Seasonal Hunger: Heterogenous Impacts of Seasonal Price Changes on Seasonal Consumption in Rural Zambia

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Selected Paper prepared for presentation at the 2016 Agricultural & Applied Economics Association Annual Meeting, Boston, Massachusetts, July 31-August 2

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May 23th (Mon), 2016

Abstract

The hunger season is the time of year when many farmers in developing countries run out of their previous year's harvest and have trouble purchasing staple foods because this time of year has the highest prices. This paper constructs a theoretical model to address such seasonality of food deprivation, and by using three years of weekly household panel data, empirically tests the extent to which farmers in rural Zambia can smooth their consumption from season to season, as well as from year to year, in response to income shocks. The theoretical model provides an explanation of how farmers try to smooth their consumption. This paper allows for heterogenous impacts of seasonal price changes on consumption. Some farmers buy staple food when prices are low and store it for the hunger season, while others run out of staple food, and so buy it when prices are high. Results indicate that the former group successfully smooths its consumption from season to season, as well as from year to year. In contrast, the latter group reduces consumption of non-food items and non-staple food items, especially relatively soon after harvest. These results are well explained by the theory. The theoretical model, combined with empirical evidence, depicts consumption seasonality in great detail.

Key words: seasonality, consumption smoothing, food security, credit constraints, inter-temporal arbitrage, Zambia

JEL codes: D91, O12, O13, Q18

1 Introduction

Seasonal hunger is a common concern for subsistence farmers in developing countries. Agricultural income is uncertain, and farmers receive it only at the harvest season. Farmers' previous year's harvest stocks gradually dwindle, and some farmers run out of their food before the next harvest. Such farmers need to buy their food with cash, but food prices are usually high right before harvest. Those farmers

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who run out of food must buy their food when prices are high, and cannot buy enough food. Most of malnutrition and deaths of young children occur in those periods (e.g. Devereux et al. (2012)), and so do famines (e.g. Sen (1981)). Those periods are often referred to as the hunger season (e.g. Devereux et al. (2012), Vaitla et al (2009), and Khandker and Mahmud (2012)). The purpose of this paper is to give a detailed picture of seasonal consumption smoothing of farmers in rural Zamba in response to seasonal food prices changes and income shocks, with the ultimate goal of recommending policies for tackling seasonal hunger.

There are some previous studies which address the relationships between seasonal consumption, incomes, and price changes, though results are somewhat mixed. Paxson (1993) uses the Thai Socio-Economic Surveys (SES) from 1975/76, 1981 and 1986 to conclude that seasonal consumption patterns mainly depend on seasonal variations in preferences or prices, instead of seasonal income patterns. Using household-level data from Indian villages, Chaudhuri and Paxon (2002) also show that seasonal consumption changes do not track seasonal income changes. On the other hand, Dercon and Krishnan (2000) use panel data from Ethiopia and reveal that income shocks, as well as seasonal price changes and seasonal wage changes, affect seasonal consumption patterns. Similarly, Khandker (2012) uses panel data from Bangladesh to show that seasonal income patterns under credit constraints, instead of seasonal price variation, has the main impact on seasonal consumption.

There are two aspects of seasonal hunger that previous studies have not addressed. First, they implicitly assume that the impact of seasonal price changes on seasonal consumption is identical across all the households. However, Stephens and Barrett (2011) point out that the timing of trading staple foods differs from household to household due to the presence of liquidity constraints and transaction costs. Some households buy foods when prices are high, and others buy foods when prices are low. These differences in the timing of purchasing staple foods could correspond to different consumption patterns, and could generate the mixed results of previous studies. Second, although previous studies have discussed seasonal patterns of total consumption, seasonal patterns of each component of consumption have not yet been discussed in the literature. In particular, from the policy perspective, micronutrient deficiencies are an acute problem in Zambia, and increasing food diversity is an important policy challenge (Zambia (2011)). Thus, seasonal consumption of goods other than staple foods, especially vegetables and meats, also should be discussed. Taking credit constraints and transaction costs into consideration, the theoretical model is developed to discuss how differences in the timing of trading staple foods are related to differences in consumption patterns. Then, it empirically examines how different types of farmers smooth seasonal consumption against harvest shocks. Finally, it discusses how the composition of consumption changes in response to harvest shocks under seasonal price changes of staple foods.

This paper uses a unique household panel data set to analyze these research topics. The household survey data were collected as part of the Resilience Project conducted by the Research Institute for Humanity and Nature (RIHN) and the Zambia Agricultural Research Institute (ZARI). The study area from which the data were collected is located in Choma and Sinazongwe Districts, in the Southern Province of Zambia, and is divided into three ecological zones. From each ecological site, 16 households were chosen randomly for a total sample size of 47 households.[1] These households were interviewed every week, from May, 2008, to April, 2011, so that about 150 interviews were conducted during this period for each household. In addition, retrospective data were collected at two different times, on September, 2010, and on March, 2011. More specifically, in September of 2010, farmers were asked about crop yields for each of their plots during the survey periods. Then, on March 2011, farmers were asked about maize trade patterns. They were asked whether they bought maize during each season from 2007 to 2011. If they purchased maize, they were asked when, how often, and the amounts they purchased at each time.

The farmers in this study area grow their staple food, maize, for self-consumption. If their maize yields are not enough for their annual consumption, they buy maize. Since maize prices steadily rise after the harvest season, those farmers who have enough money buy maize relatively soon after the harvest, when maize prices are low, and store that maize for the hunger season. On the other hand, those farmers who do not obtain enough money at the end of the harvest to buy enough maize to consume during the hunger season must work to obtain cash, and will buy maize at later date, at a higher price. The one-year utility maximization model of the choice of consumption of staple foods and consumption of other goods, with the year divided into two seasons, explains these differences in the timing of purchases staple foods, and explains heterogenous impacts of seasonal price changes, income shocks, and the market for short-term credit on both type of farmer. Farmers are allowed to save in the form of maize and/or in the form of money. Several assumptions, which characterize the study area and would be broadly applicable to many other rain-fed agricultural areas, are imposed on the model. First, the credit market is assumed to be incomplete. Second, transaction costs of maize selling in the hunger season are assumed to be large. These transaction costs take the form of social pressure to give some of surplus maize to other farmers in bad situations during the hunger season, additional investment for the maize storage, and the opportunity costs for maize trade in agricultural busy season. For simplicity, these transaction costs are assumed to be large enough so that there is no maize selling during the season. Lastly, the seasonal increase rate of maize prices are assumed to be larger than the interest rate, that is, savings in the form of maize is more profitable than saving in the form of money as long as the farmer does not incur any transaction costs when selling maize.

The implications of theoretical model are as follows. The farmer who has enough money to buy sufficient maize for the hunger season just after harvest does not need to buy maize at higher prices. On the other hand, the farmer whose income in the season just before harvest is a big part of his or her annual income needs to buy maize at higher prices. The former group of farmers saves maize only for self-consumption,

[1] One household was dropped because it moved away.

and for additional savings, saves in the form of money. Seasonal price changes affect neither the seasonal consumption patterns nor the welfare of these farmers. These farmers may want to use the short-term credit market for season specific expenditures such as school fees, but not for maize purchases. On the other hand, the latter group of farmers borrows money up until their credit limit and use it for current consumption, or save in the form of maize to consume at a later time during the year. For this farmer, increases in the price of maize in the hunger season decrease his or her welfare, and affect seasonal consumption patterns of both maize and other goods. The farmer in this group uses the short-term credit market for maize savings or for current consumption, but the marginal utility of current consumption is larger than the marginal utility of maize savings. For this farmer, binding credit constraints do not mean that he or she is unable to reallocate consumption across seasons, because this farmer can do so by saving maize. Instead, if the maize savings of this farmer are zero, it indicates that he or she is unable to reallocate his or her consumption across seasons.

The panel data set described above is used to estimate consumption functions separately for both types of farmer, taking endogeneity of maize purchase patterns into consideration. Estimated consumption functions are used to discuss how farmers smooth their consumption from season to season, as well as from year to year, in response to harvest shocks. The estimation results, along with the theoretical model, indicate that those who do not buy maize at the higher prices that prevail in the hunger season successfully smooth their consumption from season to season, as well as from year to year, in response to harvest shocks. On the other hand, those who buy maize at higher prices fail to smooth their consumption from year to year. Cash incomes earned after their harvest are not enough to recover from harvest shocks, thus they adjust their composition of consumption from season to season. In spite of the seasonal price hike of maize, they smooth their consumption of that staple food. Instead, they decrease consumption of non staple food items, such as vegetables and meats, as well as decrease consumption of non-food items, in response to harvest shocks. In the hunger season, they run out of their stored maize, and their consumptions depend on income earned in the hunger season. These results suggest that the policy to improve food diversity should be discussed with seasonal price changes of maize, because these changes have a larger influence on the consumption of non-staple food items. In addition, according to the theoretical model, in which decisions for the whole crop year are made just after harvest, zero savings of maize for the hunger season implies the failure of reallocating of consumption from the consumption in the later time during the crop year to consumption in the earlier time of the year, while, in general, the hunger season in the village is recognized as the later time during the crop year. Possible explanations for this result will be discussed in the concluding section.

This paper is organized as follows. Section 2 describes the data from the household survey, and outlines seasonality in study area. Section 3 proposes the two-period model. Section 4 derives the econometric specification, based on the two-period model, and section 5 provides estimation results. Section 6 discusses policy implications and the limitations of this study.

2 Data

2.1 Survey Outline

The household survey data used in this paper were collected as part of the Resilience Project - Vulnerability and Resilience of Social-Ecological Systems, administered by the Research Institute for Humanity and Nature (RIHN), Inter-University Research Institute Corporation, National Institutes for the Humanities, Japan. The study area is located in Choma and Sinazongwe Districts, in the Southern Province of Zambia, and data were collected from three ecological zones: site A (the lower flat land zone near Lake Kariba), site B (the middle slope zone), and site C (the upper land zone on the plateau). These three sites are located within a radius of 15 km, but cover a wide diversity of agricultural ecosystems. Annual rainfall and natural vegetation are different due to the variation in altitude, but ethnicity and culture of the local population are the same across the survey sites. From each site, 16 households were chosen randomly, and the sample size is 47. More information on the survey is found in Sakurai (2008).

The household survey was conducted from November 2007 to December 2011 and consists of an annual household survey, a monthly household survey, and a weekly household survey. The weekly household survey collects detailed data on consumption. This paper uses the data for three crop years.[2] Moreover, in September 2010, additional retrospective data were collected on the crop yields in the harvest seasons (April or May) of 2008, 2009 and 2010. For each plot, farmers were asked about planted crops, and asked to rate their crop yields according to three categories - above average, average, and below average. To evaluate the farmers' relative value of each plot, they were asked the rental cost of each plot. In addition, in March 2011, farmers were interviewed to collect data on their maize purchases from the beginning of the research period, and those who purchased maize were asked when, how often and the amounts they purchased at each time. Summary statistics for consumption per week per adult equivalent,[3] and for other key variables used in this paper, are reported in Table 1.

2.2 Seasonal Patterns of Income and Consumption

In the study area, almost all the villagers are subsistence farmers whose main income source is agricultural production. All the sampled households are farmers who grow their staple food, maize, for self-consumption and, if their harvests exceed their annual consumption, for sale. If their maize yields are not enough for their annual consumption, farmers buy maize with cash. The farming season is from November to April,

[2] The data used are from May, 2008 to April, 2011. We define crop year 08/09 as the 12 months from May, 2008 to April, 2009, crop year 09/10 from May 2009 to April 2010, and crop year 10/11 from May 2010 to April 2011. The data from November 2007 to April 2008 are not used because there are no crop data for that year. The data from May 2011 to December 2011 are not used because there are no data regarding maize trade patterns in those periods.

[3] Adult-equivalent is defined as: (Number of adult males) + (Number of adult females) * 0.9 + (Number of children) * 0.52. Children are defined as age 12 years or younger.

and the off-farm season is from May to October. Typically, farmers plant seeds in November and harvest in April or May. During the agricultural off-season, farmers engage in on-farm or off-farm work in various ways. Farmers who have fields near the river cultivate a second crop. Table 2 shows the number of households who grow maize in the off-farm season. In the study area, 22 households (6 in Site A, 4 in Site B, and 12 in Site C) have fields near the river. In addition, the sample households can engage in a variety of work activities to obtain cash. The major way to obtain cash in Site A is to work at a fisheries company at Lake Kariba. In Site B, production and trade of lumber is a major work activity, and in Site C, trading food crops, such as double cropping maize and vegetables, is important. Varieties of piece work, such as selling handiwork, by the farmer's wife is also a major source of cash in each site. In this way, every household engages in some kind of work during the off-farm season, and their seasonal income patterns can be used to classify these households into two groups : One group whose members have their own fields near the river and so can grow maize in the off-farm season, and the other group whose members do not. The households in the group whose members grow maize in the off-farm season obtain their incomes in a lump sum in both seasons after the harvest. On the other hand, the households in the group that does not grow maize in the off-farm season obtain their income several times during off-farm season.

Their typical meal consists of Nsima (a very thick porridge made from maize flour) and one or two side dishes. Side dishes are usually sauteed seasonal vegetables (e.g. cabbage, tomato, onion, okra, pumpkin leaves, mushroom, and so on) in oil and salt, which is an important source of micronutrients, such as vitamin A, zinc, and so on. Their source of proteins is kapenta (dried small fish), which is sometimes added into the sauteed vegetables. Only on very special days, meats are added to the side dish. For example, many households celebrate Christmas, and eat chicken or goat on that day. Figure 1 shows the average composition of values of consumption per week per adult-equivalent over the 3 years of data, calculated based on the weekly household survey data. Food consumption accounts for 84% of their total consumption, half of which is for staple foods, mostly maize. The other half is for vegetables and fruits, animal products, and industrial food products, which is mainly for side dishes.[4] Note that agricultural production materials such as fertilizers or seeds are excluded from the household consumption. Figure 2 shows seasonal patterns of average total consumption per week per adult-equivalent, and Figure 3 presents seasonal patterns of average consumption for staple foods, other foods, and non-food items. The spike of consumption of other foods in December is due to Christmas. Although non-food items account for only 16% of the value of their total consumption, their consumption is relatively concentrated just after harvest, that is, in May, June and July. It is partly due to season specific cash demand, such as payments for transportation fees and school fees, which are relatively concentrated in May and June. But this is not the main reason for this trend.[5] The main reason for this trend is that these are purchases of household goods such as clothes and kitchen utensils, and they tend to purchase such household goods just after the

[4] Cooking oil and salt are categorized as industrial food products.

[5] Values per week per adult-equivalent for transportation fees and school fees are only 170 ZMK and 129 ZMK, respectively.

harvest.

2.3 Seasonal Price Changes and the Way Farmers Buy Maize

Figure 4 shows average maize prices per bucket over the three crop years, and Figure 5 shows average maize prices per bucket[6] by crop year. In each crop year, maize prices are cheapest after the harvest season, and gradually increase until next harvest season. Compared with the lowest prices in each crop year, peak prices increased by 88%, 71%, and 23% in crop years 08/09, 09/10, and 10/11, respectively.[7] Given those seasonal price changes, it is profitable for households to buy maize when maize prices are low and sell when maize prices are higher. However, only a few villagers sell maize in the hunger season, and thereby practice an inter-seasonal price arbitrage.[8] Possible reasons for this would be high transaction costs when they sell maize in the hunger season, and incomplete credit markets. One source of transaction costs for selling maize in the hunger season is social pressure. In the study village, it is a common custom that farmers with surplus maize in the hunger season give some of their maize to other farmers in bad situations. Thus, in order to practice an inter-seasonal price arbitrage of maize, farmers also need to secure enough maize to distribute to other poorer farmers. Another source of transaction costs for selling maize in the hunger season is fixed costs for storage. Since farmers do not have additional storage capacity for an inter-temporal price arbitrage, they need to invest in additional storage capacity. The opportunity costs for maize trade in hunger season can be considered as transaction costs, because this time of year is the agricultural busy season. Those transaction costs would prevent farmers from selling maize in the hunger season.

