Buy As You Need: Nutrition and Food Storage Imperfections

Jeremie Gross, Catherine Guirkinger and Jean-Philippe Platteau*†

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Abstract

In this paper, we investigate how the activation of local food markets impacts the nutritional status of both children and adults, in a context characterized by large seasonal fluctuations in the price and availability of foodgrain. Taking advantage of the random scaling-up of a program of Food Security Granaries (FSGs) in Burkina Faso, we reach three conclusions. First, especially in remote areas where local markets are thin, food market activation considerably dampens nutritional stress. The effect is strongest among children, and young children in particular, for whom deficient nutrition has devastating long-term consequences. Second, and surprisingly, this beneficial effect is obtained despite the fact that total food consumption does not increase as a result of the external intervention. Third, it is a change in the timing of food purchase, translated into a change in the timing of consumption, that drives the nutritional improvement. A simple two-period model shows that an increase in consumption needs not take place when the price surge in the lean season is dampened. More than the waste of the foodgrain stored, it is the urge to consume purchased foodgrain which gives rise to storage imperfections: foodgrain purchased in anticipation of uncertain future supply results in immediate consumption and body mass accumulation, which is less efficient than nutrition-smoothing consumption flows.

*University of Namur, Center for Research in the Economics of Development (CRED).

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1 Introduction

In spite of almost continuous attention over several decades, food insecurity and malnutrition continue to plague important regions of the world. In sub-Saharan Africa, in particular, 40 percent of all children are stunted and more than 20 percent are underweight (Black et al. 2013). We know that experiences of malnutrition early in life have highly detrimental consequences for adults' health and well-being (Glewwe et al., 2001; Alderman et al., 2006; Maluccio et al., 2009; Berg et al., 2016; Dinkelman, 2017). There are various factors behind food insecurity and malnutrition and their relative importance is still debated. Sen (1981) has drawn our attention to the need to distinguish between entitlement and aggregate availability of foodgrain to understand hunger. Entitlement refers to factors, income and prices in particular, that condition economic access to food. High prices and strong price fluctuations, which lower entitlement and threaten food security, often arise from the isolation of local food markets (De Janvry et al., 1991; Fafchamps, 1992; Renkow et al., 2004; Barrett, 2008). It is noteworthy that poor food market integration is not only observed in many remote areas of the developing world today but was also a major feature of many European countries on the eve of modern economic growth (see e.g. Hoffman, 2000, for France), or of planned economies with centrally regulated food markets (see e.g. Riskin, 1987 for a thourough analysis of the disastrous impact of segmented food markets during the great famine of China under Mao).[1]

Recent research has nevertheless questioned the necessity of greater aggregate availability of foodgrain or better economic access conditions for improved nutrition. Thus, Duh and Spears (2016) and Coffey et al. (2017) show the importance of disease exposure and the health environment in determining nutrition levels. For example, this mechanism helps (partially) solve the so-called calorie consumption puzzle observed in India: in spite of an increase in income and a decrease in the relative price of food, the Indians witnessed a decline of their average calorie intake during the last 30 years (Deaton and Drèze, 2009). It bears emphasis, however, that disease exposure accounts for only one-fifth of the decline in calorie intake.[2]

In this paper, we investigate a puzzle of a similar kind and with equally important policy implications. On the one hand, nutrition improves substantially for both children and adults as a result of a program aimed at ensuring better availability across seasons. On the other hand, consumption of food-

[1] Another striking historical example is post-war Germany where local food markets became isolated as a result of the imposition of occupation zones and the widespread destruction of communication links. These factors sparked acute hunger episodes (Kesternich et al., 2015).

[2] Another candidate explanation is the reduction in the levels of physical activity over the period considered. Eli and Li (2013) argue that this explanation is unlikely to account for more than one-third of the calorie decline.

grain does not increase, and the composition of consumption does not change, although the effective price of food has declined. Our explanation of this odd combination of results implies that economic access conditions do matter, yet in a manner that gives pride of place to the timing of consumption. With the help of a theoretical argument, we show that the improvement in nutrition resulting from a more steady local supply of foodgrain throughout the agricultural cycle need not be caused by an increase in total food purchases and consumption. It may be the outcome of delayed purchases that allow a more efficient allocation of consumption through time. In other words, the timing of purchases and the timing of consumption are not independent of each other as would be the case if there were no savings and storage imperfections. If future food supply is better assured, households can minimize storage and postpone purchases to times of need. This conclusion is reinforced if storage imperfections in the sense of a physical waste of stored food are compounded by the presence of a pressure to consume stored foodgrain too quickly. The latter amounts to a behavioral explanation involving present bias, for example.

The policy prescription that follows from this diagnosis is that food security programs ought to be developed that aim at (1) smoothing inter-seasonal price fluctuations and guaranteeing better availability of foodgrain in the lean season; and (2) setting up mechanisms that allow villagers to overcome the pressure-to-consume problem. In a context characterized by an extremely low incidence of local foodgrain sales and by large seasonal fluctuations in the price and availability of this good, a policy of market activation may induce villagers to postpone their food purchases.

Our empirical analysis uses a randomized control trial setting, where the degree of local food market activity varies randomly across villages. The market is activated as a result of a community storage and marketing activity that allow villagers to get access to foodgrain imported from surplus areas. This is in a context where malnutrition is pervasive and almost all farmers do not sell foodgrain because they need it for self-consumption. We collected exceptionally rich data including the nutritional status of all household members, detailed information about foodgrain transactions and stock availability at the household level. Moreover, we rely on qualitative investigation tools that we especially designed for the purpose of complementing our quantitative evidence and buttressing our interpretation of the main findings. These tools go beyond simple group discussions to include interactive activities in which a restricted number of participants were invited to make critical intertemporal allocation choices and explain them in detail.

Before presenting the outline of the paper, we mention several strands of the literature to which it contributes. First a relevant but restricted set of studies queries about the effectiveness of the type of interventions we are concerned with, namely community-based interventions aimed at stabilizing food supply or prices throughout the year. While there is limited evidence of their impact (Basu and Wong, 2015; Barrett, 1996, Aggarwal et. al., 2017), these interventions, which include cereal banks, have benefited from a resurgence of interest over the last decade. The World Food Program, the European Union, Non-Governmental Organizations and local authorities, have started again to fund thousands of initiatives designed to promote food security through the building of local food reserves in Sahelian countries (Oxfam International, 2013; World Bank, 2012). Most of these interventions are explicitly intended for stabilizing the supply of food throughout the year, denting the traders' market power and/or reducing transaction costs and storage losses. Our study shows that physical storage losses are insignificant, and there is little evidence of monopoly pricing. By contrast, it uncovers a neglected channel of influence of food security interventions: an improvement in the timing (in constrast to the amount) of food consumption, and the related impact on nutrition. A similar argument has recently been proposed by Aggarwal et. al. (2017) to explain the positive impact of a community storage scheme in a context where farmers are net grain sellers: an improvement in the timing of sales translates into a net income gain. Interestingly, much in the same line as we do, they argue that moving foodgrain out of farmers' home "would make it less prone to being claimed by others of falling prey to temptation."

Second, there is a literature dealing with issues of stock management and savings at the family level yet it largely focuses on the self-insurance property of stocks to confront unpredictable shocks (see the pioneering works of Newbery, 1991: 284-8 and Platteau, 1991). Moreover, this literature tends to illustrate stock management strategies by reference to livestock (Fafchamps et al., 1998). In our study, we are concerned with foodgrain stocks and with their management in a context of anticipated seasonal shortages rather than unpredictable shocks. A literature also exists that analyzes optimal household behavior in the presence of seasonality and risk aversion or credit market imperfections (Park, 2006; Stephens and Barrett, 2011, Burke et al., 2017). In the empirical literature on this topic, a salient issue is the impact of seasonality on current consumption. No clear consensus has emerged here: while some studies conclude that consumption is largely smoothed over the agricultural cycle, others point to the opposite conclusion (see, for example, Paxson, 1993, for the former conclusion, and Dercon and Krishnan, 2000b, for the latter). The impact of seasonality on health status has also drawn attention and its adverse effect on nutritional quality has been frequently emphasized (see, for example: Behrman, 1988; Sahn, 1989; Behrman, 1993; Branca et al., 1993; Bhagowalia et al., 2011).

Our theoretical approach based on nutrition, requires that we use anthropometric measures instead of consumption. In the literature, attention is usually given to the determinants and consequences of fluctuations in the nutritional level of individual household members (Dercon and Krishnan, 2000a; Alderman et al., 2006; Vaitla et al., 2009), and to the short-term and long-term effects of various policies designed to combat malnutrition (Hoddinott et al., 2008; Yamano et al., 2005). Closely related to our endeavour, Abay and Hirvonen (2016) examine the seasonal weight fluctuations of young children in Ethiopia and provide evidence that market integration dampens children's exposure to seasonal shortages. They suggest that diet diversity may explain the observed patterns.

Finally, our pressure-to-consume argument relates to a large literature on self-control problems and their economic consequences (see DellaVigna, 2009 for a review). This literature is more limited, however, when it comes to addressing the same problems in the context of acute poverty (Ashraf et al. 2006, Banerjee and Mullainathan, 2010; Bernheim et al., 2015).

The outline of the paper is as follows. In Section 2, we present a simple two-period model to investigate how a decrease in the real price of foodgrain in the second (lean) period affects consumption behavior and nutritional outcomes in both periods. This is done under various setups, including the possibility of self-control problems and price risks. In Section 3, we describe the context of our experiment and the data. In Section 4, we discuss our empirical strategy before estimating the impacts of market activation on food access, purchase, consumption and nutrition. Section 5 focuses on the interpretation of the results and draws on a variety of qualitative and quantitative evidence gathered ex post. Section 6 concludes.

2 Model

2.1 Storage, consumption and nutrition: a simple set-up

We propose a simple framework to analyze the household's problem of allocating food consumption across two periods that follow a single harvest.

We consider a household whose utility depends on its nutritional status in period t, N_t, and the consumption of a numeraire, O_t. It is written as: $U(N_t, O_t)$, where U is twice differentiable and concave in both arguments. There are two periods: a dry, post-harvest season ($t = 1$) succeeded by a rainy, lean season ($t = 2$). The household enters period 1 with a nutritional status N_0. Its problem is to intertemporally allocate food consumption to maximize:

$$U(N_1, O_1) + \gamma U(N_2, O_2)$$

where γ is a discount factor.

We follow Dercon and Krishnan (2000a) by modelling the nutritional status as a stock or durable, and specifying the nutritional status in each period as:

$$\begin{aligned} N_1 &= f(N_0) + n(C_1) && (1) \\ N_2 &= f(N_1) + n(C_2) && (2) \end{aligned}$$

These equations indicate that the nutritional status in each period is a function of the nutritional status in the previous period, where the function f captures the depreciation of the nutrition stock between periods, with $0 < f' < 1$. The nutritional status also increases with current period consumption (C_1 or C_2), according to the transformation function n, with $n' \geq 0$ and $n'' < 0$.

In our study area, food deficit is the rule since there are only a few net sellers of foodgrain. This implies that decreases in food prices have an unambiguously positive effect on the households' welfare, dispensing us with the need to examine their negative income effect on richer (surplus) households. For the sake of simplicity, we assume that households' own production is nil, which forces them to rely on externally provided food for their entire consumption in the two periods. In period 1, the household consumes the food bought on the market, m_1, minus the quantity stored for period 2's consumption, denoted by s. In period 2, food consumption is equal to m_2, the quantity bought on the market, plus the quantity stored in period 1, discounted by a retention coefficient β $(0 \leq \beta \leq 1)$ to account for physical storage losses. Food availability constraints are:

$$\begin{aligned} C_1 &= m_1 - s \\ C_2 &= \beta s + m_2 \end{aligned}$$

Combining the two equations and the non-negative stock constraint, we can write:

$$\begin{aligned} \beta C_1 + C_2 &= \beta m_1 + m_2 && (3) \\ C_1 &\leq m_1 && (4) \end{aligned}$$

We now need to specify the budget constraint. We assume that the household has an exogenous income R, which is obtained in period 1 only. R can be saved and will yield rR in period 2. The market price for food is P_1 in period 1 and P_2 in period 2, with $P_2 > P_1$ to account for the price increase between the two seasons. The budget constraints in periods 1 and 2 are:

$$\begin{aligned} P_1 m_1 + b + O_1 &\leq R \\ P_2 m_2 + O_2 &\leq rb \end{aligned}$$

where b is the amount of income saved in period 1.[3] The two constraints are linked together through b and can be combined in a single expression:

$$rP_1 m_1 + rO_1 + P_2 m_2 + O_2 \leq rR \tag{5}$$

In solving the above problem of the household, two cases arise depending on whether food purchase in period 2 is positive (Case 1) or zero (Case 2).[4]

Case 1: $P_2 < \frac{rP_1}{\beta}$

When $P_2 < \frac{rP_1}{\beta}$, the household buys food in period 2: $m_2 > 0$. For food to be purchased in period 2, the unit price in this period cannot exceed the value of one unit of food bought in period 1 and stored, when in computing this value, we take account of the cost caused both by storage losses and the interest foregone as a result of lost savings (see Appendix 1). According to intuition, food purchase in period 2 is more likely if storage losses are more important (β is small) and/or if the interest rate r is high.

The intertemporal allocation of nutrition is characterized by the following equation, where U_N is the marginal utility of nutrition (details are provided in Appendix 1):

$$\frac{U_N(N_1, O_1)}{\gamma U_N(N_2, O_2)} = \frac{\frac{1}{n'(C_1)} r P_1 - \frac{f'(N_1)}{n'(C_2)} P_2}{\frac{P_2}{n'(C_2)}} \tag{6}$$

[3] The amount saved verifies: $0 \leq b \leq R$.

[4] We restrict attention to cases where consumption is positive in both periods, implying that the effectiveness of body mass storing as measured by f is never high enough to enable a household to achieve a minimum nutritional level without consuming some food during the current season. Formally, when f is linear and the utility function is additively separable in nutrition and the numeraire, we assume that either one of the following conditions must hold: $f' < r\frac{P_1}{P_2}$ or $f' < \beta$.

This expression has an intuitive interpretation. The marginal rate of substitution between N_1 and N_2 must be equal to the ratio of the marginal cost of increasing nutrition via current consumption in the first period relative to the cost of increasing it in the second period. The denominator of the right-hand-side is the current value of the cost of acquiring an additional unit of nutrition in period 2. The numerator has two terms : since it measures the future value of the marginal cost of nutrition via current consumption in period 1, it takes into account the benefit corresponding to the carryover effect from improved nutrition in period 1 (the body mass storing effect). This benefit is measured by the marginal cost of a nutritional unit in period 2 that is avoided as a result of body mass stored since period 1.

If we assume that the transformation function, n, and the depreciation function, f, are linear and that the utility function is additively separable in nutrition and the numeraire (as in Dercon and Krishnan, 2001a), we can rewrite (6) as $\frac{U_N(N_1)}{\gamma U_N(N_2)} = r\frac{P_1}{P_2} - f'$, from which the roles of $\frac{P_1}{P_2}$ and f' are evident. In words, when the price in the second period decreases, the ratio of marginal utilities must increase. This implies that the nutrition level in the second period will increase relative to the level in the first period. On the other hand, if the carryover effect becomes more effective (f' increases), the opposite outcome is obtained, and nutrition in the first period increases. Note that the interior solution $m_2 > 0$ requires that $f' < r\frac{P_1}{P_2}$: the carry-over effect must not be too large.

Case 2: $P_2 \geq \frac{rP_1}{\beta}$

When $P_2 \geq \frac{rP_1}{\beta}$, it follows that $m_2 = 0$. In this case, it is less expensive to buy a unit of food in period 1 and to store it than to buy it in period 2 for immediate consumption. The intertemporal allocation of nutrition across time is then characterized by the following equation (see Appendix 1):

$$\frac{U_N(N_1, O_1)}{\gamma U_N(N_2, O_2)} = \frac{\frac{1}{n'(C_1)} - \frac{1}{\beta n'(C_2)} f'(N_1)}{\frac{1}{\beta n'(C_2)}} \tag{7}$$

This expression has a similar interpretation as (6), except that the price ratio is replaced by β. Given that there is no purchase in period 2, the relevant cost of waiting until period 2 to consume a unit of food purchased in period 1 is measured by $\frac{1}{\beta}$, the inverse of the retention coefficient.

Assuming again linearity of the functions f and n and separability of the utility function, equation (7) can be simply rewritten as: $\frac{U_N(N_1)}{U_N(N_2)} = \gamma(\beta - f')$. This expression suggests that, if the storage loss increases relative to the effectiveness of body mass storing, that is, if the retention coefficient, β, decreases (within the range where $\beta > f'$, so that consumption remains positive in both periods), the marginal utility of food in period 1 must decrease relative to the one in period 2. This implies that the nutrition level will be boosted in period 1 compared to period 2. Note that for the case $m_2 = 0$ to correspond to an interior solution where $N_1$and N_2 are strictly positive, we need not only that $\beta \geq \frac{rP_1}{P_2}$, but also that $\beta \geq f'$, that is : $\beta \geq max\left(\frac{rP_1}{P_2}, f'\right)$.

This set of results is summarized in Proposition 1.

Proposition 1. *Assume that the utility is additively separable in nutrition and the numeraire. There exists a threshold price for the lean period, $P_2^* = \frac{rP_1}{\beta}$, above which the household stops purchasing food in period 2. When this is the case and both the transformation and depreciation functions are linear, the marginal rate of substitution between nutrition levels in the two periods is given by $\frac{U_N(N_1)}{U_N(N_2)} = \gamma(\beta - f')$. It thus depends on the effectiveness of physical storage relative to body-mass storage.*

We are now ready to look at the impact of the intervention. When the local market is activated, since local markets are particularly thin during the lean season, we expect P_2 to decrease. The condition $P_2 \leq \frac{rP_1}{\beta}$ is then more likely to be satisfied, implying that the household will be more likely to buy food in the second period ($m_2 > 0$), and less likely to resort to body mass or household storage. Furthermore, provided $m_2 > 0$, a decrease in P_2 will increase the nutrition level in period 2 relative to the level in period 1.[5] Because N_2 is initially lower than N_1 (since $\frac{U_N(N_1)}{U_N(N_2)} = \gamma(\beta - f') < 1$), the decrease in P_2 will help smoothen nutrition across seasons, which increases utility.

