimates are shown in columns 2 and 5, and iv estimates are shown in columns 4 and 7. Robust standard errors in parentheses are clustered at the household level. *, **, *** indicate the statistical significance at the 10%, 5%, and 1% level, respectively.

likely to engage in salary jobs rather than agricultural jobs (Gould, 2004; Frijters et al., 2009; Eriksen et al., 2021).

Furthermore, we find that the mother's age and education, and the household ratio of dependent to active members are statistically significant indicators of the mother's labor supply. But in contrast with the farm labor supply outcomes, we find that education is positively associated with the mother's participation in non-agricultural wage labor, suggesting that more educated mothers will most likely participate in this type of labor.

2.4.1.4 Effects on Non-Agricultural Self-Employment

Table 2.7 indicates the estimation results for the case when the mother is self-employed. We find that a mother is less likely to engage in self-employment, mostly informal (restaurant, manufacturing, trade, etc.) if her child is sick. Column 5 of table 2.7 reveals that a SD increase in the child stunting severity decreases the mother's labor participation in self-employment by about 0.23. The extensive margin of labor supply result in column 3 shows the opposite result. However, we find that these findings are not statistically significant.

The finding that child health has no significant effects on mother's self-employment is similar to Dessy and Bago (2022) who found no significant effects of motherhood on mothers' self-employment though the focus in their paper is on motherhood rather than child health. Additionally, like in the case of non-agricultural wage labor supply, education has a positive effect on mother's labor supply. This result is surprising as formal education might not be a necessary requirement to engage in this type of activities giving its informal nature. Another key finding in table 2.7 reveals that household landholdings is negatively associated with mother's labor supply. This latter result reflects the fact that the amount of land owned by households determines women's occupational choice. Large household landholdings implies a higher likelihood of mothers engaging in farm employment while small landholdings would drive mothers to select into non-farm related businesses, especially self-employment.

Table 2.6: Non-Farm Wage Labor Estimates

		Labor participation (Extensive margin)			Nber of labor days (Intensive margin)		
	1st Stage	Reduced Form	OLS	2nd Stage	Reduced Form	OLS	2nd Stage
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Stunting severity			-0.0021	-0.0395		-0.0243*	-0.3382
			(0.0032)	(0.0979)		(0.0136)	(0.4880)
Male child=1	0.0789***	-0.0031			-0.0267		
	(0.0273)	(0.0077)			(0.0378)		
Mother's age in years	-0.0018	0.0085**	0.0085**	0.0084**	0.0513***	0.0514***	0.0507**
	(0.0168)	(0.0040)	(0.0040)	(0.0041)	(0.0190)	(0.0189)	(0.0199)
Mother's age squared	0.0001	-0.0001**	-0.0001**	-0.0001**	-0.0007**	-0.0007**	-0.0007**
	(0.0003)	(0.0001)	(0.0001)	(0.0001)	(0.0003)	(0.0003)	(0.0003)
Mother has some education=1	-0.0265	0.0942***	0.0942***	0.0932***	0.4852***	0.4846***	0.4763***
	(0.0344)	(0.0155)	(0.0155)	(0.0154)	(0.0891)	(0.0889)	(0.0896)
Mother has a chronic disease=1	0.1134	0.0208	0.0210	0.0253	0.0848	0.0865	0.1231
	(0.0842)	(0.0246)	(0.0246)	(0.0256)	(0.1335)	(0.1337)	(0.1297)
Father's age in years	-0.0001	0.0006	0.0006	0.0006	-0.0019	-0.0019	-0.0020
	(0.0022)	(0.0007)	(0.0007)	(0.0007)	(0.0024)	(0.0024)	(0.0025)
Father labor participation=1	0.0087	-0.0366	-0.0363	-0.0362	-0.0848	-0.0828	-0.0819
	(0.0527)	(0.0303)	(0.0303)	(0.0304)	(0.0940)	(0.0935)	(0.0943)
Child has siblings under five=1	0.0204	-0.0038	-0.0037	-0.0030	-0.0294	-0.0287	-0.0225
	(0.0289)	(0.0076)	(0.0076)	(0.0081)	(0.0339)	(0.0339)	(0.0374)
Ratio dependent to active	0.0433**	-0.0255***	-0.0255***	-0.0238***	-0.1027***	-0.1026***	-0.0881**
	(0.0220)	(0.0063)	(0.0063)	(0.0083)	(0.0300)	(0.0297)	(0.0395)
Household landholdings (ha)	0.0001	-0.0000	-0.0000	0.0000	-0.0000	-0.0000	0.0000
	(0.0008)	(0.0000)	(0.0000)	(0.0000)	(0.0001)	(0.0001)	(0.0002)
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic	24.05	4.856	4.814	4.608	3.512	3.517	3.291
Observations	5104	5104	5104	5104	5104	5104	5104

Notes: This table reports the iv estimates of child stunting severity on maternal non-farm wage labor supply. The dependent variable in columns 2-4 is binary and equals 1 if positive number of labor days. The dependent variable in columns 5-7 is the weekly average number of non-farm labor days. The first column reports the first stage results. Reduced form estimates are shown in columns 2 and 5, and iv estimates are shown in columns 4 and 7. Robust standard errors in parentheses are clustered at the household level. *, **, *** indicate the statistical significance at the 10%, 5%, and 1% level, respectively.

Table 2.7: Self-Employment Labor Estimates

		Labor participation (Extensive margin)			Nber of labor days (Intensive margin)		
	1st Stage	Reduced Form	OLS	2nd Stage	Reduced Form	OLS	2nd Stage
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Stunting severity			0.0129	0.0639		0.0485	-0.2370
			(0.0101)	(0.2191)		(0.0440)	(1.0598)
Male child=1	0.0789***	0.0050			-0.0187		
	(0.0273)	(0.0173)			(0.0832)		
Mother's age in years	-0.0018	0.0012	0.0012	0.0013	0.0433	0.0436	0.0429
	(0.0168)	(0.0114)	(0.0113)	(0.0115)	(0.0563)	(0.0563)	(0.0566)
Mother's age squared	0.0001	0.0000	0.0000	0.0000	-0.0006	-0.0006	-0.0006
	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0009)	(0.0009)	(0.0009)
Mother has some education=1	-0.0265	0.0908***	0.0912***	0.0925***	0.4416***	0.4428***	0.4353***
	(0.0344)	(0.0251)	(0.0251)	(0.0259)	(0.1329)	(0.1329)	(0.1382)
Mother has a chronic disease=1	0.1134	0.0788	0.0775	0.0716	0.4696	0.4632	0.4965
	(0.0842)	(0.0566)	(0.0559)	(0.0630)	(0.3310)	(0.3277)	(0.3823)
Father's age in years	-0.0001	0.0010	0.0010	0.0010	0.0074	0.0075	0.0074
	(0.0022)	(0.0019)	(0.0019)	(0.0019)	(0.0091)	(0.0091)	(0.0092)
Father labor participation=1	0.0087	0.0274	0.0270	0.0268	0.1509	0.1522	0.1530
	(0.0527)	(0.0438)	(0.0441)	(0.0444)	(0.1938)	(0.1944)	(0.1964)
Child has siblings under five=1	0.0204	0.0334	0.0331	0.0321	0.1312	0.1304	0.1361
	(0.0289)	(0.0206)	(0.0206)	(0.0208)	(0.0962)	(0.0963)	(0.1000)
Ratio dependent to active	0.0433**	-0.0246	-0.0250*	-0.0274	-0.1157*	-0.1186*	-0.1055
	(0.0220)	(0.0151)	(0.0150)	(0.0186)	(0.0696)	(0.0693)	(0.0866)
Household landholdings (ha)	0.0001	-0.0002**	-0.0002**	-0.0002	-0.0007**	-0.0007*	-0.0007**
	(0.0008)	(0.0001)	(0.0001)	(0.0001)	(0.0003)	(0.0004)	(0.0003)
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic	24.05	6.464	6.456	6.040	5.803	5.801	6.325
Observations	5104	5104	5104	5104	5104	5104	5104

Notes: This table reports the iv estimates of child stunting severity on maternal self-employment labor. The dependent variable in columns 2-4 is binary and equals 1 if positive number of labor days. The dependent variable in columns 5-7 is the weekly average number of non-farm labor days. The first column reports the first stage results. Reduced form estimates are shown in columns 2 and 5, and iv estimates are shown in columns 4 and 7. Robust standard errors in parentheses are clustered at the household level. *, **, *** indicate the statistical significance at the 10%, 5%, and 1% level, respectively.

The present findings suggest that child health negatively affect mothers' employment outcomes. The direction of the effects is consistent across different types of employment though we do not find enough statistical evidence to support this claim. Nonetheless, our results are in line with previous findings on the role of child care burden on mothers' participation in productive activities, more specifically in developing countries. The findings underscore the importance of addressing child stunting given its welfare implications (Hoddinott et al., 2013). Our findings also reveal that other key factors such as the mother's education and the household's landholdings might play a bigger role in the mother's decision to select into a particular employment or work for a certain amount of time.

2.4.2 Estimations of the Impacts of Child Health on Maternal Labor Supply by Child Age Groups

To better understand the findings and the differential effects by child's age, we explore how the child health effects vary by child age groups. We look at the effects for the age groups 6-18 months, 12-24 months, 18-30 months, and 24-36 months. The results are shown on figure 2.2. The figure reveals that for farm-related jobs and salary jobs, the age group 18-30 months has the highest child health effects. The figure also reveals that for salary jobs, the child health effects are negative across all age categories, which points to the fact that regardless of the child age, poor child health negatively affects mother's wage employment. The figure also reveals that for younger children (6-24), the negative effects of child sickness on maternal labor supply are larger for farm employment (family plots and ganyu) relative to non-farm employment (salary and self-employment). For older children (24-36), we find the opposite; the negative child health effects are larger for non-farm employment relative to farm employment.

2.4.3 Estimations of the Effects by Household Wealth Levels

We further investigate the role of household economic status in worsening or mitigating the negative effects of poor child health on mother's employment. To do that, we approximate household wealth using household assets and create four household wealth quartiles, from the poorest (quartile 1) to the wealthiest (quartile 4) households. We then estimate separately the effects of poor child health on mother's labor allocation for each of the four wealth quartile sub-samples (figure 2.3). As per the figure, the negative child health effects on mother's farm labor supply appear to be larger on average for the poorest households (wealth quartile 1). On the other hand, for the wealthiest households (wealth quartile 4), the negative child health effects appear to be pronounced for non-farm employments.

2.4.4 Estimations of the Effects in Matrilineal vs Patrilineal Communities

Some studies have suggested that maternal autonomy is negatively associated with child stunting (Chilinda et al., 2021; Shroff et al., 2009). If this is the case, we would expect the effects of poor child health to be less severe with women's empowerment. Hence, we explore the role of women empowerment in mitigating the negative effects of poor child health. We do this by looking at the mother's employment effects of poor child health separately for mothers living in matrilineal communities and for mothers in patrilineal communities. In a matrilineal system, land and other family assets are inherited by women from their parents instead of men. Malawi as some other countries in Africa have the unique feature of having the coexistence of both types of inheritance systems. Also, previous literature suggests that women in matrilineal families are more likely to have more power than their counterparts who live in patrilineal families (Gneezy et al., 2009; Rink et al., 2021). In our data, respondents were asked the following question: *Do individual here trace their descent through their father,*

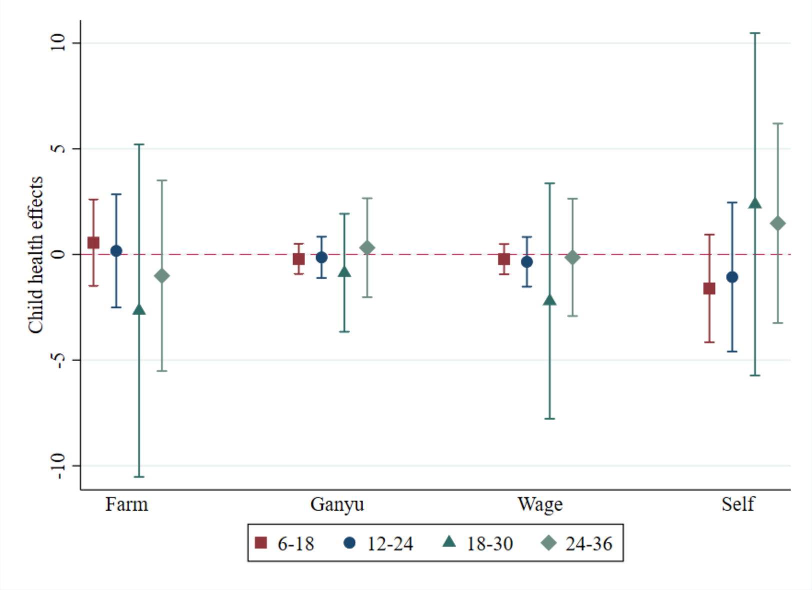


Figure 2.2: 2SLS effects for different age windows with 95% Confidence Interval

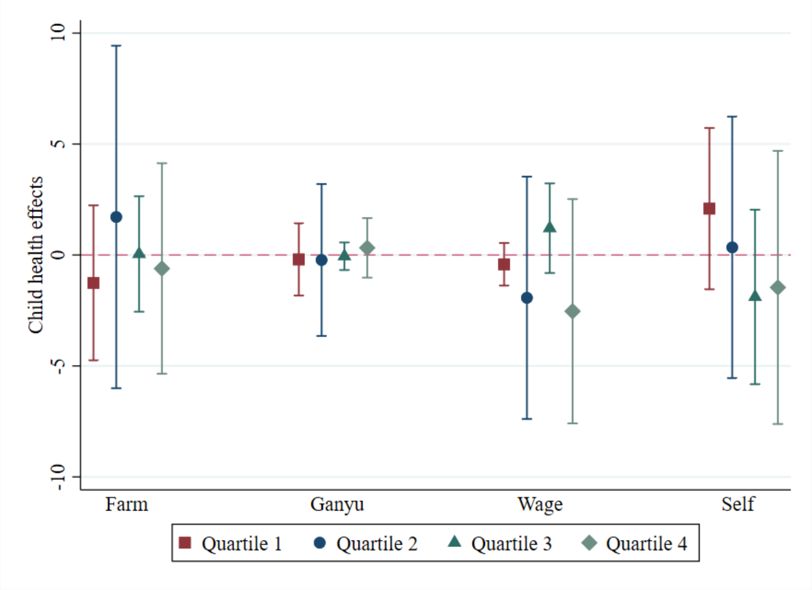


Figure 2.3: 2SLS effects by wealth quartile with 95% Confidence Interval

mother or both?. We use the responses to this question to identify patrilineal and matrilineal households.

The results of the estimations for patrilineal vs matrilineal communities are summarized on figure 2.4 and show that for non-farm employment (salary job and self-employment), the effects of child sickness on mother's employment is less severe for mothers living in matrilineal communities. The results are ambiguous for farm employment. While the effects of child sickness appear to be negative on paid farm work in patrilineal communities, these effects appear to be non negative on non-paid farm work in the same communities. These findings suggest that mothers are affected differently by their child health issues depending on whether they live in communities where women are relatively more empowered.

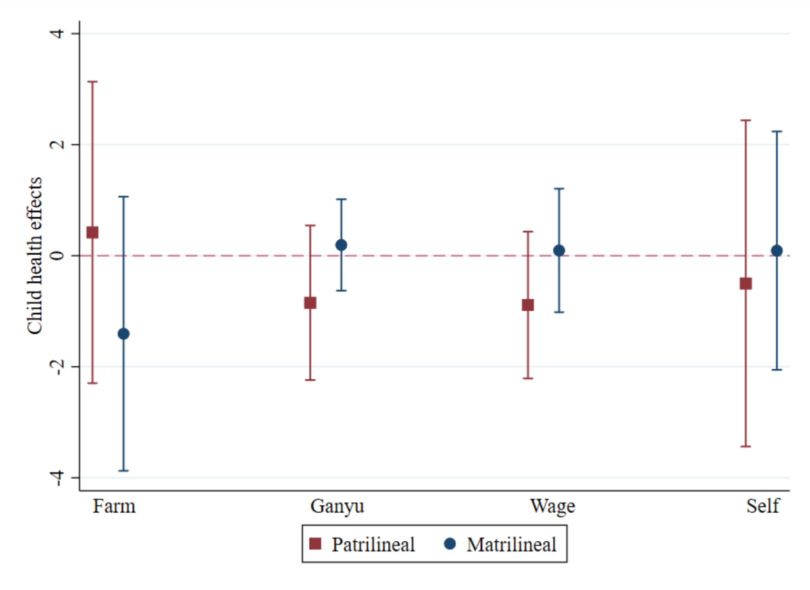


Figure 2.4: 2SLS effects for matrilineal and patrilineal communities with 95% Confidence Interval

2.4.5 Correcting for Sample Selection

In this section, instead of estimating separately the extensive and the intensive margins of labor supply, we address the issue of sample selection bias, that is, the bias arising from the mother's non-random decision to participate into any specific type of labor. To correct for the self-selection bias, we use the Heckman two-step sample selection correction approach (Heckman, 1976, 1979), which is common in the labor economics literature. Given that our main explanatory variable (the child stunting severity) is also endogenous, we address jointly the selection bias issue and the endogenous treatment issue.

To do this, we estimate in the first stage the selection equation, a probit model where the dependent variable indicates whether the mother participates in the labor type. We then conduct an IV estimation in the second stage where the dependent variable is now the number of work days while including the inverse Mills' ratio obtained from the first stage. We exclude some exogenous variables in this latter stage, as discussed in Wooldridge (2010). The Heckman second stage standard errors are bootstrapped.

Table 2.8 reports the Heckman-type correction estimates. After correcting for selection bias, the results do not differ from the IV estimation findings in section 2.4.1. We find no significant negative effects of child health on mother's number of work days. Although the magnitudes of the estimates are slightly different from the IV results, we find no statistically significant effects. However, for self-employment, we find that the first stage results are statistically significant and different from the second stage results.

In addition to the Heckman sample selection correction method, we use Tobit estimation with instrumental variables, where we assume the number of work days is censored at 0. Table 2.9 reports the ivtobit correction estimates. The second stage results are consistent with previous findings and show no statistically significant effects of child health on maternal labor supply. Instead, the results support the findings that education is a better predictor of women's labor supply, and that the more educated women tend to select into non-farm employment while the least educated women choose to work in farm activities. Similarly, the results suggest that as the household landholdings increase, the mother is more likely to select into farm activities and less likely to do non-farm activities.

Table 2.8: Labor supply estimates correcting for selection bias and treatment endogeneity

	Farm labor		Ganyu labor		Wage labor		Self-employment	
	Participation	Labor days	Participation	Labor days	Participation	Labor days	Participation	Labor days
	1st stage	2nd stage	1st stage	2nd stage	1st stage	2nd stage	1st stage	2nd stage
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Stunting severity	-0.0295	-0.3275	-0.0303	-0.1409	-0.0128	-0.3568	0.0532*	-0.0529
	(0.0291)	(0.6949)	(0.0245)	(0.6049)	(0.0577)	(1.6272)	(0.0291)	(2.6365)
Male child=1	0.0242		-0.0202		-0.1587**		0.0143	
	(0.0419)		(0.0377)		(0.0754)		(0.0448)	
Mother's age in years	-0.0845***	0.1193***	0.0191	0.0252	0.1730***	0.0507	0.0541*	0.0533
	(0.0299)	(0.0356)	(0.0245)	(0.0517)	(0.0540)	(0.0445)	(0.0297)	(0.7147)
Mother's age squared	0.0013***	-0.0017***	-0.0004	-0.0004	-0.0024***	-0.0007	-0.0008	-0.0007
	(0.0005)	(0.0006)	(0.0004)	(0.0009)	(0.0008)	(0.0006)	(0.0005)	(0.0104)
Mother has some education=1	-0.5085***	0.7500***	-0.7153***	-0.7173	0.8851***	0.3053	0.2982***	0.2897
	(0.0486)	(0.1167)	(0.0543)	(2.5065)	(0.0786)	(0.1996)	(0.0529)	(3.6649)
Mother has a chronic disease=1	-0.2186**	0.4199***	0.2262***	0.2195	0.2530	0.0733	0.1122	0.0454
	(0.1009)	(0.1181)	(0.0857)	(0.7452)	(0.1580)	(0.1670)	(0.1019)	(1.2467)
Father's age in years	-0.0048	0.0112**	-0.0070*	-0.0068	0.0035	-0.0032	0.0048	0.0016
	(0.0039)	(0.0047)	(0.0036)	(0.0244)	(0.0071)	(0.0039)	(0.0042)	(0.0471)
Father labor participation=1	0.8742***	-1.1313***	0.2242**	0.2170	-0.0784	0.0198	0.2276**	0.2040
	(0.1007)	(0.1565)	(0.0924)	(0.7637)	(0.1670)	(0.0968)	(0.1128)	(2.3423)
Child has siblings under five=1	0.1533***	-0.1798***	0.0078	-0.0049	-0.1180	-0.0100	0.0789	0.0542
	(0.0453)	(0.0553)	(0.0405)	(0.0511)	(0.0853)	(0.0543)	(0.0484)	(0.8331)
Ratio dependent to active	0.1494***	-0.1821***	0.0762**	0.0864	-0.3834***	-0.0732	-0.0519	-0.0816
	(0.0402)	(0.0558)	(0.0324)	(0.2711)	(0.0807)	(0.1070)	(0.0380)	(0.7154)
Household landholdings (ha)	1.1350***		0.0036		-0.3859***		-0.1193***	
	(0.1045)		(0.0025)		(0.1023)		(0.0421)	
Mills' ratio (IMR)		-4.3391***		0.9474		-0.1456		-0.2745
		(0.1631)		(4.5124)		(0.4024)		(14.0947)
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R-squared	0.187		0.0454		0.215		0.0525	
Wald chi2	467.9	1939.2	262.6	151.5	281.6	78.99	202.7	96.34
Observations	5104	5104	5104	5104	5104	5098	5104	5100

Notes: This table reports the Heckman estimates of child stunting severity on maternal labor supply, correcting for both the treatment endogeneity and the sample selection bias. Columns 1, 3, 5, 7 show the probit estimates for participation into labor. Columns 2, 4, 6, 8 report IV estimates for the corresponding intensive margin of labor supply. The standard errors in parentheses in columns 2, 4, 6, and 8 are corrected using bootstrapping. *, **, *** indicate the statistical significance at the 10%, 5%, and 1% level, respectively.

