Buy As You Need: Nutrition and Food Storage Imperfections

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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.

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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). The problem is especially serious because experiences of malnutrition early in life have highly detrimental consequences for adults' health and well-being (Glewwe et al., 2001; Alderman et al., 2006; Hoddinott et al., 2008; Maluccio et al., 2009; Berg et al., 2016; Dinkelman, 2017). Two key features make marginal agricultural areas particularly prone to malnutrition: 1) due to poor soil conditions and erratic rainfall, weak land productivity and high vulnerability to weather shocks severely constrain people's livelihoods; 2) due to economic and physical isolation, market integration is low in the sense that local price variations and problems of foodgrain availability are not significantly dampened by broader market forces (see, for example, De Janvry et al., 1991; Fafchamps, 1992; Renkow et al., 2004; Barrett, 2008).

In this paper we are interested in policies aimed at takling the second problem, that is at deepening food market integration. One powerful justification for such a focus is the difficulty of raising land productivity in marginal areas. Irregular and insufficient supply of water seriously limit technical progress and crop choice. Here we take advantage of a program intended for facilitating a steady supply of foodgrain to poor and isolated areas of Burkina Faso with a view to exploring the impacts on people's livelihood of a steadier supply of food on local markets. Specifically, we take advantage of a randomized extension of this program and measure the causal impact of the intervention on children and adult nutrition (using anthropometric indicators) and the household's purchase and consumption of foodgrain.

The intervention's main objective is the smoothening of the distribution of foodgrain across the territory by directing foodgrain from surplus- to deficit-growing areas. It operates through a nationwide farmer organization and consists in setting up village-level cooperatives in charge of buying grain from outside sources and selling it locally. The idea is to spark a decrease in local prices, particularly during the lean season (over the rainy months during which land is prepared and sown for the next harvest) and hence to mitigate interseasonal price fluctuations. The program management expected the program to lead to increases in food purchases, food consumption and the nutritional levels of the villagers.

Although straightforward economic analysis confirms these expectations in a static framework, it is not obvious that they continue to hold when the possibility of inter-temporal household storage is allowed for. This is because the program reduces the need for household storage and the associated losses. When these losses are accounted for, improved nutrition does not necessarily require more grain purchases.

We formally develop this argument with the help of a simple two-period theoretical framework, where, as in Dercon and Krishnan (2000), an individual's utility depends on her nutritional level (a stock) instead of (only) her consumption level (a flow). Nutrition is then determined both by current consumption and by the carry-over of food consumed in the previous period. Both forms of storage imply costs. While, under the first form, the cost refers to conventional storage losses, the cost of the second type is associated with the metabolic processes that accumulation of body-mass entails (Dugdale and Payne, 1987; Branca et al., 1993; IFPRI, 2015).[1] We find that aggregate purchases over the year may decline when either type of storage exists, and aggregate food consumption may simultaneously decrease when food is stored in the body mass. In other words, economic theory invites scepticism about the way food purchases and possibly even food consumption evolve over the post-harvest and the lean season onces prices have been smoothened.

Empirically, we show that the program succeeded in decreasing foodgrain prices, especially in the lean season, and in significantly improving children and adult's nutrition. This is in spite of the fact that the program increased neither foodgrain purchases nor consumption in targetted villages. Moreover, physical storage losses are extremely small. Taken together and interpreted in the light of the theory, these results suggest that body-mass storing is used by people in anticipation of food scarcity in the lean season. While we have no data to track body-mass variations during the year of the intervention, we use non experimental evidence (pre and post-intervention) to prove the existence of seasonal body-mass storing and its correlation with purchasing behavior. We argue that the main effect of the program is to modify the timing of purchases and the timing of consumption by inducing households to postpose purchases and smooth nutrition. The mechanism is that better assurance about future food availability and affordability dispenses households with the need to store food before hard times (the lean season) come.

While seasonal variation in body-mass is advantageous when food losses in household granaries are important, in humid environments in particular (CITE), its presence in a dry climate where losses in household granaries are very limited appears surprising. On the basis of rich qualitative evidence, we suggest that households face self-control problems (and to a lesser extent redistributive pressures)

[1] For the long term consequences of seasonnal hunger, see Alderman et al. (2006) and Vaitla et al. (2009).

constraining the management of their foodstock. More precisely, storage of accessible food sparks the temptation of immediate consumption, leading to body-mass storing. A new mechanism, unintended by the conceivers of the program, thus emerges to improve nutrition: by postponing food purchases, households better resist the urge to consume food in the post-harvest period.