What about the effect of a decrease in P_2 on food consumption? Provided that $m_2 > 0$, the increase in N_2 relative to N_1 results from an increase in C_2. Whether or not total consumption $(C_1 + C_2)$ increases is not clear a priori. Indeed the increase in C_2 implies that the household has less need for body mass storing and, therefore, N_1 and C_1 may decrease concomitantly. We illustrate the possibility that $C_1 + C_2$ decreases with the help of a numerical simulation (details are provided in Appendix 1). Figures 6 and 7 summarize the findings obtained.

Figure 6 shows that the relationships between N_1 and N_2 to P_2 are both monotonous.[6] A decrease in P_2 increases N_2 and decreases N_1 for $P_2 < P_2^*$, where $P_2^* = \frac{rP_1}{\beta}$ is the threshold price above which the household prefers to buy exclusively in period 1 and to store for period 2. Beyond P_2^*, nutrition levels thus become insensitive to further increases in P_2. The continuous line on Figure 7 depicts the way total consumption, $C_1 + C_2$, responds to an increase in P_2 in the simple set-up. We can see that the relationship is not monotonous and, starting from P_2^*, total consumption first decreases when P_2

[5]Assuming again linearity of the functions f and n and separability of the utility function.

[6]Since the first period nutrition is increasing in P_2, the substitution effect dominates the income effect in period 1.

falls, and then increases. Again, beyond P_2^*, the household does not buy anymore in period 2 and total consumption becomes insensitive to further increases in P_2.

The above results are summarized in the following Proposition.

Proposition 2. *A marginal decrease in the lean period price P_2 increases purchases in the lean period and smoothens nutrition across periods. The effect on total food consumption $C_1 + C_2$ is indeterminate.*

2.2 Storage, consumption and nutrition in the presence of self-control

While storage enables households to protect themselves against seasonal price increases, the immediate availability of food stored in the household dwelling may trigger excessive consumption in the presence of a self-control problem. This reduces the attractiveness of storage since the household may prefer to delay purchase so as to suppress the temptation born of easily accessible food inside the dwelling. Because our qualitative investigation points to the importance of this strategy (evidence reported in Section 6), we now discuss how the above predictions would change in the presence of a self-control problem.

To incorporate self-control, we assume that the household has a present bias (it has time-inconsistent preferences as in Laibson, 1997). For present bias to play a role beyond time-discounting, we need to consider more than two time periods. In practice we distinguish between the decision to purchase foodgrain and the decision to consume it. In period 1P (P for Purchase), purchases are made, and in period 1C (C for Consumption) the household decides how much to consume and how much to keep for the lean period 2C. Similarly, we split period 2 into 2P and 2C.[7] In period 1P, the household maximizes the same expected utility as the time-consistent household of Section 2.1: $U(N_1, O_1) + \gamma U(N_2, O_2)$. In contrast, in period 1C the household is tempted to consume more than what was deemed optimal in period 1P. It now maximizes:

$$U(N_1, O_1) + \delta\gamma U(N_2, O_2)$$

where $0 < \delta < 1$ represents the time-inconsistent discount factor. A self-control problem arises because the discount of the future is increased by δ once consumption takes place. As a result, the household may store less food for period 2C than what was considered optimal in period 1P.

[7] We assume the same separation between the purchase and the consumption of the numeraire.

Assuming that the household is sophisticated (it anticipates the urge to consume readily available food), it may avoid storage and delay the purchase of the food intended for consumption in period 2. Purchasing in period 2P then serves as a perfect commitment device: the household effectively controls the quantity consumed in period 1C by limiting its purchase in period 1P to the optimal quantity of food chosen for consumption in 1C.[8] The commitment device may yet prove too costly if the second period price is too high. The question is how high it needs be to annihilate the advantage of commitment. Since storage in the first period leads to an inefficient intertemporal consumption pattern, this price threshold, labelled P_2^{**} , must exceed the threshold obtained in the absence of a present bias, $P_2^* = \frac{rP_1}{\beta}$. In other words, a household with present bias will want to continue to purchase foodgrain in period 2 at price $P_2^*$and beyond.[9] This is illustrated by Figure 7: while households with no present bias start storing at $P_2^* = \frac{rP_1}{\beta}$, households with a present bias (dashed line) purchase foodgrain in period 2 until $P_2 = P_2^{**} > P_2^*$.[10] Above this threshold, total food consumption is insensitive to further increases in P_2 since the household buys food only in period 1. For prices above the threshold, the total quantity of food purchased is larger than in the absence of present bias. Note that there is now a discontinuity in the total quantity consumed at the threshold price. This is because present bias kicks-in at P_2^{**} and, therefore, the optimization problem of the household changes. Of course, the price of indulging in over-consumption in period 1C is a lower expected utility $U(N_1, O_1) + \gamma U(N_2, O_2)$ (Figure 8).[11]

Regarding the expected impact of the intervention, the conclusions reached earlier hold a fortiori with present bias: while the household always benefits from a decrease in the lean period price, total consumption may actually decrease and, as Figure 7 indicates, the decrease in total consumption caused by a fall in the lean period price occurs over a larger price range. The following proposition summarizes this set of results.

Proposition 3. *In the presence of a self-control problem, the threshold lean period price P_2^{**} above which the household stops purchasing food in period 2 exceeds P_2^*. The marginal rate of substitution between nutrition levels in the two periods then becomes $\frac{U_N(N_1)}{U_N(N_2)} = \delta\gamma(\beta - f')$. Central results obtained in the absence of a self-control problem continue to hold: (i) a marginal decrease in the lean period price P_2 increases purchases in the lean period and smoothens nutrition across periods; (ii) the effect*

[8]We assume that no purchase can be made in the "consumption phase".

[9]This is formally established in Appendix 1.

[10]Parameters used for the simulations are provided in Appendix 1.

[11]Expected utility for the sophisticated present bias household is evaluated in period 1P, before consumption choices are made. It thus has the same functional form as the household with no present bias.

on total food consumption $C_1 + C_2$ is indeterminate.

2.3 Storage, consumption and nutrition in the presence of price risk

When households take their storage decision, the lean period price is unknown and while they anticipate a seasonal increase in the price, uncertainty may be an important determinant of storage for risk-averse households. In fact the intervention aims not only at decreasing the expected lean period price but also the price risk. The effect of price risk on storage is well established in the literature. Newbery and Stiglitz (1981) have shown that a reduction in price risk induces a household to decrease storage under reasonable assumptions.[12] Denoting by $\tilde{P}_2$ the stochastic lean period price (and using the same notations as above), a risk-neutral household stores food if $P_1 < \frac{\beta}{r} E\tilde{P}_2$, where E is the expectation operator. In words, if the cost of buying food in period 1 and storing it is lower than the present value of the expected second period price, the household chooses to buy in period 1 and store. For the risk averse household, the condition becomes $P_1 < \frac{\beta}{r} \frac{E[\tilde{P}_2 V_P(P_2)]}{E\tilde{P}_2}$, where V_P is the first derivative of the indirect utility function with respect to P_2 (for proof and discussion, see pp. 195-6 and 116-7). This second threshold value is generally smaller than the first value, implying that a risk averse household responds to a decrease in price risk by decreasing storage. In other words, a decrease in price risk is predicted to enlarge the range of expected lean period prices where the household chooses to buy in the second period instead of storing. The effect of a decrease in price risk is therefore similar to that of a decrease in the price level in the lean period.

3 Program and Experimental Design

3.1 The Food Security Granaries program

In the late 1970s, in order to mitigate the food access problem, many aid organizations and governments have widely promoted the creation of local community organizations aimed at activating local food markets. Cereal banks are a typical example of these community-based interventions seeking to reduce market risks understood as either availability risk (food supply becomes less reliable in times of need) or price risk (food price rises in times of need). However, most of the 4000 cereal banks that were inventoried in Sahelian countries in 1991 collapsed in the late 90s owing to mismanagement, embezzlement of funds, and lack of trade opportunities (for a review of the problems, see World Bank,

[12] Formally, the coefficient of relative risk aversion must be greater than the income elasticity of demand for the good, which Newbery and Stiglitz consider “a most plausible condition for most agricultural goods” (p. 196).

2011). A new generation of initiatives inspired by the principles of cereal banks has nonetheless developed over the last decade. Foremost among them is the program of Food Security Granaries (FSG) undertaken in 2002 in Northern Burkina Faso by the NGO "SOS Faim" and financed by the Belgian Fund for Food Security (FBSA). It is aimed at revitalizing a network of about 400 former cereal banks in a setup that pays strong attention to financial viability considerations.

The northern part of Burkina Faso is of particular interest because it belongs to the Sudano-Sahelian dry zone where, given the absence of irrigation, there is only one agricultural cycle per year and production is highly sensitive to rainfall shocks. Few crops can be cultivated and the diversification of the food diet is very low: foodgrain represents more than two-thirds of daily caloric intakes (Cheyns, 1996). Subsistence agriculture dominates but while some households are systematically able to produce enough grain to satisfy their own basic consumption needs, most of them are not and depend crucially on food markets. Food access is especially critical in the rainy season when people engage in heavy agricultural work, grain stored in family granaries start depleting, food prices tend to increase, and access to villages becomes more difficult because of rain. Hence the name lean season to characterize this period of acute stress.

The pillars of the FSG intervention consist of 1) setting up a local, informal storing and marketing organization whose function is to buy foodgrain from surplus areas (in the south of the country), store and sell it throughout the agricultural year at a price that covers costs and includes a predetermined margin[13], 2) facilitating the shift of grain from surplus to deficit village communities by mobilizing a network of pre-existing farmer organizations, 3) providing training and capacity-building for local management teams, as well as monitoring and multi-level technical assistance on a continuous basis and 4) granting (gradually scaled up) annual credit to village organizations so that they can purchase externally provided foodgrain for sales in cash to local villagers.

The last three functions are expected to provide village granaries with a comparative advantage over the private sector, thereby enabling them to operate even where and when private merchants are absent. Training and monitoring, credit-giving and foodgrain redistribution between surplus and deficit areas can be performed rather effectively thanks to the network-based operation of the scheme. As a matter of fact, FSGs are organized as local antennas belonging to a national federation (called FNGN - Federation Nationale des Groupes Naam) in charge of managing the program. The resulting advantages are manyfold. First, economies of scale can be reaped through the pooling of food purchases

[13]The recommendation of the program is to set the margin at 500 CFA-F per bag, corresponding to a moderate 7% markup.

and the collective organisation of transportation from surplus areas. Second, information regarding local food availability and prices is easily circulated through the organization. Third, monitoring of the use of credit and the management of village granaries is facilitated by the peer pressure arising from continuous comparisons between member units. Thus, credit demands are analyzed during a public meeting organized by the Federation in which village representatives are expected to motivate their credit demand and prove their ability to effectively manage the activity. Credit performance is carefully monitored throughout the year and future access to loans is strictly denied in the case of failure to comply with the established rules. When blatant embezzlement occurs, the Federation does not hesitate to sue the perpetrators in court, thus adding external sanctioning to mutual pressures.

A last remark is in order. To be able to disentangle the impacts of these different components, one would have needed to implement a series of appropriate treatments to isolate the effect of each dimension. This did not prove to be feasible not only because the program management opposed such an approach, but also, and more fundamentally, because the aforementioned components of the program are complementary attributes. This is particularly evident in the case of credit and the setting up of village granaries: provisioning of these granaries is not possible in the absence of externally provided loans.

3.2 The experimental design

The program started in 2002 and we took advantage of its scaling-up in 2011 to evaluate its impact on food security. In the area targeted for gradual scaling-up of the program, the NGO had identified eligible villages that had never benefited from the intervention in the past and had expressed an interest for the intervention. Among these eligible villages, 40 were selected to be part of the experimental framework. Half of them were randomly assigned to the treatment group while the remaining 20 villages, used as control units, were to benefit from the program two years later. The intervention consists in setting up a FSG in the village without fixing the level of financial support. While the operational framework is identical in all villages, the amount of credit granted varies across villages and over time, depending on the needs of each village.[14] As it turns out, the amount of credit granted tends to be larger in more isolated villages.[15]

[14]The mean credit corresponds to 3,150 euros while all credits granted to the sampled villages were between 1,500 and 5,500 euros.

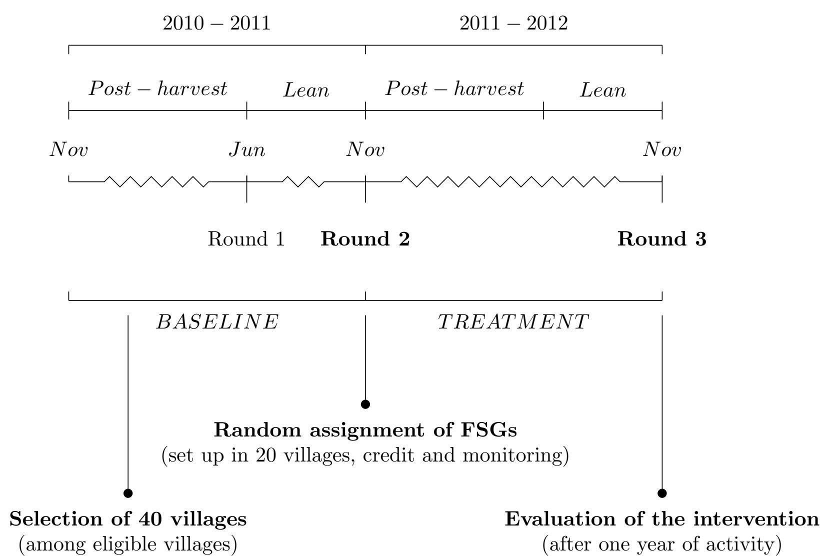
[15]This variation in credit does not create a problem for our estimation strategy. Indeed, credit is part of the program package and serves the function of alleviating the liquidity constraint of the village granary. In some sense what we are estimating is therefore an "intent to treat" effect where the intensity of the treatment can be chosen.

4 Data and descriptive statistics

4.1 Data

Our sample households were surveyed three times during the agricultural years 2010-2011 and 2011-2012. Figure 1 presents the timing of the intervention and the surveys. The first survey was undertaken before the 2011 lean season and the second survey after that season. Both surveys include baseline characteristics. As for the third survey, it was implemented after the 2012 lean season and it coincides with the end of the first year of the intervention. As a consequence, our impact assessment relies mainly on Rounds 2 and 3. In the descriptive section as well as in the final discussion, we also use two additional rounds of data that were collected in 2012-2013 with a setting similar to Rounds 1 and 2. We do not use this data for impact evaluation because the intervention was no longer randomly assigned during that year.[16]

Figure 1: Timing of the intervention and the surveys



Based on administrative census, 10 households were randomly selected in each of the 40 villages sampled. The sample thus includes a total of 400 households, standing for 4750 individuals and about 5 percent of the population studied. Attrition is low - less than 3 percent of households - and its causes are known and unrelated to treatment assignment.

[16]The renewal of the program revealed to be problematic as the result of embezzlement. A grassroot employee of the Federation who was in charge of 6 villages stole the money entrusted to him to pay back the village loans.

Broad surveys were implemented in Round 1 and more focused follow-up surveys were used in Rounds 2 and 3. While general information about the household was obtained from the household head, personal information on each adult member and its dependents - e.g. mother and children - was gathered directly from them. Special attention was paid to agricultural production and food stock management, as they are key determinants of food vulnerability. All surveys also include a comprehensive set of questions on food and nutrition. An original section was designed to gather detailed information on all cereal transactions made by household members over the agricultural cycle. It includes not only the timing, quantity and price of each transaction, but also the characteristics of the seller involved and the transaction motives. Also, data on diet diversity, perception of food access and the quality of meals were collected at Round 3. In addition, we measured and weighed all individuals following WHO standards. We use this data to construct indicators of the nutritional status of all household members in each round.

In addition to this main data collection effort, we conducted a detailed investigation of the effects of seasonality in the 14 most remote villages. In these villages, a subsample of 70 of the original households was selected to be surveyed on a monthly basis in 2016. Each month, detailed data on food stock management and transactions were collected and all household members were weighed and measured. In the following, we use this data mainly for descriptive purposes.

4.2 Descriptive statistics

Tables 1 and 2 provide descriptive statistics. Table 1 focuses on baseline characteristics and shows that there was no significant difference between treatment and control villages on a large set of village and household characteristics. Table 2 reports food and nutrition indicators for households in control villages and for each of the three agricultural years.

Nutritional stress — Panel A of Table 2 reports measures of nutritional status after the lean season and differences in nutritional status before and after the lean season. The measures used include Body Mass Index (BMI) for adults and BMI-For-Age (BFA) z-score for children.[17] These constitute

[17]Because body fat varies with age and gender during childhood and adolescence, BMI is age and gender specific. Therefore we use a standardized BMI-for-Age z-score, which is defined as the difference between the value for an individual and the median value of a reference (well-nourished) population for the same age and gender, divided by the standard deviation for the reference population. For children below 5, the reference population comes from the WHO Child Growth Standard database. It includes a large sample of children from Brazil, Ghana, India, Norway, Oman and United States. The WHO 2007 Growth Reference database provides similar information for children between 6 and 18. We prefer BMI-for-Age to Weight-for-Height because the former can be computed for all children up to 18 while performing equally well in predicting underweight (Mei et al., 2002). Note however that the results presented in the paper hold if we use Weight-for-Height instead.

objective measures that are sensitive to short-term variations in food consumption. Based on weight and height, they are proxy measures of adiposity - the amount of fat in the body - and are used as a screening tool to identify individuals who are underweight or suffering from wasting.[18]

We observe that the incidence of malnutrition varies according to age category: 16 percent of adults, 13 percent of children between 5 and 18 years, 2 percent of children between 3 and 4 years, and 4 percent of children aged 2 or younger were initially identified as underweight. As reflected in changes in both nutritional indices and prevalence rates between 2010-11 and 2011-12, the nutritional situation of all individuals deteriorated over the 2011-12 agricultural year. Children aged 2 or younger were particularly adversely affected since the prevalence of wasting went beyond the 10 percent high level of severity defined by the World Health Organization (WHO, 1995): it went up from 4 percent in 2010-11 to 12 percent in 2012-13. We also observe that the nutritional status of young children continued to deteriorate in 2012-13. Moreover, variations in the children's BMI between the period preceding and the period following the lean season were quite significant in the years 2010-11 and 2012-13 (last four variables, panel A), suggesting a large seasonal stress including for young children. This is an important finding given that seasonal energy stresses are considered as a major contributor to undernutrition (Vaitla et al., 2009).