On the maize purchasing side, Table 3 presents data on households by their purchase patterns for maize. Over three crop years, 68 out of 141 households purchased maize, and there are two distinctive patterns for their maize purchases. One is the group those who purchased maize from May to December, and almost all of them bought maize only one or two times. They bought maize relatively soon after the harvest, when maize prices are low, and store them for the hunger season. The other group is those who purchased some maize even from December to April, and almost all of them bought maize more than 3 times. They bought maize frequently, because they repeated the cycle that they went to work, worked until they had enough money to buy some units of maize (for example, one bucket of maize), which is likely to be a cycle of every week, every 15 days, or every month. The three possible reasons why some farmers bought maize at high prices include seasonal income patterns and incomplete credit market, impatience or lack of storage. However, impatience seems not to be plausible, because the increase in the price of maize from the lowest

[6] In the study area, a bucket is a standard unit in the market. One bucket of maize is a bucket filled with maize, and the bucket size is standardized within the study area.

[7] Note that this number is in real terms, that is, deflated by GDP deflater, which is about 12% during the year

[8] As far as I know, in our study area, only one villager with an obviously large amount of capital practices such an inter-temporal price arbitrage, and he is not one of our sample households. There are some outside inter-village traders, called briefcase businessman, who practice such an inter-temporal price arbitrage.

season to the highest season, which ranged from 23% to 88% after deflating Zambia's GDP deflater. Also, lack of storage seems not to be the case in the study area, because every household has enough storage for annual consumption (direct observation by the author).

Given these seasonal price changes of maize, the different timing of maize purchase could be a result of different seasonal consumption patterns. Figure 6 shows seasonal patterns of average total consumption over 3 years by maize purchase patterns, and Figure 7 shows its breakdown into staple foods, other foods, and non-food items. Those who do not buy maize at higher prices (NBH) consume more than those who buy maize at higher prices (BH), and most of those differences come from the difference in consumption of non-food items. Consumption of staple foods is similar for both groups. Those seasonal consumption patterns reflect several factors: seasonal preference for consumption, heterogenous impacts of seasonal price changes, sensitivity against income shocks, and so on. Given those several factors, this paper focuses on the impact of harvest shocks on seasonal consumption patterns. In the empirical part, how farmers adjust their consumption from season to season, as well as from year to year when their harvest decreases marginally are addressed.

3 Theoretical Framework

To explain the different timing of maize purchases and to see how this difference relates to the different impact of seasonal price changes, income shocks, and short-term credit market on farmers, a two-period model is constructed. Based on the observation that no sample households sell maize in the hunger season to take advantage of its highly profitable inter-seasonal price arbitrage, the model assumes that high transaction costs, as well as incomplete credit markets, prevent maize selling in the hunger season.

3.1 Two-period Model

Start with a simple one-year model, with the year divided into two seasons, the off-farm season (t = 1) and the farming season (t = 2). At the beginning of the off-farm season, the previous farming season ends and the household harvests an amount of maize, denoted by y. In addition, farmers obtain an exogenous cash income wL_t from wage work at the beginning of each season t (t = 1,2). As for prices, assume that only the price of the staple food changes during the year, while the prices of the other goods are the same throughout the year, and are normalized to one. The prices of the staple food in the off-farm season and in the farming season are denoted by p_1 and p_2, respectively. For simplicity, we assume that there is no uncertainty in future prices, that is, the price p_t (t = 1,2) is assumed to be determined at the beginning of the season 1. This assumption reflects that seasonal price changes of maize highly depend on the amount of maize harvested around the village.

In this setting, consider a farmer's utility maximization problem. Assume that the farmer's utility function is continuous, strictly increasing, strictly quasiconcave and twice differentiable in all its arguments, and that the farmer chooses in both time periods the consumption of the staple food (c_t) and consumption of the composite good (x_t) to maximize his or her utility. The farmer's utility maximization problem at the beginning of season 1 can be written as;

$$\max_{c_1,x_1,c_2,x_2} U(c_1, x_1, c_2, x_2 \mid \beta, \theta) \tag{1}$$

s.t.

$$x_1 + p_1c_1 + p_1S = p_1y + wL_1 + B \tag{2}$$

$$x_2 + p_2c_2 + (1 + r)B = p_2(1 - \nu)S + wL_2 \tag{3}$$

$$B \leq \bar{B} \tag{4}$$

$$S \geq 0 \tag{5}$$

$$q_2 = c_2 - (1 - \nu)S \geq 0 \tag{6}$$

where β is the discount rate, θ is household season specific preferences, ν is the depreciation rate of maize storage, r is the interest rate, B is the amount of borrowing[9] in the form of money with upper limit of $\bar{B}$,[10] S is the amount of maize storage, and q_2 is the amount of staple foods a farmer buys in season 2.[11] The price of the other composite good (x_t) is normalized to one for both time periods. Equations (2) and (3) represent budget constraints for season 1 and season 2, respectively. Note that the farmer can choose the saving either in the form of maize (S) or in the form of money (B), or both. If the farmer saves in the form of money, then $B < 0$. Equation (4) represents a borrowing constraint in the form of money, and equation (5) rules out the "borrowing" of maize, that is, it represents a borrowing constraint in the form of maize. Equation (6) represents the situation in which transaction costs of maize selling in the hunger season are large enough so that there is no maize selling during season 2. Although this assumption seems to be relatively strong, it is consistent with the fact that large-scale maize selling is not popular in the study village, and no sample households do that.

Assume that p_2 is always higher than p_1 and that p_2 is always high enough to satisfy:

$$\frac{p_2}{p_1}(1 - \nu) > 1 + r \tag{7}$$

The left hand side of equation (7) can be interpreted as the return to saving in the form of maize without transaction costs of maize selling during season 2, and the right hand side can be interpreted as the interest rate of saving in the form of money. The equation (7) requires that saving in the form of maize is more

[9] Informal loans between friends and relatives are common in the study village.

[10] Note that this paper does not discuss resource allocation across crop years, that is, the borrowing from later time after the next harvest (e.g. credit for seeds or fertilizers). Even if the farmer successfully optimize his or her inter-seasonal resource allocation, he or she might be unable to optimize his or her resource re-allocation across crop years, that is, he or she might want to consume more in season 1, immediately after the harvest, by borrowing money from a later year after the next harvest.

[11] If $q_2 > 0$, then the farmer buys maize in season 2.If $q_2 = 0$, then the farmer is in autarky in season 2.

profitable than saving in the form of money as long as the farmer saves maize for self-consumption.[12] For additional savings more than the amount of his or her maize consumption during season 2, he or she owes transaction costs, because maize is sold during season 2. Denote the average transaction costs per one unit of maize saving for sale by τ, then the return to maize saving for sale is $\frac{p_2}{p_1}(1-\nu)-\tau$. If $1+r$ is larger than $\frac{p_2}{p_1}(1-\nu)-\tau$, then the farmer saves in the form of money. If $\frac{p_2}{p_1}(1-\nu)-\tau$ is larger than $1+r$, then the farmer saves in the form of maize and sells it during season 2. Equation (6) ensures that the return to maize saving for sale is less than the return to saving in the form of money. In sum, the following inequality holds:

$$\frac{p_2}{p_1}(1-\nu) > 1+r > \frac{p_2}{p_1}(1-\nu)-\tau \tag{8}$$

where $\frac{p_2}{p_1}(1-\nu)$ is the return to maize saving for self-consumption, $1+r$ is the return to money saving, and $\frac{p_2}{p_1}(1-\nu)-\nu$ is the return to maize saving for sale.

3.2 Solution of the Utility Maximization Problem

The utility maximization problem for the farmer is to maximize (1) subject to (2)-(7). The solution of the problem leads to four possible cases;

- $q_2 > 0$ and $S > 0$
- $q_2 > 0$ and $S = 0$
- $q_2 = 0$ and $B < \bar{B}$
- $q_2 = 0$ and $B = \bar{B}$

Thus, four consumption functions are derived from the model, and the following characterizes each consumption function. Note that the first two cases ($q_2 > 0$) represent the farmer who buys maize at higher prices (BH), and the last two ($q_2 = 0$) represent the farmer who does not buy maize at higher prices (NBH).

[12] Stephens and Barrett (2011) discuss "Sell low, buy high" behavior without discussing the assumption of equation (7). Their theoretical model compares the market participation choice of the farmer with a binding credit constraint and of the farmer without a binding credit constraint. They conclude that the farmer with a binding credit constraint is more likely to sell maize at lower prices, and buy maize at higher prices. But their theoretical model has a problem. If they assume inequality of equation (7), every farmer borrows up until his or her upper limits, that is, every farmer binds credit constraints regardless of maize purchase patterns. Thus, their comparison of both types of farmer is invalid. On the other hand, if they assume equality of equation (7), "Sell low, buy high" behavior is no more a paradox, because such behavior is equivalently "Buy low, sell high" in terms of money, that is, the farmer buys money at lower prices by using maize, and sells money at higher prices to obtain maize.

3.2.1 The Farmer Who Buys Maize at Higher Prices (BH: $q_2 > 0$)

Combining (2) and (3) by substituting out S, the following intertemporal budget constraint equation is derived:

$$p_2(1-\nu)c_1 + \frac{p_2}{p_1}(1-\nu)x_1 + p_2c_2 + x_2$$
$$= p_2(1-\nu)y + \frac{p_2}{p_1}(1-\nu)wL_1 + wL_2 + \{\frac{p_2}{p_1}(1-\nu) - (1+r)\}B \quad (9)$$

This farmer maximizes equation (1) subject to (9) and (5). Given equation (7), maximized utility can be achieved by borrowing money up to the limit, that is, equation (4) binds.

$$B = \bar{B} \quad (10)$$

Intuitively, this farmer is purchasing maize in season 2 at a high price, p_2. He or she can save money by borrowing as much as possible at interest rate r to purchase as much maize as possible in season 1 at the lower price, p_1, so he or she does that as much as the borrowing constraint allows. Substituting (10) into (9), the inter-temporal budget constraint is derived as follows:

$$p_2(1-\nu)c_1 + \frac{p_2}{p_1}(1-\nu)x_1 + p_2c_2 + x_2$$
$$= p_2(1-\nu)y + \frac{p_2}{p_1}(1-\nu)wL_1 + wL_2 + \{\frac{p_2}{p_1}(1-\nu) - (1+r)\}\bar{B} \quad (11)$$

The right hand side of equation (11) represents the full income of the farmer for the whole year, and $p_2(1-\nu)$, $\frac{p_2}{p_1}(1-\nu)$, and 1 can be interpreted as the values of y, wL_1, and wL_2, respectively. Note that the upper bond of borrowing ($\bar{B}$) can be interpreted as a part of full income. Put differently, giving additional short-term credit can be interpreted as income transfer in season 1 for this farmer. Another thing to note is that the prices of y, wL_1 and $\bar{B}$ are higher than the price of wL_2. This indicates that cash in hand in season 1 is more valuable than cash in hand in season 2. The intuitive explanation for this is that cash in hand in season 1 can be used to buy maize at lower prices, while cash in hand in season 2 can be used to buy maize at higher prices. This also indicates that the loss of cash in hand in season 1 requires a larger increase of cash in hand in season 2 to maintain the same inter-temporal budget constraint.

The utility maximization problem for the farmer is reduced to maximizing (1) subject to (11) and (5). Define λ and μ ($\lambda \geq 0$ and $\mu \geq 0$) as Lagrange multipliers which correspond to the equation (11) and (5) respectively, then the first order conditions for this problem are

- w.r.t c_1 $$\frac{\partial U}{\partial c_1} = \left\{p_2(1-\nu) + \frac{\mu}{\lambda}\right\}\lambda \quad (12)$$
- w.r.t x_1 $$\frac{\partial U}{\partial x_1} = \left\{\frac{p_2}{p_1}(1-\nu) + \frac{\mu}{p_1\lambda}\right\}\lambda \quad (13)$$
- w.r.t c_2 $$\frac{\partial U}{\partial c_2} = p_2\lambda \quad (14)$$
- w.r.t x_2 $$\frac{\partial U}{\partial x_2} = \lambda \quad (15)$$

where $\lambda > 0$, and if equation (5) binds (i.e. $S = 0$), $\mu > 0$ and otherwise $\mu = 0$. Consumption functions $c_t^{BH}, x_t^{BH} (t = 1, 2)$ are determined by equations (11),(12)-(15), and can be represented as follows:

$$c_t^{BH} = c_t^{BH}(p_1, p_2, Z) \quad (16)$$
$$x_t^{BH} = x_t^{BH}(p_1, p_2, Z) \quad (17)$$

where Z is the vector of exogenous variables $y, wL_1, wL_2, r, \bar{B}, \nu, \beta$, and θ. Define $p^*_{c_1}, p^*_{x_1}, p^*_{c_2}$ and $p^*_{x_2}$ be as follows;

- $p^*_{c_1} = p_2(1-\nu) + \frac{\mu}{\lambda}$ (18)
- $p^*_{x_1} = \frac{p_2}{p_1}(1-\nu) + \frac{\mu}{p_1\lambda}$ (19)
- $p^*_{c_2} = p_2$ (20)
- $p^*_{x_2} = 1$ (21)

Then, $p^*_{c_1}, p^*_{x_1}, p^*_{c_2}, p^*_{x_2}$ can be interpreted as shadow prices of c_1, x_1, c_2, x_2 in the sense that the farmer allocates his or her consumption depending on those shadow prices as if there were no constraint in the equation (5).[13] Note that the increase of p_2 increases not only $p^*_{c_2}$, but also $p^*_{c_1}, p^*_{x_1}$. This is because c_1 and x_1 can be used to take advantage of highly profitable inter-seasonal arbitrage of maize. The increase of p_2 does not increase $p^*_{x_2}$, because x_2 cannot be used to take advantage of highly profitable inter-seasonal arbitrage of maize. Thus, given high price of p_2, the farmer has a strong incentive to restrain himself not only from consuming staple foods in season 2 but also from consuming staple foods and other goods in season 1. Seasonal consumption patterns is determined so that marginal rate of substitution is equal to the ratio of shadow prices, that is,

- $\frac{U_{c_1}}{U_{c_2}} = (1-\nu) + \frac{p_2\mu}{\lambda}$ (22)
- $\frac{U_{x_1}}{U_{x_2}} = \frac{p_2}{p_1}(1-\nu) + \frac{\mu}{p_1\lambda}$ (23)

where U_{c_1},U_{x_1},U_{c_2} and U_{x_2} represent the first derivative of utility function with respect to c_1,x_1, c_2 and x_2.

Next, consider the impact of seasonal price hikes of maize in the hunger season on this farmer's welfare. Define the indirect utility function $V(P, W)$ where P is a vector of p_1 and p_2, and W is a vector of y, wL_1, wL_2 and $\bar{B}$. Dividing both sides of equation (11) by p_2, and redefining corresponding Lagrange

[13] The first order conditions equation (12) - (15) can be derived from the utility maximization problem (1) subject to $p^*_{c_1}c_1 + p^*_{x_1}x_1 + p^*_{c_2}c_2 + p^*_{x_2}x_2 = M'$ where M' is any exogenous full income.

multipliers as $\lambda'(>0)$, the following equation is derived by applying the envelope theorem;

$$\begin{aligned}\frac{\partial V(P,W)}{\partial p_2} &= \left\{-\frac{1}{p_2^2}wL_2 + \frac{1}{p_2^2}(1+r)\bar{B} + \frac{1}{p_2^2}x_2\right\}\lambda' \\ &= \{x_2 + (1+r)\bar{B} - wL_2\}\frac{\lambda'}{p_2^2} \\ &= -q_2\frac{\lambda'}{p_2^2} \qquad (24)\end{aligned}$$

where λ' and p_2^2 are strictly positive, and q_2 is the amount of staple foods a farmer buys in season 2. Equation (24) indicates that net buyers of maize in season 2 decrease their welfare by the increase of maize prices in season 2. Equation (24) also indicates that, without transaction costs for maize trade,[14] net sellers of maize in season 2 increase their welfare by the increase of maize prices in season 2.