The outline of the paper is as follows. After presenting a short literature review in Section 2, we write down a simple two-period model in which nutrition is explictly featured (Section 3). Section 4 provides details about the nature of the intervention, the experiment and the data. In Section 5, we lay out our empirical strategy before estimating the impacts of the intervention on food access, purchases, consumption and nutrition. Section 6 is devoted to a thorough discussion of the results and proposes further evidence, of both quantitative and qualitative type, to support our interpretation of the mechanisms at work. Section 7 concludes.

2 Literature review

Our paper contributes to several strands of the literature. We start with the few studies that attempt to assess the effectiveness of community-based interventions aimed at stabilizing local food markets. While there is limited evidence of their impact (Basu and Wong, 2015; Barrett, 1996, Aggarwal et. al., 2018), 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 steadying the supply of food throughout the year, denting the traders' market power and/or reducing transaction costs and storage losses. If our study shows that physical storage losses are insignificant and there is little evidence of monopoly pricing, 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, partly because 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 in the presence of unpredictable shocks (see the pioneering works of Newbery, 1991: 284-8 and Platteau, 1991), and it often illustrates stock management strategies by reference to livestock (Fafchamps et al., 1998). In our study, the focus in on the management of foodgrain stocks in a context of anticipated seasonal shortages rather than unpredictable shocks (as in Park, 2006, Stephens and Barrett, 2011, Burke et al., 2017). In the empirical literature aimed at understanding household behavior, a salient issue is the impact of seasonality on current consumption. It is so far inconvlusive: 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). 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).

3 Model

We propose a simple framework to investigate the effect of the program on household's nutrition, consumption and purchase behavior. We perform a simple partial equilibrium analysis by focusing on the household's problem of allocating food consumption across two periods after the realization of the yearly income, when prices are exogeneously set. The absence of general equilibrium effects is discussed in Section 3 when we present the program. The effect of the intervention on food markets is represented by a decrease in food price during the lean season. Indeed supply from local sources is crucial in that season where stocks are more likely to have been depleted, and road accesses are complicate due to rain. While in this simple version of the model, there is no uncertainty, we discuss the effect of introducing price risk in Appendix 2. Finally, because survey respondents repeatedly mentioned the "pressure to consume readily available food" as an important constraint to food stock management, in Appendix 2 we also analyse the effect of time-inconsistent preferences arising from a "self-control problem".

3.1 Household food allocation decision in a two-period model

We consider a household whose utility depends on its nutritional status in period t, N_t, and the consumption of a numeraire, O_t and is additively separable in both arguments: $U(N_t) + V(O_t)$. To derive analytical expressions for our main variables of interest, we use the following functional form: $U(x) = V(x) = \frac{x^{-\rho+1}}{-\rho+1}$, with $\rho > 1$ (as in Dercon and Krishnan, 2000a).[2] 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:

$$U(N_1) + V(O_1) + \delta U(N_2) + \delta V(O_2)$$

where δ 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:

$$N_1 = \varepsilon N_0 + C_1 \quad (1)$$

$$N_2 = \varepsilon N_1 + C_2 \quad (2)$$

These equations indicate that if the nutritional status increases with current period consumption (C_1 or C_2), it is also dependent on the nutritional status in the previous period, where ε is a retention coefficient, with $0 \leq \varepsilon < 1$, that captures the depreciation of the nutrition stock between periods.

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.[3] In our study area, food deficit is the rule and there are only a few sellers of foodgrain. This implies that decreases in food

[2] By choosing a constant risk aversion utility function, we automatically assume a constant elasticity of intertemporal substitution (equal to $\frac{1}{\rho}$). To avoid an unreasonably high elasticity of intertemporal substitution we restrict attention to $\rho > 1$.

[3] Introducing foodgrain production would not bring additional insights if we would restrict attention to net grain buyers (the vast majority of households in our study area) and if we would assume separability between consumption and production decisions. Obviously if we would instead rely on a non-separable household model, predictions may change. We choose to abstract from the production side of the story because of the timing of our evaluation. Indeed we analyze short term impacts so that a potential response (or non-response) of local foodgrain production cannot materialize. Bear in mind that the GSAs were put in place after harvest only (and without any announcement during the preceding year).