The importance of seasonal variations in nutrition is confirmed by the analysis of the monthly data pertaining to the 2016 subsample. Both children above 5 and adults experience a clear decrease in their nutritional level between two harvests (Figures 9 and 11). Interestingly, the drop in adults' BMI coincides with a significant increase in the daily quantity of foodgrain prepared by households (Figure 10). This suggets that the sharp increase in energy expenditure during the period of heavy agricultural work (June to October) is not compensated by the increase in the quantity of food consumed by the household during that period. As children (including young children) participate in agricultural labor, it is not surprising that their nutritional status follows the same trend than that of adults. Our monthly data reveals that very young children (0 to 5 years old) are not protected from noxious fluctuations in nutritional status (Figure 12). Strikingly, this result is driven by children living in the most remote villages: while they experienced a sharp drop in z-score between two harvests in 2016, their counterparts in less remote villages did not.[19] While purely descriptive, this analysis confirms Abey and Hirvonen (2016)'s conclusion regarding the critical role that market access plays to shield

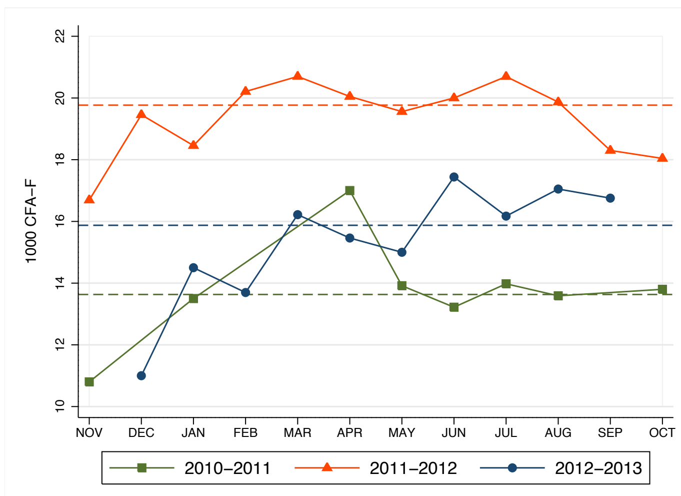
[18] Following WHO (1995), wasting or thinness "indicates in most cases a recent and severe process of weight loss, which is often associated with acute starvation and/or severe disease". According to WHO standards, adults with BMI below 18.5 are underweight. Children and adolescents presenting z-score below -2 suffer from wasting.

[19] We distinguish between villages where a weekly market takes place and other villages (most remote).

the youngest from seasonal food shortages.

A drought year — While 65 percent of sampled households produced enough foodgrain to satisfy their needs over the 2010-11 agricultural year, only 13 percent of households were in that situation in 2011-12 (Panel B of Table 2). While there are always some purchases of foodgrain, very high levels are reached after bad harvests. Thus, in 2011-12, purchases amounted to 53 kg per capita, corresponding to about one-third of annual consumption.[20] As illustrated by Figure 2, tight local market conditions translated into very high prices from the very beginning of the agricultural year. The mean price of sorghum was almost 50 percent higher in 2011-2012 than in the previous year, a rate of increase also observed for other crops (FAO et al., 2012). Clearly, the timing of our program evaluation coincides with a drought year, critically raising the potential impact of the intervention.

Figure 2: Monthly Mean Price of Sorghum across Agricultural Year



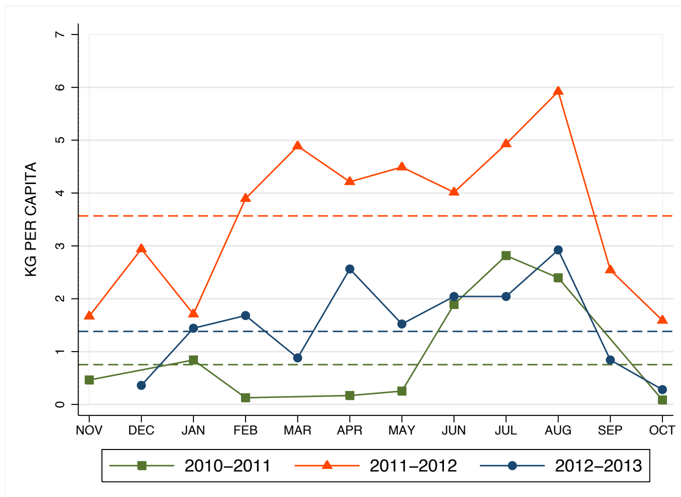
Buying further away and earlier — As evident from panel B of Table 2, almost all cereal transactions take the form of bulk purchases involving 100-kg bags.[21] The main features of these transactions are described in panel C. Sorghum is the most important traded foodgrain, far ahead of millet, maize and rice: in 2011-12, it amounted to 65 percent of all grain bought, while maize amounted to 20 percent and millet to 14 percent. While households emphasize their preference for buying close to their dwelling (more on this later), more than half of their purchases are made outside their village. In 2011-12, the situation was even worse since only 37 percent of the purchased cereals was bought

[20]Interestingly, very few households are involved in grain sales while those sales concern negligible quantities. This suggests that households prefer relying on storage rather than on market to smooth consumption within and across years.

[21]This is confirmed when computing the ratio of total cereal bulk purchases to total cereal purchases. More than 99 percent of quantities bought have been acquired through bulk purchases.

in the village of residence.[22] The timing of purchase is another important dimension to be taken into account. Figure 3 shows that households buy foodgrain through the agricultural year with a small peak during the lean season. In 2011-12, however, a larger proportion of purchased foodgrain (about two-thirds) was acquired before the lean season. This is because stocks started to deplete earlier and households bought larger quantities before own stock depletion.

Figure 3: Monthly Quantity of Grain Bought across Agricultural Year



Activity of FSGs — Over the agricultural year 2011-12, each FSG sold an average of 18.1 tons of foodgrain. Together, they represented about 3.5 percent of total annual grain requirement.[23] Our data shows that FSG renewed their stock during the year considered (1.7 times on an average), suggesting that a complete temporal arbitrage, from harvest to harvest, did not take place. When analyzing transaction data, we observe that the FSGs' overall market share was 14 percent while their share rose to 30 percent when only intra-village transactions are taken into account. Almost one-fourth of the households living in the treatment villages used the local FSG. These two pieces of information indicate that the village granaries are a significant actor in local food markets.

[22]Whereas existing traders are typically in small numbers, they have high cost structures and their activity is of limited duration and scope. Insufficient local food supply exposes populations to adverse market conditions that can eventually end up in food rationing.

[23]This number is calculated using population size and the country consumption reference level of 190 kg of foodgrain per capita per year. When using actual foodgrain consumption, FSGs activities represent 4.5 percent of total annual consumption.

5 Methodology and results

In this section, we first investigate the impact of the intervention on food access, the total foodgrain purchased and the timing of purchases. We then explore the effects on final outcomes, namely consumption and nutritional status. We also present heterogeneous effects arising from differences in market integration as measured by the availability of road connections. Because of their isolation, villages where road connections are absent during the lean season ("no-road villages") are more vulnerable to supply scarcities and therefore prices increase noticeably in times of stress (De Janvry, Fafchamps and Sadoulet, 1991; Newbery, 1989). A total of 16 villages fall into this category and they are equally distributed across treatment and control. Moreover, characteristics of village and households at baseline are well-balanced in the no-road subsample (Table 7).

We mainly use difference-in-difference (DID) estimators and thereby control for time invariant unobservable characteristics. DID allows not only to adjust for initial random differences in mean outcomes across treatment status but also to increase statistical precision, which is important given the limited number of treatment units (Glennerster and Takavarasha, 2013). Specifically, the model we estimate for individual outcomes is:

$$y_{ijt} = \beta_1 + \beta_2 P_t + \beta_3 T_j P_t + \beta_4' X_{ijt} + \tau_j + \epsilon_{ijt} \tag{8}$$

where y_{ijt} denotes the outcome of individual i from village j at time t, T_j is a binary variable indicating the treatment status of village j, and P_t a binary variable taking value 1 for post-intervention observations and value 0 otherwise. The vector X_{ijt} includes time-varying characteristics such as weather-related indicators. Village fixed effects are captured by the vector τ_j. The main coefficient of interest is β_3, which captures the causal effect of the intervention. Because the intervention is implemented at the village level, we systematically cluster standard errors at that level (Bertrand et al., 2004). Alternative approaches consist in estimating the regressions with no control variables and to estimate randomized inference standard errors rather than cluster robust standard errors (Young, 2015). When this is done, the results obtained systematically confirm those achieved with the above model (see Appendix 3).

5.1 Food Access

Table 3 reports the impact of the intervention on foodgrain availability, affordability and purchases. Before turning to our main results, two observations deserve to be made. First, as expected, differences at baseline across treatment and control units are small and non-significant for all the outcomes considered (first row of Table 3). Second, even after controlling for weather conditions, outcomes in the year of the intervention are significantly different from those at baseline, testifying to substantial pressure on food markets in 2011-12 (second row of Table 3). For example, households had to tread longer distances to acquire food (measured in time spent) and the average price of sorghum was 30 percent higher.

Foodgrain availability — The first two columns of Table 3 report the impact of the intervention on local food availability. Column (1) shows that the intervention has succeeded in boosting the proportion of foodgrain bought inside the village of residence: the probability that any bag of foodgrain was purchased locally increased by 25.3 percentage points. As shown in Table 8, Appendix 2, the impact is mainly driven by villages that are not accessible by road, and where availability of foodgrain for local purchase is critically important.

Column (2) reports the impact of the intervention on the total annual distance travelled to buy foodgrain. This aggregate measure is the sum of the amounts of time (in minutes) needed to reach the seller by walk for each transaction. We find that the FSGs allow to significantly reduce the annual distance by an average of 10.3 minutes walk per capita which corresponds to 123 minutes for the average household (a 25 percent reduction of the annual distance travelled by control households). Again the effect is larger in no-road villages (albeit not significantly).

The intervention of the FSGs has clearly succeeded in bringing food closer to rural buyers, which is one of its main goals. When asked to motivate their choice of a particular seller (at baseline), they cited proximity of the seller as the main reason for 78 percent of the quantity of foodgrain purchased (Table 2, panel C). The second most important reason, cited in 20 percent of the cases, is a strong confidence in the actual availability of foodgrain at the selling point. Interestingly lower prices are rarely cited as the main motivation to choose a specific buyer (2 percent). Focus group discussions have highlighted that families prefer to buy foodgrain closer to their dwelling not only because of time and effort gains but also because it reduces the risk of unsuccessful transactions. A transaction is unsuccessful when a villager moves to a nearby market or town to buy foodgrain but returns empty-handed because of unavailability of foodgrain or excessive price.

Foodgrain affordability — A second important dimension of food security is affordability: food may be available but at such high prices that households cannot acquire it. Column (3) of Table 3 reports the impact of the intervention on nominal sorghum prices paid. In treatment villages, the intervention is responsible for a significant reduction (1,384 CFA-F) of the price of sorghum, which represents a 7 percent cut.[24] It helped to mitigate the price surge that followed the drought by as much as 25 percent. Again we expect that the price-reducing impact of the intervention will be especialy large in remote villages, since remotness has the effect of isolating a village from price-dampening market forces in times of supply stress. Evidence reported in Table 8 in Appendix 2 confirms this expectation: the price reduction observed in no-road villages is more than four times as large as in the other villages (2445 CFA-F against 586). As seen in Rows 3 and 4 in the table, this effect fully annihilates the impact of the drought in remote villages.

Foodgrain purchase —So far, we have shown that households from treatment villages bought grain closer to their dwellings and at lower prices. What is not clear, however, is the effect of the intervention on the quantities of foodgrain purchased and on the timing of the purchases. We have argued in Section 2 that the former effect is ambiguous in a nutrition-based model with storage losses: it is possible, contrary to immediate intuition, that food purchases do not increase as a result of a decrease in foodgrain prices. As for the latter effect, the model predicts that households will delay their purchases if the intervention assures them that food will be locally available in the lean period.

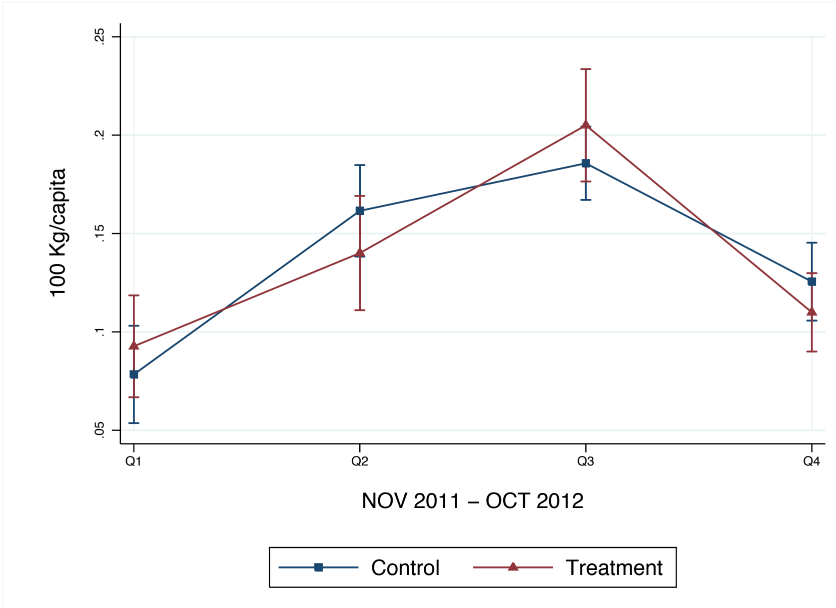
Columns (4) and (5) of Table 3 provide estimates of the impact of FSGs on the probability for households to have bought any foodgrain and on the annual foodgrain quantities purchased, respectively. First note that throughout the 2011-12 cycle, as many as 80 percent of the households did purchase foodgrain and, on the intensive margin, the quantity purchased per capita was 53 kilograms of foodgrain, that is more than one-fourth of annual requirements.[25] Turning to the impact of the intervention on these two measures, we find that the parameter estimates are small and not significantly different from zero. In the same line, we observe that the total expenditure on foodgrain has slightly decreased, albeit not significantly (column 6).

In order to investigate the impact of the intervention on the timing of purchases, we rely on three measures. The first measure consists of the quantities of foodgrain purchased in each quarter of the intervention year (as in Figure 4). The second corresponds to the number of months the household

[24] Impact on prices reported in Table 3 have been obtained considering each grain bag purchased as the unit of analysis. Results are very similar when considering instead the mean price paid per bag and the household as the unit of analysis.

[25] We use the country consumption reference level of 190 kilograms of foodgrain per capita per year.

Figure 4: FSGs impact on quarterly quantity bought



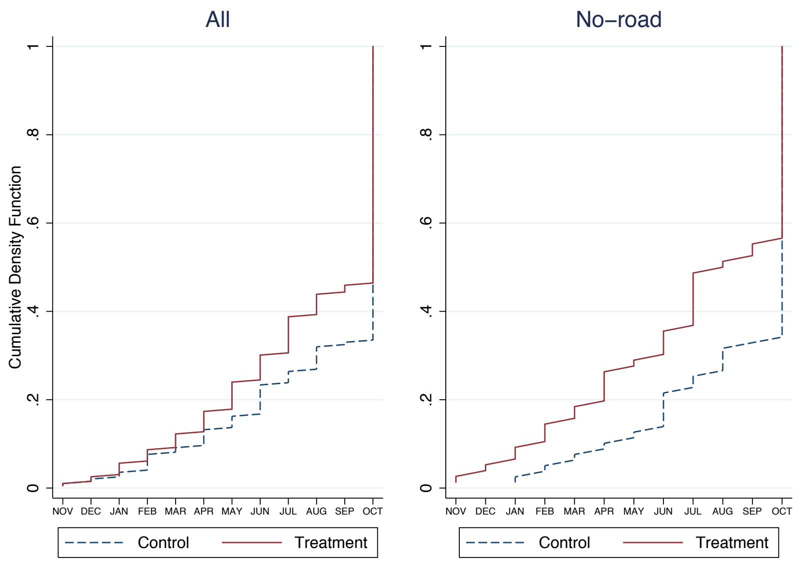
holds a stock of foodgrain in the granary located inside the household compound (as in Table 4). The third relies on both a binary and a continuous variable that capture purchases made before the depletion of the granary (as in Table 4 again). We know that only grain produced on the family farm goes to the granary, hence the name "own stock" chosen to denote this form of storage. Own foodgrain is stored on ear, while purchased foodgrain is always bought and held in the form of grain inside the household's main dwelling. A critical observation is that because grain deteriorates faster than ears, the foodgrain purchased is always consumed first, thereby lengthening the duration of own stock. We actually observe that households do not necessarily deplete their entire granary before starting to purchase foodgrain: a majority of them, 65 percent, thus extend the duration of their granary stock by purchasing foodgrain before the depletion of their own stock.

Figure 4 compares quarterly purchases in treatment and control villages. It is based on per capita quantities purchased as have been estimated with the help of a negative binomial regression (see regression results in Appendix 2, Table 9).[26] It suggests that households in treatment areas have tended to delay their purchases compared to control areas. The difference is not statistically significant though.

Turning to the second measure, we expect that households in treatment areas depleted their own

[26] By using a negative binomial regression, we account for the Poisson structure of the quarterly data and the high proportion of zero entries in the data.

Figure 5: FSGs impact on the cumulative distribution of own stock depletion



stock faster than control households. This expectation is confirmed by Figure 5. The left panel reports the cumulative distribution of the duration of own stock (in months) for all control and treatment households while the right panel reports the same statistic but only for households living in no-road villages. For both the complete sample and the sample restricted to no-road villages, the cumulative distribution for the control group first-order stochastically dominates the distribution for the treatment group. Kolmogorov-Smirnov tests confirm that the differences across these distributions are statistically significant. We also estimate the impact of the program on the duration of own stock in a regression framework where basic controls are introduced. Table 4 reports the results (columns 1 and 2). The intervention shortens the duration of own stock by 0.63 months for the whole sample and by 1.19 months for the restricted sample. Only in the latter case however, is the effect statistically significant.