Table 2.9: Labor supply estimates using ivtobit model with continuous endogenous treatment

		Intensive margin of labor supply			
		Farm labor	Ganyu labor	Wage labor	Self-employment
	1st stage	2nd stage	2nd stage	2nd stage	2nd stage
	(1)	(2)	(3)	(4)	(5)
Stunting severity		-0.2839	-1.1531	-6.5999	1.4950
		(1.1508)	(1.0590)	(10.3542)	(5.2856)
Male child=1	0.0789***				
	(0.0273)				
Mother's age in years	-0.0018	-0.1542***	0.0583	0.6155	0.0581
	(0.0168)	(0.0578)	(0.0489)	(0.4688)	(0.2668)
Mother's age squared	0.0001	0.0030***	-0.0008	-0.0079	-0.0001
	(0.0003)	(0.0009)	(0.0008)	(0.0073)	(0.0043)
Mother has some education=1	-0.0265	-0.8111***	-0.9168***	6.4510***	2.1638***
	(0.0344)	(0.1359)	(0.1307)	(0.9642)	(0.5376)
Mother has a chronic disease=1	0.1134	-0.5950*	0.6134**	2.0579	1.6492
	(0.0842)	(0.3161)	(0.2502)	(2.0845)	(1.1491)
Father's age in years	-0.0001	0.0023	-0.0130*	0.0430	0.0332
	(0.0022)	(0.0071)	(0.0079)	(0.0652)	(0.0368)
Father labor participation=1	0.0087	1.7969***	0.2969	-2.7131	0.9524
	(0.0527)	(0.2104)	(0.1935)	(1.6614)	(1.0617)
Child has siblings under five=1	0.0204	0.2639***	0.0601	-0.5546	0.7821*
	(0.0289)	(0.1007)	(0.0938)	(0.9271)	(0.4413)
Ratio dependent to active	0.0433**	0.1828**	0.1259	-2.5684***	-0.5369
	(0.0220)	(0.0895)	(0.0787)	(0.9054)	(0.4248)
Household landholdings (ha)	0.0001	0.0035***	0.0039***	-3.1491***	-0.9310**
	(0.0008)	(0.0007)	(0.0008)	(0.9102)	(0.3636)
Wave FE	Yes	Yes	Yes	Yes	Yes
R-squared	0.0448				
F-statistic	24.05				
Wald chi2		248.2	93.05	104.1	126.9
Observations	5104	5104	5104	5104	5104

Notes: This table reports the ivtobit estimates of the intensive margin of labor supply. Standard errors in parentheses. *, **, *** indicate the statistical significance at the 10%, 5%, and 1% level, respectively.

Overall, consistent with our IV results, the Heckman and the ivtobit models confirm that child sickness has a negative effect on mother's employment albeit non statistically significant. Mother's education on the other hand might be a more significant explanator of mother's labor supply than child health.

2.4.6 Robustness Checks

In this section, we address the threats to the identification strategy. Specifically, we address the concern of child gender preference effects on mother's labor supply. We also investigate the robustness of the findings using alternative measures of the treatment variable.

2.4.6.1 Child Gender Preferences Effects

The central assumption of our identification is that child gender is independent of the outcomes of interest. However, the major concern regarding this identification strategy is the fact that there may be child gender preferences, that is, a mother would react differently to a stunted boy than a stunted girl. In other words, mothers are more likely to spend more time with or spend more resources on sick boys relative to sick girls.

The issue of gender preferences in household resource allocation is quite common in developing countries. We evaluate this concern of gender preferences in our sample by regressing the instrument (child gender) on the per week average health expenditures and education expenditures separately for the sample of children aged 0-3 years and the sample of children aged 0-5 years. A significant correlation between the child gender and the resources used on the child may threaten the validity of our exclusion restriction.

The results are presented in table 2.10 and show the relationship between the child gender and the health and education expenditures on the child. In each case, we estimate the relationship with and without controls. As shown in the table, the estimated coefficients

Table 2.10: Relationship between child gender and child education and health expenditures

	Children 0 - 3 yrs old				Children 0 - 5 yrs old			
	Health Expenses		Education Expenses		Health Expenses		Education Expenses	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Male child=1	8.8759	5.7635	-9.2505	-9.6374	4.6686	5.7635	10.3576	12.7358
	(8.6322)	(5.8651)	(13.6482)	(13.7762)	(5.9426)	(5.8651)	(19.1272)	(18.4280)
Mother's age in years		-2.9696		-23.3309		-2.9696		-11.7500
		(6.1645)		(16.1340)		(6.1645)		(10.8315)
Mother's age squared		0.0802		0.5092*		0.0802		0.2474
		(0.1231)		(0.2984)		(0.1231)		(0.1875)
Mother has some education=1		33.1581***		42.8579*		33.1581***		56.3966**
		(12.2489)		(23.3114)		(12.2489)		(23.3793)
Mother has a chronic disease=1		4.4340		45.8402		4.4340		9.6571
		(11.7926)		(65.0802)		(11.7926)		(37.3622)
Father's age in years		-1.9143		-6.2624*		-1.9143		-2.8351
		(1.4082)		(3.6285)		(1.4082)		(2.3630)
Father labor participation=1		-9.7524		21.9700***		-9.7524		27.7113**
		(10.5888)		(8.2416)		(10.5888)		(10.9469)
Child has siblings under five=1		3.7977		7.7067		3.7977		-10.3146
		(5.2916)		(16.8083)		(5.2916)		(32.6826)
Ratio dependent to active		-2.7477		1.4768		-2.7477		31.3619
		(5.8184)		(12.5883)		(5.8184)		(50.2879)
Household landholdings (ha)		-0.0179		-0.0333		-0.0179		-0.0461
		(0.0119)		(0.0273)		(0.0119)		(0.0463)
Household controls	No	Yes	No	Yes	No	Yes	No	Yes
Wave FE	No	Yes	No	Yes	No	Yes	No	Yes
R-squared	0.0008	0.0558	0.0001	0.0154	0.0003	0.0558	0.0001	0.0084
F-statistic	1.057	3.848	0.459	1.691	0.617	5.760	0.293	2.494
Mean Dep. Var.(Malawian Kwatcha)	24.25	24.25	24.43	24.43	21.95	21.95	26.88	26.88
Observations	5108	5104	5108	5104	8654	8647	8654	8647

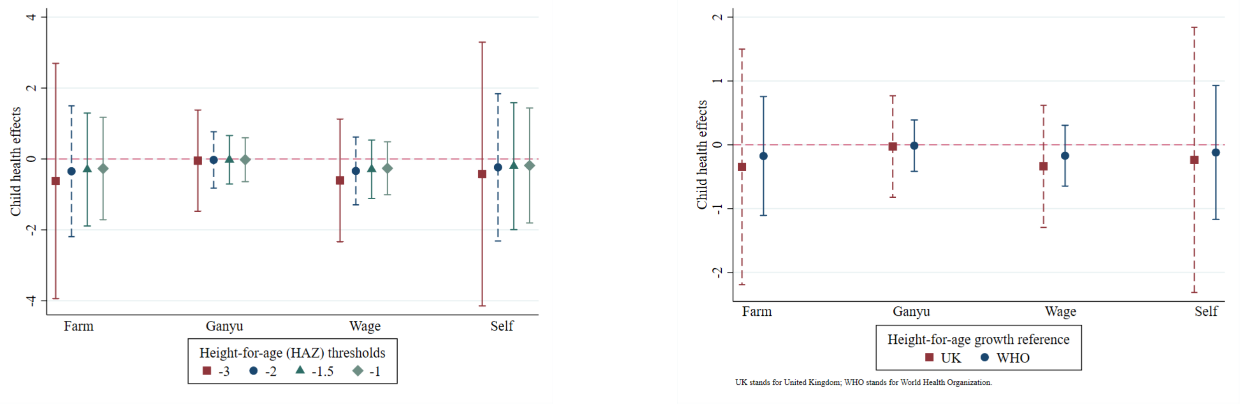
Notes: This table reports the relationship between child gender and child health and education expenditures (per week average). Robust standard errors in parentheses are clustered at the household level. *, **, *** indicate the statistical significance at the 10%, 5%, and 1% level, respectively.

suggest no significant relationship across all specifications, thereby supporting the validity of our instrumental variable.

2.4.6.2 Using Alternative Measures of Stunting Severity

We use different measures of stunting severity. First, we proceed as in sub-section 2.2.1 but instead of centering the height-for-age at -2, we center the height-for-age respectively at -3, -1.5, and -1 thresholds. In all cases, the severity of the child stunting is positive only among children whose height-for-age values fall below the defined threshold and 0 otherwise. Second, we calculate the child height-for-age using the United Kingdom (UK) child growth reference and the World Health Organization (WHO) growth reference. Finally, we estimate our models separately for the sub-samples of children aged 0-3 years, 0-4 years, and 0-5 years.

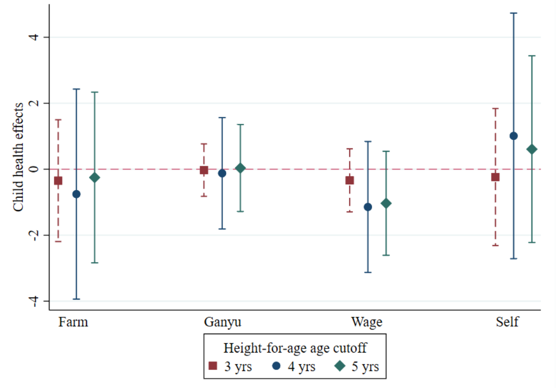
The findings are presented on figure 2.5. The dashed line represents our benchmark model, the main estimation used in this paper. The figure illustrates that the estimated coefficients are fairly stable across all specifications. The figure shows a slight discrepancy in the estimated coefficients by sample age cutoff. For instance, the results differ as we move the child cutoff age from 3 to 5 years, especially for salary employment and self-employment. Nonetheless, though this latter result suggests that the conclusions in this paper apply mostly to mothers with children aged 0-3 years, the figure reveals that the findings hold quite well regardless of how the treatment variable is constructed or regardless of the child age cutoff of the sample.



UK stands for United Kingdom; WHO stands for World Health Organization.

(a) HAZ thresholds

(b) HAZ calculation



(c) Sample age cutoff

Figure 2.5: 2SLS effects by types of height-for-age (HAZ) threshold and calculation used for the treatment variable and by sample age cutoff, with 95% Confidence Interval

2.4.6.3 Using Binary Stunting Severity

Furthermore, we consider the treatment variable in its binary form, which indicates whether the child is stunted. The results of the 2SLS estimations for all four types of labor are shown in tables A.3 to A.6 in appendix. Overall, we find that the directions of the relationship are consistent with the results from the continuous stunting variable models. However, the magnitude of the estimated coefficients is slightly different. The consistency in the findings using either the binary or the continuous definitions of stunting severity reinforces the validity of our findings.

2.5 Conclusion

With prevailing gender norms in developing countries, the employment of mothers with younger children and their occupational choices oftentimes depend on childcare requirements. This is especially the case when the child has a medical condition or specific health issues. Hence, there is a tradeoff between the mother's time allocation to caring for a sick child and her time allocation for paid labor or productive activity.

Using a novel instrumental variable, the gender of the child, to address the endogeneity of the relationship between child health, hereby proxied by the severity of the child stunting, and mother's employment, we estimate the extent to which poor child health affects mother's employment in Malawi. We exploit the fact that stunting is prevalent in developing countries to construct a measure of child health using the child anthropometric indicator height-for-age, and assuming stunting is associated with poor child health. We also exploit the randomness of a mother having a young male child in the age range of 0 to 3 years to isolate the causal impacts of the child's health status on mother's employment.

We use IV estimations on a three-wave household panel data and show that male children are more likely to be more stunted than female children. The validity of our identification strategy relies on the assumption that the gender of young children under 3 will most likely affect the mother's employment outcomes only through the effects on the child stunting conditions or health conditions and not through any other effects. We address a potential violation of this assumption, specifically the child gender preferences commonly observed in developing countries, by showing that household expenditures on children's health and education do not significantly differ by child gender.

We find no statistically significant effects of child health on mother's employment, except for labor supplied to paid agricultural work. However, the direction of the signs of the coefficient estimates across the different types of employment suggest that poor child health reduces mother's employment in Malawi. The child health effect is negative regardless of the mother selecting into farm or non-farm employment. We find similar results even after correcting for the selection bias potentially emanating from the mother's self-selection into the labor market. This lack of statistical significance could be due to the child health variable used in the paper. Future research can for instance rely on natural experiment settings to better capture the child health impacts on maternal labor supply in developing countries.

On the other hand, results show that mother's education and household landholdings are key predictors of maternal labor supply but their effects differ depending on the type of labor. Agriculture related employments are negatively affected by mother's education and positively affected by landholdings. Non-farm related employments indicate the opposite effects.

Although the child health effects show no statistical significance in most cases, the consistent labor reduction effect of poor child health across employment types suggests that child health to some degree plays a role in explaining maternal labor supply in Malawi. From a policy perspective, interventions that could improve child nutrition and health such as programs promoting diet improvement solutions or programs enhancing the quality of child care in general will have the double benefits of improving child and maternal nutrition and health, and maternal employment outcomes, thereby contributing to improving household welfare.

CHAPTER 3

CONSUMPTION-SIDE SEPARABILITY TEST OF AGRICULTURAL HOUSEHOLDS

3.1 Introduction

In the field of development, there are different approaches to improving the food security of poor rural households. Many believe that diversifying crop production alone is not sufficient especially if the goal is to achieve a nutrient-dense diet and that we are best strengthening rural markets and improving livelihoods, which will generate income and help households improve their quality of life by enabling them to purchase their preferred foods, health goods, etc (Sibhatu et al., 2015; Koppmair et al., 2017; Montalbano et al., 2018; Rosenberg et al., 2018; Sibhatu & Qaim, 2018; Muthini et al., 2020; Ogutu et al., 2020). This approach implies that we have well-functioning agricultural markets with low transaction costs (Stifel & Minten, 2017; Headey et al., 2019; Kihiu & Amuakwa-Mensah, 2021).

On the other hand, some camps believe that a focus on markets has little effects on diet improvement (Carletto et al., 2017), and that a more hands-on approach to improving food security by focusing on promoting a set of nutritionally desirable crops that farmers should grow on their own plots, with the expectation that farmers eat what they grow, would be more effective (Ecker, 2018). However, as noted by Ickowitz et al. (2019) and evidenced by Olabisi et al. (2021), this approach has a overly strong focus on calorie consumption and does not necessarily consider the dietary quality component of food security. Others also believe that a more effective strategy is the one that combines both a market-oriented and a nutrition-sensitive agriculture approaches (Mulenga et al., 2021). At the heart of this debate is a set of questions about how well markets work, both for selling farm output, purchasing foods, selling wage labor and hiring farm labor, procuring key inputs such as fertilizer or seeds, and for financial services that allow farmers to borrow or save or insure risk (De Janvry et al., 1991). Investigating the effectiveness of these nutrition enhancement policies requires to understand beforehand how farming households actually behave relative to food production, consumption, and markets, which can be reformulated as a separability hypothesis test of agricultural households' consumption and production decisions. This is the focus of our study.

The study therefore contributes to the ongoing debate about promoting nutrition sensitive agriculture and the most efficient ways to improve household dietary intake in sub-Saharan Africa (Ecker, 2018). Exploring the question of whether smallholder agricultural households derive the most nutritional benefits from their own production, through higher farm income or through a combination of both has implications for how we think about agriculture-nutrition nexus and income-diet enhancing interventions. We therefore ask the following questions. Do farmers behave as though they trust market and thus grow what maximizes profits so they can buy what they want to consume? Or do they grow what they want to eat because they cannot rely on markets? If consumption and production decisions are recursive, the optimal diet improving strategy would be to make healthy crops cheaper in markets and improve the incomes of smallholder farmers so that they can afford healthier foods. If the separability hypothesis fails, we need to work on promoting specific mixes of crops for farmers to grow that achieve dual objectives of raising income and nutrition.

We seek to answer these questions in the context of smallholder Nigerian households. In particular, we want to understand whether farming households consume the foods they prefer regardless of their crop portfolio, or whether their cropping decisions are entangled with their food consumption decisions. This can be restated as a formal test of household separability hypothesis, that is, whether households manage their production in order to maximize residual profits and then choose a utility-maximizing mix of consumption goods based on those residual profits. Whether or not production and consumption decisions follow this recursive process, affects household labor allocation, income, and nutrition, among other outcomes. We build on the separability literature that mostly focuses on production side tests (Lopez, 1984; Pitt & Rosenzweig, 1986; Delforce, 1994; Behrman et al., 1997; Bowlus & Sicular, 2003; Le, 2010; LaFave & Thomas, 2016; Dillon & Barrett, 2017; Dillon et al., 2019; Jacoby, 1993; Barrett et al., 2008). We extend the novel consumption side test proposed by LaFave et al. (2020), which uses a setting where monthly market price data for agricultural inputs are not available. Our hypothesis states that food demand by farming households is determined by their preferences and by how much income is derived from agricultural activities and not by how much land is allocated to each food crop that enters the demand system. A rejection of this hypothesis would imply market failure.

In our consumption side approach, we estimate the parameters of a demand system and then test whether crop allocation affects consumption decisions apart from through farm residual profits. To estimate the demand system parameters, we use an Exact Affine Stone Index (EASI) demand model which has the advantages of being flexible to Engel curve functional forms, allowing interactions between price and expenditures, and also allowing error terms to account for unobserved preference heterogeneity (Lewbel & Pendakur, 2009). We estimate the demand system over nineteen (19) food groups and one (1) numeraire group that includes non-food goods. We address the issues of censored food purchases by using Tobit model and the issues of endogeneity of price and expenditures by using instrumental variables (IV). More specifically, to estimate the demand system, we implement an IV Tobit using the extended Amemiya's generalized least squares (AGLS) estimator developed by Zhen et al. (2014). Furthermore, exploiting the panel structure of our data, the estimations also include correlated random effects to control for time-invariant unobserved heterogeneity in household food preferences at the community level (Meyerhoefer et al., 2005).

To test our predictions we examine the demand for a subset of five of these groups of food crops that are also commonly produced in Nigeria: (1) maize, (2) cassava, (3) roots, tubers, and other starches, (4) pulses, and (5) nuts and seeds. The ratios of demand parameters for each of the five food groups serve as the basis for the test. We implement nonlinear Wald tests of equality of the demand parameters using pairwise combinations of all five food groups.

We find that production decisions affect food consumption apart from through the profit effects. Results show that farmers' food consumption is determined by their cropping patterns, and thus we reject the null that households first optimize production then choose consumption based on farm residual profits. Our findings reflect the fact that agricultural households in Nigeria are likely to base their production decisions upon their consumption. In this case, the optimal diet enhancing strategy would be to promote a diverse crop portfolio that has the propensity not only to improve households' diet but also to raise their income. Our results shed light on the role of food preferences in household food production, and inform policy makers about the relationships between food production, markets and nutritional preferences of agricultural households in Nigeria.

This paper makes three major contributions to the literature. First, we contribute important new demand-side evidence on household separability test where it is limited. Although our approach closely relates to the work by LaFave et al. (2020) who developed a consumption-side test that examines whether demand for goods is a function of production decisions, we add a novel contribution to the literature. In LaFave et al. (2020), the separability hypothesis is tested using a flexible demand model and detailed output and input price data at different market levels for rice producers in Java, Indonesia. Our separability test is based on allocation of farmland, which is readily observed in household surveys. Detailed input price data collected at different market levels and at different time periods are scarce. Input price can be obtained through the unit values of farmers' reported purchases, though these unit values are often subject to measurement errors (Cox & Wohlgenant, 1986; Deaton, 1988; Perali & Chavas, 2000). However, we also implement LaFave et al. (2020) method as a robustness check using the observed input purchase unit values. Hence, we use the median input unit value at the lowest administrative level for which we have at least 3 observations in order to reduce the extent of measurement errors bias. We consider the median unit value for fertilizer and maize seed. Our results using this approach are consistent with the land allocation approach, and corroborate that farmers' production decisions affect their food consumption apart from through the profit effects. Furthermore, as noted by LaFave et al. (2020), our consumption-side approach to testing for agricultural household recursive assumption is less likely to be subject to issues of functional form mis-specifications as in the case of the production-side test approach, hence enabling to apply the test on a variety of settings.

Second, we add new evidence that addresses the completeness of markets for farming households (Lopez, 1984; Pitt & Rosenzweig, 1986; Delforce, 1994; Behrman et al., 1997; Bowlus & Sicular, 2003; Le, 2010; LaFave & Thomas, 2016; Dillon & Barrett, 2017; Dillon et al., 2019). This body of literature typically tests the recursive property based on farm management decisions, such as examining the relationship between household characteristics and farm inputs or testing the equality between the implicit prices of inputs that enter the farm production function with the market level prices of these inputs (Jacoby, 1993; Barrett et al., 2008). The main separability test considered in previous literature is that a positive and significant relationship between household characteristics and household farm labor implies a rejection of the assumption of separability and complete markets. Our findings are consistent with previous research and provide a demand-side evidence to the separability test.

Third, our work builds on the growing literature that documents the tradeoffs between subsistence and market-oriented crop production and the role of functioning agricultural markets in achieving food security for low-income households (Sibhatu et al., 2015; Sibhatu & Qaim, 2018; Ecker, 2018). With well-functioning food markets, farmers will improve their diet by purchasing a diverse range of affordable and healthy foods in the markets with the residual profits from farming. Policy makers could for instance design interventions that target the affordability of foods or general enhancement of farm profits to foster that goal. On the other hand, a market failure situation would necessitate the focus on nutrition sensitive crop production. We also note that relative to the aforementioned studies which mostly use a reduced form approach to investigate the separability assumption, we add a novel methodological contribution to investigating this question by using a structural approach, which allows us to impose theoretical assumptions on our model.

Our findings have important implications for diet improvement interventions in developing countries in general and in Africa in particular. The finding that farming households' production decisions are entangled with their consumption implies that to improve diet, policy interventions should focus on enhancing the productivity of diverse nutritional crops, while improving food market conditions in Africa. Furthermore, even at higher farm income, farmers might divert their residual profits from purchasing nutrient-dense foods to calorie-based foods. Whether farmers should diversify more their crop portfolio according to their diet, or according to the market demand, or whether diet improvement interventions should target the production of staple vs cash crops in order to improve diet, is a crucial debate for many rural areas in developing countries. We provide an answer to that question in Nigeria.

The paper proceeds as follows. The next section presents the theoretical background that supports our separability test. We then describe the data in section 3.3 and explain the empirical strategy in section 3.4. Section 3.5 presents the results of the separability tests. We discuss the results and provide concluding remarks in the last section.

3.2 Theoretical Framework

To illustrate the recursion assumption of the agricultural household, we develop our hypothesis tests from the canonical agricultural household model by Singh et al. (1986). Using the basic model, we derive the demand expressions for food goods c_i, non-food goods g, and leisure l. If the recursive household model holds, then agricultural production decisions should only affect food demand through residual farm profits. Our test assesses whether crop allocation decisions influence farm demand apart from profits.

Let us assume an agricultural household endowed with total time $\bar{L}$ allocated between leisure l, and time spent on household and non-household businesses $\bar{L} - l$. We represent the household preferences over a set of food crops and other foods c_i, non-food goods g, and leisure l, by $U(c_i, g, l)$. If the household production and consumption decisions are recursive, then the household's process can be solved sequentially, first with maximizing farm profits then with maximizing consumption utility conditional on the budget constraint. Let us also assume the household faces a production technology for each crop c, $Q_c = Q(L_c, A_c, V_c)$, where L_c stands for labor for crop c, A_c represents farm land, V_c represents variable inputs such as fertilizer and seeds.

Given the production technology function $Q_c()$, market rental rate r, market wage w, variable input prices p_v, and output prices p_c, the household chooses labor L_c, land A_c, and variable inputs V_c that maximize farm profits:

$$\max_{\{L,A,V\}} \pi = \sum_c p_c Q_c(L_c, A_c, V_c) - wL_c - rA_c - \sum_v p_v V_c \tag{3.1}$$

Solving equation (3.1) results in the input demand functions $L_c^* = (p_c, r, w, p_v)$, $A_c^* = (p_c, r, w, p_v)$, and $V_c^* = (p_c, r, w, p_v)$, where A_c^*, L_c^* and V_c^* represent respectively the optimized allocations of land, labor and variable inputs. By substituting these inputs demand functions into equation (3.1), the profit function becomes:

$$\pi^* = \sum_c p_c Q_c(L_c^*, A_c^*, V_c^*) - wL_c^* - rA_c^* - \sum_v p_v V_c^* \tag{3.2}$$

Therefore, the optimal total household farm profits can be expressed as:

$$\pi^* = \pi^* \Big[L_c^*(p_c, r, w, p_v), A_c^*(p_c, r, w, p_v), V_c^*(p_c, r, w, p_v) \Big] \tag{3.3}$$

For simplicity, we assume farmers know input and output prices after the production decisions are made, and that the household is a price taker for both input and output prices.