Lastly, consider the role of the equation (5) on seasonal consumption patterns.[15] Shadow prices in season 1 ($p^*_{c_1}$ and $p^*_{x_1}$) increase if this borrowing constraint binds ($\mu > 0$), that is, the farmer for whom this borrowing constraint is binding allocates his or her consumption as if the price in season 1 increases. Intuitively, the farmer with a binding borrowing constraint wants to consume more in season 1 instead of in season 2, but the borrowing constraint prevents him or her from doing so. In sum, a binding borrowing constraint of maize implies the failure of inter-seasonal resource reallocation. Note that the consumption in season 2 of the farmer with a binding borrowing constraint of maize does not respond to harvest shocks (decrease of y) as long as the equation (5) binds. To see this, the utility maximization problem of the farmer with a binding this borrowing constraints ($S = 0$) is re-written as follows;

$$\max_{c_1,x_1,c_2,x_2} U(c_1,x_1,c_2,x_2 \mid \beta,\theta) \qquad (25)$$

s.t.

$$x_1 + p_1c_1 = p_1y + wL_1 + \bar{B} \qquad (26)$$

$$x_2 + p_2c_2 + (1+r)\bar{B} = wL_2 \qquad (27)$$

Equations (26) and (27) implies that harvest shocks (decrease of y) affect consumption only in season 1. Intuitively, this farmer wants to borrow from income in season 2 to increase consumption in season 1. A small increase in y allows the farmer to increase consumption in season 1, but has no effect on consumption in season 2.

[14] In other words, there is no constraint of equation (6)

[15] Remember that the equation (5) can be interpreted as the borrowing constraint in the form of maize. Since maize saving for self-consumption is more profitable than saving in the form of money, this farmer smooth his or her consumption by maize saving.

3.2.2 The Farmer Who Does Not Buy Maize at Higher Prices (NBH: $q_2 = 0$)

This farmer saves enough maize for self-consumption.[16] For additional savings to purchase non-staple food or non-food items, he or she saves in the form of money due to the prohibitively high transaction costs of maize selling during season 2. This saving implies that $B < 0$. Combining (2), (3) and (6) with equality by substituting out B, the inter-temporal budget constraint can be derived as follows;

$$p_1 c_1 + x_1 + \frac{p_1}{1-\nu} c_2 + \frac{1}{1+r} x_2 = p_1 y + wL_1 + \frac{wL_2}{1+r} \tag{28}$$

The right hand side of equation (28) represents the full income of the farmer, and $p_1, 1$, and $\frac{1}{1+r}$ can be interpreted as the prices of y, wL_1, and wL_2, respectively. Note that the prices of y and wL_1 are no longer relatively higher than the price of wL_2 in the sense that the coefficients of y and wL_1 do not include p_2. This indicates that cash in hand in season 1 is no more valuable than cash in hand in season 2, because additional cash in hand in season 1 is not saved in the form of maize any more, but is saved in the form of money with interest rate of $1 + r$. This saving is used only for purchase of non-staple foods, and non-food items in season 2. This also indicates that the loss of cash in hand in season 1 no more requires a larger increase of cash in hand in season 2 to maintain the same inter-temporal budget constraint.

The utility maximization problem for the farmer is reduced to maximizing (1) subject to (28) and (4). Define λ and ϕ as Lagrange multipliers which correspond to the equation (28) and (4) respectively, then the first order conditions for this problem are

- w.r.t c_1 $$\frac{\partial U}{\partial c_1} = \left(p_1 + \frac{p_1 \phi}{\lambda}\right) \lambda \tag{29}$$
- w.r.t x_1 $$\frac{\partial U}{\partial x_1} = \left(1 + \frac{\phi}{\lambda}\right) \lambda \tag{30}$$
- w.r.t c_2 $$\frac{\partial U}{\partial c_2} = \left\{\frac{p_1}{1-\nu} + \frac{p_1}{1-\nu}\frac{\phi}{\lambda}\right\} \lambda \tag{31}$$
- w.r.t x_2 $$\frac{\partial U}{\partial x_2} = \frac{1}{1+r} \lambda \tag{32}$$

where $\lambda > 0$, and $\phi > 0$ if equation (4) binds, and otherwise $\phi = 0$. Consumption functions $c_t^{NBH}, x_t^{NBH} (t = 1, 2)$ are determined by equations (28),(29)-(32), and can be represented as follows;

$$c_t^{NBH} = c_t^{NBH}(p_1, p_2, Z) \tag{33}$$
$$x_t^{NBH} = x_t^{NBH}(p_1, p_2, Z) \tag{34}$$

where Z is the vector of exogenous variables $y, wL_1, wL_2, r, \bar{B}, \nu, \beta$, and θ. Define $p^*_{c_1}, p^*_{x_1}, p^*_{c_2}$ and $p^*_{x_2}$ be

[16] The amount of maize saving is strictly positive ($S > 0$) and it provides for all consumption during season 2 ($c_2 = (1-\nu)S$).

as follows;

$$\bullet\, p_{c_1}^{**} = p_1 + \frac{p_1\phi}{\lambda} \tag{35}$$

$$\bullet\, p_{x_1}^{**} = 1 + \frac{\phi}{\lambda} \tag{36}$$

$$\bullet\, p_{c_2}^{**} = \frac{p_1}{1-\nu} + \frac{p_1}{1-\nu}\frac{\phi}{\lambda} \tag{37}$$

$$\bullet\, p_{x_2}^{**} = \frac{1}{1+r} \tag{38}$$

Then, $p_{c_1}^{**} p_{x_1}^{**}, p_{c_2}^{**}$ can be interpreted as shadow prices of c_1, x_1, c_2, x_2. Note that p_2 plays no role in these shadow prices. Thus, in contrast to the farmer who buys maize at higher prices, the farmer has no more strong incentive to restrain himself or herself from consuming staple foods in season 1, staple foods in season 2, and other goods in season 1. Seasonal consumption patterns are determined so that marginal rate of substitution is equal to the ratio of shadow prices, that is,

$$\bullet\, \frac{U_{c_1}}{U_{c_2}} = 1 - \nu \tag{39}$$

$$\bullet\, \frac{U_{x_1}}{U_{x_2}} = (1+r) + \frac{(1+r)\phi}{\lambda} \tag{40}$$

These results show that seasonal price changes of maize do not affect seasonal consumption patterns for any goods. Thus, seasonal price changes of maize does not affect this farmer's welfare, that is,

$$\frac{\partial V(P,W)}{\partial p_2} = 0 \tag{41}$$

Lastly, consider the role of the equation (4) on seasonal consumption patterns.[17] Shadow prices of goods purchased during season 1 ($p_{c_1}^{**}, p_{x_1}^{**}$,and $p_{c_2}^{**}$) increase if this borrowing constraint binds ($\phi > 0$), that is, the farmer with a binding borrowing constraint of money allocates his or her consumption as if the prices of those goods increase. Intuitively, the farmer with a binding this borrowing constraint wants to consume more in season 1 and wants to purchase more maize in season 1 for season 2, instead of consuming other goods in season 2, but the borrowing constraint of money prevents from doing so. The binding borrowing constraint of money implies a failure of inter-seasonal resource reallocation. Note that the consumption of other goods in season 2 of the farmer with a binding borrowing constraint of money does not respond to harvest shocks (decrease of y) as long as the equation (4) binds. To see this, the utility maximization problem of the farmer with a binding this borrowing constraints ($B = \bar{B}$) is re-written as follows;

$$\max_{c_1,x_1,c_2,x_2} U(c_1, x_1, c_2, x_2 \mid \beta, \theta) \tag{42}$$

s.t.

$$x_1 + p_1(c_1 + c_2) = p_1 y + wL_1 + \bar{B} \tag{43}$$

$$x_2 + (1+r)\bar{B} = wL_2 \tag{44}$$

[17] Remember that the equation (4) can be interpreted as the borrowing constraint in the form of money. Since this farmer saves in the form of maize up until the amount he or she consumes during season 2, this farmer smooth his or her consumption by borrowing or saving money.

Equations (43) and (44) imply that the consumption of other composite goods in season 2 is determined separately from the amount of harvest (y). Intuitively, this farmer wants to borrow from income in season 2 to increase consumption in season 1. A small increase in y allows the farmer to increase consumption in season 1 and maize savings to consume in season 2, but has no effect on consumption of non-staple items in season 2.

3.3 Diagramatic Representation of the Utility Maximization Problem

A diagram provides an intuitive explanation for the utility maximization problem. For simplicity, preferences over time are assumed to be additive, that is,

$$U(c_1, x_1, c_2, x_2 \mid \beta, \theta) = U(u_1, u_2 \mid \beta, \theta) = u_1(c_1, x_1 \mid \theta) + u_2(c_2, x_2 \mid \beta, \theta) \tag{45}$$

The farmer's utility maximization problem can be divided into two stages; at the first stage, expenditure is allocated to either season 1 or season 2, and at the second stage, expenditure in each season is allocated to staple goods and other goods.[18] To simplify the notation, β and θ are not shown unless otherwise noted.

3.3.1 The Farmer Who Buys Maize at Higher Prices (BH: $q_2 > 0$)

Figure 8(a) illustrates the utility maximization problem for the farmer who buys maize at higher prices in season 2 (BH: $q_2 > 0$) with $S > 0$. The first quadrant represents the decision making on the first stage, that is, total expenditure is allocated to either season 1 or season 2. Its horizontal axis is for the expenditure in season 1, denoted by M_1, and the vertical axis for the expenditure in season 2, denoted by M_2. Equation (45) can be re-written as;

$$\begin{aligned} U(c_1, x_1, c_2, x_2) &= u_1(c_1, x_1) + u_2(c_2, x_2) \\ &= u_1(c_1(P, M_1), x_1(P, M_1)) + u_2(c_2(P, M_2), x_2(P, M_2)) \\ &= U(M_1, M_2 \mid P) \end{aligned} \tag{46}$$

where P is a vector of p_1 and p_2. Note that the change of P changes the functional form of $U(M_1, M_2 \mid P)$, which makes it difficult to conduct comparative statistics with respect to P on this diagram. OA, AB, BC, and OD represent wL_1, $\bar{B}$, $p_1 y$, and wL_2, respectively. This farmer borrows $\bar{B}$ in season 1 and repays $(1+r)\bar{B}$ in season 2, which is represented by DE in the diagram. OC represents the total money the farmer can spend in season 1 without maize savings and borrowing up to the limit of $\bar{B}$, and OE represents the total money the farmer can spend in season 2 without maize savings. Since this farmer can save maize from season 1 to season 2 with the return rate of $\frac{p_2}{p_1}(1-\nu)$, GFC represents the inter-seasonal budget constraint for this farmer in which the slope of GF is $\frac{p_2}{p_1}(1-\nu)$. This farmer maximizes his or her utility $U(M_1, M_2 \mid P)$, given this budget constraint. As a result of utility maximization, OJ represents total expenditure in season 1, and OI represents total expenditure in season 2. Note that JC represents the amount of maize savings in monetary terms, that is, $p_1 S$. At the second stage of the utility maximization

[18] See Chapter 5 in Deaton and Muellbauer (1980) for more details.

problem, these expenditures OJ and OI are allocated to staple foods and other goods in each season. The fourth quadrant represents the decision making on the second stage for season 1. Horizontal axis is for the amount of other goods consumed in season 1 (x_1), and vertical axis is for the amount of staple foods consumes in season 1 (c_1). Since one unit of maize is worth p_1 units of money, the slope of budget constraint (JK) is p_1. The optimal amounts of c_1 and x_1 are determined to maximize a contemporaneous utility function $u_1(c_1, x_1)$ given this budget constraint JK. As a result of this utility maximization, OM represents the amount of maize consumed in season 1 (c_1^*) and OB represents the amount of other goods consumed in season 1 (x_1^*). LB represents the value of maize sold in season 1, that is, $-p_1 q_1$. If OL is bigger than OB, in other words, if x_1^* is bigger than $wL_1 + \bar{B}$, the farmer sells maize in season 1. If OL is smaller than OB, the farmer buys maize in season 1. The second quadrant represents the decision making on the second stage for season 2. Vertical axis is for the amount of other goods consumed in season 2 (x_2), and horizontal axis is for the amount of staple foods consumes in season 2 (c_2). Since one unit of maize is worth p_2 units of money, the slope of budget constraint (IN) is p_2. The optimal amounts of c_2 and x_2 are determined to maximize a contemporaneous utility function $u_2(c_2, x_2)$ given the budget constraint IN. As a result of this utility maximization, OP represents the amount of maize consumed in season 2 (c_2^*) and OQ represents the amount of other goods consumed in season 2 (x_2^*). EQ represents the value of maize bought in season 2, that is, $p_2 q_2$.

One thing to note is that the binding credit constraint ($B = \bar{B}$) does not mean that the farmer cannot re-allocate income across seasons, because he or she re-allocates income by using maize.[19] For this farmer, the upper limit of borrowing money can be interpreted as income in season 1, which is $\{1 - \frac{p_1(1+r)}{p_2(1-\nu)}\}\bar{B}$, where $\frac{p_1(1+r)}{p_2(1-\nu)}\bar{B}$ is the value of repayment measured in season 1. Another thing to note is that, regardless of whether the farmer sells or buys maize at higher prices or lower prices (the sign of $q_t (t = 1, 2)$), the cost structure of this farmer does not change in the sense that neither the budget constraint nor the shadow prices change, unless transaction costs of maize trade (equation (6)) are taken into consideration. "Sell low" behavior happens if the proportion of cash income in season 1 ($\bar{B} + wL_1$) to full income is too low to satisfy goods demand in season 1 (x_1^*). "Buy high" behavior happens if the proportion of income in season 1 ($p_1 y + wL_1 + \{1 - \frac{p_1(1+r)}{p_2(1-\nu)}\}\bar{B}$) to full income over both seasons is so low that the farmer chooses not to save a sufficient amount of maize to satisfy the demand of maize consumption in season 2 (c_2^*). In other words, the farmer does not buy maize at higher prices if he or she borrows enough money, or has sufficient income, in season 1 to purchase enough maize in season 1 to fully satisfy the demand for maize in season 2.

Figure 8 (b) illustrates the utility maximization problem for the farmer who buys maize at higher prices (BH: $q_2 > 0$) with $S = 0$. OA and OB represent wage income in season 1 (wL_1) and in season 2 (wL_2),

[19] The theoretical model in this paper is consistent with Kazianga and Udry (2006) in which there is almost no risk sharing, and households almost exlcusively on self-insurance in the form of adjustments to grain stocks to smooth out consumption in rural Burkina Faso.

respectively. For simplicity, $\bar{B}$ and y are assumed to be zero. Notice that wL_2 is much longer than wL_1, which means that the farmer's problem is that he or she cannot borrow from income in season 2 to finance consumption in season 1, so all maize household in season 1 is consumed in season 1, and none is saved for season 2. If borrowing maize were allowed ($S < 0$), then the optimal indifference curve is $\bar{U}'$ and the budget constraint at second stage is A'G' for season 1 and B'F' for season 2. However, the inability to borrow maize decreases the optimized utility to $\bar{U}$. As a result, the budget set in season 2 expands, while budget set in season 1 shrinks. This indicates that this farmer wants to consume more in season 1, instead of consuming in season 2.

Figure 9 illustrates how harvest shocks ($p_1 y$) affect seasonal consumption (the first quadrant of the diagram.). For simplicity, $\bar{B}$ and wL_1 are assumed to be zero, and OA and OB represent $p_1 y$ and wL_2 respectively. If the farmer's harvest is more than OA', the farmer saves positive amounts of maize ($S > 0$), and if the farmer's harvest is less than OA', the farmer does not save maize ($S = 0$). In this case, the decrease of the harvest affects only the total consumption in season 1. This diagram indicates that, if the harvest shock is large enough to reduce maize savings to zero ($S = 0$), harvest shocks mainly reduce consumption in season 1.