Finally, concomitantly to the shortening of the duration of stock, we expect that the intervention reduces anticipated purchases understood as purchases made before the depletion of own stock. Table 4 broadly confirms this prediction. On the extensive margin, households in treatment villages are less likely to make anticipated purchases, but the effect is significant only for no-road villages. In the latter, beneficiaries were 30 percent less likely to make any purchase before stock depletion. On the intensive margin, the intervention lowers substantially the quantities bought before own stock depletion: households in treatment villages decreased their anticipated purchases of foodgrain by 11 kg per capita, which represents a 36 percent decrease. It is noticeable that the impact is more than twice as large in no-road villages as in the full sample.

5.2 Consumption and Nutrition

We are left with the most important task of examining the impact of the intervention on final outcome variables, food consumption and nutritional status. To assess the impact on nutrition, we rely on anthropometric indicators, as explained earlier. We distinguish between adults (19-59) and three age groups for children (0-2, 3-4 and 5-18). To measure consumption in terms of both quantity and quality, we use a set of household-level variables based on annual grain balance, self-reported daily ration, and recall data on food diet.[27] First, foodgrain balance, which corresponds to the disposable foodgrain, is obtained by adding purchases and gifts received to the quantity produced and then subtracting losses, sales and gifts made.[28] We also compare the disposable foodgrain to the consumption reference level of 190kg per capita per year and construct a binary variable equal to one if the former quantity exceeds the latter. Second, households have been asked about their daily foodgrain ration during the week preceding the survey (at the end of the lean season), and whether they considered it sufficient to satisfy their basic needs. Third, if foodgrain consumption approximates the caloric intake relatively well in a context where cereals account for two-thirds of this intake, it does not capture the micronutrient adequacy of the diet. To remedy this lacuna, we construct a diet diversity score (DDS), corresponding to the number of food groups to which items consumed over the last day belonged.[29] As an alternative measure, we use an indicator based on a one-month recall period, which is better adapted to contexts where food diets are very poor, as suggested by Hoddinott (1999). Tables 5 and 6 show the impact of the program on these various outcomes.

Consumption — The overall picture that comes out of Table 5 is that there is no clear evidence of an impact of the intervention on food consumption. All coefficients but one are small and not significant. The intervention does not significantly increase the disposable foodgrain, the probability that the latter exceeds the consumption reference level, and the daily ration. By contrast, treated households are more confident that their daily ration meets their needs, a finding that will make more

[27] As data on food diet were not collected at baseline, impact estimates on this outcome are obtained with simple difference across treatment status.

[28] While different types of foodgrain are consumed (mainly sorghum, millet and maize, see above for details), their nutritional content is very similar, both in terms of total energy and micronutrient content. As a result, we can sum them up in a unique variable. The results obtained hold if we use other aggregations, based on prices or exact calorie-contents.

[29] Following Steyn et al. (2006), we distinguish between nine foodgroups: (1) cereals, roots and tubers, (2) vitamine-A rich fruits and vegetables, (3) other fruits, (4) other vegetables, (5) legumes and nuts, (6) meat, poultry and fish, (7) fats and oils, (8) dairy, (9) eggs.

sense in the light of our overall discussion in Section 6. The lack of effect of the FSG program on total foodgrain consumption does not come as a surprise since we earlier found that total foodgrain purchases did not increase in FSG villages.

One could argue that, if the program did not increase the quantity of foodgrain consumed, it may have improved the diversity of the diet, as the increase in purchasing power may translate into a greater demand for animal products, vegetables or fruits. That this second effect is also absent is evident from columns (5) and (6) of Table 5: coefficients are small, not significant and even negative. Because the diversity measures only cover the month before the survey, we cannot rule out the possibility that the intervention enabled beneficiary households to improve their diet at other moments of the agricultural cycle (Savy et al., 2006). Nevertheless, evidence from our monthly survey suggests that this is unlikely. While we do observe some changes in food diversity at certain times of the year, they are systematically associated with the availability of some fruits or vegetables that are not purchased.

The analysis of heterogeneous effects along the dimension of remoteness status leads to a similar conclusion: we do not detect any effect of the FSGs on consumption outcomes.

Nutrition — Estimates of the impact on nutritional outcomes are reported in Table 6. The first three columns suggest that the intervention has a large and positive impact on nutritional outcomes for both adults and children. The estimated effect for adults is positive and significant and corresponds to 0.3 BMI point which, on average, corresponds to about one-kilo difference for an individual with mean BMI. Column (2) shows a positive impact on children 5 to 18 years old. Since the post-treatment mean z-score for this age group in control villages is -1, the estimated effect of 0.2 z-score in BMI-for-age corresponds to a 20 percent reduction in the existing gap with the well-nourished reference population. Column (4) shows that children below 3 have been positively affected by the program as well. The effect corresponds to a 70 percent reduction in the existing gap between them and the well-nourished reference population. In contrast we do not find any impact of the program for the group of children aged 3 to 4.

Column (5) of Table 6 reveals no significant impact on the prevalence of underweight among adults. More interestingly, the intervention has substantial effect on the incidence of wasting among children. Column (6) thus shows a 4 percentage points decrease in the incidence of wasting among children between 5 and 18, that is, a 25 percent net reduction in the prevalence of wasting. The impact is even greater for the youngest children. In the control villages, the prevalence rate among children under 3 reaches the 10 percent high level of severity defined by the World Health Organisation while it remains stable at moderate levels in the treatment villages. For the sake of comparison, the prevalence of wasting in poor countries is usually below 5 percent in the absence of severe food shortages (WHO, 1995). Again the program appears to have had no effect on the nutrition of the children aged 3 to 4.

Heterogeneous effects on nutrition are presented in Table 11 in Appendix 2. The effects of the intervention on nutritional outcomes for both adults and children appear mainly driven by the no-road villages.

6 Discussion

The presence of FSG enables household to buy foodgrain closer to their dwelling, at lower price and when the need arises rather than in anticipation. The program thus appears to fulfill its objective of activating local food markets. The ultimate goal of improving nutrition is also reached: FSG enhance children's as well as adults' nutritional status. Nevertheless, the lack of impact on total quantity of food consumed deserves elucidation. Two questions arise. First, why is it that households have not increased the quantity of grain purchased while prices have decreased ? And second, how can we account for an improvement in nutrition when total grain available (the sum of own production and purchase) has not increased as a result of the program ?

Ruling out Giffen and quality effects

The Giffen effect constitutes the most straightforward explanation for both facts. The decrease in foodgrain price leads to an increase in purchasing power that induces the households to diversify their food diet away from foodgrain. If this income effect outweighs the substitution effect, we expect a net decrease in foodgrain consumption. Recent evidence from China confirms that the Giffen effect may be observed in contexts that resemble ours: households are poor and obtain most of their calories from the consumption of staple grains (Jensen and Miller, 2008). The second fact can also be explained by the Giffen effect if an increase in food diversity improves the quality of nutrition (Steyn et al., 2006).

Surprisingly, however, our evidence does not support this explanation. As seen in Table 5, there is no impact of the program on various food diversity scores (at least at the end of the lean season). Of course, diversification needs not concern only food: an increase in real income may prompt households to increase the consumption of other goods and services that have a positive influence on nutrition. In particular, health expenditures could increase and improve nutrition to the extent that healthier individuals have a more efficient metabolism and better absorb nutrients. We actually have a detailed measure of health expenditures yet, unfortunately not for the year of the intervention: health expenditures have been measured only at the baseline and two years after the start of program. If we cannot rule out an effect of the program during the year of the intervention, qualitative evidence runs against this interpretation. The sample households, indeed, confessed to not using preventive medicine and to have recourse to medical treatment (conventional or traditional) only as a last resort solution. The data confirm that health expenditures are small (2 percent of total cash expenditure). Furthermore, we find no impact of the program on the occurrence and duration of episodes of disease for children and adults, suggesting that the improvement of nutritional outcomes does not result from a reduction in disease exposure in treatment villages.[30]

Different from a Giffen effect is an explanation based on a change in the quality of foodgrain. Thanks to a higher nutrition content of a given quantity of cereals, households would be able to improve their nutrition status as a result of the program, even if they do not increase the quantity purchased. Again, our evidence does not support this second explanation. First, a change in the quality of cereals was never mentioned by the sample households when we asked them about the advantages of the program (in an open question). Second, if this explanation was relevant, we would expect no impact of the program for households who did not purchase cereals in the FSGs. Table 12 in Appendix 2 indicates that this is not the case.

Note finally that the impact of the program on nutrition does not seem to be driven by a reduction in energy expenditures. First the reduction in the travel distance to acquire cereals is too small to explain any significant increase in weight among households in FSG villages (it represents less than 1000 kcal per household per year). Second, we find no evidence that households in FSG villages have exerted less effort as reflected in the activities undertaken or in the amount of agricultural production in the post-intervention campaign.[31] If anything, yields have slightly improved.

Intertemporal reallocation of purchases and stock management imperfections: quantitative evidence

In line with our model (see Section 2), Table 4 has shown that the program significantly affects the timing of food purchases. Specifically, households in control areas tend to anticipate scarcity by buying food even though they still have foodgrain available from their own harvest. By contrast, being more

[30] Results available upon request.

[31] There is no effect of the program on the propensity of treated individuals to engage in income generating activities or on the income generated by these activities (see Table 13, Appendix 2). There is no difference either in the variation of the herd owned by treatment and control households.

assured of future supply, households in treatment villages tend to postpone their purchases until their own stock is depleted. At any point of time, therefore, they have smaller quantities of foodgrain stored in their household. In the presence of storage losses, they may thus enjoy higher effective consumption than households in control villages, even though they purchase the same quantity of foodgrain.[32]

We have already mentioned two forms of physical storage: storage of own production in the household granary in the form of ears, and storage of purchased food inside the dwelling in the form of grain. There also exists the possibility of storing in the body: body mass is then accumulated and thereafter gradually depleted during the lean season when consumption of cereal decreases and/or effort increases. There is a narrow literature investigating this mechanism in the context of subsistence farming (Dugdale and Payne, 1987; Branca et al., 1993; IFPRI, 2015).

All these forms of storage obviously entail costs. For body mass storing, there are costs associated with storing and de-storing as well as costs associated with the maintenance of a larger body mass (Dugdale and Payne, 1987).[33] For foodgrain storing, two different types of costs are involved. The first and most well-known type consists of foodgrain losses caused by rodents and moisture. The second type results from the difficulty to protect household grain from demands of visitors and household members themselves. When the stocks of food are ill-protected against non-household members, the source of storage costs lies in redistributive pressures (Platteau, 2000; Baland et al., 2011; Dupas and Robinson, 2013; Platteau, 2014; Jakiela and Ozier, 2015). When they are ill-protected against household members themselves, the source lies more in an inability to withstand the pressure to consume purchased foodgrain quickly. This inability is akin to a self-control problem (Ashraf et al., 2006; Bernheim et al., 2015). Regarding redistributive pressures, interviews with sample farmers reveal that large household stocks signal abundance and attract solicitations. In particular, visitors are likely to stay longer. Regarding the urge to consume, the idea is that people may find it difficult not to consume food that is readily accessible and in apparent (albeit temporary) abundance. The problem is expected to be especially acute when people go hungry. Finally, it may be noted that body mass accumulation may itself be the consequence of a self-control problem, in this case the urge to eat when food is plentiful.

What evidence do we have about the different forms that storage cost can take? First, physical

[32] It is interesting to note that storage costs play a role similar to improved quality of foodgrain purchased.

[33] A back-of-the-envelop calibration suggests that the magnitude of the impact on nutritional status after the lean season is easily compatible with a more efficient timing of consumption, unaccompanied by an increase in the total quantity consumed. Thus, one additional kilogram gained before the lean season is completely lost after a period of 5 months if no compensatory energy is consumed in the meantime for its maintenance (for a moderately active woman, FAO, 2001). By smoothing weight over this period, such a loss can be avoided and a net gain can be obtained.

losses turn out to be much less important than we expected. Only 1.5 percent of households in the sample declared that they had suffered any loss due to physical storage problems, and the quantities concerned were always small (never more than 5 percent). This result confirms the finding of a recent World Bank Report that storage losses are small in dry and semi-dry areas (World Bank, 2011). Second, turning to evidence about redistributive pressures, we note that while treatment households received fewer visits of people staying and eating in the household, the effect is not quantitatively important. In the analysis presented above, we have actually accounted for these visits when computing the quantity of grain consumed by household members, and, as we know, there is no significant effect of the program on the quantity of food consumed per capita (see Table 5). Redistribution can also take the form of gifts of cereals to non-residents. We have detailed information on such transfers made over the agricultural year. It appears that there is a significant difference in such transfers between households in the treatment and control villages. However, the quantities concerned are small (see Table 13, Appendix 2) and they have again been taken into account when computing the total foodgrain disposable. We must therefore conclude that even though there may be a mitigating impact of FSGs on redistributive pressure, it is too insignificant to explain our results.

Third, the existence of a self-control problem as defined above cannot be formallly tested on the basis of our data. Yet, we find supportive evidence, both quantitative and qualitative, that cannot be easily dismissed. Quantitatively, we would have liked to measure the impact of the program on the intra-year fluctuations in body mass in order to test whether these fluctuations have been dampened. Unfortunately, because we have only one wave of survey during the year following the intervention, we are unable to carry out this test. We can nevertheless adduce indirect evidence based on data on body mass fluctuations observed during years 2010-11 and 2012-13. What we find is that the delaying of foodgrain purchases is associated with less body mass fluctuations. Specifically, the variation in adult body mass for households who purchased cereals after depletion of own stock is significantly smaller than the variation for households who made anticipated purchases. The same significant difference is observed when, instead of comparing households which did or did not make anticipated purchases, we use a continuous variable consisting of the quantities purchased before stock depletion. Table 14 in Appendix 2 thus indicates that anticipated purchases (made before stock depletion) are associated with higher body mass indices before the lean season (column 1 or 4) but similar body mass indexes after the lean season (columns 2 or 5), implying a higher variation in body mass compared to the other households (columns 3 or 6). These findings suggest that because it induced households to limit their anticipated purchases, the program also led to a reduction in body mass fluctuations. Better timing of cereal purchases therefore appears as an effective way to dampen the urge to quickly consume readily accessible foodgrain. This conclusion is supported by the analysis of the relationship between the timing of purchase and the quantity of food prepared at home in the subsample of households surveyed monthly in 2016. Controlling for the annual foodgrain disposable, households appear to prepare significantly more food right after having made a purchase (Table 15, Appendix 2). Thus delaying purchase until the need arises in the lean season may help smooth nutrition.

Intertemporal reallocation of purchases and stock management imperfections: qualitative evidence

In order to ascertain our interpretation of the results, we have returned to the field to conduct in-depth interviews in the framework of follow-up workshops organized in both treatment and control villages (June 2015). In a first step, we devised visual tools for the purpose of summarizing our most salient quantitative findings in an easily understandable manner (see Figures 7 to Figure 16, Appendix 4). Group discussion was then aimed at eliciting opinions about these findings and their interpretation. In particular, participants were explicitly asked whether the paradox discovered - quantities of foodgrain consumed have not been affected by the intervention yet the nutritional status has improved - was an artefact born of ill-measured variables and, if not, what could possibly explain it.

In a second step, we used boards that allowed individual participants to illustrate their stock management and consumption strategies (see photo in Figure 19).[34] Specifically they were given twelve cards representing the monthly rations available for their household: eight of them were quantities drawn from their own stock and the four remaining cards corresponded to purchases. They were asked to allocate these cards month by month so as to allow us to visualize the timing of their purchases. Participants were then asked to justify their choice. A striking outcome of this exercise was the emergence of two neatly differentiated time patterns: one in which purchases occurred rather early, that is, before the lean season, and the other in which they occurred later (Figure 17, Appendix 4). Local availability of foodgrain during the lean season came out as the most important concern guiding their choice. Subsequently, in the light of their purchase pattern, participants were asked to indicate month by month the daily quantities of foodgrain prepared by their household. Their choice was restricted to three possibilities: a big, a medium and a small bowl. The main lesson here is that

[34] A total of 15 individuals participated in this activity.

households who purchased earlier also tended to consume greater quantities during the months of purchase. Figure 18 in Appendix 4 illustrates two canonical patterns. In the left panel, the household purchases early and consumes relatively large quantities of food before the lean season. In the right panel, by contrast, purchases are delayed and consumption improves later in the year when agricultural work is at its highest. This exercise highlighted the existence of a pressure-to-consume problem that has been confirmed in in-depth individual interviews conducted afterwards. Interviewees, indeed, recurrently mentioned and documented how the temptation to quickly consume foodgrain within easy reach drive their consumption time pattern. Such temptation appears to be especially strong among mothers who cannot bear the sight of their hungry children: "we are the ones who have to calm down the children when they cry of hunger during the night", said one of the interviewed women. Revealingly, household heads admitted that it is hard for them to resist the pressure of their wife (wives), particularly when bags of purchased foodgrain are available inside the dwelling.

Recent technical reports from various inventory credit (warrantage) programs implemented in Burkina Faso point to the same interpretation. Inventory credit programs provide credit against the deposit of cereals in community granaries. The purpose of warrantage is to relax the farmers' liquidity constraint while allowing them to avoid the costly "sell low, buy high" behavior - producers sell foodgrain at low price just after the harvest and buy it back at high price during the lean season. A striking lesson from these reports, however, is that pressure-to-consume and redistributive pressure are major issues confronting households in managing their cereal stocks. Thus Ghione et al. (2013) note that during the 2012-13 campaign 17 percent of bags stored belong to producers who did not request a loan yet paid for the storage. To explain this counter-intuitive behavior the authors mention two effects. The ability to store food outside of the compound enables the household not only to reduce the quantity of food consumed by the family itself but also to reduce the food distributed to other members of the community as a result of social pressure. In the words of a program beneficiary, since home storage attracts repeated demands from family members, "storing at home entails losses, and the family is the most damaging pest". The report by Oxfam International (2015) goes into the same direction: having less foodgrain readily accessible inside the compound has the advantage of mitigating social pressure, itself justified in terms of solidarity obligations. Moreover, the households are protected against the temptation to sell grain as soon as need arises. Hence households reach the lean period with greater quantities of foodgrain than in the absence of the warrantage program. For Coulter (2014), finally, households view warrantage as a form of forced savings and as a way to withdraw part of their harvest from the sight of their close kin or to avoid the temptation to sell cereals to finance weddings, baptisms, funerals, etc ... A new insight that emerges from the above statements is that social pressure and pressure to consume are intimately related. The pressure arises not only from the drive to consume today what is better left for tomorrow but also from the drive to satisfy social needs, including helping relatives or villagers.