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. 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 F. In period 2, food consumption is equal to m_2, the quantity bought on the market, plus the quantity stored in period 1, duly discounted to account for physical storage losses ($0 \leq \alpha \leq 1$).

Food availability constraints are:

$$\begin{aligned} C_1 &= m_1 - F \\ C_2 &= \alpha F + m_2 \end{aligned}$$

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

$$\alpha C_1 + C_2 = \alpha m_1 + m_2 \quad (3)$$

$$C_1 \leq m_1 \quad (4)$$

As for the budget constraint, we assume that the household has an exogenous income Y, which is obtained in period 1 only. Y can be saved (saving is denoted by S, with $0 \leq S \leq Y$) and will yield a return of rS in period 2.[4] 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, respectively:

$$\begin{aligned} P_1 m_1 + S + O_1 &\leq Y \\ P_2 m_2 + O_2 &\leq rS \end{aligned}$$

The two constraints are linked together through S and can be combined in a single expression (assuming that the first constraint binds):

$$rP_1 m_1 + rO_1 + P_2 m_2 + O_2 \leq rY \quad (5)$$

In solving the above problem of the household, we start from the degenerate case where the nu-

[4]Note that r may not correspond strictly to an interest rate, if redistributive pressures operate that have the effect of discounting the amount of savings. In this case, r can be smaller than 1.

tritional level of the current period does not depend on the nutritional level of the previous period ($\varepsilon = 0$). Ignoring the dynamics of nutrition helps highlight the effect of physical storage costs. In particular we show that, in the presence of physical storage costs, a change in grain price, P_2, has an ambiguous effect on the total quantity purchased. When we move to the general case, we find that the dynamics of nutrition leads to a similarly ambiguous effect not only on the total quantity purchased but also on the total quantity consumed.

Case 1: $\varepsilon = 0$

Suppose first that $\varepsilon = 0$: current nutrition is equal to current consumption in both periods. Depending on the relative prices of foodgrain in periods 1 and 2, the household decides to buy food in both periods (Case 1), or in the first period only (Case 2). In the latter case, the household stores foodgrain in a household granary in period 1 for consumption in the period 2.

Case 1a: low second-period price, $P_2 \leq \frac{rP_1}{\alpha}$**.** When $P_2 \leq \frac{rP_1}{\alpha}$, the unit price of food in period 2 does not exceed the value of one unit of food bought in period 1 and stored, taking into account the cost caused both by storage losses and the interest foregone as a result of lost savings. The household then chooses to buy food in period 2 rather than storing food (see Appendix 1). According to intuition, food purchase in period 2 is more likely if storage losses are more important (α is small) and/or if the interest rate r is high.

At equilibrium , the intertemporal marginal rate of substitution for nutritional levels is simply equal to the ratio of food prices (U_N is the marginal utility of nutrition):

$$\frac{U_N(N_1)}{\delta U_N(N_2)} = \frac{rP_1}{P_2}$$

Analytical expressions for equilibrium levels of nutrition, consumption and purchase can be derived from the first order conditions of the problem (see Appendix 1).

Case 1b: high second-period price, $P_2 > \frac{rP_1}{\alpha}$**.** When $P_2 > \frac{rP_1}{\alpha}$, it follows that $m_2 = 0$. In this case, it is less expensive to buy a unit of food in period 1 and store it than to buy it in period 2 for immediate consumption. The marginal rate of substitution between first- and second-period nutrition is equal to the retention coefficient at equilibrium:

$$\frac{U_N(N_1)}{\delta U_N(N_2)} = \alpha$$

The analytical expressions for all variables of interest are presented in Appendix 1.

Effects of a decrease in P_2 (with $\varepsilon = 0$). In this simple storage model, a decrease in P_2 increases second period purchases either continuously or discountinously: the condition $P_2 \leq \frac{rP_1}{\alpha}$ becomes more likely to be satisfied, and, provided this condition is satisfied, a decrease in P_2 increases the level of second-period purchase, consumption and nutrition. Total food consumption over the whole year, C_1+C_2, also unambiguously increases (results are derived in Appendix 1). The effect on total quantity purchased, m_1+m_2, is less clear, however. Indeed, when a decrease in P_2 induces the household to buy in period 2 rather than to store food (Case 1a becomes relevant), savings on storage costs may allows the household to simultaneously increase consumption and decrease food purchases: in Appendix 1 we thus prove that $\liminf_{P_2 \to \frac{rP_1}{\alpha}} (m_1 + m_2) > \limsup_{P_2 \to \frac{rP_1}{\alpha}} (m_1 + m_2))$. If there are no storage losses ($\alpha = 1$), as expected, a decrease in P_2 unambiguously increases the total quantity purchased, m_1+m_2.