3.3.2 The Farmer Who Does Not Buy Maize at Higher Prices (NBH: $q_2 = 0$)

Figure 10 illustrates the utility maximization problem for the farmer who does not buy maize at higher prices (NBH: $q_2 = 0$). OA, AB, BC, and OD represent wL_1, $p_1 y$, $\bar{B}$, and wL_2, respectively. Since this farmer saves enough maize for self-consumption in season 2, he or she also saves in the form of money for additional savings. Thus, this farmer's inter-seasonal budget line at the first stage is the line through the point E with slope $1 + r$, that is, FG. This farmer maximizes his or her utility $U(M_1, M_2 \mid P)$, given this budget constraint. As a result of utility maximization problem, OI represents total expenditure for c_1 and x_1, and OH represents total expenditure for c_2 and x_2. The fourth quadrant determines the allocation of c_1 and x_1. Since one unit of maize is worth p_1 units of money, the slope of budget constraint (JI) is p_1. The optimal amounts of c_1 and x_1 are OL and OK, respectively. The second quadrant determines the allocation of c_2 and x_2. Since one unit of maize is worth $\frac{1+r}{1-\nu} p_1$ units of other goods, [20] the slope of budjet constraint is $\frac{1+r}{1-\nu} p_1$. The optimal amounts of c_2 and x_2 are ON and OP. Note that the amount of maize in season 2 (ON) is equivalent to HP in monetary terms of season 2, and is equivalent to IQ in monetary terms of season 1. Thus, BQ represents the amount of borrowing (B), which is less than $\bar{B}$ (BC). If $\bar{B}$ is not large enough to satisfy B, say BC', this farmer's credit constraint is binding ($B = \bar{B}$). Note that, for this farmer, the binding credit constraint ($B = \bar{B}$) means that the farmer is unable to re-allocate income across seasons. [21] Conversely, to identify the farmer who misses optimal inter-seasonal resource allocation,

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[20] One unit of maize in season 2 is equivalent to $\frac{1}{1-\nu}$ units of maize in season 1, which is worth $\frac{1}{1-\nu} p_1$ units of other goods. In season 2, this becomes $\frac{1+r}{1-\nu} p_1$ units of other goods.

[21] As for the maize saving, it is always strictly positive ($S = \frac{c_2}{1-\nu} > 0$). But this savings can be used only for self-consumption in season 2.

credit constraint[22] can be used for NBH farmers ($B = \bar{B}$). However, for BH farmers, credit constraint should not be focused. Instead, the storage of maize should be focused ($S = 0$).

4 Estimation Strategies

4.1 Estimation of Consumption Functions

Consumption functions are estimated to examine the extent to which farmers in rural Zambia can smooth their consumption from season to season, as well as from year to year, in response to harvest shocks. Since seasonal maize prices have different impacts on those farmers who buy maize at higher prices and on those farmers who do not buy maize at higher prices, consumption functions are estimated separately for each group of farmers - the group who buys maize when prices are high (BH) and the group that does not buy maize when prices are high (NBH). [23] The following consumption function is estimated for both groups of farmers;

$$C^j_{imyw} = \alpha^j_m + \beta^j_m TI_{iy} \cdot D_m + \gamma^j X^j_{imy} + \eta^j_{yv} + \pi^j_i + \epsilon^j_{imyw} \tag{47}$$

where C^j_{imyw} is consumption in household i in month m in village v in year (crop year) y in week w, and superscript j is BH or NBH. The term α^j_m captures average seasonal consumption patterns. D_m is a dummy variable that equals one if the month is m, and 0 otherwise, and TI_{iy} represents harvest shocks for household i suffered at the beginning of the crop year y. X_{imy} is a vector of time-varying household variables, π^j_i is a household fixed effect, and η^j_{yv} is a cross product term between each year dummy variable and each village dummy variable. The error term ϵ^j_{imyw} is assumed to be independent across households, and is clustered by each household.

The farmer who buys maize at higher prices is defined as the farmer who bought maize after December. As a variable for harvest shocks, the survey data collected in September 2010, which have retrospective data on income shocks, are used. For each plot in each year, households were asked whether each plot was fallow in that year. If not fallow, the crop yield of each plot was asked on a scale of "Above average", "Average" or "Below average". The reasons for being "below average" are categorized into fallow, heavy rain, lack of seed, lack of fertilizer, or other reasons. In addition, for each plot, rental costs were asked. Note that since the land market is incomplete, rental costs are subjective. By using these data, for each reason of below average, the fraction of the value of plots that are below average divided by the total value of the land is calculated for each household in each year. As a proxy variable for harvest shocks, the fraction of "below average due to other reasons" are used, because "below average due to fallow, lack

[22] Note that credit here means the short-term credit, that is, borrowing money within the same crop year. It does not mean borrowing money from the following crop year or later.

[23] This relates to Jalan and Ravallion (1999) in which the hypothesis of perfect insurance against income risk is tested by the household wealth status. The theoretical model in our paper gives one explanation for their results, because the farmer with less wealth is more likely to fall into the BH group.

of seed, or lack of fertilizer" should relate to the farmer's management of land, which could also correlate to consumption. The fraction of "below average due to heavy rain" is not used, because the impact of heavy rain is absorbed in year variant village fixed effects.[24] Seasonal consumption patterns are captured by monthly dummy variables. To allow for different seasonal consumption patterns by different cropping patterns, the cross term of month dummy variables and dummy variable for cropping pattern, which is defined as 1 if the household cultivates a second crop and 0 otherwise, are added. Household fixed effects capture permanent income, and year variant village fixed effects capture any village level income shocks.[25] The impact of seasonal price changes is absorbed in year variant village fixed effects.

The coefficients β^j_m capture the impact of harvest shocks on consumption in each month, and are the parameters of interest. If the farmer successfully smooths consumption from year to year, all the β^j_m coefficients should be zero. If the farmer fails to smooth consumption from year to year, β^j_m coefficients should be negative at least for one month. In this case, the size of β^j_m in each month depends on the income elasticities of consumption in each month, reflecting the discount rate, season specific preferences, shadow prices of each goods, the goods the farmer consumes during the corresponding month, and so on. In addition, the size of β^j_m in each month also depends on the farmer's capability of inter-seasonal resource re-allocation. For the BH group, the farmer who runs out of maize savings ($S = 0$) mainly decreases consumption consumed before he or she runs out of maize savings, represented in Figure 9. For NBH group, the farmer who binds credit constraint ($B = \bar{B}$) mainly decreases maize consumption and consumption of other goods relatively soon after harvest.

4.2 Sample Selection and Robustness Checks

One concern of regarding identification of the consumption function is selection bias. According to the theoretical model, the farmer whose large proportion of annual income comes from the income received in the second season during the crop year is more likely to fall into the BH group. Also, the farmer who does not have enough funding to buy maize when maize prices are low is more likely to fall into the BH group. Thus, these differences of income patterns or funding ability among households can affect both consumption and the timing of maize purchase. Thus, estimation of consumption function using only the data of either group of farmers could induce an endogeneity problem caused by sample selection.

The household fixed effects fix this selection bias. To see how household fixed effects works, consider the

[24] Heterogenous impacts of heavy rain among households are absorbed in year variant household fixed effects, which is used as a robustness check. discussed in the following subsection.

[25] Two noteworthy income shocks that occurred during the study period are heavy rains in December 2007 and in February 2010. These heavy rains ruined or even washed away maize fields, and decreased households' transient income in crop years 08/09 and 10/11. The impact of these heavy rains was different depending on geographical conditions. Since differences of geographical condition almost correspond to village classification, η^j_{yv} captures village level income shocks caused by heavy rains. Note that, in this village classification, Site B is divided into two areas, because the geomorphological feature and soil conditions of these two areas are different.

following switching model;

$$C_{imyw} = \begin{cases} C^{NBH}_{imyw} = \alpha^{NBH}_{m} + \beta^{NBH}_{m} TI_{iy} \cdot D_m + \gamma^{NBH} X_{imy} + \eta^{NBH}_{yv} + \pi^{NBH}_{i} + \epsilon^{NBH}_{imyw} & \text{if} \quad d_{iy} = 1 \\ C^{BH}_{imyw} = \alpha^{BH}_{m} + \beta^{BH}_{m} TI_{iy} \cdot D_m + \gamma^{BH} X_{imy} + \eta^{BH}_{yv} + \pi^{BH}_{i} + \epsilon^{BH}_{imyw} & \text{if} \quad d_{iy} = 0 \end{cases} \tag{48}$$

$$d^*_{iy} = \sigma' Z_{iy} + \xi_i + \nu_{iy} \tag{49}$$

$$d_{iy} = \begin{cases} 1 & \text{if } d^*_{iy} > 0, \\ 0 & \text{if } d^*_{iy} \leq 0, \end{cases} \tag{50}$$

where equations (49) and (50) represent the selection process which determines either NBH or BH status. Z_{iy} is a vector of variables which determine household maize purchase patterns, the continuous variable d^*_{iy} is the latent variable, and d_{iy} equals one if d^*_{iy} exceeds zero and corresponds to household i in year y being BH. Without loss of generality, the case of $j = BH$ is considered. Define $F^{BH}_{iy} \equiv \eta^{BH}_{yj} + \pi^{BH}_{i}$, and take a conditional expectation to equation (48).

$$\begin{aligned} & E[C^{BH}_{imyw} \mid d_{iy} = 1, X_{imy}, F^{BH}_{iy}] \\ &= E[\alpha^{BH}_{my} + \beta^{BH}_{m} TI_{iy} \cdot D_m + \gamma^{BH} X_{imy} + F^{BH}_{iy} + \epsilon^{BH}_{imyw} \mid d_{iy} = 1, X_{imy}, F^{BH}_{iy}] \\ &= \alpha^{BH}_{my} + \beta^{BH}_{m} TI_{iy} \cdot D_m + \gamma^{BH} X_{imy} + F^{BH}_{iy} + E[\epsilon^{BH}_{imyw} \mid \nu_{iy} > -\sigma' Z_{iy} - \xi_i] \end{aligned} \tag{51}$$

The term $E[\epsilon^{BH}_{imyw} \mid \nu_{iy} > -\sigma' Z_{iy} - \xi_i]$ could generate the sample selection bias. Thus, the conditions that the sample selection bias generates are discussed. First, consider the case that ϵ^{BH}_{imyw} and ν_{iy} are independent. In this case, $E[\epsilon^{BH}_{imyw} \mid \nu_{iy} > -\sigma' Z_{iy} - \xi_i] = 0$, and the sample selection bias does not occur. Second, consider the case where ϵ^{BH}_{imyw} is correlated with ν_{iy}, say, $\epsilon^{BH}_{imyw} = f(\nu_{iy})$. In this case, household fixed effects correct sample selection bias if the probability that the household buys maize at higher prices is identical across years. To see this, consider the two different year y and y' and the situation that the household specific probability that buys maize at higher prices is identical across years. In this case, $E[\epsilon^{BH}_{imyw} \mid \nu_{iy} > -\sigma' Z_{iy} - \xi_i] = E[\epsilon^{BH}_{imy'w} \mid \nu_{iy'} > -\sigma' Z_{iy'} - \xi_i]$ holds and household fixed effects absorb the term $E[\epsilon^{BH}_{imyw} \mid \nu_{iy} > -\sigma' Z_{iy} - \xi_i]$. Lastly, consider the case where ϵ^{BH}_{imyw} is correlated with ν_{iy} and the probability that each household buys maize at higher prices is different across years. In this case, $E[\epsilon^{BH}_{imyw} \mid \nu_{iy} > -\sigma' Z_{iy} - \xi_i]$ is different across years for the identical household, and household fixed effects do not correct sample selection bias. However, even in this case, if the differences in the probabilities are small, the difference of $E[\epsilon^{BH}_{imyw} \mid \nu_{iy} > -\sigma' Z_{iy} - \xi_i]$ is also small and most of the term $E[\epsilon^{BH}_{imyw} \mid \nu_{iy} > -\sigma' Z_{iy} - \xi_i]$ is absorbed in household fixed effects. Thus, the sample selection bias would be small. In sum, if the same households are likely to buy maize at higher prices in each year, most of the sample selection bias is corrected by the household fixed effects. And since the sources of this sample selection bias at issues - differences of income patterns or funding ability among households - seem to be household-specific characteristics, and the probabilities that each household buys maize at higher prices seems not to change across years, the household fixed effects should work to correct sample selection bias.

As a robustness check, the case where the probabilities that each household buys maize at higher prices varies across years is considered. This can happen if funding ability, such as asset holdings, of each household varies over times. In this case, the household fixed effects does not correct sample selection bias, but year variant household fixed effects correct the sample selection bias, because the term $E[\epsilon_{imyw}^{BH} \mid \nu_{iy} > -\sigma' Z_{iy} - \xi_i]$ in equation (51) is identical if both household i and year y are identical.[26] One drawback of this estimation method is that year variant household fixed effects make it impossible to derive β_m^j, because the cross-terms $TI_{iy} \cdot D_m$ $(m = 1, \cdots, 12)$ and year variant household fixed effects are linearly dependent. Thus, one of those cross-terms for some base month should be dropped from the model (in this paper, May), and all that one can estimate are the differences of coefficient from May, that is, $(\beta_m^j - \beta_5^j)$. Thus, both the estimation results with and without year variant household fixed effects are estimated and compared. Note that the estimation using year varying household fixed effects also serves as a robustness check for omitted variable problem and measurement error of year-varying control variables.

5 Estimation Results

Estimation results of consumption functions are used to discuss how farmers in rural Zambia can smooth their consumption from season to season, as well as from year to year, in response to harvest shocks. As an dependent variable, the value of total consumption per week per adult-equivalent is used. Then, to see how the composition of consumption changes in response to harvest shocks, total consumption is decomposed into staple foods and other goods, and consumption functions of these goods are estimated separately. Lastly, in Zambia, micronutrient deficiencies, especially of infants, young children aged 6-24 months, and women on child-bearing age, are an accute problem. For example, according to the Zambia (2011), the prevalence of vitamin A deficiency in 2003 was 53.3% for children and 13.4% for women in child-bearing age. This increases the risk of disease and death from severe infections, so improving nutrition security is an important policy challenge. From this policy perspective, it is also useful to see how farmers adjust their consumption of non-staple foods in response to harvest shocks. Thus, we divide consumption of other goods into other foods (almost corresponding to their side dishes of their diet) and non-food items. Consumption functions of these goods are also estimated separately.

Table 4 reports the estimated parameters β_m^j in equation (47) in which sample selection bias is corrected by household fixed effects. Remember that most households harvest in April or May. The coefficients of other control variables and the results with year variant household fixed effects are reported in Appendix,

[26] Fixed effects approach is applicable when there are multiple equations of interest corresponding to one selection equation. In the case that one equation of interest corresponds to one selection equation, control function approach is a common way to correct sample selection bias. In the setting of Heckman (1976), the inverse Mills ratio constructed from the selection equation is added to the equation of interest. In the case of multiple equations for one selection equation, such variables can be controlled by fixed effects. Note that this fixed effects approach requires neither an exclusion restriction nor consistent estimators of the selection equation. Another thing

showing that the result of the estimation of (47) is robust. The first two columns are the results for the total consumption, the third to sixth columns are for staple foods and other goods, and the last four columns are for other foods and non-food items. For all estimations, consumption functions are separately estimated for the group that buys maize at higher prices (BH), and for the group that does not buy maize at high prices (NBH). The coefficients can be interpreted as the changes of the value of consumption per week per adult equivalent (ZMK) when all of their plots are "below average".[27]

5.1 The Farmer Who Buys Maize at Higher Prices (BH: $q_2 > 0$)

The results for total consumption show that the farmers in the BH group are unable to smooth their consumption across years, because their total consumption responds to harvest shocks. Although they engage in off-farm jobs after harvest, the income from those jobs is not enough to compensate for their harvest shocks. Part of the reason for this failure is seasonal price changes of maize, because values of cash income gradually decrease while the price of maize rises. In other words, maize prices gradually increase during the time they work to buy maize. The impact of harvest shocks is not negligible. For the farmers in the BH group, the coefficients of income shocks of each month range from 2738 in December to 7911 in June. This means that, if 10% of these farmer's land suffers from below average harvest, they decrease their consumption by 791 ZMK in June and by 274 ZMK in December. These impacts are not ignorable, considering that the total consumption per week is 8464 ZMK on average throughout a year (Figure 6).