Let us now sum up our story. As a result of the program, households feel more secure in their access to foodgrain: they believe that foodgrain will be readily available throughout the year, at reasonable prices, and within rather short distances. This perception aptly reflects reality in treatment villages. To describe their feeling of security, people use a colourful expression: the program has brought them "the peace of the heart" (la paix du coeur). Feeling less anxious about future availability of foodgrain, they are more willing to purchase cereals as the need arises. In other words, they refrain from anticipated purchases and thus avoid the costs of storage, direct or indirect. In particular, they may reduce body fat accumulation which is a second-best strategy in a context of food shortage.

7 Conclusion

This paper makes three important contributions. First, it confirms that, especially in remote areas where local markets are thin, food market activation has the effect of smoothing interseasonal nutritional status. The effect is strongest among children, and young children in particular, for whom deficient nutrition has devastating long-term consequences. Second, and surprisingly, this beneficial effect is obtained despite the fact that total food consumption has not increased as a result of the external intervention. With the help of a simple two-period model, we show that an increase in consumption needs not take place when the price of foodgrain declines during the lean season and the household optimally adjusts its consumption behavior to the change in price.

The question then arises as to how nutritional status can improve in the absence of an increase in consumption. The answer to this question constitutes our third key finding: a change in the timing of food purchases translates into a change in the timing of consumption that drives the nutritional improvement. The underlying mechanism is the better ability of the household to mitigate food storage imperfections understood in a broad sense. Being assured of a more reliable supply of foodgrain in the lean season, households choose to first consume their own stock before starting to purchase foodgrain. In other words, they postpone their purchases, which allows them to economize on the costs of storage. More than the waste of the foodgrain stored, these costs mainly consist of an ineffective distribution of consumption over time due to excessive consumption of foodgrain purchased before the lean season (before the stocks are depleted). The problem is one of pressure-to-consume that is aggravated by the fact that, unlike the harvest grain stored on ears in the household granary, food purchased is kept in the house in an immediately accessible and eatable form. This explanation is perfectly compatible with the mechanism behind our two-period model: in the presence of a self-control problem, the possibility that total consumption does not increase when the lean-period price decreases is enhanced. It is also enhanced in the presence of price risk. Interestingly, the problem of self-control in food (or alcohol) consumption and the disciplining role of controlled purchases have received increasing attention in advanced countries. In this case the ill to be addressed is obesity (or addiction) instead of under-nutrition (Wertenbroch, 1998; Christensen and Nafziger, 2016; Bernheim et al., 2016). Some authors have also analyzed whether obesity can be attributed to imperfect access to fresh food in areas labelled as "food-deserts" (Lee, 2012; Leung et al. 2011).

The problem of storage imperfections as understood above has not received adequate attention in the literature dealing with nutritional stress and savings behavior. This paper has offered a first and necessarily incomplete approach towards explaining the behavior of households subject to nutritional stress in conditions of highly imperfect foodgrain markets. The important role of losses stemming from a sub-optimal timing of food consumption is an unexpected finding of our empirical study. This explains why our investigation tools were not designed to address this issue systematically, in particular to formally test for the presence of a self-control problem. We leave this task for future research.

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Figure 6: Nutrition in each period as a function of P_2 in the absence of present-bias ($P_1 = 1$)

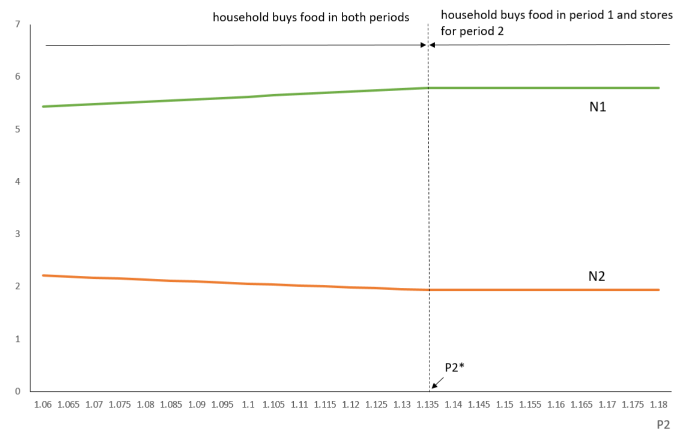

Figure 7: Total quantity consumed over the two periods as a function of P_2 with and without present bias ($P_1 = 1$)

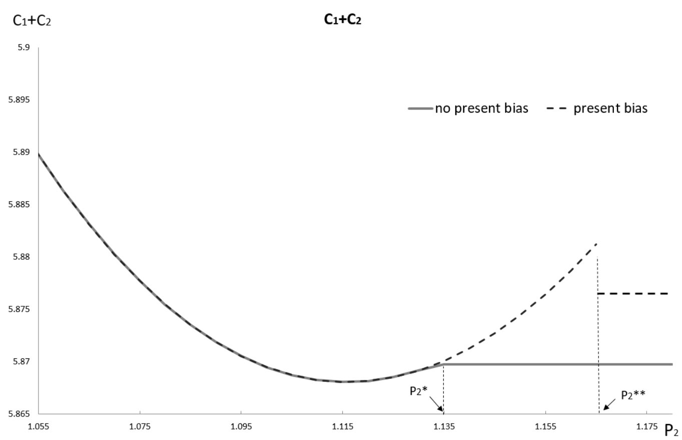

Figure 8: Expected utility as a function of P_2 with and without present bias ($P_1 = 1$)

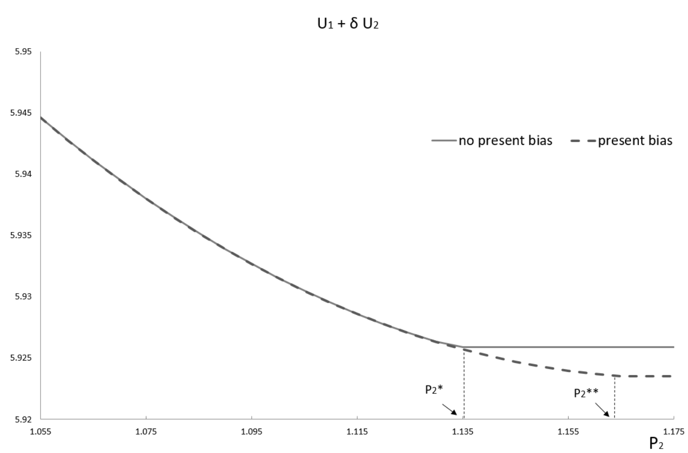

Figure 9: Seasonal variations in adults BMI (2016 subsample)

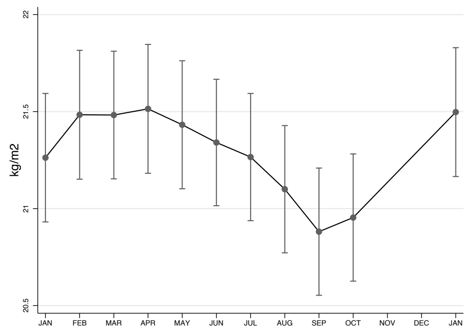

Figure 10: Seasonal variations in daily per capita foodgrain ration (2016 subsample)

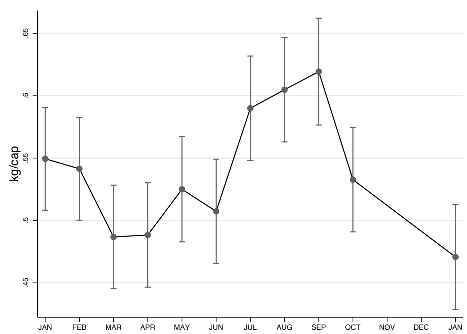

Figure 11: Seasonal variations in BMI-for-age for children age 5 to18 (2016 subsample)

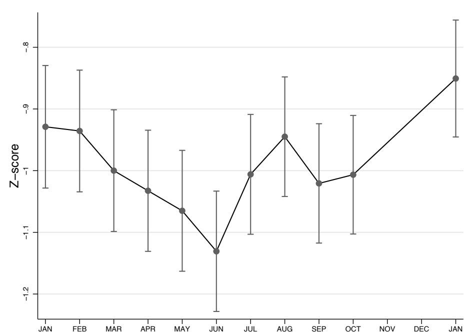

Figure 12: Seasonal variations in BMI-for-age for children below 5, by remoteness (2016 subsample)

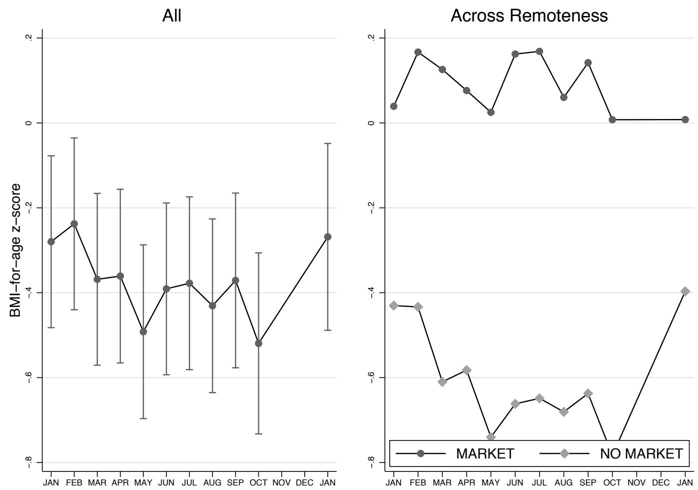

Table 3: Impact of FSGs on foodgrain access

	AVAILABILITY		AFFORDABILITY	PURCHASE		
	=1 IF GRAIN BAG BOUGHT LOCALLY	ANNUAL DIST. TRAVELLED PER CAPITA IN MINUTES	PRICE PAID BAG OF SORGHUM IN 1000 CFA-F	=1 IF HH MAKES ANY GRAIN PURCHASE	ANNUAL QUANTITY BOUGHT IN 100KG/CAP (7)	ANNUAL EXPENDITURES PER CAPITA IN 1000 CFA-F
	(1)	(2)	(3)	(4)	(5)	(6)
DIFF. AT BASELINE (5)	-0.130	1.038	0.403	-0.015	-0.004	-0.092
	[0.177]	[2.103]	[0.502]	[0.056]	[0.025]	[0.342]
AFTER (=1 IF POST-TREAT)	0.027	37.971***	5.767***	0.521***	0.443***	7.366***
	[0.114]	[6.081]	[0.607]	[0.054]	[0.064]	[1.322]
AFTER ∗ TREAT (DID)	0.253*	-10.276*	-1.384**	0.030	-0.034	-0.703
	[0.143]	[5.920]	[0.593]	[0.056]	[0.057]	[1.136]
CONTROL GROUP MEAN (6)	0.367	44.127	19.769	0.817	0.532	8.591
LEVEL OF ANALYSIS	BG	HH	BG	HH	HH	HH
OBSERVATION	2516	791	1628	791	791	791

(1) The dependent variables are at bag of grain (BG) or household (HH) level.
(2) All regressions include village fixed effects and control variables corresponding to village-level time-varying exogeneous factors : WRSI end-of-season indicator (based on rainfall characteristics) and a set of dummy variables on self-reported agricultural shocks (drought, flood, pest attack). All controls were determined prior to treatment.
(3) Standard-Errors in brackets are village-level Cluster-Robust-Standard-Errors (CRSE).
(4) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
(5) Baseline difference in outcomes are computed through separate OLS regressions.
(6) Control group mean corresponds to the mean of the dependent variable for control villages after treatment.
(7) Annual foodgrain quantity bought includes retail transactions in addition to bulk purchases.

Table 1: Descriptive statistics and balance tests on baseline characteristics

	Treatment (T)			Control (C)			(T) - (C)	
	N	MEAN	SD	N	MEAN	SD	DIFF	SE
Village-level characteristics								
Village population (# individuals)	20	2735.20	3018.77	20	3793.55 (4)	6619.97	-1058.35	1626.91
Distance to the nearest community health center (km)	20	2.35	3.75	20	3.25	3.60	-0.90	1.16
Distance to the nearest town (km)	20	17.00	7.58	20	15.35	9.68	1.65	2.75
=1 if no road passing through the village	20	0.40	0.50	20	0.40	0.50	-0.00	0.16
Distance to the nearest road (km)	20	3.15	4.76	20	4.25	6.53	-1.10	1.81
=1 if no market place in the village	20	0.50	0.51	20	0.50	0.51	0.00	0.16
Distance to the nearest market place (km)	20	3.50	4.14	20	3.35	4.70	0.15	1.40
=1 if no permanent cereal trader in the village	20	0.70	0.47	20	0.65	0.49	0.05	0.15
Transport cost city-village (in CFA-F/sack of grain)	20	642.50	408.23	20	655.00	377.28	-12.50	124.30
End-of-season harvest indicators (2011 WRSI for sorghum (5))	20	84.35	9.21	20	87.15	11.12	-2.80	3.23
=1 if 2011 rain started late (in july)	20	0.55	0.51	20	0.50	0.51	0.05	0.16
=1 if 2011 precipitations were less abundant than usual	20	0.95	0.22	20	1.00	0.00	-0.05	0.05
Household-level characteristics								
Household (HH) size (# HH members)	200	11.98	5.36	200	11.94	5.92	0.05	0.74
Number of HH members below 14	200	6.18	3.17	200	6.18	3.92	0.00	0.50
=1 if polygamous HH	200	0.62	0.49	200	0.56	0.50	0.06	0.07
=1 if male household-head (HH-H)	200	0.98	0.12	200	0.98	0.12	0.00	0.01
Age of HH-H	200	54.73	13.84	200	54.51	14.34	0.21	1.91
=1 if HH-H native from village	200	0.95	0.22	200	0.92	0.28	0.03	0.03
=1 if HH-H Mossi (main ethnic group)	200	0.90	0.30	200	0.74	0.44	0.15	0.10
=1 if HH-H muslim (main religious group)	200	0.81	0.40	200	0.79	0.41	0.02	0.08
=1 if HH-H close relative of a village leader	200	0.47	0.50	200	0.43	0.50	0.04	0.05
=1 if HH-H went to formal school	200	0.36	0.48	200	0.38	0.49	-0.01	0.06
=1 if HH-H part of a village organisation	200	0.20	0.40	200	0.20	0.40	0.01	0.05
=1 if house made of concrete wall	200	0.05	0.22	200	0.04	0.20	0.01	0.02
=1 if HH owns a motorcycle	200	0.38	0.49	200	0.45	0.50	-0.07	0.05
=1 if any small business	200	0.54	0.50	200	0.63	0.48	-0.09	0.06
=1 if HH owns some livestock	200	0.97	0.16	200	0.95	0.22	0.03	0.02
Cattle size (# of head)	200	20.27	21.14	200	18.63	18.98	1.64	2.32
Surface of land cultivated (Ha/cap)	199	0.28	0.16	192	0.29	0.16	-0.00	0.02
=1 if self-sufficient in cereals over the last 3 years	199	0.39	0.49	198	0.38	0.49	0.00	0.07
2011 cereal production (kg/cap)	196	107.51	118.51	194	107.49	96.11	0.02	15.64
PPI consumption index (6)	200	20.43	6.12	200	21.54	7.25	-1.10	0.94
Annual total expenditures (in 1000 CFA-F/cap)	200	73.84	38.11	200	81.51	39.37	-7.67	4.69
Share of food expenditures	200	0.73	0.14	200	0.72	0.16	0.01	0.02
Share of health expenditures	200	0.02	0.03	200	0.02	0.07	-0.00	0.01

(1) With exceptions (1 household was not involved in any grain production), missing values are due either to the absence of the respondant or to unavailable information.
(2) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
(3) Standard errors (SE) corresponds to village-level Cluster-Robust-Standard-Errors (CRSE).
(4) Higher population size in controls is explained by the presence of a small city in this subsample. Otherwise, village sizes are about the same in the two groups - on average 2500 inhabitants.
(5) WRSI is a water balance model that is used by Food and Agricultural Organization (FAO) and FEWS NET scientists to provide crop yield assessments (for more details, see Verdin, 2002).
(6) The Progress out of Poverty Index for Burkina Faso is a poverty measurement tool based on eight low-cost indicators to estimate the likelihood that a household has consumption below a given poverty line (for more details, see Schreiner, 2011).

Table 2: Nutritional outcomes and foodgrain consumption across agricultural cycles (in control villages)

	2010-2011		2011-2012		2012-2013	
	MEAN	SD	MEAN	SD	MEAN	SD
Panel A : Nutritional Outcomes (Individual level)						
BMI level (after lean season) of adults (19-59 years old)	20.79	2.52	20.57	2.56	20.68	2.56
BMI-for-age z-score of 5-18y children	-0.96	0.92	-1.02	0.91	-1.02	0.97
BMI-for-age z-score of 3-4y children	-0.21	0.87	-0.26	0.99	-0.37	1.03
BMI-for-age z-score of 0-2y children	-0.16	1.13	-0.53	1.08	-0.45	1.35
=1 if adults wasting (BMI <18.5)	0.16	0.37	0.18	0.39	0.18	0.39
=1 if 5-18y children wasting (BMI-f-age <-2)	0.13	0.34	0.15	0.36	0.17	0.37
=1 if 3-4y children wasting (BMI-f-age <-2)	0.02	0.14	0.04	0.21	0.07	0.25
=1 if 0-2y children wasting (BMI-f-age <-2)	0.04	0.20	0.12	0.33	0.14	0.34
Difference (after-before lean season) in BMI level of adults	0.04	1.41	-	-	-0.74	1.26
Difference in BMI-for-age of 5-18y children	-0.97	0.97	-	-	-0.78	0.88
Difference in BMI-for-age of 3-4y old children	-0.01	1.01	-	-	-0.20	0.90
Difference in BMI-for-age of 0-2y children	-0.14	1.15	-	-	-0.32	1.15
Panel B : Foodgrain Production and Market Participation (Household level)						
Foodgrain production (Kg/cap)	242.47	145.38	104.31	101.47	158.27	110.45
=1 if foodgrain self-sufficient	0.65	0.48	0.13	0.34	0.42	0.50
=1 if any foodgrain sale	0.02	0.14	0.04	0.20	0.07	0.25
Foodgrain sales (Kg/cap)	0.70	5.96	0.61	3.23	2.05	9.53
=1 if any foodgrain purchase	0.33	0.47	0.82	0.39	0.39	0.49
Foodgrain purchases (Kg/cap)	-	-	53.17	45.55	17.99	34.02
=1 if any foodgrain bulk (>100 kg) purchase	0.34	0.47	0.76	0.43	0.38	0.49
Foodgrain bulk (>100 kg) purchases (Kg/cap)	10.00	20.22	45.30	43.11	17.59	34.11
Panel C : Foodgrain Purchases (Transaction level)						
=1 if sorghum	0.72	0.45	0.64	0.48	0.47	0.50
Nominal price paid for sorghum	13.64	2.24	19.77	3.36	15.87	2.66
=1 if bought in the village	0.50	0.50	0.37	0.48	0.45	0.50
Nominal price paid for sorghum in the village	13.82	1.55	20.39	3.01	17.11	2.32
=1 if bought during lean season	0.79	0.41	0.38	0.49	0.45	0.50
Nominal price paid for sorghum during lean season	13.66	2.28	20.17	3.75	16.90	2.41
=1 if bought before own stock depletion	0.43	0.50	0.65	0.48	0.57	0.50
=1 if bought from a particular seller because of - Proximity	0.78	0.42	0.39	0.49	0.43	0.50
=1 if bought from a particular seller because of - Availability	0.20	0.40	0.36	0.48	0.47	0.50
=1 if bought from a particular seller because of - Price	0.02	0.14	0.18	0.39	0.09	0.29

ï¿œ

(1) Foodgrain retail purchases were not investigated in depth at baseline. This explains why bulk purchases correspond to total purchases in 2010-2011.
(2) Panel C includes all bulk purchases of foodgrain and the unit of observation is the 100-kg bag of foodgrain. There are 439 bags of foodgrain bought in 2010-2011, 2076 in 2011-2012 and 670 in 2012-2013.