Case 2: $\varepsilon > 0$

Let us now turn to the general case where $\varepsilon > 0$: current period nutrition depends on both current consumption and past nutrition. Again, depending on the level of second-period prices, the household decides whether or not to purchase foodgrain in the second period.

Case 2a: low second period prices, $P_2 \leq \frac{rP_1}{\alpha}$.

When $P_2 < \frac{rP_1}{\alpha}$, the household buys food in period 2: $m_2 \geq 0$. The intertemporal allocation of nutrition is now characterized by the following equation (details are provided in Appendix 1):

$$\frac{U_N(N_1, O_1)}{\delta U_N(N_2, O_2)} = \frac{rP_1}{P_2} - \varepsilon \tag{6}$$

This expression is similar to the one presented in Case 1a, except that it takes into account the carryover effect from nutrition in period 1 (the body mass storing effect). This effect decreases the cost of nutrition in period 1 relative to period 2. Note that the interior solution where $m_2 > 0$ and

$C_2 > 0$ requires that $\varepsilon < r\frac{P_1}{P_2}$: the carry-over effect must not be too large.[5]

Case 2b: high second period prices, $P_2 > \frac{rP_1}{\alpha}$.

When $P_2 > \frac{rP_1}{\alpha}$, it follows that $m_2 = 0$. The intertemporal allocation of nutrition then becomes at equilibrium (see Appendix 1):

$$\frac{U_N(N_1, O_1)}{\delta U_N(N_2, O_2)} = \alpha - \varepsilon \tag{7}$$

This expression has a similar interpretation as (6), except that the price ratio is replaced by α. Given that there is no purchase in period 2, the relevant cost of consuming in period 1 rather than waiting until period 2 is the retention coefficient diminished by the carry-over effect. If storage losses increase relative to the effectiveness of body mass storing, the marginal utility of nutrition 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.

Effects of a decrease in P_2 (with $\varepsilon > 0$). Let us now discuss the effect of a decrease in P_2. When P_2 decreases, the condition $P_2 \leq \frac{rP_1}{\alpha}$ becomes 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 rely on body mass or household storage. Furthermore, provided $m_2 > 0$, a decrease in P_2 will increase the nutrition level in period 2 while the nutrition level in period 1 may decrease. The total quantity consumed may also decrease : the household resorts less to body mass storing and more to immediate purchases in order to boost nutrition. Because there are "losses" in the process of body mass storing ($\varepsilon < 1$), the total quantity consumed and purchased may actually go down when P_2 decreases.

These results are summarized in the following Proposition.

PROPOSITION 1. *A marginal decrease in P_2 :*

1. *Increases nutrition in the lean period, N_2.*

2. *Increases food consumption in the lean period, C_2, and purchase in the same period, m_2.*

[5] In what follows we restrict attention to cases where consumption is positive in both periods, implying that the effectiveness of body mass storing as measured by ε is never high enough to enable a household to achieve a minimum nutritional level without consuming some food during the current season. Formally, we assume that either one of the following conditions must hold: $\varepsilon < r\frac{P_1}{P_2}$ or $\varepsilon < \beta$.

3. *Yields more ambiguous effects on the total quantity of food purchased,* $m_1 + m_2$ *, and the total quantity of food consumed over the year,* $C_1 + C_2$*. These effects depend on the storage technology:*

   (a) *In the absence of body mass storing (current nutrition depends on current consumption only), total food consumption unambiguously increases but total food purchase may decrease if there are storage losses in the household granary.*

   (b) *In the presence of body mass storing (current nutrition depends on current and past consumption), both total food purchase and total food consumption may decrease and these effects may happen even with zero physical storage loss.*

In short, while a decrease in P_2 generates expected intertemporal effects on nutrition, it does not automatically cause aggregate consumption and purchase to increase over the whole year. A decrease in aggregate purchase of food and/or in aggregate consumption may occur when there are storage losses in the household granary or in the human body. In the presence of physical storage losses, increased purchases in the second period relative to the first allow the household to reduce the quantity of food wasted in storage. The implication is that total consumption may increase although total purchases have decreased. This possibility is illustrated on Figure 6 (all parameter values are described in Appendix 1). Total food consumption is represented by the continuous line and it monotoneously increases when P_2 decreases (moving to the left on the x-axis). In contrast, total food purchases (dashed line) go down when the household starts buying food in period 2, moving from the right to the left of the threshold price $P_2^* = \frac{rP_1}{\alpha}$. The corresponding levels of nutrition, N_1 and N_2 are plotted on Figure 7.