Although the farmers in the BH group decrease their total consumption in response to harvest shocks, they mostly do not decrease their consumption of staple foods, in spite of the seasonal price hike of maize.[28] Instead, they decrease other foods and non-foods at a non-negligible level. If 10% of these farmer's land suffers from below average harvest, they decreases 696 ZMK of other goods in June, which is decomposed into 453 ZMK of other foods and 243 ZMK of non-foods. Note that the other foods generally correspond to the side dishes of their diet, which are important sources of their micronutrients. Even if the farmers in this group suffer income shocks, they sustain their consumption of staple foods by purchasing maize at higher prices. As a result, they decrease their consumption of other foods. Thus, the policy to improve food diversity should be discussed with seasonal price changes of staple foods.

The different extent of the impact of harvest shocks by month is another noteworthy result. The farmers in the BH group decrease consumption of other foods and non-foods, especially in the earlier months of the year. There are several possible reasons. One possible explanation is the different compositions of the consumption goods by month. As discussed in section 2.2, the farmers in the study village tend to

[27] For example, consider the BH group in May. The coefficient for total consumption is -6113. This implies that, if 10% of the plot of the BH farmer is below average, the total consumption per week per adult equivalent decreases 611.3 ZMK in May in real terms.

[28] Only the coefficient in June is significant at the 10% level. The null hypothesis that all the coefficients of cross term of income shock and month dummy are zero are rejected, but they are week (F(12,20)=2.08 and p-value of 0.0714).

purchase household goods such as clothes and kitchen utensils just after the harvest, mainly in May, June, and July. The relatively sensitive responses of non-foods item in these months can be due to high income elasticities of these goods. Another possible explanation is the different shadow prices of other goods. As discussed in section 3.2.1, the shadow prices of other goods in the earlier months of the year are higher than the shadow prices of other goods in the later months of the year, because other goods in the earlier months of the year can be used to take advantage of highly profitable inter-seasonal arbitrage of maize, while other goods in the later months cannot. Thus, the farmers in this group may choose to decrease consumption of other goods in the earlier months, instead of decreasing in the later months, in response to harvest shocks. The other possible explanation is a binding borrowing constraints of maize. As illustrated in Figure 9, the farmer who suffers from large harvest shocks to run out of maize savings ($S = 0$) decreases consumption mainly in the earlier months of the year. This reasoning seems to be plausible, because the actual maize purchase patterns of many farmers in the BH group is consistent with the maize purchase patterns of the farmer with a binding borrowing constraint of maize predicted by the theoretical model. As discussed in Section 2.3, most farmers in the BH group repeat the cycle that they go to work, work until they have enough money to buy some maize, which is likely to be a cycle of ever week, every 15 days, or every month. This behavior is consistent with the predicted maize purchase patterns of the farmer with a binding borrowing constraint of maize ($S = 0$) in which cash in hand in each season is only used for the consumption of corresponding season. In addition, many farmers in the BH group start this cycle in the later months of the year without purchasing maize in the earlier months,[29] which implies the high marginal utility of consumption in earlier months. This is consistent with the theory that, for the farmer with a binding borrowing constraint of maize, the marginal rate of substitution of consumption in earlier months for consumption in later months is higher than the ratio of shadow prices of each month of consumption without a binding borrowing constraint of maize. Note that the theoretical model implies that this farmer wants to consume more in earlier months, instead of consuming in later months, and that the hunger season in the village is recognized as the later time during the crop year. There are several possible explanations for this. One possible explanation is farmers' hyperbolic preferences. Remember that the farmer's decision of consumption and savings is made in earlier months. Thus, results can be interpreted as the farmers' time-inconsistent preferences in the sense that their preferences just after harvest and preferences in later periods are different. Another possible explanation is income shocks in hunger season. Since the consumption of the farmers in this group fully depends on the income in this season, unexpected income shocks in hunger season directly reduce their consumption.

5.2 The Farmer Who Does Not Buy Maize at Higher Prices (NBH: $q_2 = 0$)

Looking at the results for total consumption, no coefficients are significant. These results indicate that they successfully smooth their consumption from year to year, because total consumption should respond

[29] 11 out of 35 households start purchasing maize in December. Only 10 of 35 households start to buy maize in May, June, July, or August.

to income shocks at least one month if they fail. The results also reject the hypothesis that they are unable to optimize their inter-seasonal resource allocation ($B = 0$), because if they were unable to do so, their consumption would respond to harvest shocks just after harvest. In sum, the farmer who does not buy maize at higher prices successfully smooths his or her consumption from season to season, as well as from year to year.

6 Conclusion

This paper has given a detailed picture of seasonal consumption smoothing of farmers in rural Zambia in response to seasonal food price changes and income shocks to discuss policies for tackling seasonal hunger, taking heterogenous impacts of seasonal price changes into consideration - some buy staple foods only when prices are low and others buy some of their food when prices are high. Empirical results show that the farmers of the former group successfully smooth their consumption from season to season, as well as year to year. However, the farmers of the latter group are unable to smooth their consumption from season to season, as well as from year to year. They run out of staple food, and so buy it when prices are high. Although maize prices are high in hunger season, they sustain their consumption of staple foods against income shocks. Instead, they decrease their consumption of other foods. This result indicates that the policy to improve food diversity should be discussed with seasonal price changes of staple foods.

The theoretical model shows that seasonal price changes decrease the welfare of a farmer who buys maize at higher prices, but does not affect the welfare of farmer who does not buy maize at higher prices. The theoretical model also predicts that the farmer who does not have enough funding is more likely to buy maize when maize prices are high. Thus, seasonal price changes could expand the gap between rich and poor, and mitigating seasonal price changes should be an important policy goal. One possible solution can be market integration, because it can offset the price variations of different markets. Reducing the transaction costs or enhancing competition among different markets would enhance the market integration (e.g. Moser, Barrett, and Minten (2009)), and would reduce the seasonal price changes. Another possible solution can be a short-term credit market. The farmer who buys maize at higher prices can obtain high return from a short-term credit, because he or she can take advantage of highly profitable inter-temporal maize arbitrage without owing any transaction costs of maize selling. The randomized experiment to evaluate the impact of a short-term credit is a growing literature (e.g. Basu and Wong (2015) , Fink, Jack and Maiye (2014), and Burke (2014)). Basu and Wong (2015) and Fink, Jack and Maiye (2014) offer loans of maize at the start of the agricultural season with due date to be returned after harvest, and Burke (2014) offers the loans of cash just after the harvest with due date to be returned before harvest season. Our theoretical model predicts that the return to these loans is especially high for those farmers who otherwise would buy maize at higher prices. But if they are such farmers who were unable to reallocate their consumption across seasons, the short-term credit offered just after the harvest would not be used for their consumptions in hunger season.

Regarding limitations of this study, and recommendations for the future research, two points are worth noting. First, in addition to the short term impact of seasonal price changes, the long term impact of seasonal price changes should be discussed. For those farmers who buy maize at higher prices, the shadow prices of investment goods, such as seeds or fertilizers, are higher than shadow prices for those who do not buy maize at higher prices. In that case, they may provide fewer inputs for their agricultural production, which would reduce the agricultural income and would raise the probability that they fall into the same situation again. Lastly, although this paper depicts detailed information of consumption seasonality, the number of sample households is very small and does not contain large variations across households. Additional seasonal household data should be collected on a larger scale.

Appendix : Estimation results (Full version)

Table A(a) - Table A(c) report the estimation results of equation (47) in which the dependent variables are the value of (a) total consumption, (b) staple foods and other goods, and (c) other foods and non-foods, respectively. The first three columns are for the group who do not buy maize at high prices (NBH) and the last three columns are for the group who buy maize at higher prices (BH). The first and fourth columns are the results of the estimation in which sample selection bias is controlled by household fixed effects (HH), and the third and sixth columns are the results of estimation which correct selection bias by using year variant household fixed effects (YHH). To see the extent of potential bias of HH, the result of HH and result of YHH are compared. To compare the results of coefficients of the cross term of income shock and month dummy, coefficients of each month are subtracted from the coefficient from May, and those differences are reported in second and fifth columns. Comparing those results of HH and YHH, estimated coefficients are similar, and none of the variables dose not change their significance. Thus, the estimation result of HH is robust.

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Table 1 Summary Statistics

	Observation	Mean	S.D.	Min	Max
Weekl -variant variables					
Value of Total Consumption per week per adult equivalent (ZMK)	6430	9122	7193	441	179427
Value of Consumption of staple foods per week per adult equivalent (ZMK	6430	3764	2019	48	25724
Month-variant variables					
Number of Adult males	1692	1.77	1.22	0	5
Number of Adult females	1692	1.93	1.28	0	8
Number of Children	1692	3.36	2.33	0	10
Year-variant variables					
Number of Cattle	141	3.01	3.98	0	17
Proportion of rental values of land whose crop situation is "below average, because of reasons other than heavy rain, no fertilizer, no seeds" to total rental values of land	140	0.17	0.26	0	1

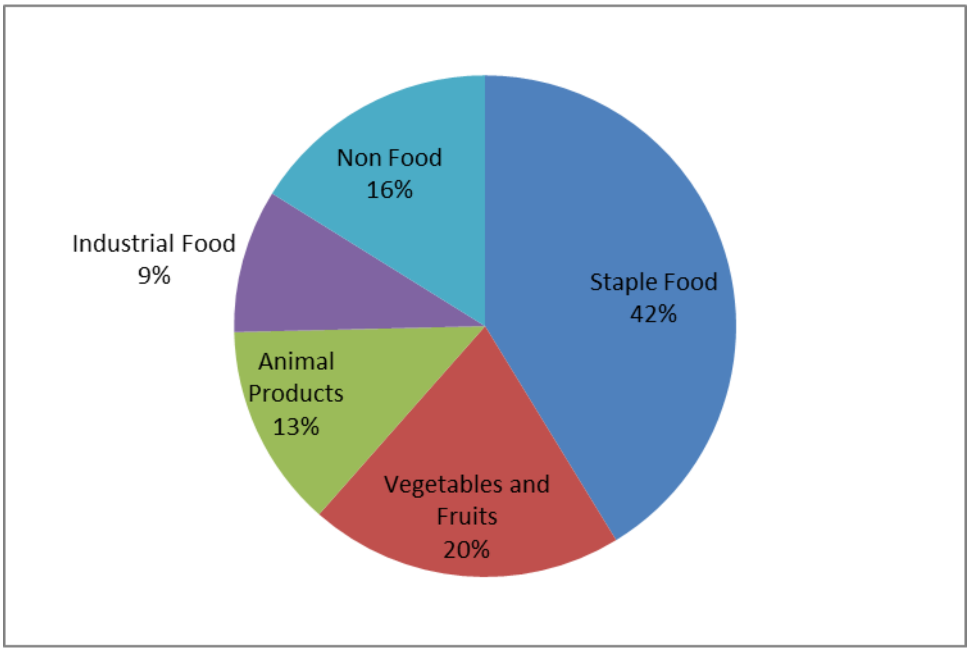
* Number is the cattle is the stock in Octobor in each period
* ZMK is deflated by a monthly price index (=1 as november 2007 in site A)

Source : Household survey data. Resilience Project

Table 2 Number of Households Who Grow Maize in Dry Season

	Number of households that grow maize in dry season	Number of households that do not grow maize in dry season	Total
Site A	6	9	15
Site B	4	12	16
Site C	12	4	16
Total	22	25	47

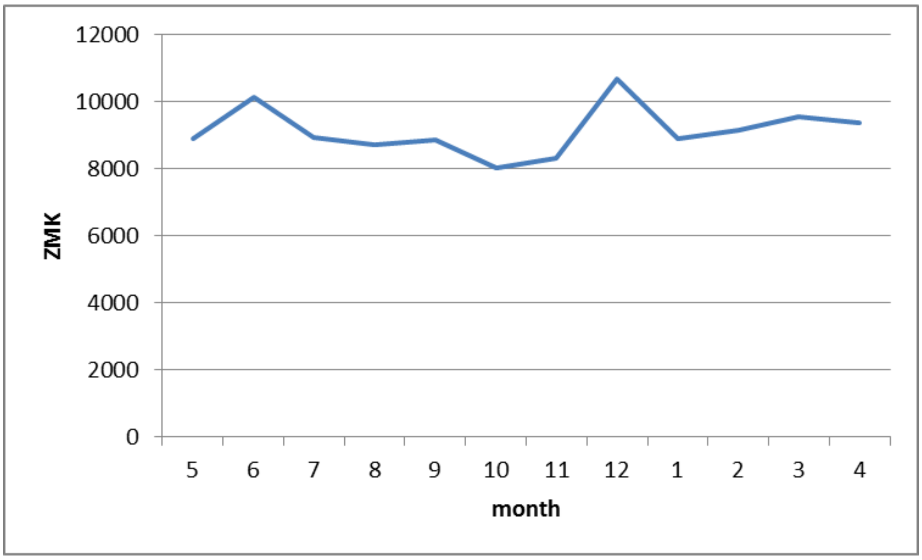
Source : Household survey data. Resilience Project



(Source) Household Survey Data. Resilience Project

※ Percentages are based on average total consumption per week per adult-equivalent, which are in ZMK deflated by a monthly price index (=1 as November 2007 in site A)

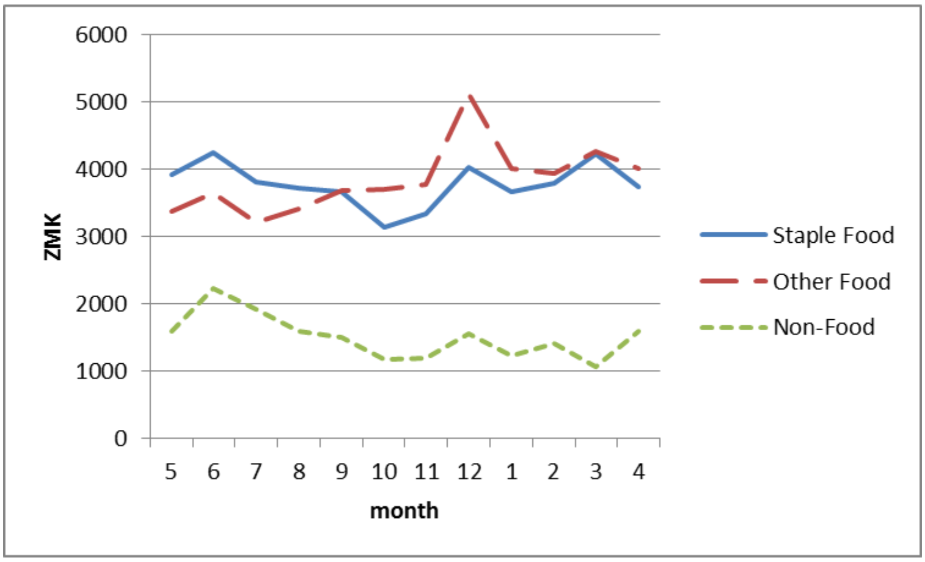
Figure 1. Average Composition of Values of Consumption over 3 Years (real terms)