Table 4: Impact of FSGs on anticipated purchases

	NUMBER OF MONTHS BEFORE OWN STOCK DEPLETION (3)		=1 IF ANY CEREAL PURCHASE BEFORE OWN STOCK DEPLETION		QUANTITY PURCHASED BEFORE OWN STOCK DEPLETION (100 KG/CAP)	
	ALL	NO ROAD	ALL	NO ROAD	ALL	NO ROAD
	(1)	(2)	(3)	(4)	(5)	(6)
TREAT	-0.631	-1.189*	-0.077	-0.302***	-0.110**	-0.260***
	[0.422]	[0.665]	[0.054]	[0.053]	[0.050]	[0.082]
CONTROL GROUP MEAN (7)	10.325	10.506	0.650	0.696	0.308	0.340
LEVEL OF ANALYSIS	HH	HH	HH	HH	HH	HH
OBSERVATION	393	155	393	155	393	155

(1) Estimates correspond to simple difference across treatment status and not to differences-in-differences using baseline.
(2) In columns (1) and (2), the dependent variable corresponds to the number of month since harvest (october 2011).
(3) The own stock refers to the stock of foodgrain produced on farm.
(4) All regressions include control variables corresponding to village-level time-varying exogeneous factors : WRSI end-of-season indicator (based on rainfall characteristics) and a set of dummy variables on self-reported agricultural shocks (drought, flood, pest attack). All controls were determined prior to treatment.
(5) Standard-Errors in brackets are village-level Cluster-Robust-Standard-Errors (CRSE).
(6) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
(7) Control group mean corresponds to the mean of the dependent variable for control villages after treatment.

Table 5: Impact of FSGs on food consumption

	DISPOSABLE		RATION		DIVERSITY	
	LN OF REAL GRAIN DISPOSABLE IN KG/YEAR/CAP	=1 IF REAL GRAIN DISPOSABLE > STANDARD	SELF-REPORTED GRAIN DAILY RATION IN KG/DAY/CAP	=1 IF DAILY RATION CONSIDERED AS SUFFICIENT	HODDINOTT DIETARY DIVERSITY SCORE	IFPRI DIETARY DIVERSITY SCORE
	(1)	(2)	(3)	(4)	(5)	(6)
DIFF. AT BASELINE (8)	0.086	0.045	-0.003	-0.055*	-	-
	[0.080]	[0.065]	[0.007]	[0.029]		
AFTER (=1 IF POST-TREAT)	-0.468***	-0.406***	0.044***	-0.108**	-	-
	[0.101]	[0.076]	[0.008]	[0.051]		
AFTER ∗ TREAT (DID)	-0.129	-0.080	-0.011	0.086**	-11.934	-0.035
	[0.089]	[0.065]	[0.008]	[0.039]	[7.946]	[0.065]
CONTROL GROUP MEAN (9)	4.930	0.281	0.183	0.845	187.345	3.964
LEVEL OF ANALYSIS	HH	HH	HH	HH	HH	HH
OBSERVATION	780	780	786	786	393	393

(1) Real grain disposable corresponds to (production + purchases + gifts in - losses - sales - gifts out).
(2) The consumption standard in Burkina Faso corresponds to 190 kg/year/capita or, equivalently, 0.520 kg/day/cap.
(3) Hoddinott (2001) dietary diversity score takes into account all food items as such and the frequency of their consumption (3-level index) over the last month. IFPRI Dietary Diversity Score relies on 9 food categories for its construction and corresponds to the number of food categories consumed over the last day. Here, it has been computed as the number of food categories consumed over the last month.
(4) All regressions include village fixed effects (except regressions from columns 5 and 6) and control variables corresponding to village-level time-varying exogeneous factors : WRSI end-of-season indicator (based on rainfall characteristics) and a set of dummy variables on self-reported agricultural shocks (drought, flood, pest attack). All controls were determined prior to treatment.
(5) Estimations in column (5) and (6) are simple differences. Baseline data on food diet do not exist.
(6) Standard-Errors in brackets are village-level Cluster-Robust-Standard-Errors (CRSE).
(7) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
(8) Baseline difference in outcomes are computed through separate OLS regressions.
(9) Control group mean corresponds to the mean of the dependent variable for control villages after treatment.

Table 6: Impact of FSGs on nutrition

	LEVEL				PREVALENCE			
	BMI	BMI-F-AGE Z-SCORE			=1 IF BMI <18.5	=1 IF BMI-F-AGE Z <-2		
	19-59	5-18	3-4	0-2 [(1)]	19-59	5-18	3-4	0-2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DIFF. AT BASELINE [(5)]	-0.069	-0.095	0.037	-0.177	0.006	0.005	0.007	0.037**
	[0.228]	[0.077]	[0.137]	[0.136]	[0.031]	[0.022]	[0.016]	[0.018]
AFTER (=1 IF POST-TREAT)	-0.075	-0.072	0.050	-0.373**	0.009	0.024	0.005	0.060*
	[0.108]	[0.044]	[0.128]	[0.147]	[0.021]	[0.019]	[0.031]	[0.031]
AFTER $*$ TREAT (DID)	0.301**	0.197***	-0.017	0.366**	-0.022	-0.040*	-0.018	-0.088**
	[0.140]	[0.052]	[0.131]	[0.165]	[0.022]	[0.023]	[0.030]	[0.041]
CONTROL GROUP MEAN [(6)]	20.575	-1.012	-0.261	-0.513	0.183	0.148	0.044	0.115
LEVEL OF ANALYSIS	IND	IND	IND	IND	IND	IND	IND	IND
OBSERVATION	2329	3069	623	721	2329	3069	623	721

(1) The 0-2 year age category corresponds to children from 6 to 36 months.
(2) All regressions include village fixed effects and control variables corresponding to village-level time-varying exogeneous factors : WRSI end-of-season indicator (based on rainfall characteristics) and a set of dummy variables on self-reported agricultural shocks (drought, flood, pest attack). All controls were determined prior to treatment.
(3) Standard-Errors in brackets are village-level Cluster-Robust-Standard-Errors (CRSE).
(4) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
(5) Baseline difference in outcomes are computed through separate OLS regressions.
(6) Control group mean corresponds to the mean of the dependent variable for control villages after treatment.

Appendix 1

Lagrangian and first-order conditions: simple set-up

The maximization problem yields the following Lagrangian, where non-negativity constraints for m_1, m_2 are included, and $\lambda_{1,} \lambda_2,\ \lambda_{3,} \lambda_{4,} \nu_1,\ \nu_2$ are (non-negative) Lagrangian multipliers:

$$
\begin{aligned}
L = U(N_1, O_1) + \gamma U(N_2, O_2) - \lambda_1 (N_1 - f(N_0) - n(C_1)) - \lambda_2 (N_2 - f(N_1) - n(C_2)) \\
- \lambda_3 (rP_1 m_1 + rO_1 + P_2 m_2 + O_2 - rR) - \lambda_4 (\beta C_1 + C_2 - \beta m_1 - m_2) \\
- \lambda_5 (C_1 - m_1) + \nu_1 m_1 + + \nu_2 m_2
\end{aligned}
$$

The first-order conditions are:

$$
\begin{aligned}
\frac{dL}{dO_1} &= U_O(N_1, O_1) - \lambda_3 r = 0 \qquad (9) \\
\frac{dL}{dO_2} &= \gamma U_O(N_2, O_2) - \lambda_3 = 0 \qquad (10) \\
\frac{dL}{dN_1} &= U_N(N_1, O_1) - \lambda_1 + \lambda_2 f'(N_1) = 0 \qquad (11) \\
\frac{dL}{dN_2} &= \gamma U_N(N_2, O_2) - \lambda_2 = 0 \qquad (12) \\
\frac{dL}{dC_1} &= \lambda_1 n'(C_1) - \lambda_4 \beta - \lambda_5 = 0 \qquad (13) \\
\frac{dL}{dC_2} &= \lambda_2 n'(C_2) - \lambda_4 = 0 \qquad (14) \\
\frac{dL}{dm_1} &= -\lambda_3 r P_1 + \lambda_4 \beta + \lambda_5 + \nu_1 = 0 \qquad (15) \\
\frac{dL}{dm_2} &= -\lambda_3 P_2 + \lambda_4 + \nu_2 = 0 \qquad (16)
\end{aligned}
$$

Case 1 If $\frac{rP_1}{\beta} > P_2$, equations (15) and (16) imply $\frac{\lambda_5 + \nu_1}{\beta} > \nu_2$ (we obtain this expression by multiplying equation (16) by $\frac{1}{\beta}$ and substracting it from (15)). Given the non-negativity of the multipliers, it follows that $\lambda_5 + \nu_1 > 0$. Since we restrict attention to cases where consumption levels are strictly positive in both periods, we necessarily have $m_1 > 0$, thus $\nu_1 = 0$ and $\lambda_5 > 0$. Given that $\lambda_5 (C_1 - m_1) = 0$, it follows that $C_1 = m_1$ and that the household buys grain in the second period (to maintain $C_2 > 0$): $m_2 > 0$ (and $\nu_2 = 0$).

Equations (11) and (12) then imply:

$$\frac{U_N(N_1,O_1)}{\gamma U_N(N_2,O_2)} = \frac{\lambda_1 - \lambda_2 f'(N_1)}{\lambda_2}$$

The multipliers $\lambda_1$and λ_2 can be easily be written as functions of λ_4. Note that (15) and (16) imply $\lambda_5 = \lambda_4.\left(\frac{rP_1}{P_2} - \beta\right)$. Then (13) implies $\lambda_1 = \frac{1}{n'(C_1)}\lambda_4\frac{rP_1}{P_2}$. And (14) implies $\lambda_2 = \frac{\lambda_4}{n'(C_2)}$. Thus $\frac{\lambda_1}{\lambda_2} = \frac{n'(C_2)rP_1}{n'(C_1)P_2}$, and:

$$\frac{U_N(N_1,O_1)}{\gamma U_N(N_2,O_2)} = \frac{\frac{1}{n'(C_1)}rP_1 - \frac{f'(N_1)}{n'(C_2)}P_2}{\frac{P_2}{n'(C_2)}}$$

Case 2 If $\frac{rP_1}{\beta} < P_2$, equations (15) and (16) imply $\frac{\lambda_5+\nu_1}{\beta} < \nu_2$. Given the non-negativity of the multipliers, it follows that $\nu_2 > 0$ and thus (by complementary slackness) $m_2 = 0$. Since we restrict attention to cases where consumption levels are strictly positive in both periods, we necessarily have $m_1 > 0$ (and thus $\nu_1 = 0$). Furthermore, $C_2 > 0$ implies $C_1 < m_1$, and therefore $\lambda_5 = 0$.

Equations (13) and (14) imply $\lambda_2 = \frac{n'(C_1)}{\beta n'(C_2)}\lambda_1$. Plugging this expression in (11): $U_N(N_1,O_1) = \lambda_1\left(1 - \frac{n'(C_1)}{\beta n'(C_2)}f'(N_1)\right)$. Plugging the same expresion in (12), we get: $\gamma U_N(N_2,O_2) = \frac{n'(C_1)}{\beta n'(C_2)}\lambda_1$. And we can write the following expression:

$$\frac{U_N(N_1,O_1)}{\gamma U_N(N_2,O_2)} = \frac{\frac{1}{n'(C_1)} - \frac{1}{\beta n'(C_2)}f'(N_1)}{\frac{1}{\beta n'(C_2)}}$$

Simulation: simple set-up

We follow Dercon and Krishnan (2000a) and assume $U(N,O) = \frac{N^{-\rho+1}}{-\rho+1} + \frac{O^{-\rho+1}}{-\rho+1}$. Using the functional forms $n(c) = c$ and $f(n) = \varepsilon n$, the nutrition equations become: $N_1 = k_1 + C_1$ and $N_2 = k_2 + \varepsilon C_1 + C_2$, where $k_1 = \varepsilon N_0$ and $k_2 = \varepsilon k_1$

We consider first the case where $\frac{rP_1}{\beta} > P_2$ (with second period purchase). Equation (6) implies $N_1 = N_2\left(\gamma\frac{rP_1 - \varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}}$. We can also write (using (9) and (10)): $O_1 = (\gamma r)^{-\frac{1}{\rho}}O_2$. Equations (10) and (12) then imply:

$$\frac{U_O(N_2,O_2)}{U_N(N_2,O_2)} = \frac{\frac{\lambda_3}{\gamma}}{\frac{\lambda_2}{\gamma}} = \frac{\lambda_3}{\lambda_2}.$$

We can express both λ_3 and λ_2 as a function of λ_4, using (16) and (14) and we obtain the following expression: $\frac{U_O(N_2,O_2)}{U_N(N_2,O_2)} = \frac{n'(C_2)}{P_2} = \frac{1}{P_2}$ or $O_2 = N_2 P_2^{\frac{1}{\rho}}$. As foodgrain is purchased in both periods, we know $C_1 = m_1$ and $C_2 = m_2$. The budget constraint can thus be written as: $rP_1C_1 + rO_1 + P_2C_2 + O_2 = rR$. Using the nutrition equations above, and the various expressions just derived, we obtain an expression of N_2 as a function of the model's parameters only:

$$\begin{aligned}
rP_1(N_1 - k_1) + rO_1 + P_2(N_2 - \varepsilon N_1 - k_2 + \varepsilon k_1) + O_2 &= rR \\
N_1(rP_1 - \varepsilon P_2) + rO_1 + P_2 N_2 + O_2 &= rR + k_1(rP_1 - \varepsilon P_2) + k_2 P_2 \\
N_2\left(\left(\gamma\frac{rP_1 - \varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}}(rP_1 - \varepsilon P_2) + r(\gamma r)^{-\frac{1}{\rho}} P_2^{\frac{1}{\rho}} + P_2 + P_2^{\frac{1}{\rho}}\right) &= rR + k_1(rP_1 - \varepsilon P_2) + k_2 P_2
\end{aligned}$$

We can then express all other decision variables as a function of these same parameters.

In the second case where $\frac{rP_1}{\beta} < P_2$, equation (7) implies $N_1 = N_2\left(\gamma(\beta - \varepsilon)\right)^{-\frac{1}{\rho}}$. Now

$$\frac{U_O(N_2, O_2)}{U_N(N_2, O_2)} = \frac{\lambda_4 \frac{\beta}{rP_1}}{\frac{\lambda_4}{n'(C_2)}} = \frac{\beta}{rP_1}.$$

Thus $O_2 = \left(\frac{\beta}{rP_1}\right)^{-\frac{1}{\rho}} N_2$. The total quantity purchased is $m_1 = C_1 + \frac{1}{\beta}C_2$. The budget constraint now is:

$$\begin{aligned}
rP_1\left(N_1 - k_1 + \frac{1}{\beta}(N_2 - \varepsilon N_1 - k_2 + \varepsilon k_1)\right) + rO_1 + O_2 &= rR \\
N_1 rP_1\left(1 - \varepsilon\frac{1}{\beta}\right) + N_2\frac{rP_1}{\beta} + rO_1 + O_2 &= rR + k_1 rP_1(1 - \frac{\varepsilon}{\beta}) + k_2\frac{rP_1}{\beta} \\
N_2\left((\gamma(\beta - \varepsilon))^{-\frac{1}{\rho}} rP_1\left(1 - \varepsilon\frac{1}{\beta}\right) + \frac{rP_1}{\beta} + r(\gamma r)^{-\frac{1}{\rho}}\left(\frac{rP_1}{\beta}\right)^{\frac{1}{\rho}} + \left(\frac{rP_1}{\beta}\right)^{\frac{1}{\rho}}\right) &= rR + k_1 rP_1(1 - \frac{\varepsilon}{\beta}) + k_2\frac{rP_1}{\beta}
\end{aligned}$$

Figures 6 and 7 present the effect of a change of P_2 (holding other prices constant) on N_1, N_2 and $C_1 + C_2$. The parameters are set to the following values: $r = 1.02$, $\rho = 0.5$, $\gamma = 0.95$, $R = 11$, $k_1 = 0.12$, $k_2 = 0.10$, $\varepsilon = 0.29$, $\beta = 0.9$.

The case of present bias

We assume that the household is sophisticated and perfectly anticipates that, while in 1P preferences are described by $U(N_1, O_1) + \gamma U(N_2, O_2)$, present bias arises in 1C (his expected utility becomes $U(N_1, O_1) + \delta\gamma U(N_2, O_2)$). In period 1C, the household overweighs the present and is tempted to choose consumption levels deemed excessive from the point of view of period 1P. In order to effectively control excessive consumption, the household may restrict the purchases in 1P to what is strictly necessary to reach the optimal N_1 and O_1. Thus for any $P_2 < P_2^*$, the household behaves as an unbiased household and neither its utility nor it consumption levels are affected by the existence of present bias. At $P_2 = P_2^*$, however, while the unbiased household is indifferent between purchasing foodgrain in period 2 or storing in period 1 for consumption in period 2, the present-biased household continues to strictly prefer purchasing in period 2 to storing food. This is because the utility (evaluated in 1P) that a present-biased household derives from storing is strictly lower than the utility that an unbiased household would reach (over-consumption in 1C kicks in when the present-biased household stores food). It follows that if the unbiased household is indifferent between purchase and storage, the biased household strictly prefers purchase.