When there is body mass storing, a similar mechanism can make even total consumption go down: a fall in P_2 drives N_2 to increase relative to N_1, so that the household's reliance on body mass storing gets reduced together with the associated losses. Here, the total quantity of food consumed - as well as total food purchases - may decrease despite an improvement in N_2. Figure 8 illustrates this possibility. To the left of $P_2^* = \frac{rP_1}{\alpha}$, a decrease in the lean period prices first causes total food consumption (and total food purchases) to fall and then to increase.[6] To sum up, because it allows the household to reduce losses caused by storage, whether it occurs through physical storage or body mass storing, intertemporal redistribution of food purchases and consumption following a decline in the second-period price may go hand in hand with a fall in aggregate food purchase, $m_1 + m_2$, and an

[6] The corresponding levels of nutrition, N_1 and N_2 are plotted on Figure 9. All parameter values used for the simulations are listed in Appendix 1.

improvement in lean period nutrition, N_2. When body mass storing is present, this increase in total nutrition may occur even though total consumption, $C_1 + C_2$, is declining.

4 Program and Experimental Design

somewhere: 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).

4.1 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, 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 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[7]; 2) mobilizing a network of pre-existing farmer organizations to facilitate the shift of grain from surplus to deficit village communities; 3) providing training and capacity-building for local management teams, as well as continuous multi-level technical assistance and close monitoring 4) granting (gradually scaled up) annual credit to village organizations so that they can purchase externally provided foodgrain for sale to local villagers against cash.

An important feature of the FSGs is that they are organized as local antennas belonging to a

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

national federation (called FNGN - Federation Nationale des Groupes Naam) in charge of managing the program. Thanks to this network, the FSGs can fulfill their first function effectively. More precisely, economies of scale can be reaped through the pooling of food purchases and the collective organisation of transportation from surplus areas. In addition, information regarding local food availability and prices is easily circulated through the organization. Because in our whole study area, most households are net buyers of food, this ability of the FSGs to easily secure foodgrain supplies coming from other parts of the country is critical for the livelihood of the local villagers. Bear in mind that the sample villages all belong to the 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. Subsistence agriculture dominates and for the large majority of households, 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 supply of training and monitoring as well as working capital strengthens the ability of the FSGs to operate as food sellers on the local markets. It is noteworthy that FSGs are required to sell against cash exclusively. This implies that the working capital they receive from the Federation is only used to finance their purchase of foodgrain and tide over the storing period. A commercial interest is charged on the corresponding loans. During a public meeting organized by the Federation annually, village representatives present and motivate their demand for funds, which implies that they give evidence of their capacity to effectively manage their granary. Once the credit is approved, the Federation controls that the money is used according to the intended purpose. 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. As a result of these organizational aspects, village granaries may possess a comparative advantage over the private sector, thereby enabling them to operate even where and when private merchants are absent.

A last remark is in order. To disentangle the impacts of the different components of the program, one would have needed to implement various treatment arms. This was not feasible not only because the program management opposed such an approach, but also, and more fundamentally, because these components are complementary.