Given the profits from the first stage π^*, the agricultural household chooses a consumption vector that maximizes utility given its full income constraint:

$$\begin{aligned} \max_{c_i, g, l} \quad & U(c_i, g, l) \\ \text{s.t.} \quad & \pi^* + I + w\bar{L} \geq \sum_{i=1}^{m} p_{ci} c_i + p_g g + wl \\ & c_i \geq 0 \\ & g \geq 0 \\ & l \geq 0 \end{aligned} \tag{3.4}$$

where I stands for any non-farm income, $w\bar{L}$ represents the total value of the household's labor endowment, p_{ci} is the market price of food c_i, and p_g is the market price of non-food goods g.

Focusing on the food goods, the first-order conditions (FOCs) from problem (3.4) equate the marginal utility of consumption with the market price times the slackness constraint for the food goods:

$$\frac{\partial U(c_i, g, l)}{\partial c_i} = \lambda p_{ci}, \forall i \in (1, ..., m) \tag{3.5}$$

Equation (3.5) also holds for non-food goods and leisure. These first order conditions in equation (3.5) give rise to the following demand equation for food goods.

$$c_i = c_i\Big[\pi^*(L^*, A^*, V^*), p_{ci}, w, r, I, \bar{L}, p_v\Big], \forall i \in (1, ..., m) \tag{3.6}$$

Equation (3.6) shows that the production decisions affect the demands for each good only through residual profits from agricultural production. Hence, the consumption demand functions should not be affected by the household choices regarding the allocation of land A or labor L or any other input decisions other than through its effects on profit (π^*).

From equation (3.6), taking the total differential of c_i with respect to demand for farmland (A_i), gives:

$$\frac{\partial c_i}{\partial A_i^*} = \frac{\partial c_i}{\partial \pi^*} \frac{\partial \pi^*}{\partial A_i^*} \tag{3.7}$$

Again, we see in equation (3.7) that household production decisions (such as the allocation of farmland to crop i, A_i) affect the demand of consumption goods only through the profit effect. Suppose the household faces the demands for two food goods, c_1 and c_2 and suppose A_1 is the allocated land to food crop c_1. Then, we expect that a change in the allocation of land to crop 1 (increase in A_1) should not affect the demand for crop 1, c_1, apart from through the effect on profits π^*. This profit effect should be the same for all food crops, and thus for any pair of goods i and j, we can take the ratio of $\frac{\partial c_i}{\partial A_i^*}$ and $\frac{\partial c_j}{\partial A_i^*}$ and the expression $\frac{\partial \pi^*}{\partial A_i}$ will cancel out.

We expect the following expression to hold for any pair of two food goods, c_i and c_j, and any input A_i:

$$\frac{\frac{\partial c_1}{\partial A_1}}{\frac{\partial c_2}{\partial A_1}} = \frac{\frac{\partial c_1}{\partial \pi^*}\frac{\partial \pi^*}{\partial A_1}}{\frac{\partial c_2}{\partial \pi^*}\frac{\partial \pi^*}{\partial A_1}} = \frac{\frac{\partial c_1}{\partial \pi^*}}{\frac{\partial c_2}{\partial \pi^*}} \tag{3.8}$$

By incorporating an additional assumption, we can rewrite this ratio as:

$$\frac{\frac{\partial c_1}{\partial A_1}}{\frac{\partial c_2}{\partial A_1}} = \frac{\frac{\partial c_1}{\partial Y}}{\frac{\partial c_2}{\partial Y}} \tag{3.9}$$

where Y is the total household income including farm profits and other household income.

We justify our assumption that these ratios of partials are equal, (i.e. $\frac{\frac{\partial c_1}{\partial \pi^*}}{\frac{\partial c_2}{\partial \pi^*}} = \frac{\frac{\partial c_1}{\partial Y}}{\frac{\partial c_2}{\partial Y}}$) for two reasons. First, we assume that the household expenditure distribution on one food relatively to another will not vary significantly based on the source of income. In other words, the allocation of income to food c_1 relatively to food c_2 is not a function of the source of income but rather a function of the total budget. Second, we assume that for agricultural households, farm profits form the core of household income. It is important to note that we do not assume equality of partials (e.g. $\frac{\partial c_1}{\partial \pi^*} = \frac{\partial c_1}{\partial Y}$) but instead we assume equality of the ratio of partials.

Equation (3.9) serves as the basis of our consumption-side household separability test. It implies that, for any input A_i, the ratio of the changes in food crops c_i and c_j from a change in input A_i is equal to the ratio of the changes in food crops c_i and c_j from a change in total budget Y. Equation (3.9) can be extended to any other good in the demand system such as non-food goods g and leisure l by substituting them for c_2.

If the equation in (3.9) does not hold, then we assume that the household farm input decisions affect consumption not through the profit effects but through a self-production effect. In other words, the household preferences are directly reflected in its production decisions and both consumption and production decisions are jointly determined, hence a failure of the separability hypothesis.

3.3 Data

Our data covers three survey years (2010/2011, 2012/2013, and 2015/2016) of the Nigeria General Household Survey (GHS) panel data. For each survey year, two separate questionnaires were administered during two different seasons – one post-planting and the other post-harvest. We observe the household's consumption at both times within each survey wave.[1]

The GHS followed a two-stage sampling procedure. First, enumeration areas were selected from a pool of all Nigerian enumeration areas. Second, households were selected from each sampled enumeration area. Each wave of data has information on household characteristics and on a wide range of food and non-food goods and services at the household level. The data also have detailed agricultural information at the plot level. The data has an original sample size of 5000 panel households in each wave. We limit our estimation sample to rural households that produce at least one of the food crops for which we model demand. Thus, we have a final balanced panel of 1,840 unique households (with an unbalanced panel of 2,646 unique households) and 13,926 household-year observations. While food consumption information is recorded in both post-planting and post-harvest surveys, the majority of farmland allocation information is present only in the post-planting survey, which captures

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[1] Wave 1 data were collected between 08/2010 and 10/2010 and wave 2 data were collected between 02/2011 and 04/2011. Wave 3 data were collected between 09/2012 and 11/2012 while wave 4 data were collected between 02/2013 and 04/2013. Wave 5 data were collected between 09/2015 and 11/2015 while wave 6 were collected between 02/2016 and 04/2016

production decisions for the main growing season. Summary statistics of variables that enter our demand system estimation are presented in table 3.1.

3.3.1 Food consumption and price data

The food consumption module collects detailed quantity and expenditures information over a 7-day recall period at the household level for 74 food items including grains and flours, starchy roots, pulses, nuts and seeds, oil and fats, fruits, vegetables, meat, poultry and poultry products, fish and seafood, milk and milk products, and non-alcoholic beverages. The original number of food items in the food consumption module is 126 but we exclude 47 food items that are consumed by fewer than 1% of households or that are not consumed in at least three waves, and also 5 alcoholic beverage items. We also include a numeraire good encompassing non-food goods and services consumed by the household.[2] To avoid estimation challenges arising from multicollinearity, we aggregate the food items into 19 food categories: 1. Rice 2. Maize 3. Wheat and other cereals 4. Cassava 5. Roots, tubers and, other starches 6. Sugar 7. Pulses 8. Nuts and seeds 9. Vegetables 10. Fruit 11. Red meat 12. Poultry 13. Eggs 14. Fish and seafood 15. Dairy 16. Fats and oils 17. Coffee, tea, and cocoa 18. Soft drink and juice 19. Other foods (salt and spices). The sources of food consumption are market purchases, own-productions, and gifts.

To get the unit price of each food item, we use the following approach. We first convert non-standard units of food consumption into kilograms and liters using conversion factors published by the LSMS group. When the conversion factor for a non-standard unit is not available, we assign to each household, and for each food item, a median price that is calculated by dividing the household reported expenditure on the food item by the quantity purchased. The median price is derived at the lowest geographic variable for which we observe at least

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[2] For the numeraire good, we include household weekly expenditure on education, health, and non-food goods and services such as clothing, transportation, celebrations, etc.

Table 3.1: Summary Statistics of Demand System Variables

	Obs.	Mean	Std. dev.	Min	Max
Panel A. Budget share					
Rice	13926	0.09	0.08	0.00	0.73
Maize	13926	0.04	0.08	0.00	0.93
Wheat & other cereals	13926	0.12	0.13	0.00	0.92
Cassava	13926	0.03	0.07	0.00	0.77
Roots, tubers & other starches	13926	0.10	0.11	0.00	0.98
Sugar	13926	0.01	0.03	0.00	0.51
Pulses	13926	0.05	0.06	0.00	0.89
Nuts & seeds	13926	0.01	0.03	0.00	0.47
Vegetables	13926	0.07	0.05	0.00	0.76
Fruit	13926	0.01	0.02	0.00	0.44
Red meat	13926	0.06	0.08	0.00	0.77
Poultry	13926	0.01	0.04	0.00	0.67
Eggs	13926	0.00	0.01	0.00	0.24
Fish & seafood	13926	0.06	0.08	0.00	0.63
Dairy	13926	0.01	0.03	0.00	0.58
Fats & oils	13926	0.06	0.05	0.00	0.60
Coffee, tea, & cocoa	13926	0.00	0.02	0.00	0.72
Soft drink & juice	13926	0.01	0.02	0.00	0.35
Other foods	13926	0.01	0.02	0.00	0.46
Non-foods	13926	0.24	0.15	0.00	0.98
Panel B. Food prices					
Rice	13926	194.32	65.12	6.87	440.44
Maize	13926	109.64	63.31	7.76	422.66
Wheat & other cereals	13926	152.44	57.29	18.26	515.09
Cassava	13926	92.54	50.72	2.52	339.23
Roots, tubers & other starches	13926	100.21	35.45	7.50	302.65
Sugar	13926	293.94	152.74	3.07	1013.41
Pulses	13926	209.13	94.23	4.70	615.94
Nuts & seeds	13926	420.89	266.73	4.80	1772.72
Vegetables	13926	167.61	78.74	8.25	698.04
Fruit	13926	111.96	51.86	5.20	469.32
Red meat	13926	732.50	195.73	29.57	1525.27
Poultry	13926	790.32	316.87	15.61	1811.59
Eggs	13926	465.60	138.60	59.57	1157.08
Fish & seafood	13926	552.36	340.90	17.39	12279.69
Dairy	13926	876.67	420.69	14.61	3150.91
Fats and oils	13926	283.03	86.15	31.80	1181.62
Coffee, tea, & cocoa	13926	1862.27	1375.45	11.31	9103.37
Soft drink & juice	13926	110.29	43.09	5.96	733.12
Other foods	13926	287.89	333.39	0.11	1889.98
Panel C. Household expenditures					
Total expenditures	13926	6976.05	4435.78	134.28	43289.29
Panel D. Land share by food group					
Maize	13926	0.24	0.32	0.00	1.00
Cassava	13926	0.28	0.38	0.00	1.00
Roots, tubers & other starches	13926	0.18	0.31	0.00	1.00
Pulses	13926	0.15	0.25	0.00	1.00
Nuts & seeds	13926	0.11	0.24	0.00	1.00
Panel E. Input prices					
Maize seed	7448	5.00	1.17	0.69	8.15
NPK fertilizer	7448	4.61	0.34	1.39	5.30
Panel F. Demand shifters					
Head age	13926	45.83	14.15	16.00	105.00
Head is married=1	13926	0.86	0.35	0.00	1.00
Head years of education	13926	4.16	4.82	0.00	18.00
Adjusted household size	13926	4.15	1.96	0.50	25.90
Head is male=1	13926	0.87	0.33	0.00	1.00
Ratio of dependents to adults	13926	1.14	1.28	0.00	9.00

Notes: This table reports the summary statistics of demand system variables. Food prices, input prices (maize seed and NPK fertilizer) are in Nigerian Naira/Kg and household expenditures are in Nigerian Naira. The input prices are reported in natural logarithm. The non-availability of inputs prices for all enumeration areas explains the reduced sample size for these prices.

three prices.[3] We also impute item level price for households who did not consume an item, using the same imputation method as described above. We clean the generated price of outliers by top and bottom coding prices using interquartile range rule with a factor of 1.5. Hence, for each household and for each food item, we have a standard unit value, even with no reported quantity purchased. For each household and for each food item, we top-code outliers based on the household per capita consumption, adjusted by adult equivalence using the interquartile range rule.

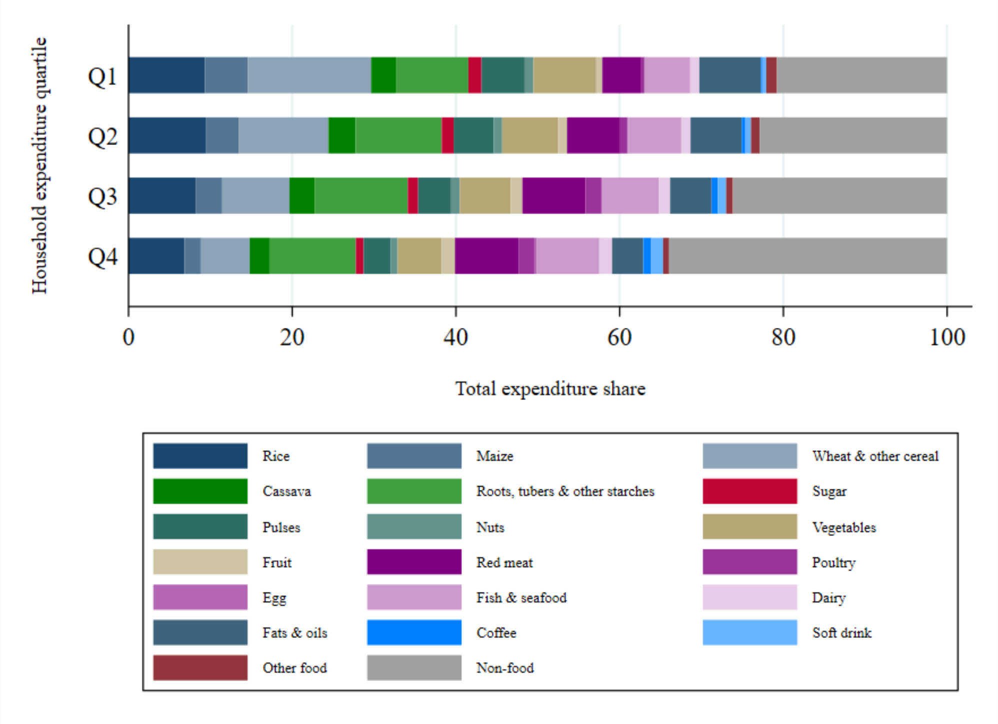

Figure 3.1: Household budget share by expenditure quartile. Q1, Q2, Q3 and Q4 represent the first, second, third and fourth expenditure quartiles, respectively.

Figure 3.1 shows the budget share on food and non-food good and the budget share on each food group, by household expenditure quartile. We provide more details on budget share and unit value in table B.1. We construct four expenditure quartiles based on household level total

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[3] We use the median price only if there are at least three households with the same unit within the same geographic level. To get the median price, we start with the most disaggregated geographic level (enumeration area), followed respectively by the local government area level, the state level, and the zone level. Remaining missing prices are imputed using median prices at the item level.

consumption per adult male equivalent per day, using international poverty lines. In the first expenditure quartile (Q1), the poorest group, we consider expenditure below $US 1.90 per capita per day in constant 2017 international $US, adjusted for 2011 purchasing power parity (PPP) and consumer price index (CPI).[4] Quartile Q2 is characterized by households with daily per capita expenditures between $US 1.90 and $US 3.20 while quartile Q3 corresponds to households with per capita daily expenditure between $US 3.20 and $US 5.50. The last expenditure quartile, Q4, has households with per capita daily expenditure above $US 5.50. As shown in figure 3.1, and consistent with consumers' patterns predicted by Engel's law and Bennett's law, wealthier consumers spend more on non-food goods as compared to poorer consumers. Similarly, wealthier households spend more on animal-based foods such as fish, egg, red meat, dairy as compared to poorer households. On the other hand, poorer households spend more on staples such as rice, maize and wheat.

3.3.2 Cropland allocation and input price data

To calculate the land allocated to each food crop, we first convert plot areas reported in non-standard units to standard units. We then collapse the converted plot areas at the household-plot-crop level for both mono-cropping and inter-cropping systems. For each food crop, we calculate its share of farmland by dividing the household-plot-crop area by the total household-plot cultivated area. Finally, we group the crop items into the food groups that correspond with those in our demand system and collapse the mean farmland share for each food group to the household level. In other words, since each food group has one or many food crops, we consider the mean share of farmland across all the food crops within that food group. The food crops and their corresponding food groups are presented in table

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[4] Using the World Bank classification, the daily per capita expenditures below $US 1.90 is the international standard for extreme poverty. The daily per capita expenditure between $US 1.90 and $US 3.20 corresponds to the international poverty standard. The daily per capita expenditure between $US 3.20 and $US 5.50 corresponds to the international poverty standard for upper-middle-income countries. Finally, the daily per capita expenditure above $US 5.50 is equivalent to the upper-income countries.

(B.2) in appendix. Although we have 19 food groups in the demand system, we focus our separability test on the most important food groups based on Nigerian diets and smallholder land allocation. The five groups of food crops are (1) maize, (2) cassava, (3) roots, tubers, and other starches, (4) pulses, and (5) nuts and seeds. Maize and cassava are the most produced crops and occupy about 52% of farmland in our sample (Table 3.1).

For our input price robustness check, we calculate input unit values using farmer reported quantities of purchased inputs. We create unit values for fertilizer and for maize seed for each household and agricultural season. We then calculate the median value of the input across households in the same geographic area during the same agricultural season, in order to reduce the unit value bias that could result from fertilizer-loving households seeking out more fertilizer. We therefore assume that households living in the same enumeration area at any point in time face similar market prices. If a minimum of three observations is unavailable at the enumeration area level, we impute the missing price by using the median price at the next larger administrative area (first local government area, then state and zone). We consider fertilizer and maize seed prices because these inputs are widely used by farmers as compared to other inputs, such as herbicides, pesticides and other seeds.

3.4 Empirical Methodology

We test our hypothesis by including farm inputs in our demand system and then calculating the test statistics in equation (3.9). We choose a utility-theoretic Exact Affine Stone Index (EASI) demand model to test our separability hypothesis (Lewbel & Pendakur, 2009). The EASI model is a flexible model appropriate for disaggregated data.

More specifically, we estimate the two-way approximate linearized EASI demand system specified as follows:

$$w^*_{hit} = \mu_i + \sum_{j=1}^{J} \alpha_{ij} logp_{hjt} + \sum_{r=1}^{L} \beta_{ir} y^r_{ht} + \sum_{r=1}^{L} \alpha_{ijy}(y_{ht} * logp_{hjt}) + \sum_{j=1}^{5} \delta_{ij} A_{hjt} + \sum_{k=1}^{K} \gamma_{ik} \mathbf{D_{hkt}} + \mu_{hit}, \tag{3.10}$$

where w^*_{hit} is the latent budget share for household h, for food item or food group i, at time period t, with $w_{hit} = \max\{0, w^*_{hit}\}$. p_{hjt} is the price index for food item or food group j at time period t, y^r_{ht} is the household total expenditure at the r^{th} polynomial. y^r_{ht} is constructed as $logx_{ht} - \sum_{j=1}^{J} w_{hjt} logp_{hjt}$, which represents the Stone price-deflated expenditure where x_{ht} is the nominal household expenditure (Lewbel & Pendakur, 2009). $\mathbf{D_{hkt}}$ is a vector of demographic variables and demand shifters, and μ_{hit} is an idiosyncratic error term. The vector of demographic shifters includes household size, household ratio of dependents (<14 and >65 years old) to adults, household head level of education, age, marital status, and gender. The model also includes wave and regional dummies. Furthermore, the model is estimated using a correlated random effects specification that controls for time-invariant unobserved heterogeneity in food preferences at the enumeration area (EA) level by including in the model for each survey wave, the EA level means of prices and interaction between prices and expenditures (Meyerhoefer et al., 2005).

We also include a vector of household farm input use variable (A_{hjt}) in our main specification. Specifically, our farm input use variable includes the mean share of land allocated to 5 food crops or groups of food crops of interest: maize; cassava; roots, tubers, and other starches; pulses; and nuts and seeds. We estimate model (3.10) over a set of 19 food groups and a numeraire good that includes other non-food goods and services.

A first estimation challenge arises from censored purchases because not all households purchased all 19 food groups during the 7-day recall period. We address this problem by using Tobit estimation for each budget share to account for the zero purchases. We also face two sources of endogeneity, which we address using instrumental variables following

Zhen et al. (2014). The first endogeneity issue in our model is due to the fact that each household's constructed Stone price-deflated household expenditure is related to its own budget shares. To correct for this source of endogeneity, we create an instrument for y_{ht} that equals $logx_{ht} - \sum_{j=1}^{J} \overline{w_{hjt}} logp_{hjt}$, where $\overline{w_{hjt}}$ is the sample-average budget share for food group j. The second endogeneity issue comes from the derivation of prices from unit values. Unobserved characteristics (such as price discount, bargaining, and the fact that consumers may choose lower quality foods to avoid high prices) will bias our estimates if not addressed properly. First, we construct at the food group level, Fisher Ideal price indexes for household h, food group j at time period t as:

$$p_{hjt} = \sqrt{\frac{\sum p_{kh} q_{k0}}{\sum p_{k0} q_{k0}} \frac{\sum p_{kh} q_{kh}}{\sum p_{k0} q_{kh}}} \tag{3.11}$$

where p_{kh} and q_{kh} represent respectively the unit value and quantity of food-item k in food group j for household h. p_{k0} and q_{k0} are respectively the average unit value and quantity over the 7 day-recall across sample households. To address price endogeneity from search behavior, we create an instrument using Hausman (1996) and Nevo (2001) approaches. We use the price index of other households in the same survey month and year to calculate a mean price index that instruments for each household's price index. The identifying assumption is that market food prices faced by neighboring households are likely to be similar to prices faced by the household, hence suggesting a strong correlation between household's food prices and neighboring households food prices. These neighbor food prices do not reflect the household's demand.

3.4.1 Derivation of Elasticity

We rely on the approach used by McCullough et al. (2021) to calculate a median demand elasticity for each food group. We first compute price elasticity and expenditure elasticity for each food group and for each household using the estimated demand system parameters.

The computed elasticity is also a function of the household's prices, total expenditures, and demand shifters. In each case, we then derive the median elasticity at the food group level. We also simulate the standard errors for each demand elasticity by assuming a normal distribution with mean equal to the vector of parameters and variance equal to the covariance matrix (Krinsky, Robb, et al., 1990).