The present-biased household thus chooses to buy food in period 2 and to suffer from second-period price increases until $P_2 > P_2^{**} > P_2^*$. Once the present-biased household stores food, it allocates its nutrition across time periods so as to maximize $U(N_1, O_1) + \delta\gamma U(N_2, O_2)$, resulting in the following expression for the marginal rate of substitution between N_1 and N_2 (assuming separability of the utility function):

$$\frac{U_N(N_1, O_1)}{\delta\gamma U_N(N_2, O_2)} = \frac{\frac{1}{n'(C_1)} - \frac{1}{\beta n'(C_2)} f'(N_1)}{\frac{1}{\beta n'(C_2)}},$$

which, with linear n and f simplifies to:

$$\frac{U_N(N_1)}{U_N(N_2)} = \delta\gamma(\beta - f').$$

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Simulation: present bias

The parameter for present bias is $\delta = 0.99$, the other parameters are the same as above. When the household purchases food in period 2, we use the same expressions as in the case of the unbiased household to find the optimal levels of nutrition and the numeraire (since the household then effectively limits the consumption of 1C by choosing the quantity purchased in 1P). When the household does not buy food in period 2, it anticipates present bias at the time of consumption and we thus solve the model by backward induction. In a first step, given the level of m_1, we determine the choice of $N_1(m_1)$ and $N_2(m_1)$ of the (present biased) household in 1C. In a second step, we solve for the choice of m_1, O_1 and O_2 in 1P when the household anticipates that it will choose $N_1(m_1)$ and $N_2(m_1)$ in 1C.

Step 1: Choice of nutrition in period 1C, for a given m_1

Using the marginal rate of substitution between nutrition in both periods as given in Proposition 3, we obtain $N_1 = N_2 \left(\gamma\delta(\beta-\varepsilon)\right)^{-\frac{1}{\rho}}$. Futhermore, the following three equations link nutrition, consumption and the quantity purchased: $N_1 = k_1 + C_1$, $N_2 = k_2 + \varepsilon C_1 + C_2$ and $m_1 = C_1 + \frac{1}{\beta}C_2$. Combining these expressions, we obtain a second equation linking $N_1(m_1)$ and $N_2(m_1)$: $m_1 = N_1(1-\frac{\varepsilon}{\beta}) - k_1(1-\frac{\varepsilon}{\beta}) + \frac{1}{\beta}N_2 - \frac{1}{\beta}k_2$. We thus obtain the following expression for $N_2(m_1)$ and $N_1(m_1)$:

$$
\begin{aligned}
N_2 &= \frac{m_1 + k_1(1-\frac{\varepsilon}{\beta}) + \frac{1}{\beta}k_2}{\left(\gamma\delta(\beta-\varepsilon)\right)^{-\frac{1}{\rho}}(1-\frac{\varepsilon}{\beta}) + \frac{1}{\beta}} \\
N_1 &= \frac{m_1 + k_1(1-\frac{\varepsilon}{\beta}) + \frac{1}{\beta}k_2}{\left(\gamma\delta(\beta-\varepsilon)\right)^{-\frac{1}{\rho}}(1-\frac{\varepsilon}{\beta}) + \frac{1}{\beta}} \left(\gamma\delta(\beta-\varepsilon)\right)^{-\frac{1}{\rho}}.
\end{aligned}
$$

Step 2: Choice of m_1, O_1 and O_2 in period 1P

The problem of the sophisticated household is to maximize the utility $U(N_1, O_1) + \gamma U(N_2, O_2)$, given $N_1(m_1)$ and $N_2(m_1)$ (and the budget constraint). As above, we have $O_1 = (\gamma r)^{-\frac{1}{\rho}} O_2$ and the budget constraint becomes $rP_1m_1 + O_2\left(1 + r(\gamma r)^{-\frac{1}{\rho}}\right) = rR$, implying $O_2 = \frac{rR - rP_1m_1}{1+r(\gamma r)^{-\frac{1}{\rho}}}$. We can thus express all arguments of the utility functions as explicit functions of m_1. In the simulation, we simply search for the optimal m_1 that maximizes the objective function.

By comparing the expected utility with and without storage at all prices, we identify the relevant second-period price threshold above which the present-bias household stores, P_2^{**}.

Appendix 2

Table 7: Balance tests on baseline characteristics: No-road sample

	2010-2011		**2011-2012**		**2012-2013**	
	MEAN	SD	MEAN	SD	MEAN	SD
Panel A : Nutritional Outcomes (Individual level)						
BMI level of adults (19-59 years old)	20.50	2.60	20.13	2.64	20.42	2.64
BMI-for-age z-score of 5-19 years children	-1.00	1.05	-0.98	1.07	-1.08	1.09
BMI-for-age z-score of 0-60 months children	-0.30	1.27	-0.38	1.41	-0.56	1.38
=1 if adults BMI <18.5	0.22	0.41	0.24	0.43	0.22	0.42
=1 if 5-19 years children BMI-for-age <-2	0.17	0.37	0.16	0.37	0.20	0.40
=1 if 0-60 months children BMI-for-age <-2	0.07	0.26	0.09	0.29	0.13	0.33
Difference (after-before rainy season) in BMI level of adults	-0.05	1.36	-	-	-0.83	1.31
Difference in BMI-for-age of 5-19 year children	-0.99	1.06	-	-	-0.82	1.08
Difference in BMI-for-age of 0-60 month children	-0.23	1.43	-	-	-0.36	1.52
Panel B : Foodgrain Production and Market Participation (Household level)						
Cereal production (Kg/cap)	257.80	143.62	109.02	99.59	159.42	118.00
=1 if cereal self-sufficient	0.68	0.47	0.12	0.33	0.41	0.50
=1 if any cereal sale	0.03	0.16	0.06	0.24	0.08	0.27
Cereal sales (Kg/cap)	0.33	2.53	0.98	4.16	1.67	6.41
=1 if any cereal purchase	0.57	0.50	0.85	0.36	0.43	0.50
Cereal purchases (Kg/cap)	13.77	26.45	46.81	45.22	22.44	39.32
=1 if any cereal bulk (>100 kg) purchase	0.39	0.49	0.80	0.40	0.40	0.49
Cereal bulk (>100 kg) purchases (Kg/cap)	13.77	26.45	46.73	45.23	21.97	39.44
Panel C : Foodgrain Purchases (Transaction level)						
=1 if sorghum	0.60	0.49	0.62	0.49	0.42	0.49
Nominal price paid for sorghum	12.79	1.36	19.87	3.45	15.73	2.80
=1 if bought in the village	0.63	0.48	0.25	0.43	0.45	0.50
Nominal price paid for sorghum in the village	13.11	1.28	20.73	3.18	17.18	2.55
=1 if bought during rainy season	0.65	0.48	0.38	0.49	0.46	0.50
Nominal price paid for sorghum during rainy season	12.87	1.36	20.00	4.22	16.65	2.42
=1 if bought before stock depletion	0.57	0.50	0.70	0.46	0.52	0.50
=1 if bought to a particular seller because of - Proximity	0.94	0.24	0.33	0.47	0.45	0.50
=1 if bought to a particular seller because of - Availability	0.03	0.18	0.41	0.49	0.40	0.49
=1 if bought to a particular seller because of - Price	0.03	0.16	0.23	0.42	0.16	0.36

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(1) All figures concern the sub-sample of 200 households from contol villages.
(2) Foodgrain retail purchases were not investigated in depht at baseline. This explains why bulk purchases correspond to total purchases in 2010-2011.
(3) Panel C includes all bulk purchases of foodgrain and the unit of observation is the 100-kg bag of foodgrain. There are 439 bags of foodgrain bought in 2010-2011, 2076 in 2011-2012 and 670 in 2012-2013.

Table 8: Heterogeneous effects on foodgrain access

	AVAILABILITY		AFFORDABILITY	PURCHASE		
	=1 IF GRAIN BAG BOUGHT LOCALLY	ANNUAL DIST. TRAVELLED PER CAPITA IN MINUTES	PRICE PAID BAG OF SORGHUM IN 1000 CFA-F	=1 IF HH MAKES ANY GRAIN PURCHASE	ANNUAL QUANTITY BOUGHT IN 100KG/CAP (5)	ANNUAL EXPENDITURES PER CAPITA IN 1000 CFA-F
	(1)	(2)	(3)	(4)	(5)	(6)
NOROAD = 1 if no road through the village						
AFTER	0.082	34.365***	5.217***	0.540***	0.457***	7.556***
	[0.111]	[6.081]	[0.642]	[0.044]	[0.065]	[1.392]
AFTER * TREAT	0.005	-7.165	-0.586	0.034	-0.054	-0.528
	[0.174]	[5.354]	[0.625]	[0.062]	[0.064]	[1.313]
AFTER * NOROAD	-0.436***	14.195*	2.613***	-0.051	-0.035	0.334
	[0.169]	[7.838]	[0.840]	[0.111]	[0.087]	[1.827]
AFTER * TREAT * NOROAD	0.651**	-8.533	-2.445**	-0.019	0.037	-1.045
	[0.268]	[12.160]	[1.167]	[0.164]	[0.125]	[2.295]
LEVEL OF ANALYSIS	BG	HH	BG	HH	HH	HH
OBSERVATION	2516	791	1628	791	791	791

(1) The dependent variables are at bag of grain (BG) or household (HH) level.
(2) All regressions include village fixed effects and control variables corresponding to village-level time-varying exogeneous factors : WRSI end-of-season indicator (based on rainfall characteristics) and a set of dummy variables on self-reported agricultural shocks (drought, flood, pest attack). All controls were determined prior to treatment.
(3) Standard-Errors in brackets are village-level Cluster-Robust-Standard-Errors (CRSE).
(4) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
(5) Annual foodgrain quantity bought includes retail transactions in addition to bulk purchases.

Table 9: Quantity of foodgrain purchased across quarters

	QUANTITY OF FOODGRAIN PURCHASED			
	OLS		**NB** [2]	
	ALL	NO ROAD	ALL	NO ROAD
	(1)	(2)	(3)	(4)
Q2	0.086***	0.091***	0.723***	0.711**
	[0.018]	[0.029]	[0.179]	[0.335]
Q3	0.111***	0.133***	0.863***	0.923**
	[0.025]	[0.041]	[0.219]	[0.381]
Q4	0.049**	0.057**	0.471**	0.496
	[0.021]	[0.029]	[0.228]	[0.330]
TREAT	0.021	0.030	0.167	0.150
	[0.019]	[0.035]	[0.255]	[0.462]
Q2 ∗ TREAT	-0.040	-0.058	-0.310	-0.421
	[0.026]	[0.036]	[0.258]	[0.419]
Q3 ∗ TREAT	-0.002	-0.031	-0.069	-0.217
	[0.035]	[0.068]	[0.308]	[0.579]
Q4 ∗ TREAT	-0.032	-0.046	-0.300	-0.397
	[0.030]	[0.050]	[0.318]	[0.521]
CONTROL GROUP MEAN [6]	0.116	0.124	0.116	0.124
OBSERVATION	1580	624	1580	624

(1) Regressions correspond to simple difference estimations and not to differences-in-differences ones.
(2) NB corresponds to negative binomial estimation.
(3) All regressions include control variables corresponding to village-level time-varying exogeneous factors : WRSI end-of-season indicator (based on rainfall characteristics) and a set of dummy variables on self-reported agricultural shocks (drought, flood, pest attack). All controls were determined prior to treatment.
(4) Standard-Errors in brackets are village-level Cluster-Robust-Standard-Errors (CRSE).
(5) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
(6) Control group mean corresponds to the mean of the dependent variable for control villages after treatment.

Table 10: Heterogeneous effects on foodgrain consumption

	DISPOSABLE		**RATION**		**DIVERSITY**	
	LN OF REAL GRAIN DISPOSABLE IN KG/YEAR/CAP	=1 IF REAL GRAIN DISPOSABLE > STANDARD	SELF-REPORTED GRAIN DAILY RATION IN KG/DAY/CAP	=1 IF DAILY RATION CONSIDERED AS SUFFICIENT	HODDINOTT DIETARY DIVERSITY SCORE	IFPRI DIETARY DIVERSITY SCORE
	(1)	(2)	(3)	(4)	(5)	(6)
NOROAD = 1 if no road through the village						
AFTER	-0.410***	-0.383***	0.047***	-0.098*	-	-
	[0.102]	[0.082]	[0.006]	[0.057]		
AFTER ∗ TREAT	-0.226**	-0.155*	-0.016	0.045	-	-
	[0.111]	[0.082]	[0.009]	[0.041]		
AFTER ∗ NOROAD	-0.188*	-0.111	-0.009	-0.081*	-	-
	[0.107]	[0.097]	[0.018]	[0.046]		
TREAT ∗ NOROAD	0.000	0.000	0.000	0.000	-14.599	0.107
	[0.000]	[0.000]	[0.000]	[0.000]	[17.207]	[0.154]
AFTER ∗ TREAT ∗ NOROAD	0.233	0.193	0.011	0.125*	-	-
	[0.148]	[0.129]	[0.021]	[0.070]		
LEVEL OF ANALYSIS	HH	HH	HH	HH	HH	HH
OBSERVATION	780	780	786	786	393	393

(1) Real grain disposable corresponds to (production + purchases + gifts in - losses - sales - gifts out).
(2) The consumption standard in Burkina Faso corresponds to 190 kg/year/capita or, equivalently, 0.520 kg/day/cap.
(3) Hoddinott (2001) dietary diversity score takes into account all food items as such and the frequency of their consumption (3-level index) over the last month. IFPRI Dietary Diversity Score relies on 9 food categories for its construction and corresponds to the number of food categories consumed over the last day. Here, it has been computed as the number of food categories consumed over the last month.
(4) All regressions include village fixed effects (except regressions from columns 5 and 6) and control variables corresponding to village-level time-varying exogeneous factors : WRSI end-of-season indicator (based on rainfall characteristics) and a set of dummy variables on self-reported agricultural shocks (drought, flood, pest attack). All controls were determined prior to treatment.
(5) Estimations in column (5) and (6) are simple differences. Baseline data on food diet do not exist.
(6) Standard-Errors in brackets are village-level Cluster-Robust-Standard-Errors (CRSE).
(7) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 11: Heterogeneous effects on nutrition

	LEVEL				**PREVALENCE**			
	BMI	BMI-F-AGE Z-SCORE			=1 IF BMI <18.5	=1 IF BMI-F-AGE Z <−2		
	19-59	5-18	3-4	0-2 (1)	19-59	5-18	3-4	0-2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NOROAD = 1 if no road through the village								
AFTER	-0.102	-0.109**	-0.007	-0.403**	0.021	0.043*	0.029	0.088**
	[0.124]	[0.052]	[0.126]	[0.169]	[0.025]	[0.024]	[0.028]	[0.037]
AFTER*TREAT	-0.056	0.126**	-0.079	0.331	0.023	-0.035	-0.089**	-0.134**
	[0.175]	[0.062]	[0.165]	[0.217]	[0.027]	[0.035]	[0.036]	[0.059]
AFTER*NOROAD	-0.280	0.033	0.150	0.035	0.008	-0.037	-0.128***	-0.059
	[0.180]	[0.071]	[0.185]	[0.211]	[0.028]	[0.038]	[0.037]	[0.056]
AFTER*TREAT*NOROAD	0.991***	0.189*	0.095	0.117	-0.122***	-0.014	0.176***	0.079
	[0.253]	[0.104]	[0.246]	[0.327]	[0.044]	[0.053	[0.054]	[0.078]
LEVEL OF ANALYSIS	IND	IND	IND	IND	IND	IND	IND	IND
OBSERVATION	2329	3069	623	721	2329	3069	623	721

(1) The 0-2 year age category corresponds to children from 6 to 36 months.
(2) All regressions include village fixed effects and control variables corresponding to village-level time-varying exogeneous factors : WRSI end-of-season indicator (based on rainfall characteristics) and a set of dummy variables on self-reported agricultural shocks (drought, flood, pest attack). All controls were determined prior to treatment.
(3) Standard-Errors in brackets are village-level Cluster-Robust-Standard-Errors (CRSE).
(4) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 12: Heterogeneous effects on nutrition for households who did not use FSGs

	LEVEL				PREVALENCE			
	BMI	BMI-F-AGE Z-SCORE			=1 IF BMI <18.5	=1 IF BMI-F-AGE Z <-2		
	19-59	5-18	3-4	0-2 (1)	19-59	5-18	3-4	0-2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DIFF. AT BASELINE (5)	-0.173	-0.088	0.053	-0.184	0.025	0.008	0.015	0.035
	[0.245]	[0.079]	[0.153]	[0.134]	[0.033]	[0.022]	[0.019]	[0.023]
AFTER (=1 IF POST-TREAT)	-0.064	-0.088**	0.042	-0.359**	0.000	0.030	-0.001	0.060*
	[0.106]	[0.043]	[0.125]	[0.142]	[0.023]	[0.020]	[0.034]	[0.032]
AFTER $*$ TREAT (DID)	0.249*	0.193***	-0.093	0.498***	-0.025	-0.047*	-0.024	-0.084
	[0.143]	[0.053]	[0.140]	[0.180]	[0.025]	[0.026]	[0.033]	[0.053]
CONTROL GROUP MEAN (6)	20.575	-1.012	-0.261	-0.513	0.183	0.148	0.044	0.115
LEVEL OF ANALYSIS	IND	IND	IND	IND	IND	IND	IND	IND
OBSERVATION	2072	2696	556	642	2072	2696	556	642

(1) The 0-2 year age category corresponds to children from 6 to 36 months.
(2) All regressions include village fixed effects and control variables corresponding to village-level time-varying exogeneous factors : WRSI end-of-season indicator (based on rainfall characteristics) and a set of dummy variables on self-reported agricultural shocks (drought, flood, pest attack). All controls were determined prior to treatment.
(3) Standard-Errors in brackets are village-level Cluster-Robust-Standard-Errors (CRSE).
(4) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
(5) Baseline difference in outcomes are computed through separate OLS regressions.
(6) Control group mean corresponds to the mean of the dependent variable for control villages after treatment.