4.2 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.[8] As it turns out, the amount of credit granted tends to be larger in more isolated villages.[9]

5 Data and descriptive statistics

5.1 Data

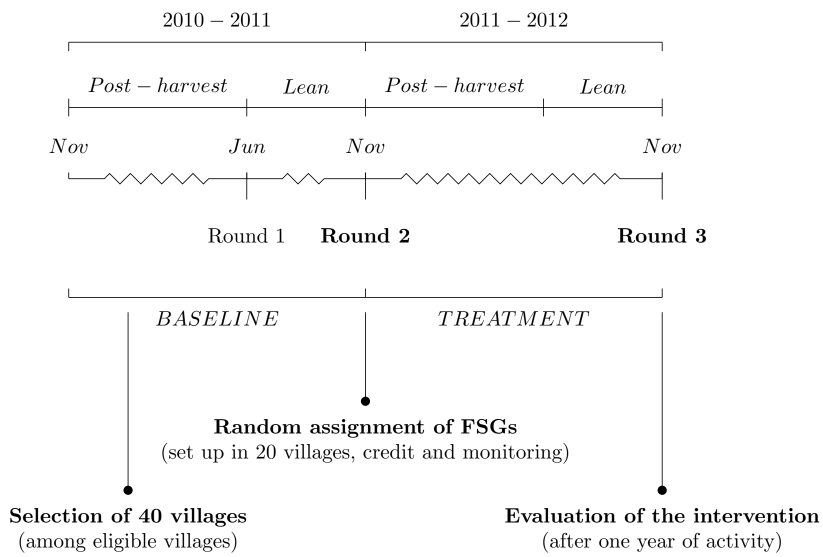
Our sample households were surveyed three times during the agricultural years 2010-2011 and 2011-2012. Figure 1 presents the timing of the intervention and the surveys. The first survey was undertaken before the 2011 lean season and the second survey after that season. Both surveys include baseline characteristics. 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.[10]

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

[9] 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.

[10] 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.

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.

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.

5.2 Descriptive statistics and balance tests

Table 1 provides descriptive statistics that help draw a picture of the context of the intervention.

Nutritional stress — Panel A of Table 1 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.[11] These constitute 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.[12]

We observe that the incidence of malnutrition varies according to age category: 15 percent of adults, 13 percent of children between 5 and 18 years, 2 percent of children between 3 and 4 years, and 3 percent of children aged 4 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. 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 10 and 12). Interestingly, the drop in adults' BMI coincides with a significant increase in the daily quantity of foodgrain prepared by households (Figure

[11] 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.

[12] 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.

11). 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 13). 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.[13] While purely descriptive, this analysis confirms Abey and Hirvonen (2016)'s conclusion regarding the critical role that market access plays to shield 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 1). 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.[14] 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 foodgrain was almost 50 percent higher in 2011-2012 than in the previous year (Panel B), 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.

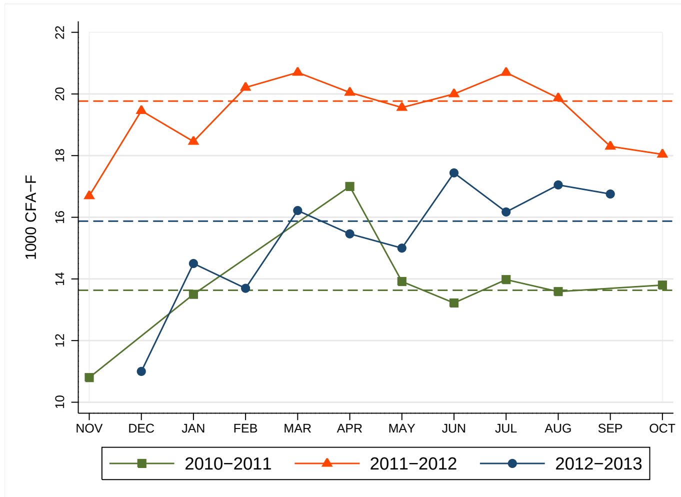
Buying further away and earlier — As evident from panel B of Table 1, most cereal transactions take the form of bulk purchases involving 100-kg bags. Sorghum is the most important traded foodgrain, far ahead of millet, maize and rice: in 2011-12, it amounted to 80 percent of all grain bought. While households emphasize their preference for buying close to their dwelling (more on this later), nearly than half of their purchases are made outside their village. In 2011-12, the situation was even worse since only 40 percent of the purchased cereals was bought in the village of residence.[15] 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

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

[14] 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.