3.4.2 Separability Test

After estimating the system of equations depicted in (3.10), we use the estimated parameters to test prediction (3.9). For each combination of food crop i and food group $j \neq i$, $\forall i \in K$ the subset of food groups that are major production crops, the following equality should hold:

$$\frac{\left[\sum_{r=1}^{L} r\beta_{ir} * y^{r-1}\right] + \left[\sum_{j=1}^{J} \alpha_{ijy} * logp_{hjt}\right]}{\left[\sum_{r=1}^{L} r\beta_{jr} * y^{r-1}\right] + \left[\sum_{j=1}^{J} \alpha_{jjy} * logp_{hjt}\right]} = \frac{\delta_{ii}}{\delta_{ji}} \tag{3.12}$$

which can be rewritten as:

$$\frac{\frac{\delta_{ii}}{\delta_{ji}}}{\frac{\left[\sum_{r=1}^{L} r\beta_{ir} * y^{r-1}\right] + \left[\sum_{j=1}^{J} \alpha_{ijy} * logp_{hjt}\right]}{\left[\sum_{r=1}^{L} r\beta_{jr} * y^{r-1}\right] + \left[\sum_{j=1}^{J} \alpha_{jjy} * logp_{hjt}\right]}} = 1 \tag{3.13}$$

where δ_{ji} represents the marginal effect of a change in demand for food j with respect to land allocation to crop i, β_{jr} is the marginal effect of a change in expenditure at the r^{th} polynomial on the demand for food j, and α_{jjy} is the parameter of the interaction between expenditure and price of food j.

We rearrange equation (3.12), following Gregory and Veall (1985), so we can test whether the following expression holds:

$$\delta_{ji} * \Big\{\Big[\sum_{r=1}^{L} r\beta_{ir} * y^{r-1}\Big] + \Big[\sum_{j=1}^{J} \alpha_{ijy} * logp_{hjt}\Big]\Big\} - \delta_{ii} * \Big\{\Big[\sum_{r=1}^{L} r\beta_{jr} * y^{r-1}\Big] + \Big[\sum_{j=1}^{J} \alpha_{jjy} * logp_{hjt}\Big]\Big\} = 0 \tag{3.14}$$

We test the hypothesis in (3.14) at the r polynomial using a pairwise combination of food crops/groups. We perform the test for a total of 10 pairwise combinations of the five (5) food crop groups in our demand system. A failure to reject the null hypothesis in (3.14) for all pairwise combinations indicates that the separability hypothesis holds and household behavior can be described recursively. A rejection of the hypothesis in (3.14) for one pairwise combination of food groups otherwise indicates a rejection of the separability hypothesis.

3.4.3 Threats to the Identification Strategy

The major advantage of our separability test methods is that it applies to settings where detailed price data are often not available, while input use, such as cropland allocation, is readily observed. Our method could be threatened by endogenous cropland allocation decision issues, potential sources of omitted variable bias, which we discuss in this section. The sources of this endogeneous land allocation decision in this case are diverse.

First, our method might be subject to measurement error issues. It is often difficult to correctly determine the exact allocation of each land (or other inputs) to each crop, especially when farmers often use intercropping systems, given that land area is self-reported by farmers (Gourlay et al., 2019). To address this issue, we use GPS-measured field areas to reduce the extent of measurement errors relatively to farmer-reported field areas.[5]

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[5] To avoid the double counting of cropping areas in generating the allocated land to each food crop and its corresponding share of total planted areas, we calculate shares at the plot level before collapsing that information to the household level.

Second, there might be concerns that farmers are growing what they prefer and that changes in their preferences are driving changing crop allocation. In other words, cropping decisions are endogenous to land allocations. For instance, if some farming households have preferences for cassava consumption, they will allocate more land to cassava production relative to other crops, which implies that land allocation is endogenously determined in the cassava budget share equation in the demand system. If this is the case, our land allocation parameters, δ_{ii}, will be biased. To circumvent this issue, we rely on the sequential nature of agricultural household decision making process. Based on our model assumptions, prior to making consumption decisions, choice of cropping area is made based on information about market prices of output and inputs. Assuming our model assumptions hold, crop choices are independent of land choices and are only function of market prices of input and output, and observed land quality. These measures would reduce the extent of bias in our land allocation parameter estimates.

3.4.4 Separability Test Using LaFave, Peet & Thomas (2020) Approach

As a robustness check, we also use the methodology by LaFave et al. (2020), who hypothesize that for the separability assumption to hold, the vector of prices of farm variable and fixed inputs enter the profit function and have no direct impact on demand, thus will only affect demand through an income effect. To test their approach, we include in our demand system the median unit values of two major inputs, fertilizer and maize seed. We calculate these unit values at the enumeration area (EA) level, or replacing with a higher demographic level if we do not observe more than 3 unit values of that input in the EA.

Applying the LaFave et al. (2020) approach to our data introduces a few limitations. First, there are likely unobserved factors to the econometrician but observed by the farmer, such as the quality of the input or the farmer price bargaining that will affect the price paid by the farmer. Without good input price data, we must derive the unit value of input by dividing the total household expenditure on the input by the total quantity purchased. Second, these purchased quantities and values are reported by farmers, who may report them with measurement errors. To address these issues, instead of using the derived unit values at the household level, we instead consider the median unit value of each input at the enumeration area (EA). Missing EA level unit values are then stepwise imputed using the median unit values from the lower to the upper administrative divisions. This approach reduces the potential bias that arises from unit value. In addition, given that we are only using the input price as a demand shifter, and because we use average EA-level input price (unit value) rather than household-level price, we assume that these prices are exogenous to the demand system because they are exogenous to each farming household's food demand decisions. To implement the LaFave et al. (2020) approach, we use in our vector A_{hjt}, the median unit values for maize seeds and fertilizer. δ_{ij} comes from the marginal effects of the input price instead of land area. This latter test using input prices is slightly different from the land allocation approach because it excludes the profit (or income) term in the equation. The null hypothesis is now formulated as follows:

$$\frac{\delta_{i1}}{\delta_{i2}} = \frac{\delta_{j1}}{\delta_{j2}} \tag{3.15}$$

where δ_{i1} indicates the change in the demand for food group i for a unit change in the market price of input 1, and δ_{j2} represents the change in the demand for food group j for a unit change in the market price of input 2. The test follows the same procedure as in equation (3.14) where the null hypothesis is linearized in order to compute the Wald statistics.

3.5 Results

3.5.1 Demand Model Estimates, and Price and Expenditure Elasticities

After estimating the structural coefficients of the EASI model, we conduct a series of tests on these parameters to evaluate the model. Overall our coefficient estimates are jointly significant (with a p-value < 0.0001). Given the disaggregated nature of the data, we also test whether it is optimal to use a model that allows for the Hicksian demand to vary across income groups. We therefore test the joint significance of the coefficient estimates for the interaction term between prices and expenditures and find that these parameters are jointly significant (with a p-value < 0.0001), which justifies the choice for the EASI model. Finally, we evaluate the optimal order for the highest polynomial order of the Engel curve by testing the joint significance of the expenditure coefficients. We find that our specification supports a 3^{rd}-order polynomial on expenditures.

Before presenting our main results, we briefly discuss the demand elasticities for the 5 groups of foods used for testing the separability hypothesis. These elasticities are summarized in figures 3.2 and 3.3. Overall our demand system is well behaved and consistent with previous literature. For instance, we find that for all five groups, the responsiveness to expenditure is higher than that of price. In other words, a unit increase in expenditure will have a much bigger impact on food demand as compared to a unit decrease in price. This result is consistent with Cheng and Larochelle (2016). Abdulai and Aubert (2004) and McCullough et al. (2021) also find similar results for Tanzanian households. We also find that our price and expenditure elasticity estimates are similar to those of Cheng and Larochelle (2016) for rural Nigeria, although we find that our expenditure elasticities are on average slightly higher than the results obtained by Colen et al. (2018) in a meta-analysis of income elasticity across

54 African countries (rural and urban samples). These latter results could be due to the fact that we derive our estimates on a sample of rural households who are more likely to be relatively poorer and for which food consumption patterns are likely to be more responsive to expenditure as compared to the general population food demand.

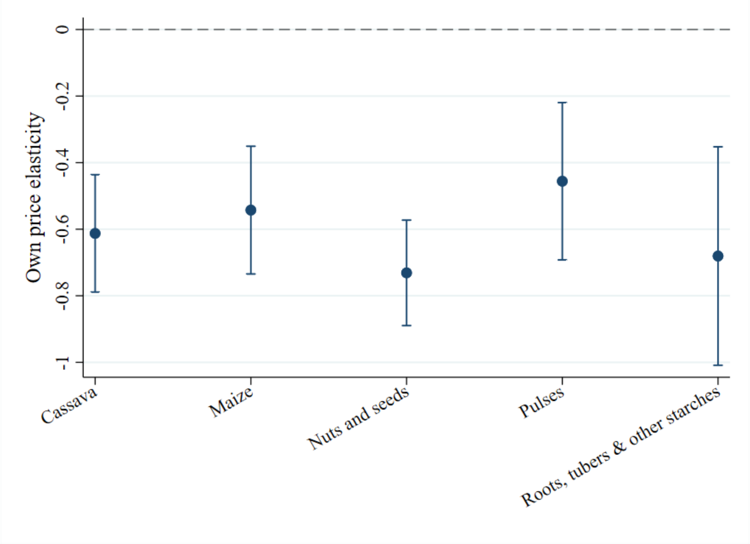

Figure 3.2: Median sample-wide own-price elasticity of demand with 95% confidence interval for the subset of 5 food groups that are included in separability test

3.5.2 Separability Test Results

We evaluate the separability assumption by testing equation (3.14) using the estimated expenditure coefficients, the estimated coefficients on the interaction terms between price and expenditure, and the estimated land allocation coefficients for the five food crop groups. Table 3.2 presents the expenditure and land allocation estimates. We perform cross-model nonlinear joint tests of equality of parameters for each pairwise combination of the five food groups. We consider only the combinations of food groups i and j with $i \neq j$, which gives us a total of 10 pairwise combinations of food groups.

Our test Wald statistics resulting p-value and the value of the ratio of the ratios are presented in table 3.3. The Wald statistics are obtained using equation (3.14). However,

Table 3.2: Demand coefficient estimates w.r.t to land allocations and total household expenditures

Variables	Dep. Var.: Budget share on foods				
	Maize (1)	Cassava (2)	Roots (3)	Pulses (4)	Nuts (5)
	Land allocation estimates				
Maize	-0.0035	-0.0054	0.0081	-0.0187**	0.0875
	(0.0056)	(0.0043)	(0.0101)	(0.0076)	(0.0543)
Cassava	-0.0026	-0.0123	0.0545**	-0.0089	0.1930*
	(0.0068)	(0.0096)	(0.0257)	(0.0087)	(0.1137)
Roots	0.0107*	0.0074	-0.0126	0.0099	-0.0832
	(0.0065)	(0.0079)	(0.0205)	(0.0080)	(0.0913)
Pulses	0.0133*	0.0063	-0.0165	-0.0141	-0.0278
	(0.0073)	(0.0051)	(0.0127)	(0.0099)	(0.0669)
Nuts	0.0285***	0.0019	-0.0036	0.0131	-0.0103
	(0.0066)	(0.0050)	(0.0134)	(0.0090)	(0.0649)
	Expenditure estimates				
Expenditure (1st deg. poly.)	0.0117***	-0.0166***	0.0192***	0.0772***	0.2644***
	(0.0044)	(0.0028)	(0.0068)	(0.0081)	(0.0333)
Expenditure (2nd deg. poly.)	-0.0041	-0.0018	-0.0017	-0.0217***	0.0421
	(0.0032)	(0.0025)	(0.0063)	(0.0057)	(0.0275)
Expenditure (3rd deg. poly.)	0.0007	-0.0022	0.0003	0.0039	-0.0275
	(0.0022)	(0.0013)	(0.0030)	(0.0050)	(0.0183)
	(Expenditure x Price) estimates				
Expenditure x Maize	0.0007				
	(0.0031)				
Expenditure x Cassava	0.0054***	0.0119***			
	(0.0018)	(0.0026)			
Expenditure x Roots	-0.0033	-0.0056**	0.0094		
	(0.0030)	(0.0027)	(0.0059)		
Expenditure x Pulses	-0.0066	-0.0105**	0.0093	0.0650***	
	(0.0045)	(0.0045)	(0.0067)	(0.0139)	
Expenditure x Nuts	0.0083	0.0033	0.0011	0.0269***	-0.0307
	(0.0051)	(0.0034)	(0.0084)	(0.0091)	(0.0398)

Notes: This table shows the coefficient estimates of food demand (budget share) w.r.t land allocated to food group, w.r.t total household expenditures at the 1st, 2nd, and 3rd degree polynomial, and w.r.t interactions btw prices and expenditures. Robust standard errors are in parentheses. *, **, *** denotes significance at the 10%, 5%, and 1% level.

for ease of interpretation and in order to compare the ratios relative to 1, we use equation (3.13) to calculate the ratios. These ratios are summarized in figure 3.4. According to our predictions in section 3.2, we expect this latter ratio to be equal to 1 for the separability hypothesis to hold. For a combination of maize and cassava for instance, the ratio is -0.10 with a Wald statistic is 7,088.01 and a p-value < 0.0001. In other words, the ratio of the marginal effect of a change in land allocated to maize on the demand for maize relatively to the marginal effect of a change in land allocated to maize on the demand for cassava is statistically different from the ratio of the marginal effect of a change in expenditure on the demand for maize relatively to the marginal effect of a change in expenditure on the demand for cassava.

We find similar results for the other 9 combinations of food groups. In all cases, as illustrated in table 3.3, we reject the null hypothesis that the ratio in equation (3.12) is statistically equal to 1. Hence, our findings corroborate the fact that farm production decisions strongly affect household food preferences through pathways other than farm profits. These findings suggest that markets are not functioning well and that farmers face market failure.

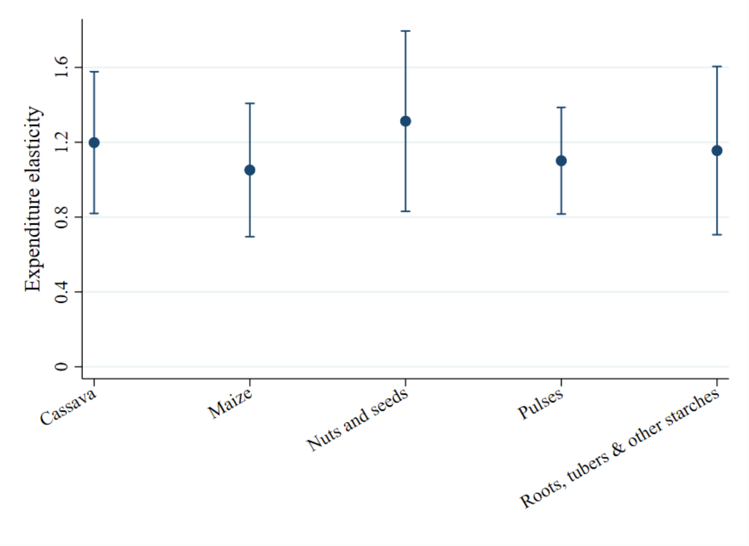

Figure 3.3: Median sample-wide expenditure elasticity of demand with 95% confidence interval for the subset of 5 food groups that are included in separability test

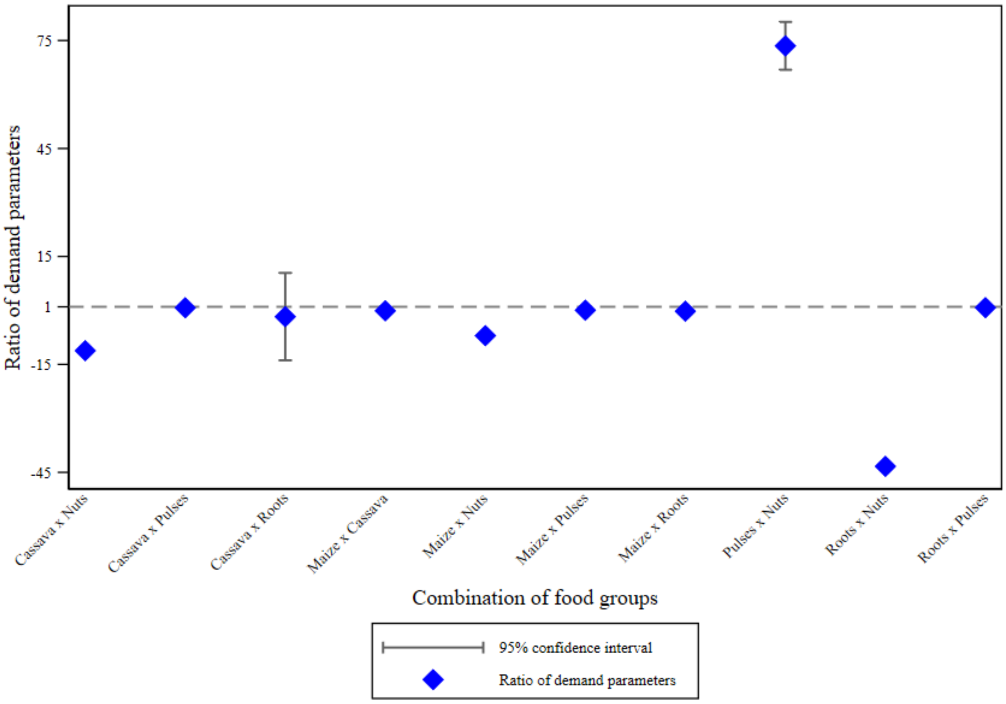

Figure 3.4: Ratio of demand parameters (separability test results) for the entire sample, with 95% confidence interval. The dots represent the calculated ratios using equation (3.13).

Table 3.3: Separability test results

	Budget share on foods			
	(1)	(2)	(3)	(4)
	Cassava	Roots	Pulses	Nuts & seeds
Test of ratio of parameters				
Maize				
Ratio 1 (w.r.t land allocation)	1.29	-0.78	4.50	158.07**
	(17.49)	(3.52)	(243.35)	(27.57)
Ratio 2 (w.r.t expenditure)	-12.93**	3.82**	69.99**	-22.54
	(1.38)	(0.87)	(8.26)	(9,632.10)
Ratio 1 / Ratio 2	-0.10	-0.21	0.06	-7.01**
	(0.12)	(0.47)	(0.05)	(0.07)
Wald statistic	7,088.01	2,419.17	4,816.12	4,866.59
pvalue	0.00	0.00	0.00	0.00
Cassava				
Ratio 1		-0.61**	3.49	122.60**
		(0.18)	(3.74)	(19.96)
Ratio 2		0.35	4.72	-10.96
		(0.66)	(5.50)	(7,463.48)
Ratio 1 / Ratio 2		-1.73	0.74**	-11.18**
		(6.19)	(0.28)	(0.18)
Wald statistic		1,627.71	5,230.96	4,492.41
pvalue		0.00	0.00	0.00
Roots, tubers and other starches				
Ratio 1			-5.74	-201.58**
			(16.11)	(9.06)
Ratio 2			-7.53	4.65
			(9.43)	(12,297.89)
Ratio 1 / Ratio 2			0.76**	-43.33**
			(0.19)	(0.24)
Wald statistic			1,501.89	1,409.53
pvalue			0.00	0.00
Pulses				
Ratio 1				35.11**
				(0.52)
Ratio 2				0.48
				(2,155.01)
Ratio 1 / Ratio 2				73.51**
				(3.39)
Wald statistic				31,062.09
pvalue				0.00
Obs.	13920	13920	13920	13920

Notes: This table shows the ratio of coefficient estimates w.r.t to land allocations and total household expenditures, for each combination of food groups. The table also shows the wald statistic and p-value of the test. Robust standard errors are in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

3.5.3 Results by households' landholdings, value of assets, and access to markets

In this section, we provide more evidence on the non-recursion of Nigerian farming households' production and consumption decisions. Using our demand side approach, we examine the possible mechanisms through which market failure occurs. We investigate the role of households' wealth and households' remoteness relative to food markets in explaining our results that agricultural production decisions and consumption decisions are not separable for farming households in Nigeria. We specifically look at whether the separability test results differ based on the size of land owned by the household, the value of the household assets, or the distance the household is from the nearest local market.

To better assess the heterogeneity of the findings, we estimate the demand system separately for households above and below the sample median value of landholdings, assets and geographic distance to nearest markets, and then conduct the separability test using these subsamples. The distance to the nearest market is measured in kilometers (km) and ranges from 0.28 km to 214.36 km, with a median value of 61.07 km.[6] The value of landholdings for the sample ranges from 0 to 809 hectares (ha) with a median value of 0.55 ha while the value of household assets ranges from 0 to 85,437,400 Nigerian Naira with a median value of 37,300 Naira. The density distributions of household assets, landholdings, and distance to nearest market are illustrated in figure B.1.

Figure 3.5 shows the distribution of the separability ratios by landholdings, value of assets and access to markets. The figure illustrates the ratios for households above and below the sample median values. In each case, we find no noticeable pattern in the results. Nonetheless, the detailed results presented in tables B.5, B.7, and B.9 in appendix show that the values

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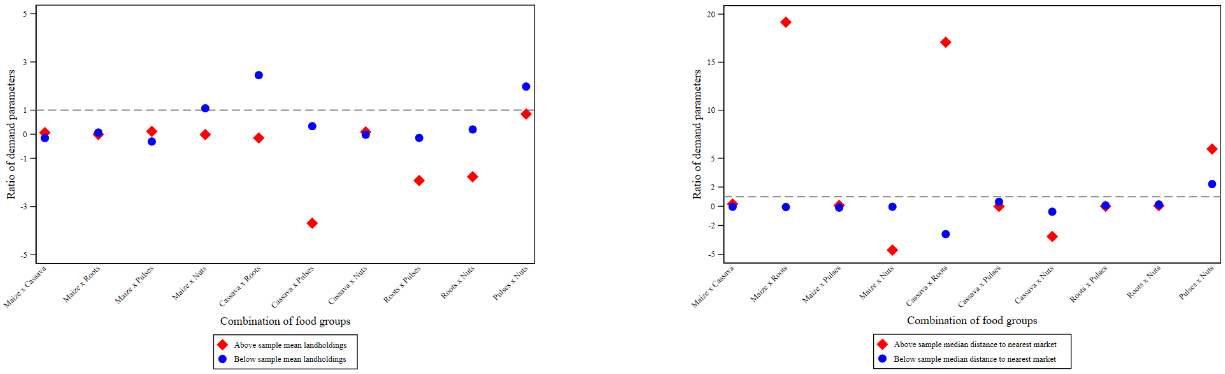
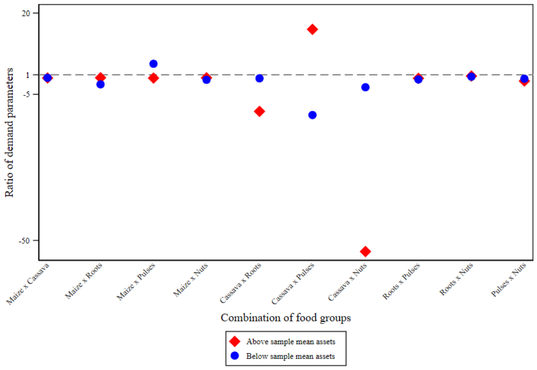
[6] The questionnaire does not provide further details on the type of distance considered in the data. More specifically, the questionnaire does not indicate whether it is a driving distance, walking distance, or simply a geographic distance. We assume the latter in our analysis. However, the results will not change significantly if other types of distance measure are considered for this purpose.

of the calculated Wald statistic associated with the ratios are very large, further suggesting that the separability hypothesis does not hold regardless of whether the farmer is wealthy or whether the farmer is near a local market. These latter results imply that further issues such as the difficulty for farmers to sell their output at the right price could be much more important in explaining the non-recursion of farming households' agricultural production and consumption decisions in Nigeria, hence supporting the overwhelming evidence in the literature of the importance of improving market conditions for smallholder farmers to enhance their livelihood conditions, through schemes such as well-defined and practical contract farmings, or farmers' cooperative sales.