Table 13: Impacts of FSGs on production, income generating activities and visits to the household

	2012 CEREAL PRODUCTION KG/CAP	=1 IF ANY MEMBER INCOLVED IN IGA	TOTAL INCOME FROM IGA 1000 CFA/CAP	ANNUAL CEREAL TRANSFER KG/CAP	=1 IF ANY NON-MEMBER STAY IN IN 2011-2012	NUMBER OF NON-MEMBER STAYING IN MAN/DAY
	(1)	(2)	(3)	(4)	(5)	(6)
TREAT	10.460	-0.013	-22.406	-1.573*	-0.043	-0.926
	[14.323]	[0.036]	[35.176]	[0.848]	[0.061]	[0.789]
CONTROL GROUP MEAN (5)	158.266	0.943	213.887	1.961	0.648	3.510
LEVEL OF ANALYSIS	HH	HH	HH	HH	HH	HH
OBSERVATION	390	391	391	387	386	386

(1) Estimates correspond to simple difference across treatment status and not to differences-in-differences using baseline.
(2) All regressions include village fixed effects and control variables corresponding to village-level time-varying exogeneous factors : WRSI end-of-season indicator (based on rainfall characteristics) and a set of dummy variables on self-reported agricultural shocks (drought, flood, pest attack). All controls were determined prior to treatment.
(3) Standard-Errors in brackets are household-level Cluster-Robust-Standard-Errors (CRSE).
(4) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
(5) Control group mean corresponds to the mean of the dependent variable for control villages after treatment.

Table 14: Effects of anticipated purchases on adult nutrition, before and after the lean season (years 2010-2011 and 2012-2013 pooled together)

	ADULTS BMI LEVEL					
	HOUSEHOLD FE			INDIVIDUAL FE		
	BEFORE (B)	AFTER (A)	(A)−(B)	BEFORE (B)	AFTER (A)	(A)−(B)
	(1)	(2)	(3)	(4)	(5)	(6)
EFFECT OF =1 IF ANY PURCHASE BEFORE STOCK DEPLETION	0.424***	0.063	-0.482***	0.307**	-0.060	-0.426**
	[0.135]	[0.132]	[0.172]	[0.139]	[0.105]	[0.178]
EFFECT OF QUANTITIES BOUGHT BBEFORE STOCK DEPLETION	0.100***	0.022	-0.094***	0.101***	-0.005	-0.093**
	[0.029]	[0.023]	[0.036]	[0.034]	[0.020]	[0.038]
LEVEL OF ANALYSIS	IND	IND	IND	IND	IND	IND
OBSERVATION	2582	2515	2317	2582	2515	2317

(1) Standard-Errors in brackets are household-level Cluster-Robust-Standard-Errors (CRSE).
(2) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 15: Daily foodgrain ration and the timing of purchase using monthly data

	CEREAL DAILY RATION IN KG/CAP			
	P = 1 IF ANY CEREAL PURCHASE		P = CEREAL QUANTITIES PURCHASED IN KG/CAP	
	(1)	(2)	(3)	(4)
FEB	-0.052	-0.039	-0.018	-0.021
	[0.040]	[0.036]	[0.035]	[0.032]
MAR	-0.121***	-0.091***	-0.097**	-0.072**
	[0.045]	[0.034]	[0.043]	[0.032]
APR	-0.105**	-0.087**	-0.078**	-0.074**
	[0.045]	[0.040]	[0.037]	[0.036]
MAY	-0.083**	-0.075**	-0.041	-0.051
	[0.039]	[0.037]	[0.034]	[0.035]
JUN	-0.098**	-0.080**	-0.068**	-0.060*
	[0.038]	[0.036]	[0.033]	[0.034]
JUL	-0.000	0.016	0.039	0.036
	[0.032]	[0.030]	[0.029]	[0.028]
AUG	0.011	0.029	0.034	0.041
	[0.041]	[0.038]	[0.034]	[0.035]
SEP	0.028	0.045	0.042	0.052*
	[0.036]	[0.034]	[0.032]	[0.031]
OCT	-0.076*	-0.055	-0.042	-0.030
	[0.040]	[0.038]	[0.034]	[0.034]
P	-0.143***	-0.078*	-0.002	-0.001
	[0.053]	[0.042]	[0.001]	[0.001]
FEB ∗ P	0.121*	0.110*	-0.000	0.005
	[0.068]	[0.058]	[0.004]	[0.004]
MAR ∗ P	0.209	0.102	0.010	0.002
	[0.135]	[0.065]	[0.007]	[0.002]
APR ∗ P	0.125*	0.090*	0.004	0.004
	[0.068]	[0.053]	[0.003]	[0.003]
MAY ∗ P	0.197**	0.194**	0.004	0.011
	[0.097]	[0.097]	[0.007]	[0.008]
JUN ∗ P	0.165**	0.102	0.005	0.002
	[0.066]	[0.065]	[0.004]	[0.005]
JUL ∗ P	0.115**	0.057	-0.002	-0.002
	[0.055]	[0.047]	[0.003]	[0.002]
AUG ∗ P	0.126*	0.059	0.005*	0.002
	[0.068]	[0.062]	[0.003]	[0.003]
SEP ∗ P	0.123*	0.052	0.006	0.002
	[0.064]	[0.056]	[0.004]	[0.003]
OCT ∗ P	0.188**	0.112*	0.009	0.001
	[0.073]	[0.062]	[0.006]	[0.006]
CEREAL DISPOSABLE IN KG/CAP	0.001***	-	0.001***	-
	[0.000]		[0.000]	
FE HH	NO	YES	NO	YES
CRSE HH	YES	YES	YES	YES
LEVEL OF ANALYSIS	MONTH	MONTH	MONTH	MONTH
OBSERVATION	726	726	726	726

(1) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
(2) HH-level Cluster-Robust-Standard-Errors in brackets.

Appendix 3

Table 16: Impact of FSGs on foodgrain access (Table 3 in paper): without control variables

	AVAILABILITY		AFFORDABILITY	PURCHASE		
	=1 IF GRAIN BAG BOUGHT LOCALLY	ANNUAL DIST. TRAVELLED PER CAPITA IN MINUTES	PRICE PAID BAG OF SORGHUM IN 1000 CFA-F	=1 IF HH MAKES ANY GRAIN PURCHASE	ANNUAL QUANTITY BOUGHT IN 100KG/CAP (7)	ANNUAL EXPENDITURES PER CAPITA IN 1000 CFA-F
	(1)	(2)	(3)	(4)	(5)	(6)
DIFF. AT BASELINE	-0.130	1.038	0.403	-0.015	-0.004	-0.092
	[0.177]	[2.103]	[0.502]	[0.056]	[0.025]	[0.342]
AFTER (=1 IF POST-TREAT)	-0.164	36.583***	5.729***	0.490***	0.430***	7.126***
	[0.106]	[4.296]	[0.448]	[0.039]	[0.042]	[0.905]
AFTER * TREAT (DID)	0.236	-11.006*	-1.318**	0.026	-0.040	-0.828
	[0.144]	[5.829]	[0.640]	[0.057]	[0.060]	[1.143]
CONTROL GROUP MEAN	0.367	44.127	19.769	0.817	0.532	8.591
LEVEL OF ANALYSIS	BG	HH	BG	HH	HH	HH
OBSERVATION	2516	791	1628	791	791	791

Table 17: Impact of FSGs on anticipated purchases (Table 4 in paper): without control variables

	NUMBER OF MONTHS BEFORE OWN STOCK DEPLETION (3)		=1 IF ANY CEREAL PURCHASE BEFORE OWN STOCK DEPLETION		QUANTITY PURCHASED BEFORE OWN STOCK DEPLETION (100 KG/CAP)	
	ALL	NO ROAD	ALL	NO ROAD	ALL	NO ROAD
	(1)	(2)	(3)	(4)	(5)	(6)
TREAT	-0.626	-1.467	-0.058	-0.170**	-0.093*	-0.195**
	[0.454]	[0.925]	[0.059]	[0.081]	[0.051]	[0.082]
CONTROL GROUP MEAN	10.325	10.506	0.650	0.696	0.308	0.340
LEVEL OF ANALYSIS	HH	HH	HH	HH	HH	HH
OBSERVATION	393	155	393	155	393	155

Table 18: Impact of FSGs on food consumption (Table 5 in paper): without control variables

	DISPOSABLE		**RATION**		**DIVERSITY**	
	LN OF REAL GRAIN DISPOSABLE IN KG/YEAR/CAP	=1 IF REAL GRAIN DISPOSABLE > STANDARD	SELF-REPORTED GRAIN DAILY RATION IN KG/DAY/CAP	=1 IF DAILY RATION CONSIDERED AS SUFFICIENT	HODDINOTT DIETARY DIVERSITY SCORE	IFPRI DIETARY DIVERSITY SCORE
	(1)	(2)	(3)	(4)	(5)	(6)
DIFF. AT BASELINE	0.086	0.045	-0.003	-0.055*	-	-
	[0.080]	[0.065]	[0.007]	[0.029]		
AFTER (=1 IF POST-TREAT)	-0.447***	-0.349***	0.051***	-0.120***	-	-
	[0.068]	[0.054]	[0.007]	[0.030]		
AFTER ∗ TREAT (DID)	-0.127	-0.083	-0.012	0.087**	-15.248*	-0.005
	[0.087]	[0.066]	[0.009]	[0.039]	[8.878]	[0.071]
CONTROL GROUP MEAN	4.930	0.281	0.183	0.845	187.345	3.964
LEVEL OF ANALYSIS	HH	HH	HH	HH	HH	HH
OBSERVATION	780	780	786	786	393	393

Table 19: Impact of FSGs on nutrition (Table 6 in paper): without control variables

	LEVEL				**PREVALENCE**			
	BMI	BMI-F-AGE Z-SCORE			=1 IF BMI <18.5	=1 IF BMI-F-AGE Z <−2		
	19-59	5-18	3-4	0-2	19-59	5-18	3-4	0-2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DIFF. AT BASELINE	-0.069	-0.095	0.037	-0.177	0.006	0.005	0.007	0.037**
	[0.228]	[0.077]	[0.137]	[0.136]	[0.031]	[0.022]	[0.016]	[0.018]
AFTER (=1 IF POST-TREAT)	-0.195*	-0.079**	-0.050	-0.397***	0.019	0.027	0.024	0.088***
	[0.102]	[0.038]	[0.091]	[0.109]	[0.016]	[0.017]	[0.022]	[0.027]
AFTER ∗ TREAT (DID)	0.346**	0.204***	0.047	0.399**	-0.028	-0.039*	-0.020	-0.094**
	[0.153]	[0.053]	[0.130]	[0.167]	[0.024]	[0.024]	[0.028]	[0.038]
CONTROL GROUP MEAN	20.575	-1.012	-0.261	-0.513	0.183	0.148	0.044	0.115
LEVEL OF ANALYSIS	IND	IND	IND	IND	IND	IND	IND	IND
OBSERVATION	2329	3069	623	721	2329	3069	623	721

Table 20: Impact of FSGs on foodgrain access (Table 3 in paper): randomized inference standard errors (for simple difference estimations)

	AVAILABILITY		**AFFORDABILITY**	**PURCHASE**		
	=1 IF GRAIN BAG BOUGHT LOCALLY	ANNUAL DIST. TRAVELLED PER CAPITA IN MINUTES	PRICE PAID BAG OF SORGHUM IN 1000 CFA-F	=1 IF HH MAKES ANY GRAIN PURCHASE	ANNUAL QUANTITY BOUGHT IN 100KG/CAP	ANNUAL EXPENDITURES PER CAPITA IN 1000 CFA-F
	(1)	(2)	(3)	(4)	(5)	(6)
TREAT	0.082*	-10.020*	-0.561*	0.009	-0.046	-0.960
	[0.072]	[6.417]	[0.660]	[0.049]	[0.069]	[1.281]
RI P-VALUE	0.054	0.053	0.091	0.848	0.296	0.213
LEVEL OF ANALYSIS	HH	HH	HH	HH	HH	HH
OBSERVATION	393	393	393	393	393	393

(1) Standard-Errors in brackets are village-level Cluster-Robust-Standard-Errors (CRSE).
(2) P-values are obtained using randomization inference.
(3) Level of significance refers to the p-values obtained through RI and corresponds to: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 21: Impact of FSGs on anticipated purchases (Table 4 in paper): randomized inference standard errors (for simple difference estimations)

	NUMBER OF MONTHS BEFORE OWN STOCK DEPLETION		**=1 IF ANY CEREAL PURCHASE BEFORE OWN STOCK DEPLETION**		**QUANTITY PURCHASED BEFORE OWN STOCK DEPLETION (100 KG/CAP)**	
	ALL	NO ROAD	ALL	NO ROAD	ALL	NO ROAD
	(1)	(2)	(3)	(4)	(5)	(6)
TREAT	-0.626**	-1.467***	-0.058	-0.170**	-0.093***	-0.195***
	[0.454]	[0.925]	[0.059]	[0.081]	[0.051]	[0.082]
RI P-VALUE	0.035	0.002	0.254	0.033	0.005	0.000
LEVEL OF ANALYSIS	HH	HH	HH	HH	HH	HH
OBSERVATION	393	155	393	155	393	155

(1) Standard-Errors in brackets are village-level Cluster-Robust-Standard-Errors (CRSE).
(2) P-values are obtained using randomization inference.
(3) Level of significance refers to the p-values obtained through RI and corresponds to: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 22: Impact of FSGs on food consumption (Table 5 in paper): randomized inference standard errors (for simple difference estimations)

	DISPOSABLE		**RATION**		**DIVERSITY**	
	LN OF REAL GRAIN DISPOSABLE IN KG/YEAR/CAP	=1 IF REAL GRAIN DISPOSABLE > STANDARD	SELF-REPORTED GRAIN DAILY RATION IN KG/DAY/CAP	=1 IF DAILY RATION CONSIDERED AS SUFFICIENT	HODDINOTT DIETARY DIVERSITY SCORE	IFPRI DIETARY DIVERSITY SCORE
	(1)	(2)	(3)	(4)	(5)	(6)
TREAT	0.142	0.096	0.029	0.165	-15.248***	-0.005
	[0.177]	[0.027]	[0.045]	[0.042]	[8.878]	[0.071]
RI P-VALUE	0.429	0.352	0.164	0.359	0.001	0.881
LEVEL OF ANALYSIS	HH	HH	HH	HH	HH	HH
OBSERVATION	392	392	390	390	393	393

(1) Standard-Errors in brackets are village-level Cluster-Robust-Standard-Errors (CRSE).
(2) P-values are obtained using randomization inference.
(3) Level of significance refers to the p-values obtained through RI and corresponds to: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 23: Impact of FSGs on nutrition (Table 6 in paper): randomized inference standard errors (for simple difference estimations)

	LEVEL				**PREVALENCE**			
	BMI	BMI-F-AGE Z-SCORE			=1 IF BMI <18.5	=1 IF BMI-F-AGE Z <−2		
	19-59	5-18	3-4	0-2 (1)	19-59	5-18	3-4	0-2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TREAT	0.312**	0.080*	0.086	0.200*	-0.031	-0.031*	-0.012	-0.053*
	[0.250]	[0.091]	[0.110]	[0.138]	[0.032]	[0.027]	[0.025]	[0.030]
RI P-VALUE	0.035	0.087	0.445	0.088	0.158	0.073	0.602	0.074
LEVEL OF ANALYSIS	IND	IND	IND	IND	IND	IND	IND	IND
OBSERVATION	1168	1509	315	358	1168	1509	315	358

(1) Standard-Errors in brackets are village-level Cluster-Robust-Standard-Errors (CRSE).
(2) P-values are obtained using randomization inference.
(3) Level of significance refers to the p-values obtained through RI and corresponds to: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Appendix 4

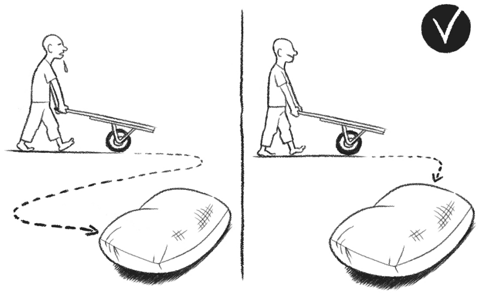

Figure 13: Visual aid example "Households bought foodgrain at lower prices in FSG villages"

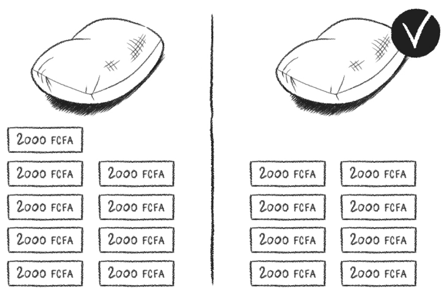

Figure 14: Visual aid example "Households did not consume more or better food in FSG villages"

Figure 15: Visual aid example "Households had a better nutritional status after the drought in FSG villages"

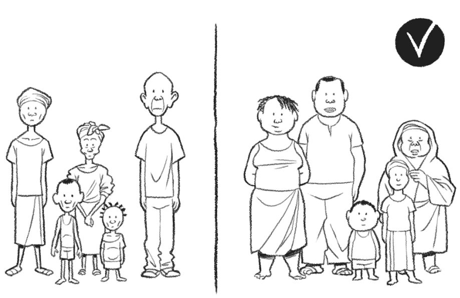

Figure 16: Visual aid example "The paradox"

Figure 17: Canonical patterns of timing of purchases

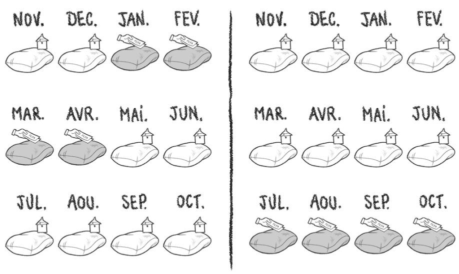

Figure 18: Canonical patterns of timing of purchases and consumption

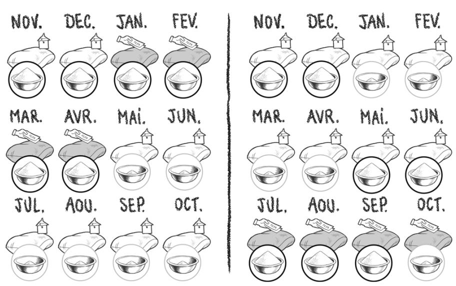

Figure 19: Example of board and cards