(Source) Household Survey Data. Resilience Project

※ Average total consumption per week per adult-equivalent. Numbers are in ZMK deflated by a monthly price index (=1 as November 2007 in site A)

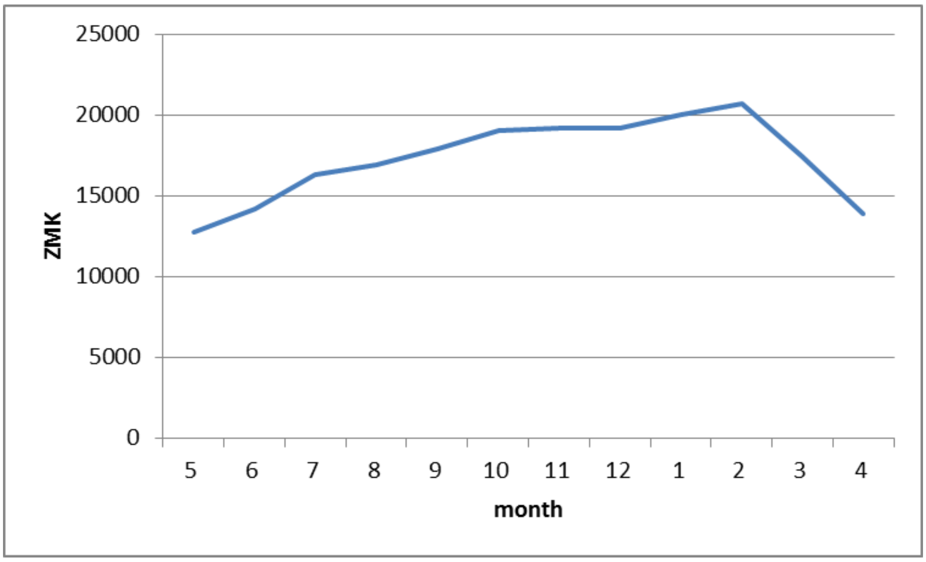
Figure 2. Seasonal Patterns of Average Total Consumption over 3 years



(Source) Household Survey Data. Resilience Project

※ Average total consumption per week per adult-equivalent. Numbers are in ZMK deflated by a monthly price index (=1 as November 2007 in site A)

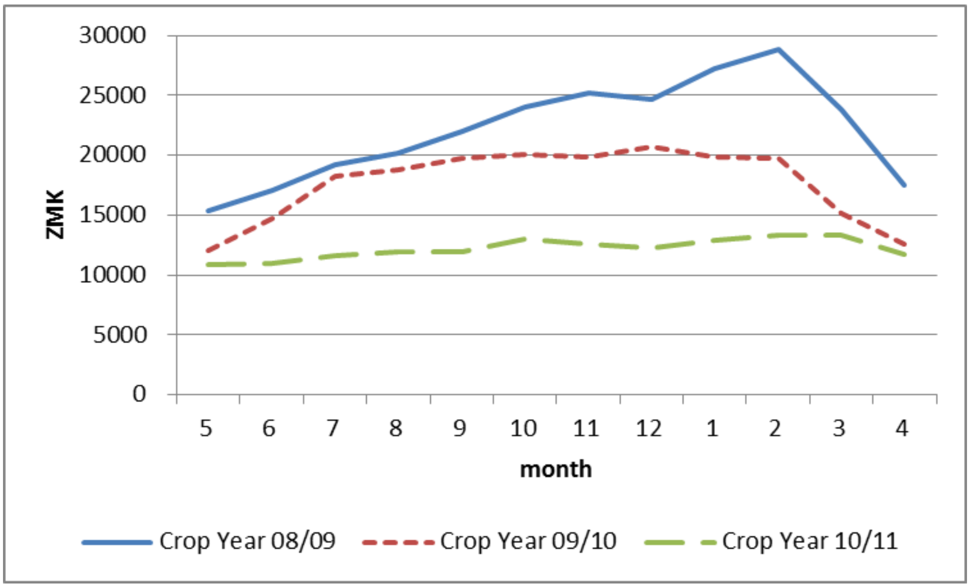
Figure 3. Seasonal Patterns of Average Consumption over 3 years



(Source) Household Survey Data. Resilience Project

※ Average total consumption per week per adult-equivalent. Numbers are in ZMK deflated by a monthly price index (=1 as November 2007 in site A)

Figure 4. Seasonal Patterns of Average Maize Price Per Bucket, over 3 years



(Source) Household Survey Data. Resilience Project

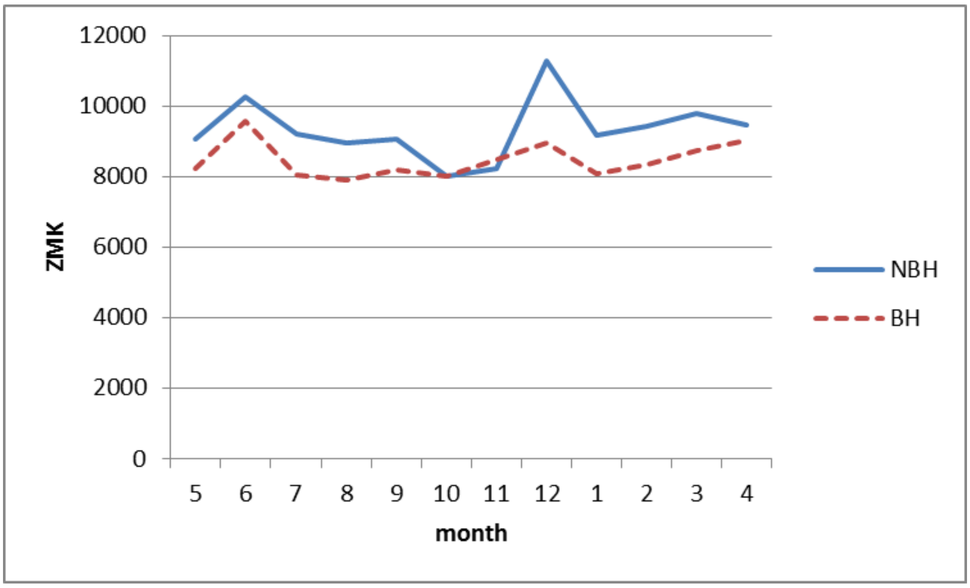
※ Average total consumption per week per adult-equivalent. Numbers are in ZMK deflated by a monthly price index (=1 as November 2007 in site A)

Figure 5. Seasonal Patterns of Average Maize Price Per Bucket by crop year

Table 3. Number of Households by Maize Purchase Patterns

		Over 3 years		Crop Year 08/09		Crop Year 09/10		Crop Year 10/11	
		Number	%	Number	%	Number	%	Number	%
Purchase		68	48%	27	57%	25	53%	16	34%
Purchase only until December	One or two times	30	21%	15	32%	8	17%	7	15%
	More than two times	2	1%	0	0%	0	0%	2	4%
Purchase some after December	One or two times	1	1%	0	0%	0	0%	1	2%
	More than two times	35	25%	12	26%	17	36%	6	13%
Does not purchase		73	52%	20	43%	22	47%	31	66%
Total		141	100%	47	100%	47	100%	47	100%

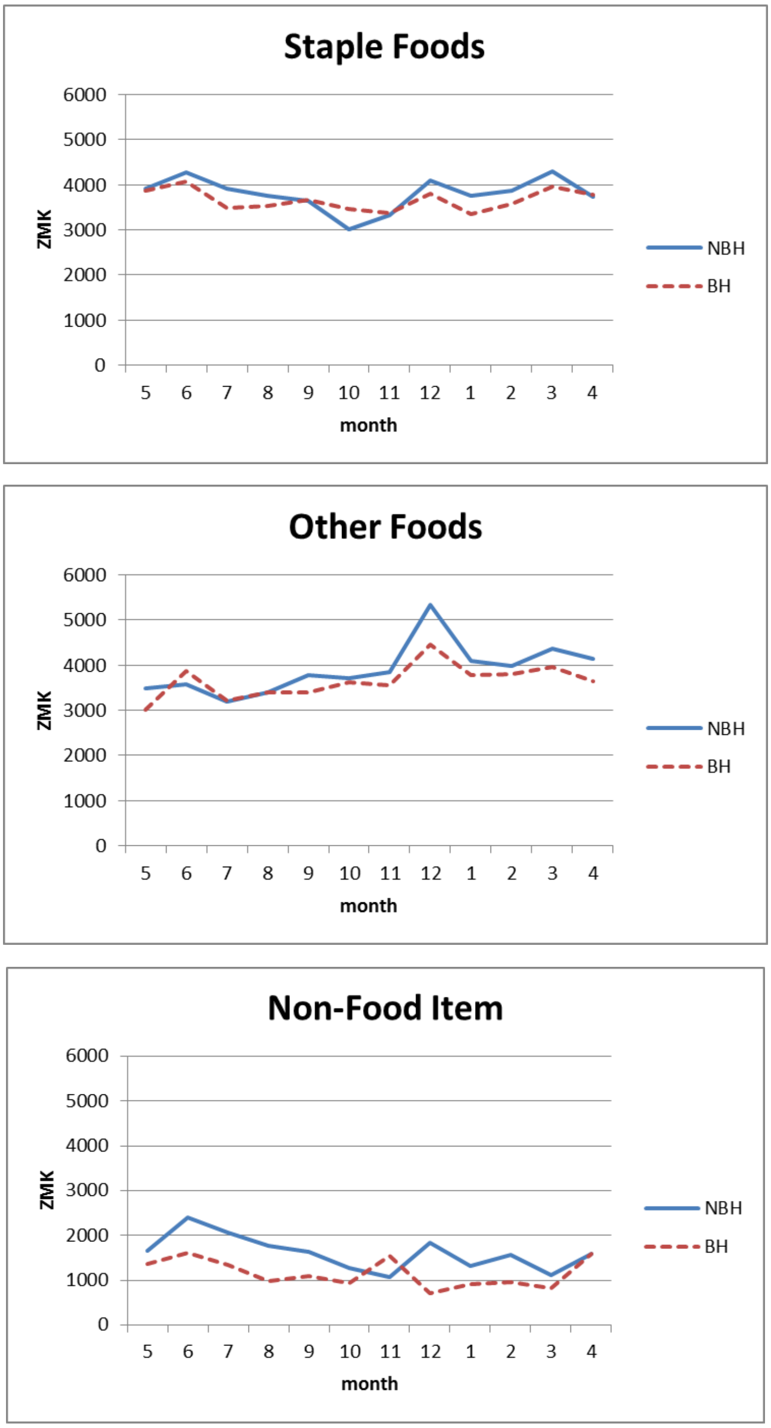
Source : Household survery data. Resilience Project



(Source) Household Survey Data. Resilience Project

※ Average total consumption per week per adult-equivalent. Numbers are in ZMK deflated by a monthly price index (=1 as November 2007 in site A)

Figure 6. Seasonal Patterns of Average Total Consumption over 3 years by maize purchase patterns



(Source) Household Survey Data. Resilience Project

※ Average total consumption per week per adult-equivalent. Numbers are in ZMK deflated by a monthly price index (=1 as November 2007 in site A)

Figure 7. Seasonal Patterns of Average Consumption (Staple Foods, Other Foods, and Non-Food Item) over 3 years by maize purchase patterns