(a) Landholdings

(b) Access to markets



(c) Value of assets

Figure 3.5: Separability test results by household landholdings, value of assets, and distance to nearest markets. The dots represent the calculated ratios using equation (3.13).

3.5.4 Robustness Checks

One major concern with our methodological approach is that we include nonfarm income, in the demand system total expenditures variable. The test is derived from the question of whether farming households maximize profits in the first stage and use the residual profits to purchase foods. A possible check to examine the robustness of the results regardless of whether we consider total household income or only farm income would be to restrict our analysis to households who do not have any other income sources apart from farm income.

We therefore consider households with farm income as the only source of income. To do that, we eliminate households that have at least one member who has worked for himself for any non-farm income generating activity (and whether the business is still functional or temporarily or seasonally closed). We also eliminate any household that has at least a member who has received any regular income, or any regular income from rental income, or any regular income of any other type. The resulting sample of households without another revenue apart from farm profits represents about 49% of our initial sample. The descriptive statistics for this sample is shown in table B.10. We note that income sources are not completely free of measurement errors because they are self-reported by farmers. Hence, there might be other possible sources of revenue that are not reported in the data. Nonetheless, we believe that this method eliminates to the extent possible households who have nonfarm revenue.

The results of the empirical test based on this new sample are presented on figure 3.6. More detailed results are presented in table B.12. Overall, the findings show that restricting the sample to households who only farm does not change our results. We reject the test of the null hypothesis in equation (3.14) for the restricted sample. As we can see on figure 3.6, the ratio of interest for each of the 10 combinations of food groups is statistically far from 1. Hence, we find that for this group of farming-only households, we also reject the null hypothesis that households follow a recursive decision process.

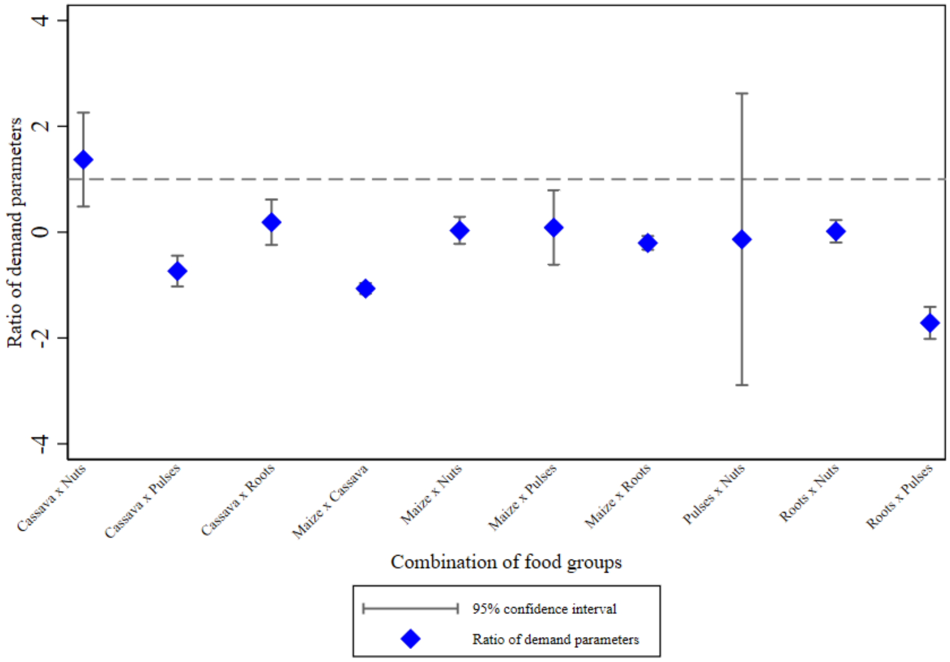


Figure 3.6: Ratio of demand parameters (separability test results) for households with only farming activities, with 95% confidence interval. The dots represent the calculated ratios using equation (3.13).

3.5.5 Using LaFave, Peet & Thomas (2020) Approach

We re-estimate the demand system using a vector of input unit values as A_{hjt} rather than land allocation. We then use the estimated demand parameters to test the hypothesis in equation (3.15), following the approach by LaFave et al. (2020). We note that given the fact that not all households have reported purchasing maize seed or using fertilizer, this approach applies to households for which we were able to calculate the median price of each input at the lowest administrative level (from enumeration area to zone). That means for each administrative division, we must have at least three households for which we were able to generate the unit value of the fertilizer or maize seed used during the agricultural season. If not, then all the households in this geographic area were excluded from our estimation sample. The results of the test are presented in table B.10. The test statistics (Wald statistic) in the table are calculated using equation (3.15) while the ratios are calculated by transforming equation (3.15) such that the ratios are comparable to 1, for ease of interpretation.

Table 3.4: Separability test results using LaFave, Peet and Thomas (2020) approach

	Budget share on food groups				
	(1)	(2)	(3)	(4)	(5)
	Maize	Cassava	Roots	Pulses	Nuts & seeds
Ratio of coefficients	-5.56	-0.54	1.44	22.15	1.50
(Fertilizer price/Maize seed price)	(11.74)	(1.72)	(3.08)	(291.24)	(84.50)
	Pairwise combination of food groups				
Maize					
Pairwise ratio (w.r.t food group)		10.26	10.26	-0.25	-3.72
Wald statistic		3,919.61	9,690.37	5,963.53	4,603.03
pvalue		0.00	0.00	0.00	0.00
Cassava					
Pairwise ratio			-0.38	-0.02	-0.36
Wald statistic			3,624.52	6,176.53	7,767.90
pvalue			0.00	0.00	0.00
Roots, tubers and other starches					
Pairwise ratio				0.06	0.96
Wald statistic				6,094.34	3,834.02
pvalue				0.00	0.00
Pulses					
Pairwise ratio					14.82
Wald statistic					15,589.63
pvalue					0.00
Obs.	7448	7448	7448	7448	7448

Notes: This table shows the ratio of coefficient estimates w.r.t to input prices, for each combination of food groups. The table also shows the wald statistic and p-value of the test. Robust standard errors are in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

As illustrated in the table, we find that the calculated ratios from the pairwise combinations of food groups are statistically different from 1. For instance, we find a ratio of 10.26 for the combination of maize and cassava food groups. More specifically, we find that the ratio of the marginal change in the demand for maize for a unit change in the market price of fertilizer to the marginal change in the demand for maize for a unit change in the market price of maize seed, is statistically different from the ratio of the marginal change in the demand for cassava for a unit change in the market price of fertilizer, to the marginal change in the demand for cassava for a unit change in the market price of maize seed. These results are indicative of market failure and are consistent with the findings of our main approach that uses land allocation information in the demand system.

3.5.6 Markets and nutrition

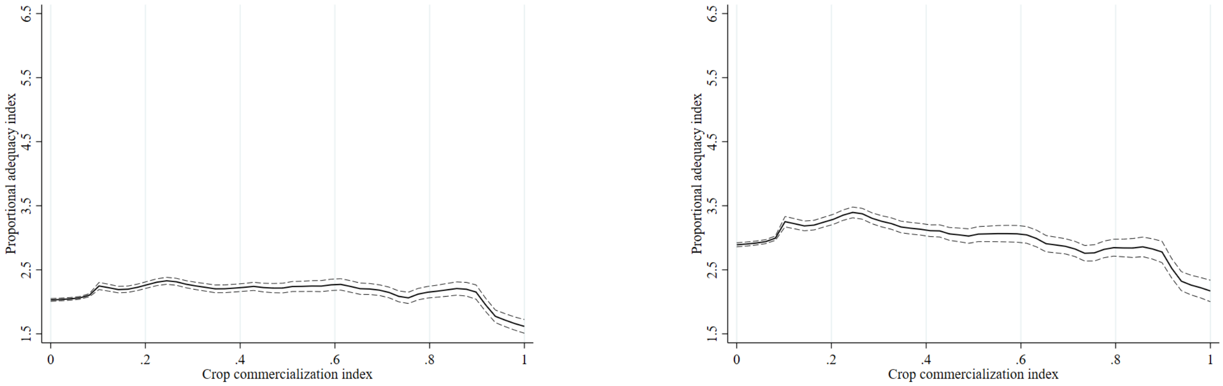
Our findings reflect the fact that smallholder farmers might rely more on their farm self-production for their food consumption rather than on their farm residual profits. In other words, the link between output sales, farm residual profits and household nutrition is weak. To further explore this finding, especially the role of market participation in household nutrition, we investigate the relationship between farming household's crop commercialization index (CCI) and some household's nutritional outcomes, using local polynomial regressions and a rich food item level nutrient content data.

For the nutritional outcomes, we consider separately the household's intakes of kcal, protein, iron, zinc, vitamin A, and folate. We also consider household's budget share on food goods as well as household's nutrient-rich food index (NRFI) which is an index that measures the amount of nutrient per calorie of food consumed or the nutrient density of the food, and hence the healthfulness of the overall diet (Drewnowski, 2010). To calculate the household nutrient intake and NRFI values, we use the nutrient content and the total quantity of food consumed. We calculate the crop commercialization index as the ratio of the gross values of crop sales to the gross values of all crop production following Carletto et al. (2017). The gross values are summed over all the crops produced by the household during the agricultural season. To reduce measurement errors in the computation of the output values, We focus on the sample of households who have completed their harvest. Figure 3.7 shows the relationships between crop commercialization index and household's nutrient intakes. The summary statistics of the nutrient intake variables are in table B.14.

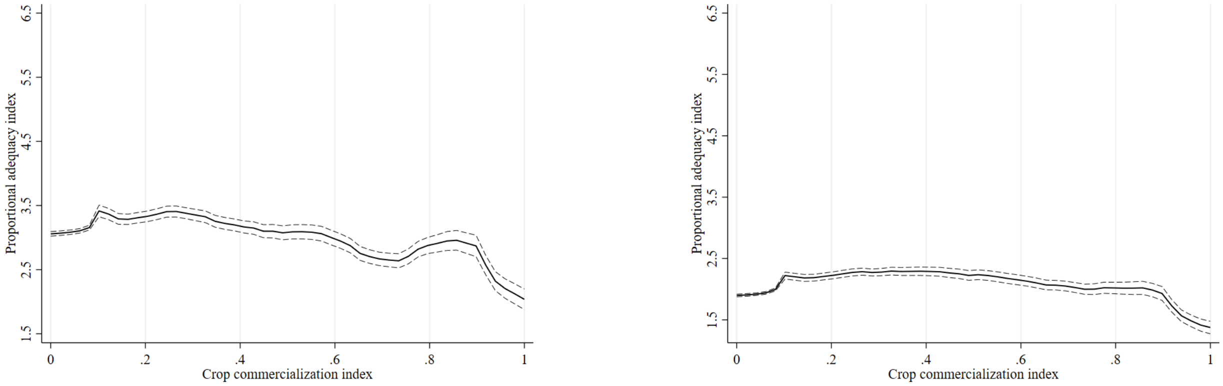
As per the figure, we find that except for vitamin A, selling farm output does not translate into increased household's nutrient intakes. Similarly, we find that except for cassava, crop commercialization does not increase the household budget share on staple foods such rice, maize, and wheat products or on fruits and vegetables (Figures B.2 and B.3). Figure B.4 also reveals a weak relationship between crop commercialization and nutrient-rich food index. These findings could be explained by the fact that farmers might not be selling output at a profit-maximizing price, or might not be generating the net margin from farm activities necessary to improve nutrition. The findings thus help explain our market failure results and align with previous literature indicating that market participation is not necessarily synonym of improved diet (Carletto et al., 2017), which reinforces the need for a nutrition sensitive agriculture policy while supporting farmers' market participation such as output price support interventions.

3.5.7 Discussions and Policy Implications

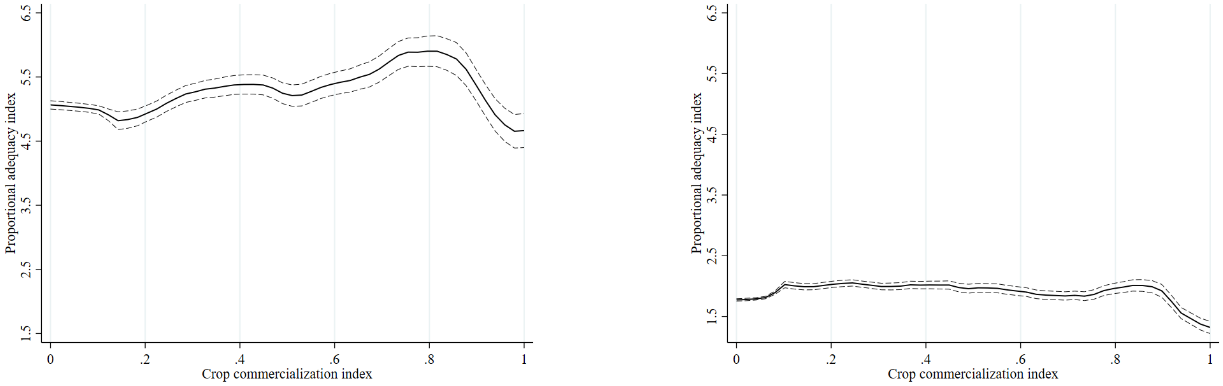
We find strong evidence that farmers do not trust agricultural markets and that the separability hypothesis according to the agricultural household model by Singh et al. (1986) does not hold. In other words, farmers do not grow what maximizes their profits in order to buy what they want to consume but instead are likely to produce what they want to consume. The results hold regardless of whether households live relatively far from local markets, or whether they are relatively wealthier. Hence, the findings reveal that Nigerian smallholder



(a) Kcal (b) Protein



(c) Iron (d) Zinc



(e) Vitamin A (f) Folate

Figure 3.7: Crop commercialization and household nutrient intakes.

farmers' cropping decisions affect their food consumption decisions. These results therefore support the evidence of the presence of market failure as documented by a large body of literature on Africa.

The resulting market failure could be explained by high transaction costs and by the fact that farmers are facing different market prices for the same products, potentially forcing some farmers to opt out of the market. This implies that a more effective strategy to help farming households improve their diet is to ameliorate agricultural market conditions while supporting a more nutrition-sensitive agriculture (Mulenga et al., 2021). This strategy should ensure to promote a diverse crop portfolio with the goal to improve households' diet but also to increase their farm profits.

Possible interventions to achieve this strategy include, but not limited to, helping farmers by improving the quality of their output, supporting the use of appropriate post-harvest technologies, and linking them with profitable markets through effective contract farming. This also includes interventions that promote the production of a mix of cash crops and staple crops to enhance the access to nutrient-dense foods, not just calorie-based staple foods. These interventions further include enhancing the nutritional quality of food crops by using improved and climate-resistant varieties. Although our paper is focused on Nigerian smallholder farmers, our findings have broader implications for diet improvement interventions in developing countries in general and in Africa in particular.

3.6 Conclusion

The recursive property of the agricultural household model implies that the household production decisions affect consumption decisions only through the residual farm profit effects. A failure of this property indicates that farmers face market failure. In this paper, we evaluate whether this property is verified for smallholder farmers in Nigeria. As opposed to most of the existing literature, we use a consumption side approach that relies on estimating a demand system over a set of 19 food groups and a non-food numeraire good. The canonical agricultural household model serves as the theoretical framework to develop our prediction that the ratio of the demand coefficients for two foods with respect to land allocated to one of the food goods is equal to the ratio of the expenditure coefficients of these two foods. We then use the estimated land allocation and expenditure parameters from the demand systems to test our prediction. The test is performed using pairwise combinations of five food groups, maize, cassava, nuts and seeds, pulses, and roots.

Our results show that the separability hypothesis fails to hold for all pairwise combinations of food groups, for our sample of study, implying that household production decisions affect consumption decisions through pathways other than through the residual farm profit effects. Specifically, we find that in Nigeria, farmers are growing what they want to eat, suggesting that their production and consumption decisions are jointly determined. This is a sign of incomplete markets in Nigerian agricultural sector. From a nutrition perspective, these results suggest that Nigerian farmers do not trust markets and that agricultural production plays an important role in households' diet. Hence, to improve diet for farmers, interventions should not only improve agricultural market conditions but also supports the production of a mix of nutrient-dense food crops and cash crops that raise households' income.

CHAPTER 4

CONCLUSIONS

In summary, this dissertation contributes to the understanding of two topics that receive less attention in the development economics literature – first, the impacts of early childhood health issues on maternal employment, second, the consumption-side approach of the household separability test and the linkages between farming households' production and consumption behaviors.

In Chapter 2, I showed that poor child health is negatively associated with the labor supply of mothers in Malawi, regardless of the mother's occupational choice, although the effects are not statistically significant. I also showed that education is an important predictor of mother's employment outcomes, and that mothers with some levels of education are more likely to engage in non-farm activities. The results underscore the importance of enhancing children's health conditions in Africa through well-designed agriculture, nutrition and health interventions. Future studies using natural experiment settings or randomized controls trials will contribute to provide further understanding of the issue of child health and household time allocation to productive activities in developing countries.

In Chapter 3, I showed that Nigerian farming households' food preferences are included in their farm production decisions, which violates the agricultural household separability hypothesis. From a policy perspective, to improve diet, these findings underscore the need to foster not only the income of farming households but also and more importantly the productivity of crops with diverse nutritional benefits. A more thorough investigation of the mechanisms that explain market failure and farming households' production and consumption behaviors using structural demand modelling is a fruitful area of future research.

APPENDIX A

ESSAY ONE

Table A.1: Sample description by wave

	Wave 1	Wave 2	Wave 3	Total
Nber of households	3303	954	501	4758
Nber of mothers	3308	965	523	4796
Mothers with boys only	1615	450	238	2303
Mothers with girls only	1596	483	262	2341
Mothers with both	97	32	23	152
Nber of children	3493	1038	577	5108

Table A.2: Children sample size by wave

	Wave 1	Wave 2	Wave 3	Total
Wave 1	3471	22	0	3493
Wave 2	22	1016	0	1038
Wave 3	0	0	577	577
Total	3493	1038	577	5108

Table A.3: Farm Labor Estimates With Binary Treatment Variable

		Labor participation (Extensive margin)			Nber of labor days (Intensive margin)		
	1st Stage	Reduced Form	OLS	2nd Stage	Reduced Form	OLS	2nd Stage
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Child is stunted=1			-0.0156	0.1227		0.0328	-1.0028
			(0.0194)	(0.6193)		(0.0855)	(2.7920)
Male child=1	0.0273	0.0033			-0.0274		
	(0.0181)	(0.0168)			(0.0740)		
Mother's age in years	0.0087	-0.0254***	-0.0253***	-0.0265**	-0.1153**	-0.1153**	-0.1065*
	(0.0115)	(0.0092)	(0.0092)	(0.0109)	(0.0490)	(0.0490)	(0.0559)
Mother's age squared	-0.0001	0.0005***	0.0005***	0.0005***	0.0022***	0.0022***	0.0021**
	(0.0002)	(0.0001)	(0.0001)	(0.0002)	(0.0008)	(0.0008)	(0.0009)
Mother has some education=1	-0.0232	-0.1898***	-0.1902***	-0.1870***	-0.4852***	-0.4845***	-0.5085***
	(0.0234)	(0.0254)	(0.0255)	(0.0291)	(0.0972)	(0.0972)	(0.1231)
Mother has a chronic disease=1	0.1064*	-0.1591***	-0.1573***	-0.1721**	-0.3650*	-0.3697*	-0.2583
	(0.0623)	(0.0533)	(0.0537)	(0.0843)	(0.1929)	(0.1946)	(0.3697)
Father's age in years	0.0006	-0.0024*	-0.0024*	-0.0025*	0.0053	0.0054	0.0059
	(0.0017)	(0.0012)	(0.0012)	(0.0013)	(0.0060)	(0.0060)	(0.0064)
Father labor participation=1	-0.0052	0.2780***	0.2776***	0.2786***	1.1791***	1.1814***	1.1739***
	(0.0463)	(0.0535)	(0.0537)	(0.0524)	(0.1061)	(0.1062)	(0.1232)
Child has siblings under five=1	-0.0327	0.0336*	0.0330*	0.0376	0.2023**	0.2036**	0.1695
	(0.0200)	(0.0184)	(0.0184)	(0.0260)	(0.0843)	(0.0845)	(0.1224)
Ratio dependent to active	0.0368**	0.0240*	0.0247*	0.0195	0.1289**	0.1267**	0.1658
	(0.0158)	(0.0133)	(0.0133)	(0.0271)	(0.0636)	(0.0641)	(0.1190)
Household landholdings (ha)	0.0003*	0.0004**	0.0004**	0.0003	0.0031***	0.0031***	0.0034***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0007)	(0.0007)	(0.0011)
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic	7.900	14.81	14.84	14.97	27.37	27.46	22.88
Observations	5104	5104	5104	5104	5104	5104	5104

Notes: This table reports the iv estimates of child stunting severity on maternal on-farm labor supply. The dependent variable in columns 2-4 is binary and equals 1 if positive number of labor days. The dependent variable in columns 5-7 is the weekly average number of labor days. The first column reports the first stage results. Reduced form estimates are shown in columns 2 and 5, and iv estimates are shown in columns 4 and 7. Robust standard errors in parentheses are clustered at the household level. *, **, *** indicate the statistical significance at the 10%, 5%, and 1% level, respectively.

Table A.4: Ganyu Labor Estimates With Binary Treatment Variable

		Labor participation (Extensive margin)			Nber of labor days (Intensive margin)		
	1st Stage	Reduced Form	OLS	2nd Stage	Reduced Form	OLS	2nd Stage
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Child is stunted=1			0.0071	-1.4718		-0.0192	-0.0785
			(0.0222)	(1.2316)		(0.0348)	(1.1739)
Male child=1	0.0273	-0.0402**			-0.0021		
	(0.0181)	(0.0192)			(0.0321)		
Mother's age in years	0.0087	0.0064	0.0067	0.0193	0.0353*	0.0355*	0.0360
	(0.0115)	(0.0127)	(0.0127)	(0.0233)	(0.0190)	(0.0190)	(0.0223)
Mother's age squared	-0.0001	-0.0001	-0.0001	-0.0003	-0.0005	-0.0005	-0.0005
	(0.0002)	(0.0002)	(0.0002)	(0.0004)	(0.0003)	(0.0003)	(0.0004)
Mother has some education=1	-0.0232	-0.2059***	-0.2058***	-0.2400***	-0.2031***	-0.2036***	-0.2050***
	(0.0234)	(0.0231)	(0.0232)	(0.0527)	(0.0321)	(0.0322)	(0.0434)
Mother has a chronic disease=1	0.1064*	0.1579***	0.1555***	0.3145*	0.1411	0.1430	0.1494
	(0.0623)	(0.0518)	(0.0524)	(0.1844)	(0.1096)	(0.1103)	(0.1873)
Father's age in years	0.0006	-0.0043**	-0.0042**	-0.0035	-0.0027	-0.0027	-0.0027
	(0.0017)	(0.0019)	(0.0018)	(0.0033)	(0.0034)	(0.0034)	(0.0035)
Father labor participation=1	-0.0052	0.0696	0.0726	0.0619	0.0718	0.0718	0.0714
	(0.0463)	(0.0440)	(0.0445)	(0.0872)	(0.0586)	(0.0589)	(0.0592)
Child has siblings under five=1	-0.0327	0.0190	0.0196	-0.0292	-0.0014	-0.0020	-0.0039
	(0.0200)	(0.0221)	(0.0221)	(0.0528)	(0.0381)	(0.0382)	(0.0509)
Ratio dependent to active	0.0368**	0.0185	0.0168	0.0727	0.0200	0.0207	0.0229
	(0.0158)	(0.0167)	(0.0167)	(0.0526)	(0.0261)	(0.0265)	(0.0486)
Household landholdings (ha)	0.0003*	0.0008***	0.0008***	0.0012**	0.0025***	0.0025***	0.0026***
	(0.0002)	(0.0001)	(0.0001)	(0.0005)	(0.0002)	(0.0002)	(0.0004)
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic	7.900	15.77	15.73	3.607	31.48	32.34	35.94
Observations	5104	5104	5104	5104	5104	5104	5104

Notes: This table reports the iv estimates of child stunting severity on maternal ganyu labor supply. The dependent variable in columns 2-4 is binary and equals 1 if positive number of labor days. The dependent variable in columns 5-7 is the weekly average number of casual paid farm labor days. The first column reports the first stage results. Reduced form estimates are shown in columns 2 and 5, and iv estimates are shown in columns 4 and 7. Robust standard errors in parentheses are clustered at the household level. *, **, *** indicate the statistical significance at the 10%, 5%, and 1% level, respectively.