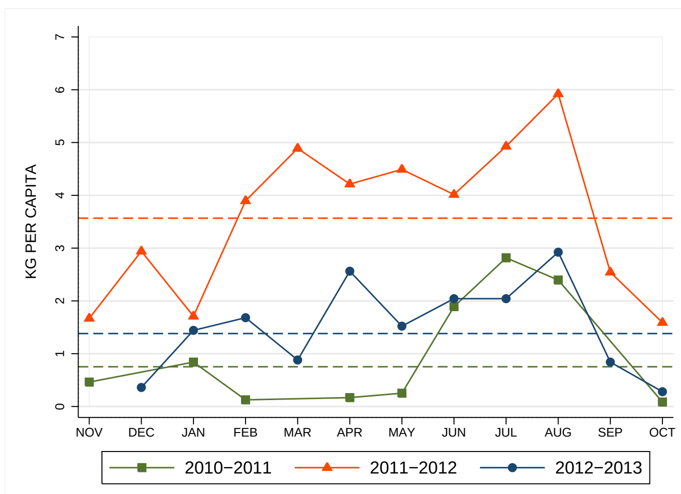
[15] Whereas existing traders are typically in small numbers, they have high cost structures and their activity is of limited duration and scope. Insufficient local food supply exposes populations to adverse market conditions that can eventually end up in food rationing.

Figure 2: Monthly Mean Price of Sorghum across Agricultural Year



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.[16] 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

[16]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.

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. Clearly the FSGs have not substituted for private suppliers in our sample villages. It must be stressed that such was not the intention of the program and, moreover, the year of our study was the initial year of its operation in the villages selected for an extension.

Balance tests — Tables 2 and 3 present balance test on baseline characteristics and outcomes, respectively. Tables 10 and 11 present the same for the sample of "no-road villages" for which we will show heterogenous effects. These tables reveal that there are no significant difference between treatment and control villages on a large set of village and household characteristics and that for most outcomes there are no pre-existing difference either across treatment and control villages. In case of of no-road villages, there are statistically significant differences in two food access variables AND? ADD SOMETHING. As anthropometric indicators were collected twice before the intervention, we also verify that changes across time in nutritional status are not systematically different across control and treatment villages (testing the "parallel trend assumption"). We present the results of this test after introducing our methodology in the next section.

6 Methodology and results

In this section, we first investigate the impact of the intervention on food acces: we verify that the program reached its objective of making foodgrain more available at a reasonable price locally. We then explore the effects on the nutritional status of both children and adults. Finally we turn to the impacts on purchase and consumption, so as to understand the pathways to the program's impacts on nutrition. 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 to noticeable prices increase 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 (CHANGE Table 10).

Our preferred estimation method uses difference-in-difference (DID) which controls 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, an important consideration given the limited number of treatment units (Glennerster and Takavarasha, 2013). Specifically, the model we estimate for individual outcomes is:

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

where y_{ijt} denotes the outcome of individual i from village j at time $t \in \{0, 1\}$, 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. Village fixed effects are included in the vector τ_j. The main coefficient of interest is β_2, which captures the causal effect of the intervention. DID relies on the assumption that, in the absence of the program, the differences between treatment and control groups would be the same as at baseline (the "parallel trend assumption"). To verify that this assumption is reasonable, we test whether control and treatment groups were on the "same trend" before the program for the outcomes for which we have two observations prior to the intervention (notably nutrition). As shown in Table 4 (and in Table 12 for the no-road villages), this is the case.

Beside violation of the parallel trend assumption, spillover effects could affect the internal validity of our results. In particular, we can think of a general equilibrium effect going through the foodgrain market: if local markets in control villages are affected by the GSA operated in the treatment villages, foodgrain prices would be expected to decrease even in the former and not only in the latter. Note that if this were true, the impacts we calculate would be underestimated. In fact, however, the spillover effect from treatment to control villages is unlikely. Households from control villages do not purchase foodgrain in treatment villages (no household from the control group bought foodgrain from a GSA), which is not surprising since villages are not easily accessible in our study area. Moreover, the 20 treatment villages represent a small share of the overall regional market.

An alternative estimation method relies on an analysis of covariance (ANCOVA). McKenzie (2012) argues that when the autocorrelation in the outcomes of interest is low, it may be inefficient to fully correct for baseline imbalances in a DID framework. ANCOVA can then increase the power of the estimation. Specifically, we estimate the following least-squares regressions:

$$y_{ij1} = \gamma_1 y_{ij0} + \gamma_2 T_j + \epsilon_{ijt} \tag{9}$$

The idea is to control for the past outcome of each observation. An important drawback of running this estimation in our setting is that it induces a change in the observations that are effectively used for the estimation of the program's effect when a specific outcome for a given household is observed for only one time period. For example, if a given household did not buy foodgrain at baseline, it does not contribute to the estimation of the program's impact on the mean price paid. This is in contrast with the DID strategy where all observations participate to the identification of the treatment effect (say, on average price paid) that is estimated at the village level (the unit of randomization). Another reason why we prefer the DID estimation is that, for our main outcomes of interest, anthropometric measures of nutrition, autocorrelation is notably important, reducing the advantage of the technique (McKenzie, 2012).