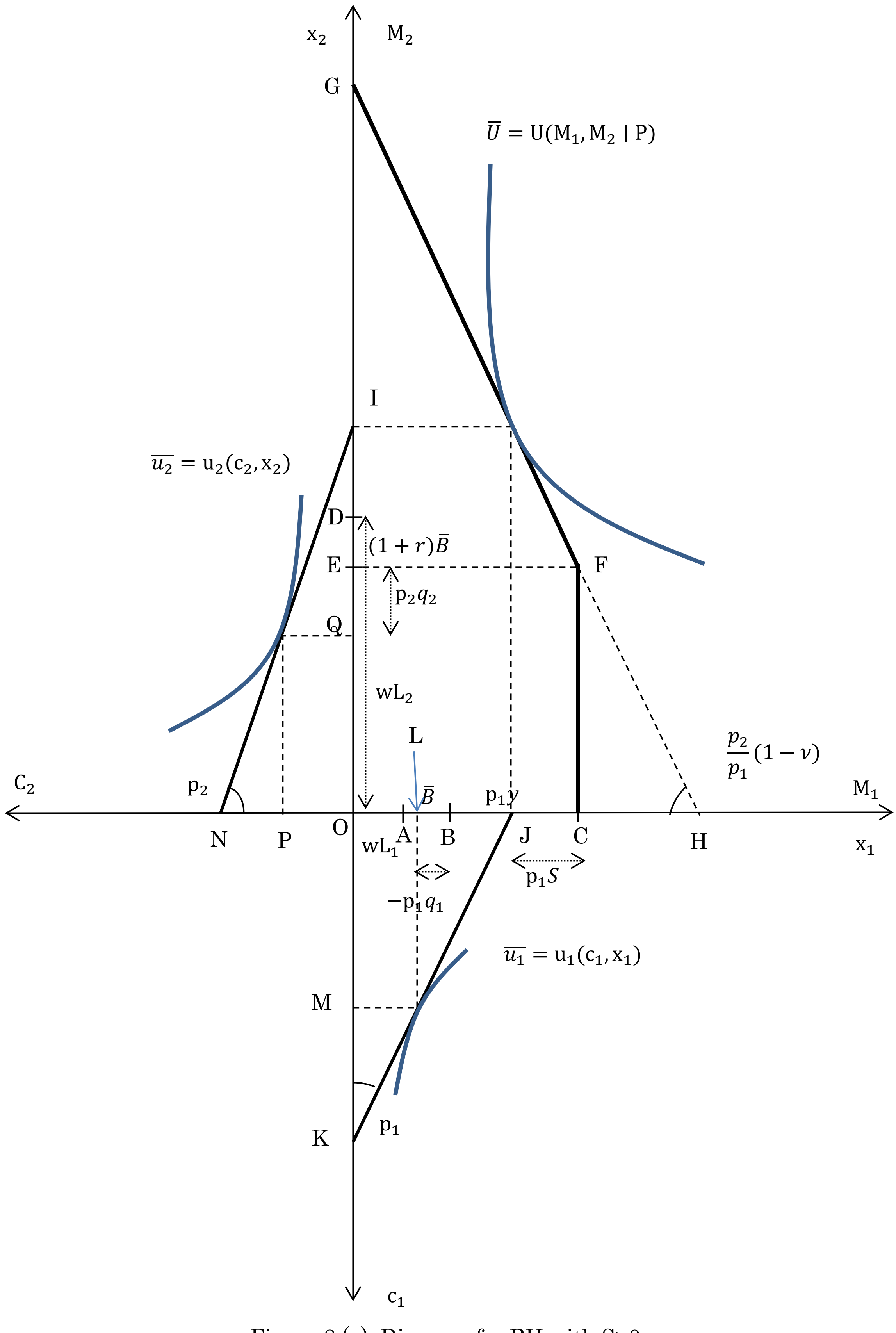


Figure 8 (a). Diagram for BH with S>0

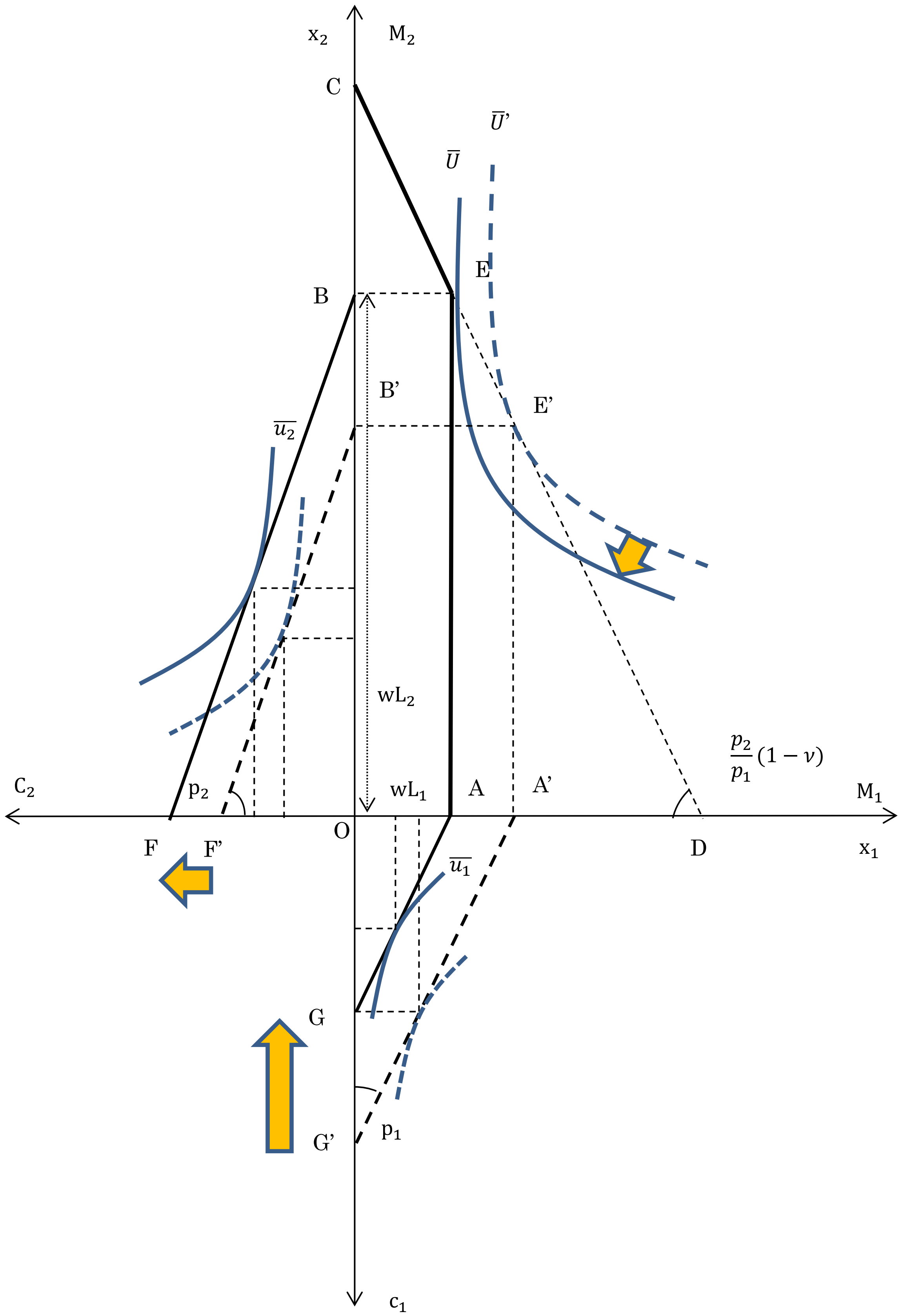


Figure 8 (b). Diagram for BH with S=0

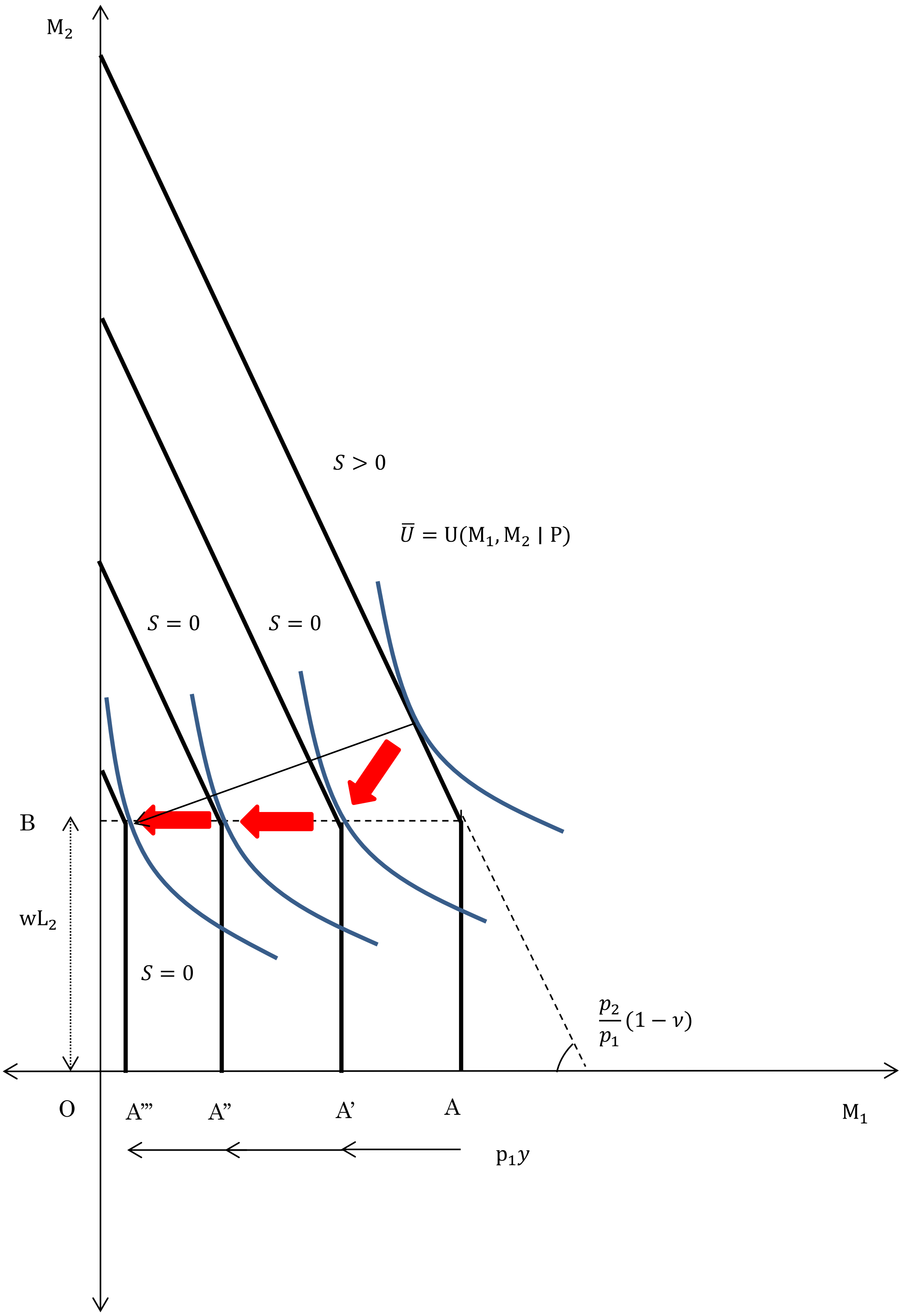


Figure 9. Impact of harvest shock on seasonal consumption

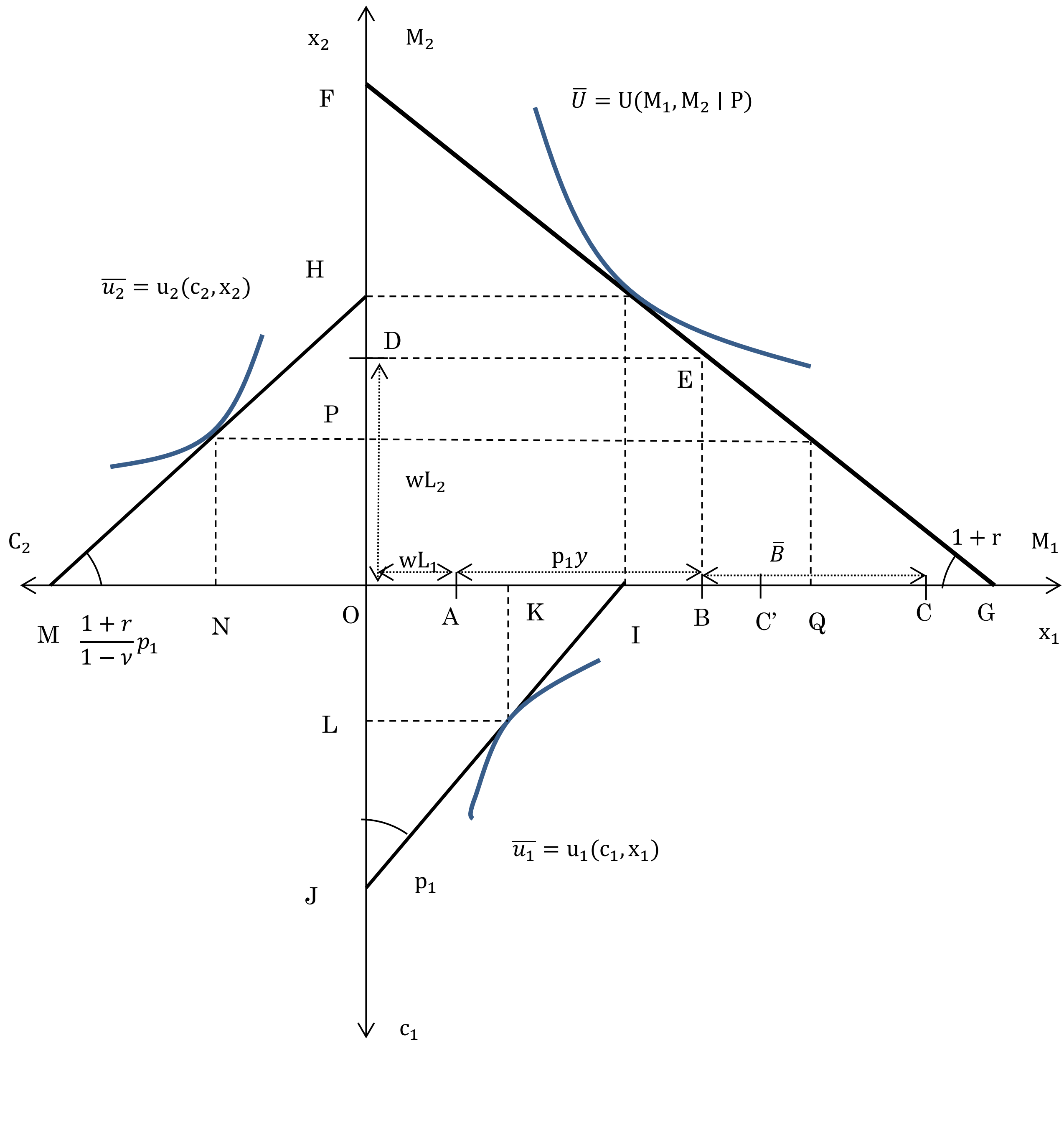


Figure 10. Diagram for NBH

Table 4. Estimation Results

	(1) Total Consumption		(2) Staple Foods vs Other Goods				(3) Other Foods vs Non-foods			
	Total Consumption		Staple Foods		Other Goods		Other Foods		Non-foods	
VARIABLES	BH	NBH	BH	NBH	BH	NBH	BH	NBH	BH	NBH
Income Shock * Month Dummy										
May	-6113***	-2618	-45	-823	-6069**	-1794	-3163**	-843	-2905**	-952
	(2044)	(2084)	(544)	(703)	(2138)	(1835)	(1393)	(1022)	(1261)	(1060)
June	-7911***	1090	-952*	-578	-6958***	1668	-4526***	804	-2433**	864
	(1636)	(2248)	(508)	(888)	(1836)	(1801)	(980)	(757)	(1022)	(1335)
July	-3918**	-1365	220	-445	-4138**	-920	-1774*	-289	-2364***	-630
	(1752)	(1897)	(438)	(734)	(1544)	(1389)	(951)	(584)	(808)	(1171)
August	-3649**	-5	38	-437	-3687**	432	-1655**	-132	-2032**	564
	(1374)	(1650)	(575)	(606)	(1318)	(1319)	(748)	(498)	(794)	(1061)
September	-4310**	-2310	538	-305	-4848**	-2005	-2419**	-179	-2429**	-1826
	(1654)	(1905)	(591)	(593)	(1779)	(1641)	(1002)	(649)	(1018)	(1371)
Octobor	-4460**	-313	276	143	-4736**	-457	-2489*	152	-2247***	-609
	(1999)	(1520)	(490)	(459)	(1878)	(1190)	(1386)	(595)	(773)	(903)
November	-5917**	-2066	102	-171	-6018**	-1894*	-2417*	-1273**	-3602**	-621
	(2451)	(1297)	(555)	(583)	(2455)	(1061)	(1300)	(524)	(1629)	(798)
December	-2738	-1997	-464	261	-2274	-2258	-845	-274	-1429*	-1984
	(1609)	(2183)	(472)	(630)	(1517)	(1858)	(886)	(814)	(754)	(1512)
January	-2913*	-196	-306	-192	-2606*	-4	-1239	518	-1367*	-522
	(1591)	(1746)	(331)	(565)	(1438)	(1430)	(826)	(761)	(690)	(1042)
February	-3019*	-1919	-335	-398	-2684*	-1522	-855	-116	-1829**	-1406
	(1463)	(1801)	(453)	(517)	(1325)	(1527)	(617)	(577)	(848)	(1252)
March	-3963**	-630	-609	-378	-3355*	-252	-2073*	-75	-1282*	-177
	(1401)	(1567)	(546)	(575)	(1662)	(1304)	(1168)	(811)	(699)	(802)
April	-7204*	-1821	-1135	-250	-6069*	-1571	-2572	-400	-3497*	-1171
	(3520)	(1977)	(699)	(658)	(3382)	(1501)	(1522)	(789)	(1940)	(937)
Observations	1,561	4,816	1,561	4,816	1,561	4,816	1,561	4,816	1,561	4,816
R-squared	0.148	0.224	0.280	0.262	0.106	0.172	0.196	0.269	0.069	0.088

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

(Coontrol) Month dummy, Moth dummy*income patterns, number of cattle, number of male household member, number of female household member, number of child household member