Table A.5: Self-Employment Labor Estimates With Binary Treatment Variable

		Labor participation (Extensive margin)			Nber of labor days (Intensive margin)		
	1st Stage	Reduced Form	OLS	2nd Stage	Reduced Form	OLS	2nd Stage
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Child is stunted=1			0.0191	0.1849		0.1380	-0.6856
			(0.0189)	(0.6400)		(0.0997)	(3.1187)
Male child=1	0.0273	0.0050			-0.0187		
	(0.0181)	(0.0173)			(0.0832)		
Mother's age in years	0.0087	0.0012	0.0010	-0.0004	0.0433	0.0423	0.0493
	(0.0115)	(0.0114)	(0.0113)	(0.0122)	(0.0563)	(0.0562)	(0.0626)
Mother's age squared	-0.0001	0.0000	0.0000	0.0000	-0.0006	-0.0006	-0.0007
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0009)	(0.0009)	(0.0010)
Mother has some education=1	-0.0232	0.0908***	0.0913***	0.0951***	0.4416***	0.4447***	0.4257***
	(0.0234)	(0.0251)	(0.0251)	(0.0293)	(0.1329)	(0.1327)	(0.1593)
Mother has a chronic disease=1	0.1064*	0.0788	0.0770	0.0592	0.4696	0.4540	0.5426
	(0.0623)	(0.0566)	(0.0555)	(0.0899)	(0.3310)	(0.3230)	(0.5394)
Father's age in years	0.0006	0.0010	0.0010	0.0009	0.0074	0.0074	0.0078
	(0.0017)	(0.0019)	(0.0019)	(0.0019)	(0.0091)	(0.0091)	(0.0096)
Father labor participation=1	-0.0052	0.0274	0.0271	0.0283	0.1509	0.1533	0.1473
	(0.0463)	(0.0438)	(0.0440)	(0.0438)	(0.1938)	(0.1924)	(0.2035)
Child has siblings under five=1	-0.0327	0.0334	0.0340*	0.0395	0.1312	0.1359	0.1088
	(0.0200)	(0.0206)	(0.0206)	(0.0308)	(0.0962)	(0.0962)	(0.1371)
Ratio dependent to active	0.0368**	-0.0246	-0.0252*	-0.0314	-0.1157*	-0.1216*	-0.0905
	(0.0158)	(0.0151)	(0.0150)	(0.0294)	(0.0696)	(0.0692)	(0.1387)
Household landholdings (ha)	0.0003*	-0.0002**	-0.0002**	-0.0002	-0.0007**	-0.0007**	-0.0005
	(0.0002)	(0.0001)	(0.0001)	(0.0002)	(0.0003)	(0.0004)	(0.0009)
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic	7.900	6.464	6.439	6.137	5.803	5.738	5.880
Observations	5104	5104	5104	5104	5104	5104	5104

Notes: This table reports the iv estimates of child stunting severity on maternal self-employment labor. The dependent variable in columns 2-4 is binary and equals 1 if positive number of labor days. The dependent variable in columns 5-7 is the weekly average number of non-farm labor days. The first column reports the first stage results. Reduced form estimates are shown in columns 2 and 5, and iv estimates are shown in columns 4 and75. Robust standard errors in parentheses are clustered at the household level. *, **, *** indicate the statistical significance at the 10%, 5%, and 1% level, respectively.

Table A.6: Non-Farm Wage Labor Estimates With Binary Treatment Variable

		Labor participation (Extensive margin)			Nber of labor days (Intensive margin)		
	1st Stage	Reduced Form	OLS	2nd Stage	Reduced Form	OLS	2nd Stage
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Child is stunted=1			-0.0081	-0.1141		-0.0609**	-0.9782
			(0.0072)	(0.2885)		(0.0302)	(1.4926)
Male child=1	0.0273	-0.0031			-0.0267		
	(0.0181)	(0.0077)			(0.0378)		
Mother's age in years	0.0087	0.0085**	0.0086**	0.0095**	0.0513***	0.0520***	0.0598***
	(0.0115)	(0.0040)	(0.0040)	(0.0045)	(0.0190)	(0.0190)	(0.0222)
Mother's age squared	-0.0001	-0.0001**	-0.0001**	-0.0001**	-0.0007**	-0.0007**	-0.0009**
	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0003)	(0.0003)	(0.0004)
Mother has some education=1	-0.0232	0.0942***	0.0940***	0.0916***	0.4852***	0.4838***	0.4626***
	(0.0234)	(0.0155)	(0.0155)	(0.0162)	(0.0891)	(0.0888)	(0.0953)
Mother has a chronic disease=1	0.1064*	0.0208	0.0216	0.0330	0.0848	0.0903	0.1889
	(0.0623)	(0.0246)	(0.0246)	(0.0369)	(0.1335)	(0.1337)	(0.1856)
Father's age in years	0.0006	0.0006	0.0006	0.0006	-0.0019	-0.0018	-0.0014
	(0.0017)	(0.0007)	(0.0007)	(0.0007)	(0.0024)	(0.0024)	(0.0031)
Father labor participation=1	-0.0052	-0.0366	-0.0364	-0.0372	-0.0848	-0.0833	-0.0899
	(0.0463)	(0.0303)	(0.0303)	(0.0295)	(0.0940)	(0.0931)	(0.0981)
Child has siblings under five=1	-0.0327	-0.0038	-0.0040	-0.0075	-0.0294	-0.0312	-0.0615
	(0.0200)	(0.0076)	(0.0076)	(0.0118)	(0.0339)	(0.0339)	(0.0593)
Ratio dependent to active	0.0368**	-0.0255***	-0.0253***	-0.0213	-0.1027***	-0.1014***	-0.0668
	(0.0158)	(0.0063)	(0.0062)	(0.0135)	(0.0300)	(0.0293)	(0.0678)
Household landholdings (ha)	0.0003*	-0.0000	-0.0000	0.0000	-0.0000	-0.0000	0.0003
	(0.0002)	(0.0000)	(0.0000)	(0.0001)	(0.0001)	(0.0001)	(0.0004)
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic	7.900	4.856	4.855	4.758	3.512	3.516	3.175
Observations	5104	5104	5104	5104	5104	5104	5104

Notes: This table reports the iv estimates of child stunting severity on maternal non-farm wage labor supply. The dependent variable in columns 2-4 is binary and equals 1 if positive number of labor days. The dependent variable in columns 5-7 is the weekly average number of non-farm labor days. The first column reports the first stage results. Reduced form estimates are shown in columns 2 and 5, and iv estimates are shown in columns 4 and 7. Robust standard errors in parentheses are clustered at the household level. *, **, *** indicate the statistical significance at the 10%, 5%, and 1% level, respectively.

APPENDIX B

ESSAY TWO

Table B.1: Descriptive Statistics on Food Expenditures and Prices

	Average Share in Total Expenditures				Average Unit Value (NGN/kg)			
Food groups	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Grains								
Rice	0.098	0.099	0.084	0.068	0.195	0.194	0.191	0.207
Maize	0.052	0.040	0.031	0.019	0.107	0.109	0.112	0.120
Wheat2	0.153	0.113	0.083	0.061	0.149	0.153	0.153	0.164
Starches								
Cassava	0.025	0.028	0.025	0.021	0.090	0.093	0.094	0.101
Roots2	0.082	0.100	0.113	0.101	0.101	0.099	0.099	0.108
Sugar								
Sugar	0.017	0.015	0.013	0.009	0.276	0.295	0.308	0.337
Pulses & nuts								
Pulses	0.056	0.052	0.041	0.033	0.203	0.210	0.211	0.235
Nuts2	0.009	0.010	0.010	0.007	0.438	0.421	0.396	0.412
Fruits & vegetables								
Vegetables	0.077	0.070	0.063	0.053	0.170	0.164	0.166	0.180
Fruit	0.007	0.010	0.014	0.017	0.115	0.110	0.110	0.113
Animal source foods								
RedMeat	0.047	0.065	0.080	0.081	0.726	0.732	0.734	0.765
Poultry	0.004	0.008	0.017	0.017	0.783	0.794	0.798	0.780
Eggs	0.001	0.002	0.002	0.004	0.457	0.464	0.474	0.496
Fish2	0.054	0.064	0.069	0.076	0.523	0.557	0.568	0.636
Dairy	0.012	0.012	0.014	0.016	0.930	0.876	0.810	0.822
Oils & fats								
Fats2	0.078	0.064	0.051	0.038	0.285	0.282	0.279	0.288
Coffee & soft drink								
Coffee2	0.002	0.005	0.008	0.010	2.034	1.877	1.634	1.629
SoftDrink2	0.005	0.007	0.010	0.015	0.112	0.111	0.107	0.108
Other food								
OtherFood	0.013	0.011	0.008	0.007	0.278	0.289	0.293	0.323
Food (total)	0.791	0.772	0.738	0.654	0.205	0.228	0.249	0.266
Non-food	0.209	0.228	0.262	0.346				
N (total)	5064	4891	3069	902	5064	4891	3069	902

Notes: This table shows the mean value of each food group's share in total expenditures (and the non-food numéraire good's share) in columns 1-4 and each food group's mean unit value (and the non-food numéraire good's median unit value) in columns 5-8. Both budget shares and unit values are summarized by per-capita total expenditures quartile. Mean budget shares and prices are weighted using survey weights. The unit price for total food is also weighted by budget share. Food groups whose names have been shortened are marked with 2; the full food group names are listed here: 1. Rice 2. Maize 3. Wheat and other cereals 4. Cassava 5. Roots, Tubers and, other starches 6. Sugar 7. Pulses 8. Nuts and seeds 9. Vegetables 10. Fruit 11. Red meat 12. Poultry 13. Eggs 14. Fish and seafood 15. Dairy 16. Fats and oils 17. Coffee, tea, and cocoa 18. Soft drink and juice 19. Other foods.

Table B.2: Food crops and food items by food groups

Food groups	**Food crops**	**Food items**
Rice	Rice Unshelled rice(paddy) Shelled rice(milled)	Rice - local Rice - imported
Maize	Maize Unshelled maize(cob) Shelled maize(grain) Pop corn maize	Maize Maize flour
Wheat and cereals	Guinea courn/sorghum Millet/maiwa Wheat	Guinea corn/sorghum Millet Bread Yam flour Wheat flour Other grains and flour
Cassava	Cassava	Cassava flour Cassava - roots
Roots, tubers and other starches	Cocoyam Yam White yam Yellow yam Water yam Three leave yam Plantain Potato Sweet potato	Yam - roots Gari - white Gari - yellow Cocoyam Plantains Sweet potatoes Potatoes
Pulses	Beans/cowpea Pigeon pea Soya beans Locust bean	Soya beans Brown beans White beans
Nuts and seeds	Ground nut/peanuts Unshelled ground nuts Shelled ground nuts Melon Unshelled melon Water melon Bambara nut Beeni-seed/sesame Pumpkin Pumpkin fruit Pumpkin seed Cashew Agbono(oro seed)	Groundnuts Other nuts/seeds/pulses
Vegetables	Carrot Cucumber Cabbage Letus Garden egg Ginger Okro Onion Pepper Sweet pepper Small pepper Pumpkin leave Green vegetable Tomato	Tomatoes Tomato puree (canned) Onions Garden eggs/egg plant Okra - fresh Okra - dried Pepper Leaves (Cocoyam, Spinach, etc.) Other vegetables
Fruits	Banana Pineapple Sugar cane Mango Orange Fresh fruit bunch Avocado pear	Bananas Orange/tangerine Mangoes Avocado pear Pineapples Other fruits

Notes: The first column shows the food groups we use in the demand estimation and for the test . The second column shows the food crops for which we calculated the land allocation. The last column shows the food items consumed by households.

Table B.3: Food demand elasticities with respect to food prices and total household expenditures

	Rice	Maize	Wheat	Cassava	Roots	Sugar	Pulses	Nuts	Vegetables	Fruit	RedMeat	Poultry	Eggs	Fish	Dairy	Fats	Coffee	SoftDrink	OtherFood	Exp.
1. Rice	-0.70**	0.01	0.02	-0.12**	-0.08	-0.01	-0.11	0.06*	-0.08*	-0.05	0.09	-0.03	0.04	-0.03	-0.10*	-0.03	0.10**	0.11*	-0.05**	1.00**
	(0.10)	(0.04)	(0.08)	(0.04)	(0.07)	(0.03)	(0.06)	(0.03)	(0.03)	(0.05)	(0.08)	(0.05)	(0.05)	(0.05)	(0.05)	(0.03)	(0.03)	(0.04)	(0.01)	(0.12)
2. Maize	0.02	-0.54**	0.06	0.09	-0.09	-0.02	0.00	0.05	-0.06	0.06	0.08	-0.06	0.04	-0.07	-0.14**	0.06*	-0.02	-0.04	-0.03*	1.05**
	(0.07)	(0.10)	(0.12)	(0.06)	(0.10)	(0.03)	(0.06)	(0.04)	(0.04)	(0.06)	(0.09)	(0.09)	(0.07)	(0.06)	(0.05)	(0.03)	(0.04)	(0.06)	(0.01)	(0.18)
3. Wheat	0.03	0.04	-0.44	-0.08	0.00	-0.05	-0.04	0.09	0.01	-0.04	-0.06	0.04	0.09	0.08	-0.01	0.00	-0.01	0.04	0.01	0.93**
	(0.09)	(0.08)	(0.28)	(0.08)	(0.15)	(0.04)	(0.07)	(0.06)	(0.05)	(0.08)	(0.11)	(0.17)	(0.09)	(0.09)	(0.07)	(0.04)	(0.05)	(0.07)	(0.01)	(0.26)
4. Cassava	-0.19**	0.09	-0.17	-0.61**	-0.41**	0.07**	0.06	0.05	-0.04	0.15*	0.15	-0.09	0.10	-0.09	0.16**	-0.10**	0.08*	0.19**	0.03*	1.20**
	(0.07)	(0.06)	(0.12)	(0.09)	(0.11)	(0.02)	(0.06)	(0.04)	(0.03)	(0.06)	(0.08)	(0.08)	(0.06)	(0.07)	(0.05)	(0.03)	(0.04)	(0.05)	(0.01)	(0.19)
5. Roots	-0.09	-0.07	-0.02	-0.27**	-0.68**	-0.01	0.02	-0.03	-0.06	0.04	-0.09	0.06	-0.11	0.07	-0.01	-0.08*	-0.06	-0.05	-0.02	1.16**
	(0.08)	(0.07)	(0.17)	(0.10)	(0.17)	(0.03)	(0.07)	(0.05)	(0.04)	(0.07)	(0.08)	(0.13)	(0.09)	(0.09)	(0.06)	(0.04)	(0.05)	(0.06)	(0.01)	(0.23)
6. Sugar	-0.04	-0.07	-0.28*	0.19**	-0.02	-0.68**	-0.32**	0.07	0.16**	-0.24**	0.30*	0.09	0.26**	-0.28*	-0.14	0.19**	-0.18**	-0.32**	-0.01	1.14**
	(0.11)	(0.08)	(0.13)	(0.06)	(0.12)	(0.07)	(0.09)	(0.05)	(0.05)	(0.08)	(0.12)	(0.07)	(0.09)	(0.12)	(0.08)	(0.05)	(0.05)	(0.07)	(0.02)	(0.18)
7. Pulses	-0.19	-0.01	-0.11	0.08	0.05	-0.14**	-0.46**	0.03	-0.05	0.05	0.01	-0.04	0.12	0.08	0.12	-0.25**	-0.07	0.06	0.01	1.10**
	(0.10)	(0.06)	(0.11)	(0.06)	(0.10)	(0.04)	(0.12)	(0.04)	(0.04)	(0.06)	(0.10)	(0.06)	(0.08)	(0.08)	(0.07)	(0.05)	(0.04)	(0.07)	(0.01)	(0.15)
8. Nuts	0.16	0.10	0.35	0.10	-0.13	0.05	0.04	-0.73**	-0.11*	-0.01	-0.19	0.07	0.08	-0.18	-0.03	0.01	0.02	0.09	-0.03	1.31**
	(0.10)	(0.10)	(0.18)	(0.09)	(0.16)	(0.04)	(0.09)	(0.08)	(0.05)	(0.08)	(0.11)	(0.12)	(0.10)	(0.10)	(0.08)	(0.04)	(0.05)	(0.08)	(0.02)	(0.25)
9. Vegetables	-0.09*	-0.06*	0.04	-0.02	-0.06	0.07**	-0.03	-0.04*	-0.85**	0.05	-0.02	0.02	0.17**	0.09**	0.03	-0.06**	-0.00	0.03	-0.01	0.78**
	(0.04)	(0.03)	(0.05)	(0.02)	(0.04)	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.01)	(0.07)
10. Fruit	-0.26	0.14	-0.30	0.40*	0.09	-0.28**	0.07	-0.01	0.08	-1.55**	-0.27	-0.35	-0.19	0.07	-0.23	-0.30**	0.05	0.15	-0.01	1.75**
	(0.21)	(0.15)	(0.35)	(0.16)	(0.24)	(0.09)	(0.14)	(0.09)	(0.09)	(0.18)	(0.20)	(0.26)	(0.15)	(0.15)	(0.14)	(0.10)	(0.10)	(0.14)	(0.03)	(0.45)
11. RedMeat	0.02	0.04	-0.21	0.10	-0.16	0.08*	-0.03	-0.07	-0.08	-0.07	-0.72**	-0.19**	0.13*	0.03	-0.03	-0.05	0.03	-0.09	0.06**	1.81**
	(0.09)	(0.07)	(0.13)	(0.06)	(0.10)	(0.03)	(0.07)	(0.04)	(0.05)	(0.06)	(0.13)	(0.07)	(0.06)	(0.07)	(0.06)	(0.03)	(0.04)	(0.06)	(0.02)	(0.19)
12. Poultry	-0.24*	-0.15	-0.18	-0.12	-0.10	-0.01	-0.13*	-0.00	-0.14	-0.12	-0.36**	-0.88*	0.03	-0.19	-0.02	-0.14*	-0.07	-0.02	-0.04*	3.24**
	(0.10)	(0.09)	(0.27)	(0.08)	(0.17)	(0.03)	(0.07)	(0.04)	(0.08)	(0.08)	(0.10)	(0.36)	(0.07)	(0.11)	(0.09)	(0.06)	(0.05)	(0.06)	(0.02)	(0.66)
13. Eggs	0.12	0.14	0.64	0.41	-0.86	0.41*	0.36	0.14	0.62*	-0.33	0.69	0.17	-0.93	0.09	0.23	-0.05	-0.23	0.00	0.07	1.90*
	(0.46)	(0.34)	(0.70)	(0.34)	(0.71)	(0.18)	(0.37)	(0.22)	(0.25)	(0.32)	(0.45)	(0.49)	(0.57)	(0.39)	(0.31)	(0.17)	(0.23)	(0.33)	(0.07)	(0.94)
14. Fish	-0.06	-0.09	0.11	-0.08	0.09	-0.11*	0.06	-0.07	0.05	0.04	0.06	-0.04	0.03	-0.80**	-0.02	-0.11**	-0.02	-0.05	0.01	1.23**
	(0.09)	(0.07)	(0.15)	(0.07)	(0.13)	(0.05)	(0.08)	(0.05)	(0.04)	(0.06)	(0.09)	(0.11)	(0.08)	(0.13)	(0.07)	(0.04)	(0.05)	(0.06)	(0.02)	(0.23)
15. Dairy	-0.33*	-0.32**	-0.12	0.32**	-0.07	-0.12	0.19	-0.03	0.02	-0.18	-0.09	0.03	0.12	-0.08	-0.84**	-0.00	0.00	-0.10	-0.01	1.53**
	(0.16)	(0.11)	(0.23)	(0.12)	(0.18)	(0.06)	(0.12)	(0.07)	(0.07)	(0.11)	(0.16)	(0.21)	(0.12)	(0.14)	(0.15)	(0.06)	(0.07)	(0.11)	(0.02)	(0.35)
16. Fats	-0.00	0.09**	0.04	-0.09**	-0.09*	0.09**	-0.22**	0.02	-0.05**	-0.10**	0.01	-0.01	0.00	-0.09**	0.02	-0.68**	-0.02	-0.05*	-0.02*	0.70**
	(0.03)	(0.03)	(0.05)	(0.02)	(0.04)	(0.02)	(0.03)	(0.01)	(0.02)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.01)	(0.02)	(0.01)	(0.07)
17. Coffee	0.39	-0.15	-0.23	0.30	-0.47	-0.30**	-0.33	0.02	-0.12	0.06	0.07	-0.31	-0.20	-0.15	-0.01	-0.17	-0.83**	-0.05	-0.01	2.62**
	(0.24)	(0.19)	(0.40)	(0.18)	(0.32)	(0.09)	(0.17)	(0.10)	(0.12)	(0.18)	(0.24)	(0.30)	(0.19)	(0.23)	(0.16)	(0.10)	(0.16)	(0.15)	(0.04)	(0.66)
18. SoftDrink	0.47	-0.19	0.17	0.66**	-0.33	-0.45**	0.14	0.14	0.02	0.18	-0.44	-0.03	0.01	-0.24	-0.16	-0.22*	-0.04	-1.00**	0.18**	1.88**
	(0.26)	(0.21)	(0.38)	(0.22)	(0.32)	(0.12)	(0.22)	(0.12)	(0.11)	(0.20)	(0.30)	(0.25)	(0.23)	(0.23)	(0.20)	(0.11)	(0.12)	(0.21)	(0.05)	(0.59)
19. OtherFood	-0.30**	-0.10*	0.08	0.14**	-0.13*	-0.00	0.04	-0.05	-0.04	-0.00	0.40**	-0.03	0.09	0.09	-0.01	-0.06*	0.01	0.22**	-0.56**	0.82**
	(0.06)	(0.05)	(0.08)	(0.04)	(0.07)	(0.03)	(0.05)	(0.03)	(0.03)	(0.04)	(0.08)	(0.05)	(0.05)	(0.05)	(0.04)	(0.03)	(0.03)	(0.05)	(0.04)	(0.10)

Note: This table shows the sample-wide median elasticity of food demand (quantity consumed) with respect to food prices (columns 1 thru 19) and total household expenditures (the last column). Robust standard errors are in parentheses. * $p < 0.05$; ** $p < 0.01$

Table B.4: Demand coefficient estimates (by household landholdings)

Variables	Dep. Var.: Budget share on foods									
	Above median landholdings					Below median landholdings				
	Maize (1)	Cassava (2)	Roots (3)	Pulses (4)	Nuts (5)	Maize (6)	Cassava (7)	Roots (8)	Pulses (9)	Nuts (10)
	Land allocation estimates									
Maize	-0.0108	-0.0002	0.0168	0.0009	0.1871**	-0.0124	0.0016	-0.0199	-0.0528***	0.0577
	(0.0121)	(0.0106)	(0.0315)	(0.0104)	(0.0876)	(0.0131)	(0.0128)	(0.0249)	(0.0199)	(0.1141)
Cassava	0.0019	0.0005	-0.0285	-0.0244**	-0.2070**	-0.0001	-0.0017	0.0017	-0.0195	0.0833
	(0.0170)	(0.0133)	(0.0383)	(0.0120)	(0.0861)	(0.0107)	(0.0100)	(0.0124)	(0.0189)	(0.1052)
Roots	0.0239**	0.0169	0.0317	0.0032	0.0992	0.0029	-0.0042	0.0187	-0.0191	0.0906
	(0.0120)	(0.0119)	(0.0262)	(0.0101)	(0.0857)	(0.0106)	(0.0101)	(0.0126)	(0.0194)	(0.1094)
Pulses	0.0638***	0.0209	0.1738***	-0.0042	0.2575***	0.0114	0.0101	0.0084	-0.0403	-0.0489
	(0.0173)	(0.0129)	(0.0416)	(0.0131)	(0.0986)	(0.0254)	(0.0256)	(0.0780)	(0.0361)	(0.3275)
Nuts	0.0268	0.0101	-0.1500***	-0.0086	-0.3757***	-0.0011	0.0109	0.0036	-0.0318	0.1188
	(0.0176)	(0.0140)	(0.0448)	(0.0145)	(0.0920)	(0.0166)	(0.0155)	(0.0258)	(0.0259)	(0.1564)
	Expenditure estimates									
Expenditure (1st deg. poly.)	0.0478***	0.0044	0.0610***	0.0528***	0.4124***	-0.0073	-0.0043	0.0313***	0.0528***	0.0792
	(0.0096)	(0.0080)	(0.0193)	(0.0092)	(0.0661)	(0.0085)	(0.0073)	(0.0075)	(0.0142)	(0.0617)
Expenditure (2nd deg. poly.)	0.0020	-0.0006	-0.0014	-0.0165*	0.0336	-0.0077	0.0095	0.0002	-0.0513***	0.2357**
	(0.0068)	(0.0048)	(0.0076)	(0.0092)	(0.0667)	(0.0095)	(0.0085)	(0.0123)	(0.0170)	(0.1117)
Expenditure (3rd deg. poly.)	-0.0112*	-0.0118**	-0.0077	-0.0036	-0.0507	0.0041	-0.0011	-0.0095**	0.0030	-0.0058
	(0.0062)	(0.0052)	(0.0108)	(0.0067)	(0.0477)	(0.0052)	(0.0045)	(0.0047)	(0.0089)	(0.0417)
Expenditure (4th deg. poly.)	-0.0063***	-0.0019	-0.0008	0.0001	-0.0160	0.0014	-0.0026	-0.0016	0.0078	-0.0829**
	(0.0021)	(0.0015)	(0.0028)	(0.0020)	(0.0140)	(0.0027)	(0.0025)	(0.0034)	(0.0053)	(0.0358)
	(Expenditure x Price) estimates									
Expenditure x Maize	-0.0056					0.0035				
	(0.0056)					(0.0051)				
Expenditure x Cassava	-0.0000	0.0188***				0.0050	0.0093			
	(0.0032)	(0.0044)				(0.0039)	(0.0065)			
Expenditure x Roots	-0.0000	-0.0078*	0.0372***			0.0011	-0.0254***	0.0365***		
	(0.0056)	(0.0041)	(0.0087)			(0.0043)	(0.0052)	(0.0082)		
Expenditure x Pulses	-0.0045	-0.0124*	-0.0028	0.0342		0.0064	-0.0119	0.0206**	0.0330	
	(0.0063)	(0.0067)	(0.0083)	(0.0209)		(0.0072)	(0.0081)	(0.0089)	(0.0206)	
Expenditure x Nuts	-0.0039	0.0418***	0.0072	0.0136	0.2949***	0.0074	0.0003	0.0222**	-0.0072	0.1097
	(0.0099)	(0.0091)	(0.0137)	(0.0105)	(0.0758)	(0.0068)	(0.0063)	(0.0089)	(0.0115)	(0.0857)
Obs.	8022	8022	8022	8022	8022	5904	5904	5904	5904	5904

Notes: This table shows the coefficient estimates of food demand (budget share) w.r.t land allocated to food group, w.r.t total household expenditures at the 1st, 2nd, 3rd, and 4th degree polynomial, and w.r.t interactions btw prices and expenditures. The table shows the results for households below and above the sample median value of household landholdings. Robust standard errors are in parentheses. *, **, *** denotes significance at the 10%, 5%, and 1% level.

Table B.5: Separability test results for households above and below sample median landholdings

Food groups	Above median landholdings				Below median landholdings			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Cassava	Roots	Pulses	Nuts	Cassava	Roots	Pulses	Nuts
Test of ratios of parameters w.r.t food group:								
Maize								
Ratio 1 (w.r.t fertilizer price)	0.12	-0.07	-0.18	0.14	-2.99	-3.25	-2.43	-8.86
	(1.01)	(23.51)	(0.76)	(12.36)	(152.79)	(375.42)	(6.97)	(7.69)
Ratio 2 (w.r.t maize seed price)	1.85**	8.81**	-1.49*	-9.32**	18.89**	-47.74**	8.02**	-8.22
	(0.71)	(0.42)	(1.06)	(0.77)	(1.65)	(3.83)	(1.21)	(16.00)
Ratio 1 / Ratio 2	0.07	-0.01	0.12	-0.01	-0.16	0.07	-0.30**	1.08**
	(26.47)	(12.43)	(21.85)	(2.70)	(0.42)	(0.17)	(0.11)	(0.15)
Wald statistic	1,283.70	670.67	1,274.46	7,371.94	873.51	777.59	931.60	734.39
pvalue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cassava								
Ratio 1		-0.60	-1.43**	1.11		1.09	0.81	2.97
		(26.91)	(0.63)	(102.21)		(0.81)	(4.09)	(16,136.18)
Ratio 2		3.90**	0.39	11.53**		0.44	2.43**	-138.13**
		(0.53)	(1.26)	(0.76)		(1.90)	(1.00)	(6.82)
Ratio 1 / Ratio 2		-0.15	-3.69	0.10		2.45	0.33	-0.02
		(1.88)	(3.09)	(0.77)		(5.03)	(1.05)	(0.85)
Wald statistic		688.06	2,040.86	2,297.76		1,322.78	3,408.08	1,222.50
pvalue		0.00	0.00	0.00		0.00	0.00	0.00
Roots, tubers and other starches								
Ratio 1			2.39	-1.86			0.75	2.73
			(2.87)	(1.85)			(5.30)	(49.03)
Ratio 2			-1.24	1.06			-4.94**	13.77**
			(2.45)	(0.91)			(0.79)	(5.53)
Ratio 1 / Ratio 2			-1.92*	-1.76**			-0.15	0.20
			(1.29)	(0.88)			(0.33)	(0.27)
Wald statistic			746.37	969.19			3,664.17	1,875.64
pvalue			0.00	0.00			0.00	0.00
Pulses								
Ratio 1				-0.78				3.65
				(0.61)				(5.47)
Ratio 2				-0.93				1.85
				(0.82)				(6.79)
Ratio 1 / Ratio 2				0.84				1.98*
				(1.67)				(1.24)
Wald statistic				2,076.05				7,015.92
pvalue				0.00				0.00
Obs.	8022	8022	8022	8022	5904	5904	5904	5904

Notes: This table shows the ratio of coefficient estimates w.r.t to land allocations and total household expenditures, for each combination of food groups, and for households above and below median landholdings. The table also shows the wald statistic and p-value of the test. Robust standard errors are in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Table B.6: Demand coefficient estimates (by access to markets)

Variables	Dep. Var.: Budget share on foods									
	Above median distance to markets					Below median distance to markets				
	Maize (1)	Cassava (2)	Roots (3)	Pulses (4)	Nuts (5)	Maize (6)	Cassava (7)	Roots (8)	Pulses (9)	Nuts (10)
	Land allocation estimates									
Maize	0.0100	-0.0424***	-0.0417**	-0.0368*	0.2259**	-0.0082	0.0143	-0.0138	-0.0471**	0.1367
	(0.0079)	(0.0159)	(0.0180)	(0.0216)	(0.1058)	(0.0138)	(0.0168)	(0.0172)	(0.0222)	(0.1596)
Cassava	0.0161*	-0.0325**	-0.0460**	-0.0608***	0.1098	0.0179**	-0.0121	-0.0063	0.0408**	-0.3187**
	(0.0088)	(0.0155)	(0.0209)	(0.0190)	(0.0936)	(0.0081)	(0.0123)	(0.0116)	(0.0195)	(0.1447)
Roots	-0.0057	-0.0102	-0.0357	0.0003	0.0476	-0.0083	-0.0028	0.0030	-0.0164	0.0220
	(0.0094)	(0.0190)	(0.0238)	(0.0237)	(0.1136)	(0.0082)	(0.0120)	(0.0107)	(0.0198)	(0.1454)
Pulses	-0.0162*	0.0557***	0.0391**	0.0628***	-0.3537***	-0.1083***	0.1387***	-0.1457***	-0.1524***	1.1579***
	(0.0086)	(0.0183)	(0.0199)	(0.0244)	(0.1296)	(0.0304)	(0.0346)	(0.0389)	(0.0390)	(0.2794)
Nuts	0.0170**	0.0216	0.0294	0.0523**	-0.1248	0.0946***	-0.1019***	0.0899***	0.1256***	-0.9435***
	(0.0073)	(0.0194)	(0.0232)	(0.0210)	(0.1095)	(0.0242)	(0.0299)	(0.0317)	(0.0338)	(0.2697)
	Expenditure estimates									
Expenditure (1st deg. poly.)	-0.0008	-0.0286***	-0.0042	0.0734***	0.2858***	0.0110**	-0.0142**	0.0183**	0.0756***	0.2806***
	(0.0064)	(0.0086)	(0.0146)	(0.0148)	(0.0608)	(0.0049)	(0.0072)	(0.0078)	(0.0139)	(0.0840)
Expenditure (2nd deg. poly.)	-0.0177***	-0.0139***	0.0064	0.0104	0.0156	-0.0078	-0.0077	0.0076	-0.0647***	0.0258
	(0.0057)	(0.0051)	(0.0128)	(0.0137)	(0.0462)	(0.0074)	(0.0098)	(0.0121)	(0.0198)	(0.1028)
Expenditure (3rd deg. poly.)	0.0038	0.0177***	0.0274***	-0.0025	-0.0207	-0.0054**	0.0073	-0.0038	-0.0062	0.0514
	(0.0042)	(0.0054)	(0.0103)	(0.0099)	(0.0374)	(0.0027)	(0.0049)	(0.0053)	(0.0078)	(0.0551)
Expenditure (4th deg. poly.)	0.0007	0.0064***	0.0064**	-0.0035	-0.0001	0.0054**	-0.0015	-0.0031	0.0201***	-0.1054**
	(0.0017)	(0.0015)	(0.0026)	(0.0029)	(0.0106)	(0.0023)	(0.0034)	(0.0039)	(0.0066)	(0.0410)
	(Expenditure x Price) estimates									
Expenditure x Maize	-0.0037					-0.0020				
	(0.0053)					(0.0035)				
Expenditure x Cassava	0.0011	0.0177***				0.0060	0.0208***			
	(0.0029)	(0.0044)				(0.0043)	(0.0079)			
Expenditure x Roots	-0.0108**	-0.0070	0.0223*			-0.0034	-0.0125*	0.0157		
	(0.0055)	(0.0052)	(0.0134)			(0.0049)	(0.0071)	(0.0098)		
Expenditure x Pulses	-0.0094	0.0069	-0.0055	-0.0045		0.0005	-0.0223**	0.0144	0.0729***	
	(0.0068)	(0.0068)	(0.0112)	(0.0212)		(0.0058)	(0.0096)	(0.0097)	(0.0215)	
Expenditure x Nuts	-0.0043	0.0104	0.0043	0.0078	0.0615	-0.0004	0.0083	-0.0105	-0.0105	0.0511
	(0.0070)	(0.0073)	(0.0157)	(0.0129)	(0.0561)	(0.0054)	(0.0068)	(0.0077)	(0.0134)	(0.0761)
Obs.	7202	7202	7202	7202	7202	6724	6724	6724	6724	6724

Notes: This table shows the coefficient estimates of food demand (budget share) w.r.t land allocated to food group, w.r.t total household expenditures at the 1st, 2nd, 3rd, and 4th degree polynomial, and w.r.t interactions btw prices and expenditures. The table shows the results for households living below and above the sample median distance to nearest markets. Robust standard errors are in parentheses. *, **, *** denotes significance at the 10%, 5%, and 1% level.

Table B.7: Separability test results for households above and below sample median distance to nearest markets

Food groups	Above median landholdings				Below median landholdings			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Cassava	Roots	Pulses	Nuts	Cassava	Roots	Pulses	Nuts
Test of ratios of parameters w.r.t food group:								
Maize								
Ratio 1 (w.r.t land allocation)	-0.77	-21.15**	-1.11	14.19**	-0.17	-0.42	0.72	0.43
	(4.85)	(1.28)	(54.80)	(4.83)	(8.59)	(11.08)	(4.39)	(11.03)
Ratio 2 (w.r.t expenditure)	-3.27**	-1.10	-12.59**	-3.11	3.49**	5.44**	-5.14*	-8.81**
	(0.35)	(161.31)	(0.59)	(33.20)	(0.72)	(2.37)	(3.14)	(1.90)
Ratio 1 / Ratio 2	0.23	19.17**	0.09	-4.56**	-0.05	-0.08	-0.14	-0.05
	(0.77)	(1.18)	(0.32)	(0.33)	(8.41)	(2.39)	(0.94)	(0.69)
Wald statistic	1,232.47	529.84	842.37	500.15	1,111.25	819.19	2,313.18	2,963.63
pvalue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cassava								
Ratio 1		27.60**	1.45	-18.52**		2.40**	-4.12	-2.46*
		(0.51)	(5,363.22)	(2.94)		(0.13)	(8.71)	(1.51)
Ratio 2		1.62	-254.39**	5.89		-0.83	-8.84*	4.36*
		(216.54)	(0.40)	(41.42)		(5.29)	(5.63)	(2.43)
Ratio 1 / Ratio 2		17.08**	-0.01	-3.15**		-2.90**	0.47**	-0.57**
		(0.29)	(0.08)	(0.10)		(1.18)	(0.13)	(0.19)
Wald statistic		1,667.19	2,930.24	1,657.39		607.73	825.06	918.36
pvalue		0.00	0.00	0.00		0.00	0.00	0.00
Roots, tubers and other starches								
Ratio 1			0.05	-0.67			-1.72	-1.03
			(38.69)	(21.03)			(59.48)	(4.21)
Ratio 2			-18.87**	-11.31**			-18.45**	-5.58**
			(0.42)	(5.10)			(3.19)	(1.62)
Ratio 1 / Ratio 2			-0.00	0.06			0.09	0.18
			(8.60)	(0.75)			(0.19)	(0.31)
Wald statistic			3,540.74	1,237.78			1,472.26	2,741.34
pvalue			0.00	0.00			0.00	0.00
Pulses								
Ratio 1				-12.77**				0.60**
				(1.15)				(0.11)
Ratio 2				-2.14				0.26
				(28.37)				(0.53)
Ratio 1 / Ratio 2				5.96**				2.31
				(0.27)				(7.39)
Wald statistic				5,003.33				16,198.05
pvalue				0.00				0.00
Obs.	7202	7202	7202	7202	6724	6724	6724	6724

Notes: This table shows the ratio of coefficient estimates w.r.t to land allocations and total household expenditures, for each combination of food groups, and for households above and below median distance to markets. The table also shows the wald statistic and p-value of the test. Robust standard errors are in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Table B.8: Demand coefficient estimates (by value of household assets)

Variables	Dep. Var.: Budget share on foods									
	Above median assets					Below median assets				
	Maize (1)	Cassava (2)	Roots (3)	Pulses (4)	Nuts (5)	Maize (6)	Cassava (7)	Roots (8)	Pulses (9)	Nuts (10)
	Land allocation estimates									
Maize	0.0065	-0.0123	0.0174*	-0.0118	-0.0022	-0.0093	0.0436*	-0.0786*	-0.1314***	-0.5193**
	(0.0085)	(0.0077)	(0.0089)	(0.0090)	(0.0427)	(0.0164)	(0.0237)	(0.0429)	(0.0465)	(0.2220)
Cassava	0.0162**	0.0122	-0.0013	0.0072	0.0842*	-0.0314	0.0719**	-0.0272	-0.1163**	-0.1257
	(0.0081)	(0.0118)	(0.0102)	(0.0117)	(0.0499)	(0.0195)	(0.0357)	(0.0336)	(0.0557)	(0.1769)
Roots	0.0064	0.0023	0.0021	-0.0010	0.0768*	0.0123	-0.0202	0.0080	0.0321	-0.0646
	(0.0081)	(0.0103)	(0.0096)	(0.0103)	(0.0460)	(0.0234)	(0.0386)	(0.0381)	(0.0608)	(0.1759)
Pulses	-0.0054	-0.0030	-0.0003	-0.0124	-0.0486	-0.0091	0.0362	-0.0701	-0.1049	-0.1433
	(0.0117)	(0.0091)	(0.0119)	(0.0113)	(0.0518)	(0.0200)	(0.0309)	(0.0645)	(0.0666)	(0.3591)
Nuts	0.0288***	-0.0066	0.0007	0.0153	0.0045	0.0338	0.0706*	-0.2261***	-0.2144***	-1.2127***
	(0.0095)	(0.0081)	(0.0100)	(0.0110)	(0.0493)	(0.0215)	(0.0383)	(0.0628)	(0.0702)	(0.3631)
	Expenditure estimates									
Expenditure (1st deg. poly.)	0.0246***	-0.0248**	0.0099	0.0575***	0.2736***	0.0031	-0.0075	0.0860***	0.1385***	0.5241***
	(0.0069)	(0.0099)	(0.0069)	(0.0092)	(0.0404)	(0.0077)	(0.0130)	(0.0213)	(0.0266)	(0.1068)
Expenditure (2nd deg. poly.)	-0.0068	0.0238**	0.0112	0.0126	0.1051**	0.0000	0.0076	0.0387***	0.0141	0.0378
	(0.0118)	(0.0105)	(0.0096)	(0.0109)	(0.0535)	(0.0061)	(0.0082)	(0.0146)	(0.0184)	(0.0858)
Expenditure (3rd deg. poly.)	-0.0125**	-0.0038	0.0157***	-0.0053	-0.0832***	0.0009	-0.0026	-0.0214*	-0.0161	-0.0182
	(0.0051)	(0.0085)	(0.0052)	(0.0077)	(0.0292)	(0.0037)	(0.0054)	(0.0125)	(0.0131)	(0.0654)
Expenditure (4th deg. poly.)	0.0085*	-0.0325***	-0.0037	-0.0242***	-0.0219	-0.0019	-0.0007	-0.0084**	-0.0075*	-0.0230
	(0.0047)	(0.0050)	(0.0040)	(0.0050)	(0.0225)	(0.0015)	(0.0016)	(0.0034)	(0.0042)	(0.0292)
	(Expenditure x Price) estimates									
Expenditure x Maize	-0.0067					0.0080**				
	(0.0075)					(0.0041)				
Expenditure x Cassava	-0.0024	0.0260***				0.0006	0.0041			
	(0.0034)	(0.0057)				(0.0034)	(0.0051)			
Expenditure x Roots	-0.0017	-0.0027	0.0068			-0.0216***	-0.0138**	-0.0103		
	(0.0047)	(0.0039)	(0.0060)			(0.0053)	(0.0060)	(0.0131)		
Expenditure x Pulses	-0.0159***	-0.0170**	-0.0110	0.0414***		0.0036	-0.0092	0.0199	0.0536**	
	(0.0058)	(0.0074)	(0.0068)	(0.0157)		(0.0075)	(0.0095)	(0.0140)	(0.0267)	
Expenditure x Nuts	-0.0006	0.0006	0.0187***	0.0280***	-0.0478	-0.0173***	0.0445***	-0.0368**	-0.0468**	-0.0721
	(0.0074)	(0.0066)	(0.0067)	(0.0085)	(0.0374)	(0.0057)	(0.0091)	(0.0152)	(0.0189)	(0.0997)
Obs.	5992	5992	5992	5992	5992	7872	7872	7872	7872	7872

Notes: This table shows the coefficient estimates of food demand (budget share) w.r.t land allocated to food group, w.r.t total household expenditures at the 1st, 2nd, 3rd, and 4th degree polynomial, and w.r.t interactions btw prices and expenditures. The table shows the results for households below and above the sample median value of household assets. Robust standard errors are in parentheses. *, **, *** denotes significance at the 10%, 5%, and 1% level.