(Fixed Effects) Period*Village fixed effects, Household fixed effects

Table A (a). Estimation Results : Total Consumption

	(1) Total Consumption					
	Not Buy High			Buy High		
VARIABLES	HH	(Dif)	YHH	HH	(Dif)	YHH
Income Shock * Month Dummy						
May	-2618			-6113***		
	(2084)			(2044)		
June	1090	3708	3496**	-7911***	-1798	-1412
	(2248)		(1658)	(1636)		(901)
July	-1365	1253	879	-3918**	2195	2391
	(1897)		(1347)	(1752)		(1421)
August	-5	2613	2554**	-3649**	2464	2127
	(1650)		(1164)	(1374)		(1672)
September	-2310	308	381	-4310**	1803	1383
	(1905)		(1438)	(1654)		(1265)
Octobor	-313	2305	2340	-4460**	1653	1388
	(1520)		(1427)	(1999)		(1345)
November	-2066	552	858	-5917**	196	-250
	(1297)		(1333)	(2451)		(1490)
December	-1997	621	676	-2738	3375	3130*
	(2183)		(2274)	(1609)		(1667)
January	-196	2422	2831	-2913*	3200	2622*
	(1746)		(1726)	(1591)		(1407)
February	-1919	699	899	-3019*	3094	2596
	(1801)		(1531)	(1463)		(1941)
March	-630	1988	1952	-3963**	2150	1748
	(1567)		(1378)	(1401)		(1530)
April	-1821	797	924	-7204*	-1091	-1666
	(1977)		(1261)	(3520)		(2522)
Month Dummy by Income Patterns						
(Compared with May)						
June	-995		-920	1194*		1152*
	(606)		(613)	(643)		(607)
July	-340		-333	-797		-791
	(1142)		(1139)	(1069)		(1052)
August	-661		-797	-1170		-1093
	(713)		(728)	(1049)		(1053)
September	-6		-69	-1129		-1073
	(954)		(952)	(928)		(931)
Octobor	-1632**		-1609**	-1157		-1114
	(686)		(695)	(1043)		(1065)
November	-1496***		-1495***	-720		-685
	(488)		(488)	(1189)		(1237)
December	2166*		2230*	-1240		-1198
	(1082)		(1110)	(1154)		(1186)
January	-1163		-976	-1551		-1518
	(764)		(797)	(983)		(1011)
February	-279		-58	-771		-791
	(922)		(972)	(1289)		(1346)
March	114		334	-394		-472
	(763)		(822)	(1006)		(1066)
April	-357		-141	-467		-519
	(730)		(788)	(962)		(983)
Month Dummy* Dummy=1 if growing maize in dry season						
June	2074*		2059*	460		265
	(1229)		(1214)	(1316)		(1264)
July	561		676	211		4
	(1229)		(1185)	(1207)		(1165)
August	433		625	1602		1215
	(880)		(893)	(1304)		(1293)
September	-144		-69	1647		1311
	(1028)		(1020)	(1352)		(1272)
Octobor	304		305	1584		1304
	(890)		(892)	(1294)		(1297)
November	895		913	2373		2076
	(752)		(745)	(1703)		(1661)
December	-563		-575	2995**		2561*
	(1421)		(1443)	(1424)		(1403)
January	1311		1166	1900		1635
	(1019)		(1046)	(1351)		(1332)
February	365		253	982		753
	(1061)		(1075)	(1386)		(1430)
March	-90		-136	1109		921
	(983)		(1021)	(1110)		(1173)
April	764		694	3760		3706
	(849)		(864)	(2421)		(2382)
Year-variant control variables						
Number of cattle	159**			-552*		
	(75)			(315)		
Month-variant control variables						
Number of male HH member	-1761***		-1990***	-407		-938
	(396)		(558)	(616)		(674)
Number of female HH member	-1934***		-1115***	-1571		-1888
	(391)		(378)	-1286		-1295
Number of child HH member	-1264***		-1353***	-1424***		-910*
	(377)		(459)	(464)		(446)
Fixed Effect						
Period * Village	Yes		-	Yes		-
Household	Yes		-	Yes		-
Period * household	No		Yes	No		Yes
Observations	4,816		4,816	1,561		1,561
R-squared	0.224		0.249	0.148		0.160

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

Table A (b). Estimation Results : Staple Foods vs Other Goods

	(2) Staple Food						(3) Other Goods					
	Not Buy High			Buy High			Not Buy High			Buy High		
VARIABLES	HH	(Dif)	YHH	HH	(Dif)	YHH	HH	(Dif)	YHH	HH	(Dif)	YHH
Income Shock * Month Dummy												
May	-823			-45			-1794			-6069**		
	(703)			(544)			(1835)			(2138)		
June	-578	245	91	-952*	-907	-888*	1668	3462	3406**	-6958***	-889	-525
	(888)		(506)	(508)		(453)	(1801)		(1597)	(1836)		(720)
July	-445	378	227	220	265	298	-920	874	651	-4138**	1931	2093
	(734)		(490)	(438)		(549)	(1389)		(1405)	(1544)		(1322)
August	-437	386	351	38	83	84	432	2226	2204*	-3687**	2382	2044
	(606)		(628)	(575)		(559)	(1319)		(1268)	(1318)		(1500)
September	-305	518	587	538	583	548	-2005	-211	-206	-4848**	1221	836
	(593)		(606)	(591)		(622)	(1641)		(1453)	(1779)		(1250)
Octobor	143	966	956	276	321	250	-457	1337	1384	-4736**	1333	1138
	(459)		(583)	(490)		(799)	(1190)		(1407)	(1878)		(1092)
November	-171	652	752	102	147	80	-1894*	-100	106	-6018**	51	-330
	(583)		(719)	(555)		(580)	(1061)		(1176)	(2455)		(1444)
December	261	1084	1100	-464	-419	-463	-2258	-464	-423	-2274	3795	3593*
	(630)		(843)	(472)		(495)	(1858)		(2001)	(1517)		(1779)
January	-192	631	764	-306	-261	-323	-4	1790	2066	-2606*	3463	2945*
	(565)		(660)	(331)		(533)	(1430)		(1573)	(1438)		(1573)
February	-398	425	524	-335	-290	-332	-1522	272	375	-2684*	3385	2928
	(517)		(582)	(453)		(411)	(1527)		(1546)	(1325)		(1995)
March	-378	445	452	-609	-564	-607	-252	1542	1500	-3355*	2714	2354
	(575)		(626)	(546)		(515)	(1304)		(1416)	(1662)		(1583)
April	-250	573	615	-1135	-1090	-1137	-1571	223	309	-6069*	0	-529
	(658)		(549)	(699)		(875)	(1501)		(1173)	(3382)		(2457)
Month Dummy by Income Patterns												
(Compared with May)												
June	86		76	847***		800***	-1081**		-996**	348		352
	(253)		(258)	(264)		(251)	(476)		(464)	(562)		(545)
July	-180		-187	-258		-268	-160		-146	-540		-523
	(203)		(212)	(376)		(378)	(1151)		(1145)	(855)		(834)
August	-95		-107	42		64	-566		-691	-1212		-1157
	(276)		(277)	(467)		(471)	(645)		(650)	(863)		(872)
September	-148		-160	-180		-159	141		91	-949		-913
	(299)		(302)	(403)		(411)	(924)		(923)	(818)		(815)
Octobor	-1002***		-980***	-215		-184	-630		-629	-942		-930
	(241)		(249)	(490)		(494)	(537)		(538)	(918)		(920)
November	-647***		-664***	-501		-474	-849**		-830*	-219		-211
	(223)		(227)	(312)		(313)	(419)		(414)	(1071)		(1112)
December	-120		-119	43		65	2285**		2349**	-1283		-1264
	(254)		(261)	(372)		(373)	(1019)		(1042)	(1054)		(1080)
January	-252		-219	-266		-239	-911		-757	-1285		-1278
	(317)		(330)	(314)		(315)	(684)		(699)	(911)		(935)
February	-182		-149	-91		-78	-97		92	-680		-714
	(267)		(269)	(287)		(287)	(823)		(847)	(1306)		(1347)
March	246		279	121		126	-132		55	-514		-598
	(256)		(250)	(350)		(357)	(646)		(683)	(1049)		(1103)
April	-263		-243	-186		-164	-94		102	-281		-356
	(263)		(276)	(326)		(338)	(570)		(602)	(853)		(866)
Month Dummy* Dummy=1 if growing maize in dry season												
June	344		367	-1101		-1030	1731		1692	1561		1294
	(324)		(338)	(692)		(676)	(1055)		(1027)	(932)		(885)
July	241		278	-633		-607	320		397	844		611
	(311)		(311)	(644)		(639)	(1224)		(1195)	(977)		(919)
August	-234		-208	-1197*		-1196*	667		832	2798**		2411**
	(400)		(397)	(684)		(690)	(768)		(772)	(1058)		(999)
September	-439		-433	-969		-982	294		365	2616*		2293*
	(426)		(421)	(646)		(648)	(956)		(953)	(1397)		(1300)
October	-155		-195	-1169*		-1198*	459		500	2753**		2503**
	(376)		(372)	(658)		(660)	(792)		(785)	(1134)		(1093)
November	-258		-252	-798		-849	1154*		1164*	3171*		2925*
	(375)		(368)	(523)		(518)	(636)		(634)	(1735)		(1679)
December	90		78	-919		-956	-652		-653	3914**		3518**
	(444)		(435)	(577)		(573)	(1162)		(1194)	(1409)		(1384)
January	-195		-254	-1222**		-1277**	1505*		1420*	3122**		2911**
	(478)		(474)	(552)		(551)	(785)		(815)	(1244)		(1230)
February	-104		-165	-1066*		-1102**	470		418	2048		1855
	(414)		(401)	(522)		(515)	(900)		(912)	(1290)		(1333)
March	-47		-87	-640		-672	-43		-49	1749		1593
	(419)		(402)	(595)		(594)	(733)		(773)	(1241)		(1288)
April	-222		-236	-154		-211	986		930	3914		3917
	(303)		(296)	(745)		(754)	(707)		(733)	(2600)		(2550)
Year-variant control variables												
Number of cattle	19			-90			140**			-462		
	(24)			(54)			(69)			(317)		
Month-variant control variables												
Number of male HH member	-315**		-497***	-301		-333	-1446***		-1493**	-106		-605
	(137)		(156)	(200)		(240)	(422)		(590)	(538)		(486)
Number of female HH member	-570***		-465***	-1023***		-1170***	-1364***		-650*	-548		-717
	(131)		(143)	(191)		(261)	(369)		(372)	-1184		-1131
Number of child HH member	-399***		-487***	27		24	-865***		-865**	-1451***		-934**
	(131)		(133)	(128)		(162)	(283)		(354)	(453)		(436)
Fixed Effect												
Period * Village	Yes		-	Yes		-	Yes		-	Yes		-
Household	Yes		-	Yes		-	Yes		-	Yes		-
Period * household	No		Yes	No		Yes	No		Yes	No		Yes
Observations	4,816		4,816	1,561		1,561	4,816		4,816	1,561		1,561
R-squared	0.262		0.311	0.280		0.286	0.172		0.194	0.106		0.119

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

Table A(c). Estimation Results : Other Foods vs Non-Foods

	(4) Other Food						(4) Non Food					
	Not Buy High			Buy High			Not Buy High			Buy High		
VARIABLES	HH	(Dif)	YHH	HH	(Dif)	YHH	HH	(Dif)	YHH	HH	(Dif)	YHH
Income Shock * Month Dummy												
May	-843			-3163**			-952			-2905**		
	(1022)			(1393)			(1060)			(1261)		
June	804	1647	1649*	-4526***	-1363	-1260	864	1816	1757	-2433**	472	735
	(757)		(974)	(980)		(776)	(1335)		(1101)	(1022)		(1061)
July	-289	554	526	-1774*	1389	1440*	-630	322	126	-2364***	541	653
	(584)		(882)	(951)		(807)	(1171)		(829)	(808)		(992)
August	-132	711	689	-1655**	1508	1435	564	1516	1515*	-2032**	873	609
	(498)		(924)	(748)		(1136)	(1061)		(864)	(794)		(1189)
September	-179	664	600	-2419**	744	650	-1826	-874	-806	-2429**	476	186
	(649)		(974)	(1002)		(818)	(1371)		(1006)	(1018)		(904)
Octobor	152	995	863	-2489*	674	663	-609	343	521	-2247***	658	475
	(595)		(902)	(1386)		(483)	(903)		(859)	(773)		(1036)
November	-1273**	-430	-421	-2417*	746	644	-621	331	527	-3602**	-697	-974
	(524)		(874)	(1300)		(858)	(798)		(599)	(1629)		(1347)
December	-274	569	411	-845	2318	2305	-1984	-1032	-835	-1429*	1476	1288
	(814)		(1289)	(886)		(1450)	(1512)		(1139)	(754)		(1070)
January	518	1361	1341	-1239	1924	1793	-522	430	725	-1367*	1538	1152
	(761)		(1187)	(826)		(1390)	(1042)		(928)	(690)		(920)
February	-116	727	606	-855	2308	2153*	-1406	-454	-231	-1829**	1076	775
	(577)		(973)	(617)		(1215)	(1252)		(1040)	(848)		(1383)
March	-75	768	554	-2073*	1090	955	-177	775	946	-1282*	1623	1399
	(811)		(871)	(1168)		(1026)	(802)		(827)	(699)		(1064)
April	-400	443	239	-2572	591	396	-1171	-219	70	-3497*	-592	-925
	(789)		(692)	(1522)		(1483)	(937)		(676)	(1940)		(1506)
Month Dummy by Income Patterns												
(Compared with May)												
June	-880**		-787**	669		768	-201		-209	-321		-416
	(350)		(342)	(575)		(553)	(475)		(481)	(971)		(924)
July	-594		-616	-504		-474	435		470	-35		-49
	(403)		(384)	(429)		(431)	(1148)		(1150)	(807)		(803)
August	-502		-510	-265		-305	-64		-181	-947		-852
	(485)		(484)	(422)		(425)	(539)		(565)	(1037)		(1049)
September	-26		-35	-178		-234	167		126	-771		-679
	(391)		(391)	(458)		(453)	(768)		(758)	(736)		(748)
Octobor	-124		-65	25		-18	-507		-565	-967		-911
	(345)		(361)	(369)		(377)	(523)		(531)	(892)		(891)
November	-90		-6	-209		-247	-759**		-824**	-11		35
	(426)		(438)	(763)		(784)	(332)		(353)	(939)		(954)
December	1595***		1708***	-82		-111	690		641	-1201		-1152
	(564)		(589)	(622)		(631)	(890)		(910)	(963)		(970)
January	-137		69	-303		-345	-775		-826	-982		-933
	(526)		(543)	(795)		(806)	(479)		(506)	(780)		(784)
February	-51		192	-306		-314	-46		-100	-374		-400
	(437)		(459)	(614)		(621)	(724)		(749)	(1162)		(1181)
March	594		828*	345		327	-727		-773	-860		-925
	(450)		(488)	(702)		(708)	(494)		(519)	(862)		(882)
April	288		539	61		44	-382		-437	-343		-400
	(392)		(424)	(753)		(758)	(383)		(414)	(733)		(751)
Month Dummy* Dummy=1 if growing maize in dry season												
June	897**		829**	1220*		937	833		863	341		357
	(385)		(370)	(696)		(688)	(957)		(955)	(896)		(848)
July	378		438	1246**		1059**	-58		-41	-402		-448
	(404)		(394)	(486)		(459)	(1224)		(1205)	(824)		(804)
August	702		726	1607***		1474***	-34		107	1192		937
	(464)		(465)	(506)		(459)	(672)		(687)	(1039)		(1030)
September	396		461	1409**		1325**	-102		-97	1208		968
	(413)		(417)	(605)		(544)	(802)		(790)	(1006)		(985)
Octobor	354		370	1350**		1292**	105		130	1402		1210
	(391)		(386)	(514)		(498)	(667)		(679)	(953)		(942)
November	868*		848*	1801**		1780**	285		316	1370		1145
	(433)		(444)	(749)		(749)	(555)		(568)	(1449)		(1449)
December	135		132	2777***		2669***	-787		-785	1137		849
	(672)		(705)	(924)		(899)	(884)		(900)	(954)		(949)
January	724		661	1958**		1979**	781		759	1164		933
	(558)		(583)	(923)		(915)	(575)		(603)	(840)		(834)
February	457		410	1699**		1693**	13		7	349		162
	(451)		(480)	(718)		(737)	(780)		(790)	(1069)		(1086)
March	-107		-107	1032		1041	64		58	717		551
	(487)		(504)	(834)		(874)	(602)		(626)	(864)		(877)
April	241		200	1464		1547	744		730	2450		2371
	(431)		(453)	(1310)		(1254)	(562)		(590)	(1530)		(1555)
Year-variant control variables												
Number of cattle	127**			-144			14			-319*		
	(63)			(181)			(33)			(161)		
Month-variant control variables												
Number of male HH member	-996***		-863***	-105		-408	-450		-630	-1		-197
	(267)		(265)	(339)		(317)	(323)		(502)	(260)		(202)
Number of female HH member	-1010***		-347**	-1493**		-1004	-353		-303	945		287
	(283)		(159)	(641)		(718)	(232)		(295)	(651)		(544)
Number of child HH member	-493***		-520**	-693**		-577**	-372**		-346**	-758***		-357
	(181)		(254)	(280)		(265)	(150)		(164)	(255)		(245)
Fixed Effect												
Period * Village	Yes		-	Yes		-	Yes		-	Yes		-
Household	Yes		-	Yes		-	Yes		-	Yes		-
Period * household	No		Yes	No		Yes	No		Yes	No		Yes
Observations	4,816		4,816	1,561		1,561	4,816		4,816	1,561		1,561
R-squared	0.269		0.314	0.196		0.213	0.088		0.101	0.069		0.079

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