Table B.9: Separability test results for households above and below sample median value of assets

Food groups	Above median assets				Below median assets			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Cassava	Roots	Pulses	Nuts	Cassava	Roots	Pulses	Nuts
Test of ratios of parameters w.r.t food group:								
Maize								
Ratio 1 (w.r.t land allocation)	0.04	0.16	0.19	0.69	-1.17	3.56**	35.02**	9.43
	(1.03)	(1.11)	(435.10)	(13.09)	(145.60)	(0.81)	(9.69)	(24.57)
Ratio 2 (w.r.t expenditure)	1.17**	1.44**	-56.20**	8.44**	-16.89**	-1.83	7.98	-17.28*
	(0.07)	(0.30)	(0.36)	(1.56)	(0.30)	(2.39)	(160.88)	(10.19)
Ratio 1 / Ratio 2	0.03	0.11	-0.00	0.08	0.07	-1.94**	4.39**	-0.55**
	(240.02)	(13.75)	(0.21)	(0.40)	(0.52)	(0.25)	(0.12)	(0.11)
Wald statistic	160.42	423.69	1,500.44	1,020.80	1,987.08	1,071.17	1,081.68	1,064.77
pvalue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cassava								
Ratio 1		4.39	5.29**	19.42**		-3.05	-30.06**	-8.10**
		(3.91)	(2.49)	(2.80)		(224.44)	(1.99)	(1.21)
Ratio 2		-0.43	0.35	-0.36		32.20**	2.64	2.85
		(1.17)	(0.80)	(12.56)		(1.82)	(142.10)	(9.45)
Ratio 1 / Ratio 2		-10.26**	15.00**	-53.42**		-0.09	-11.38**	-2.84**
		(5.18)	(1.39)	(1.43)		(0.23)	(0.26)	(0.27)
Wald statistic		193.66	181.70	163.24		689.82	631.23	614.74
pvalue		0.00	0.00	0.00		0.00	0.00	0.00
Roots, tubers and other starches								
Ratio 1			1.21	4.42			9.85	2.65
			(44.41)	(8.36)			(147.16)	(11.45)
Ratio 2			-13.70**	7.20**			-23.10	6.27**
			(0.32)	(3.37)			(46.89)	(2.83)
Ratio 1 / Ratio 2			-0.09	0.61**			-0.43*	0.42*
			(0.23)	(0.18)			(0.28)	(0.31)
Wald statistic			1,152.55	432.70			5,052.20	4,672.26
pvalue			0.00	0.00			0.00	0.00
Pulses								
Ratio 1				3.67				0.27
				(8.63)				(5.35)
Ratio 2				-4.05*				-1.32
				(2.47)				(1.18)
Ratio 1 / Ratio 2				-0.90*				-0.20
				(0.53)				(26.53)
Wald statistic				2,002.37				19,077.01
pvalue				0.00				0.00
Obs.	5992	5992	5992	5992	7872	7872	7872	7872

Notes: This table shows the ratio of coefficient estimates w.r.t to land allocations and total household expenditures, for each combination of food groups, and for households above and below median value of household assets. The table also shows the wald statistic and p-value of the test. Robust standard errors are in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Table B.10: Descriptive statistics for households who only farm

	Obs.	Mean	Std. dev.	Min	Max
Panel A. Budget share					
Rice	6844	0.09	0.08	0.00	0.68
Maize	6844	0.04	0.08	0.00	0.73
Wheat & other cereals	6844	0.11	0.14	0.00	0.92
Cassava	6844	0.03	0.08	0.00	0.77
Roots, tubers & other starches	6844	0.11	0.13	0.00	0.98
Sugar	6844	0.01	0.03	0.00	0.46
Pulses	6844	0.05	0.06	0.00	0.63
Nuts & seeds	6844	0.01	0.03	0.00	0.47
Vegetables	6844	0.07	0.06	0.00	0.76
Fruit	6844	0.01	0.02	0.00	0.44
Red meat	6844	0.06	0.08	0.00	0.75
Poultry	6844	0.01	0.05	0.00	0.67
Eggs	6844	0.00	0.01	0.00	0.24
Fish & seafood	6844	0.07	0.09	0.00	0.63
Dairy	6844	0.01	0.03	0.00	0.52
Fats & oils	6844	0.07	0.06	0.00	0.60
Coffee, tea, & cocoa	6844	0.00	0.02	0.00	0.21
Soft drink & juice	6844	0.01	0.02	0.00	0.35
Other foods	6844	0.01	0.02	0.00	0.46
Non-foods	6844	0.22	0.15	0.00	0.90
Panel B. Food prices					
Rice	6844	182.63	61.93	25.56	424.25
Maize	6844	112.72	65.99	7.89	429.88
Wheat & other cereals	6844	153.49	58.09	18.44	520.25
Cassava	6844	94.36	51.89	5.21	333.86
Roots, tubers & other starches	6844	97.16	34.74	11.67	296.95
Sugar	6844	296.46	158.10	3.11	1026.45
Pulses	6844	210.85	97.02	4.72	618.50
Nuts & seeds	6844	386.24	246.47	4.49	1656.48
Vegetables	6844	165.89	77.26	8.26	650.05
Fruit	6844	114.94	55.31	5.29	474.05
Red meat	6844	713.18	194.27	29.14	1503.16
Poultry	6844	801.84	344.37	15.90	1844.92
Eggs	6844	487.30	147.58	61.43	1193.31
Fish & seafood	6844	507.13	299.66	22.55	11644.88
Dairy	6844	820.18	406.31	23.78	2859.80
Fats and oils	6844	274.19	89.66	31.37	1165.45
Coffee, tea, & cocoa	6844	1628.00	1264.95	10.39	8034.29
Soft drink	6844	113.55	46.99	6.28	742.33
Other foods	6844	306.78	361.89	0.11	1997.12
Panel C. Household expenditures					
Total expenditures	6844	5961.60	3829.27	173.80	34718.63
Panel D. Land share by food group					
Maize	6844	0.25	0.33	0.00	1.00
Cassava	6844	0.31	0.38	0.00	1.00
Roots, tubers & other starches	6844	0.22	0.33	0.00	1.00
Pulses	6844	0.14	0.25	0.00	1.00
Nuts & seeds	6844	0.09	0.23	0.00	1.00
Panel E. Input prices					
Maize seed	7448	5.00	1.17	0.69	8.15
NPK fertilizer	7448	4.61	0.34	1.39	5.30
Panel F. Demand shifters					
Head age	6844	47.01	14.75	16.00	100.00
Head is married=1	6844	0.81	0.40	0.00	1.00
Head years of education	6844	3.80	4.75	0.00	18.00
Adjusted household size	6844	3.83	1.85	0.50	18.40
Head is male=1	6844	0.84	0.37	0.00	1.00
Ratio of dependents to adults	6844	1.02	1.23	0.00	9.00

Notes: This table reports the descriptive statistics for households only farm. Food prices, input prices (maize seed and NPK fertilizer) are in Nigerian Naira/Kg and household expenditures are in Nigerian Naira. The input prices are reported in natural logarithm. The non-availability of inputs prices for all enumeration areas explains the reduced sample size for these prices.

Table B.11: Demand coefficient estimates for households with farm income as the only major source of revenue

Variables	Dep. Var.: Budget share on foods				
	Maize (1)	Cassava (2)	Roots (3)	Pulses (4)	Nuts (5)
	Land allocation estimates				
Maize	0.0092	-0.0206	-0.0527**	-0.0293	0.2593***
	(0.0060)	(0.0126)	(0.0258)	(0.0565)	(0.0891)
Cassava	0.0025	0.0044	-0.0425	-0.0445	0.0587
	(0.0063)	(0.0097)	(0.0312)	(0.0424)	(0.0906)
Roots	-0.0002	-0.0010	-0.0403	-0.0222	0.0708
	(0.0064)	(0.0100)	(0.0321)	(0.0434)	(0.0943)
Pulses	0.0072	-0.0158	-0.0037	0.0398	-0.0122
	(0.0073)	(0.0158)	(0.0277)	(0.0710)	(0.0943)
Nuts	0.0388***	-0.0109	-0.0794*	-0.0148	0.1543
	(0.0069)	(0.0113)	(0.0460)	(0.0652)	(0.1231)
	Expenditure estimates				
Expenditure (1st deg. poly.)	0.0134***	-0.0135**	0.0307**	0.0817***	0.2648***
	(0.0049)	(0.0065)	(0.0120)	(0.0214)	(0.0469)
Expenditure (2nd deg. poly.)	-0.0076**	0.0127*	-0.0022	-0.0411**	0.0080
	(0.0036)	(0.0068)	(0.0090)	(0.0186)	(0.0320)
Expenditure (3rd deg. poly.)	0.0014	-0.0001	-0.0049	-0.0121	0.0068
	(0.0028)	(0.0026)	(0.0039)	(0.0075)	(0.0204)
	(Expenditure x Price) estimates				
Expenditure x Maize	0.0061				
	(0.0042)				
Expenditure x Cassava	0.0023	0.0176***			
	(0.0032)	(0.0048)			
Expenditure x Roots	-0.0152***	0.0070	-0.0247**		
	(0.0047)	(0.0053)	(0.0112)		
Expenditure x Pulses	0.0198**	-0.0013	0.0027	0.0049	
	(0.0078)	(0.0093)	(0.0133)	(0.0339)	
Expenditure x Nuts	-0.0043	0.0101**	0.0335***	0.0633***	-0.0374
	(0.0045)	(0.0049)	(0.0090)	(0.0167)	(0.0401)
Obs.	6844	6844	6844	6844	6844

Notes: This table shows the coefficient estimates of food demand (budget share) w.r.t land allocated to food group, w.r.t total household expenditures at the 1st, 2nd, and 3rd degree polynomial, and w.r.t interactions btw prices and expenditures. Robust standard errors are in parentheses. *, **, *** denotes significance at the 10%, 5%, and 1% level.

Table B.12: Separability test results for households with farm income as the only major source of revenue

	Budget share on foods			
	(1) Cassava	(2) Roots	(3) Pulses	(4) Nuts & seeds
Test of ratio of parameters				
Maize				
Ratio 1 (w.r.t land allocation)	2.13**	3.47**	1.39	-17.39*
	(0.80)	(1.40)	(10.43)	(10.69)
Ratio 2 (w.r.t expenditure)	1.56	-4.73	7.39**	16.33
	(2.13)	(5.39)	(0.63)	(64.82)
Ratio 1 / Ratio 2	1.37**	-0.73**	0.19	-1.06**
	(0.45)	(0.15)	(0.22)	(0.05)
Wald statistic	1,201.93	1,249.82	2,558.03	1,095.34
pvalue	0.00	0.00	0.00	0.00
Cassava				
Ratio 1		1.63	0.65	-8.15
		(327.48)	(13.30)	(96.07)
Ratio 2		50.23**	7.48**	40.06
		(2.98)	(0.68)	(32.12)
Ratio 1 / Ratio 2		0.03	0.09	-0.20**
		(0.13)	(0.36)	(0.07)
Wald statistic		2,285.44	1,991.44	1,845.48
pvalue		0.00	0.00	0.00
Roots, tubers and other starches				
Ratio 1			0.40	-5.01
			(3.32)	(10,082.84)
Ratio 2			-2.96**	-305.20**
			(0.61)	(16.30)
Ratio 1 / Ratio 2			-0.13	0.02
			(1.41)	(0.11)
Wald statistic			2,790.54	6,420.38
pvalue			0.00	0.00
Pulses				
Ratio 1				-12.54*
				(7.07)
Ratio 2				7.31
				(47.22)
Ratio 1 / Ratio 2				-1.71**
				(0.15)
Wald statistic				2,564.60
pvalue				0.00
Obs.	6844	6844	6844	6844

Notes: This table shows the ratio of coefficient estimates w.r.t to land allocations and total household expenditures, for each combination of food groups. The table also shows the wald statistic and p-value of the test. Robust standard errors are in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Table B.13: Demand coefficient estimates w.r.t input prices

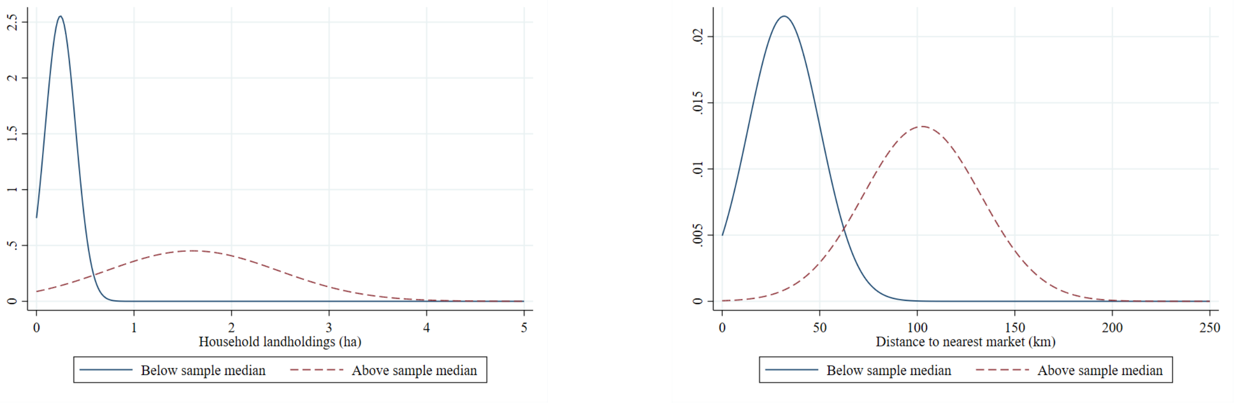
Input price	Dep. Var.: Budget share on food groups Maize (1)	Cassava (2)	Roots (3)	Pulses (4)	Nuts (5)
Fertilizer price	0.0144	0.0066	0.0101	0.0048	-0.0001
	(0.0150)	(0.0207)	(0.0191)	(0.0080)	(0.0042)
Maize seed price	-0.0026	-0.0122*	0.0070	0.0002	-0.0001
	(0.0048)	(0.0064)	(0.0070)	(0.0028)	(0.0012)
Obs.	7448	7448	7448	7448	7448

Notes: This table shows the coefficient estimates of food demand (budget share) w.r.t fertilizer and maize seed prices. *, **, *** denotes significance at the 10%, 5%, and 1% level.

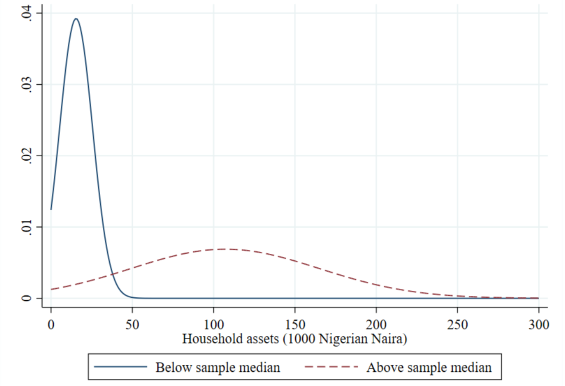
Table B.14: Summary statistics of household nutrient variables

	Obs.	Mean	Std. dev.	Min	Max
Household nutrient adequacy index					
Kcal	48078	1.94	1.58	0.00	47.44
Protein	48078	2.75	2.37	0.00	83.78
Iron	48345	2.78	2.51	0.00	49.32
Zinc	48345	1.86	1.72	0.00	89.76
Vitamin A	48345	5.19	5.07	0.00	141.03
Folate	48345	1.74	1.51	0.00	45.62
Household nutrient adequacy index					
NRFI	49430	429.44	64.76	205.93	579.13
Standardized NRFI	49430	0.07	0.98	-3.31	2.34

Notes: This table reports the summary statistics of household nutrient intakes and household nutrient-rich food index.

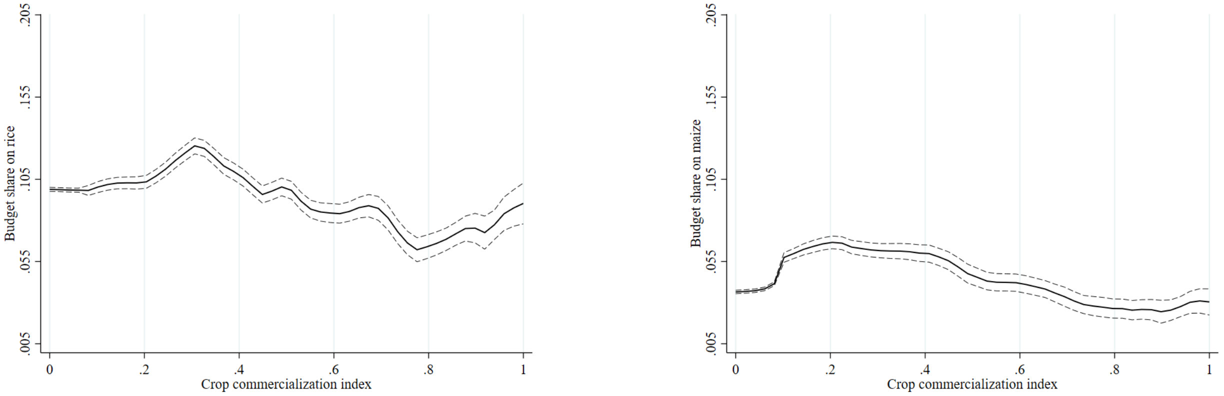


(a) Landholdings (b) Access to markets

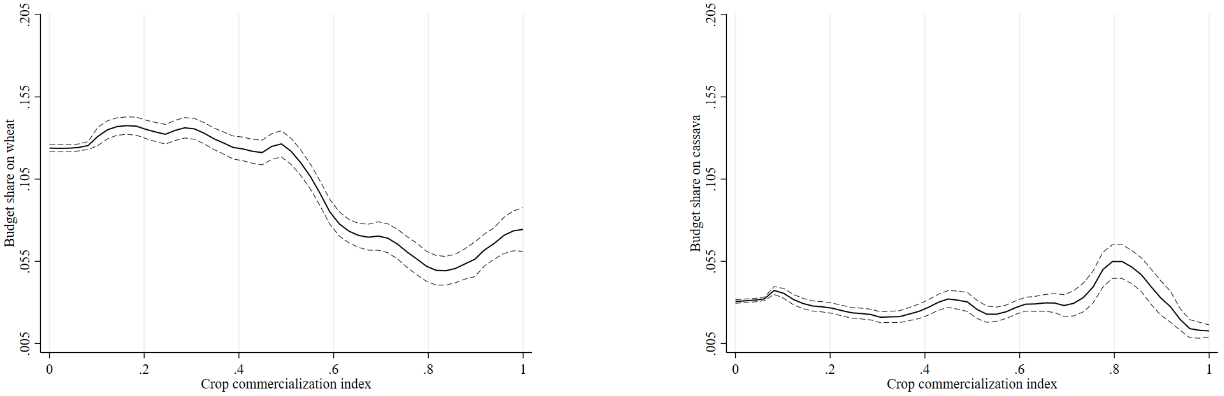


(c) Value of assets

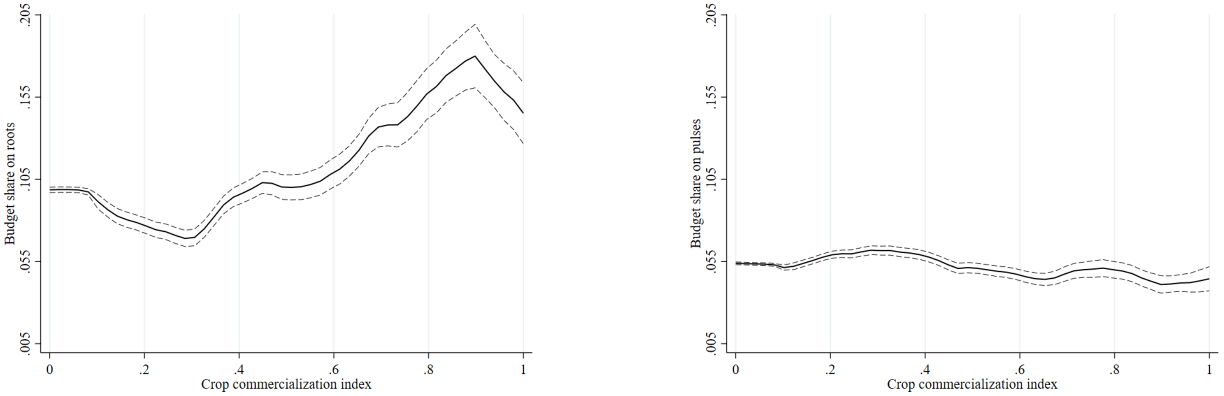
Figure B.1: Distribution of household value of landholdings, assets, and distance to nearest markets



(a) Rice (b) Maize

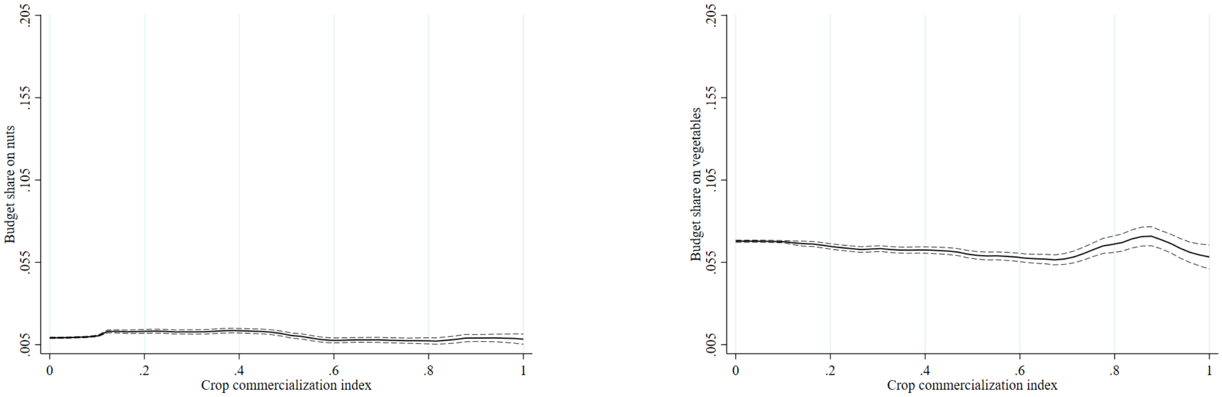


(c) Wheat & other cereals (d) Cassava



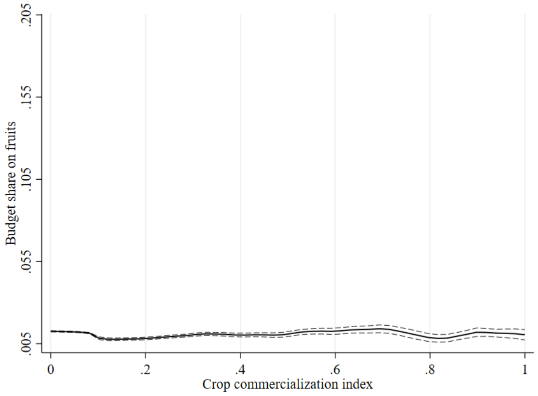
(e) Roots (f) Pulses

Figure B.2: Crop commercialization and household budget share on foods.



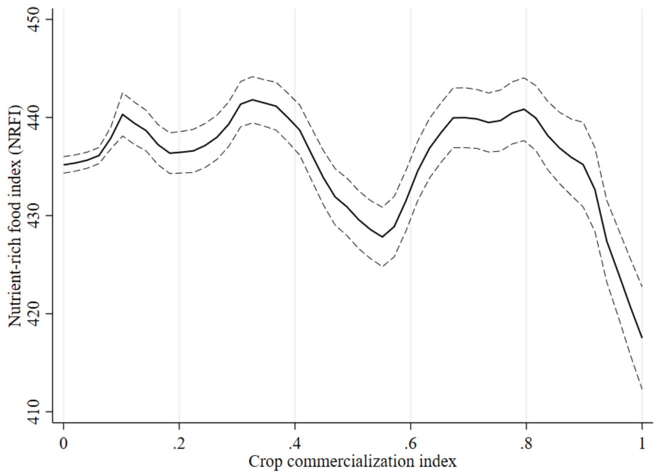
(a) Nuts

(b) Vegetables

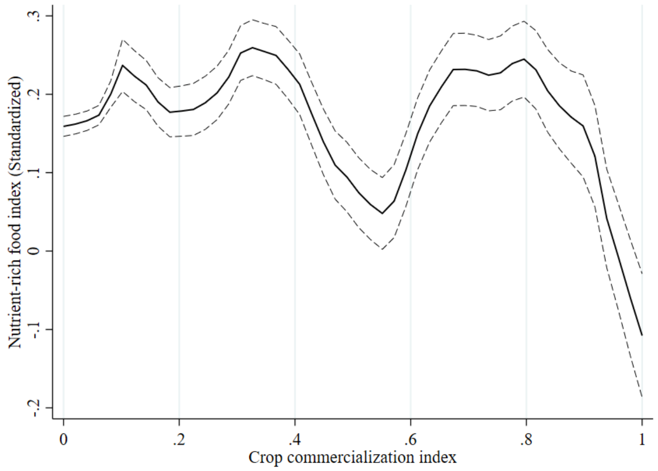


(c) Fruits

Figure B.3: Crop commercialization and household budget share on foods (continued)



(a) Nutrient-Rich Food Index



(b) Nutrient-Rich Food Index (standardized)

Figure B.4: Crop commercialization and household nutrient-rich food index (NRFI)

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