Because the intervention is implemented at the village level and because our number of villages is limitted to 40, we systematically use wild-bootstrap standard errors at the village level (Bertrand et al., 2004 CITE ON SMALL CLUSTER).

6.1 Proximate impacts: food access

Table 5 reports the impact of the intervention on foodgrain availability and affordability. Columns (1) corresponds to DID estimators, column (2) to ANCOVA estimators and column (3) and (4) reproduce the same estimations while allowing for an heterogenous effect for "no road" villages. As expected, the number of observations is considerably smaller with ANCOVA than with DID. If all households had purchased foodgrain in both periods the number of observations reported for ANOVA would be mechanically half the number reported for DID. This is not the case as it is much smaller in ANCOVA for the reason given above: many more households purchased food in the second year than in the first. When using DID all observations contribute to estimating the change in average price paid by households as a result of the program. In this sub-section, because the number of observations in ANCOVA is critically low for some outcomes (notably for prices paid by seasons), we focus only on the impact of the DID estimations.

Foodgrain local availability — The top panel of Table 5 report the impact of the intervention on foodgrain local availability. The first panel shows that the intervention has succeeded in raising the level of activity of local food markets: the probability that any bag of foodgrain was purchased locally increased by 24.7 percentage points according to the DID estimator (column 1). As shown in Column (3), the impact is mainly driven by villages that are not accessible by road, and where availability of foodgrain for local purchase is critically important. JEREMIE COMPLETE FOOTNOTE[17]

The second outcome reported is the distance travelled to buy foodgrain, as per bag of 100 kg of foodgrain purchased. We measure the number of 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 31 minutes walk per bag which corresponds to XXX123 minutes for the average household (a 25 percent reduction of the annual distance travelled by control households). Again the effect is significantly larger in no-road villages, with a decrease of 52 minutes per bag.

The intervention of the FSGs has clearly succeeded in bringing food closer to rural buyers, which was one of its main goals. When asked to motivate their choice of a particular seller (at baseline), 72 percent CHECK of households cited proximity as the main reason (Table 1, panel A). The second most important reason, cited in 23 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 (3 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 of the available food.

Foodgrain affordability — We now turn to the impact of the program on foograin prices (bottom panel of Table 5). The dependent variable in these regression is the average price paid by households for a bag of foodgrain. Foodgrain include sorghum, millet and maize. The nutritional content and price pattern are very similar for the three grains and we control for the type of grain purchased by the household.[18] In treatment villages, the intervention is responsible for a significant reduction of the price of foodgrain (1,168 CFA-F), corresponding to a 7 percent (CHECK) cut. Again we expect that the price-reducing impact of the intervention is especialy large in remote villages, since remoteness has the effect of isolating a village from price-dampening market forces in times of supply stress. Evidence reported in Column (3) confirms this expectation: the price reduction observed in no-road villages is more than twice as large as in the other villages.

We further consider separately purchases made in the post-harvest and the lean season DEFINI-

[17]The heterogenous impact does not hold with the ANCOVA estimation. Our concern regarding the small sample size when using ANCOVA is reinforced in that case, given that the number of observations effectively used to compute the heterogenous effect is further reduced. In total there are X households who bought foodgrain in both periods in no road villages.

[18]Our results hold if we restrict attention to sorghum, which represents two-thirds of purchases.

TION IN A FOOTNOTE. As discussed above, we expect the program to decrease prices especially during the lean season, when villages are more isolated (because of the rain) and the availability of foograin is more uncertain. This expectation is confirmed: prices in the post-harvest season do not appear to be affected by the program, while in the lean season they are significantly lower (by 1,403 CFA-F).

In short, the program appears to have succeeded in encouraging local grain purchases, and in decreasing the price of foodgrain for the local population.

6.2 Impacts on children's and adult's nutrition

We now turn to the impacts of the program on nutrition. We use measures of nutritional status both at the household and at the individual level. If all household members face the same budget and food availability constraints, it can be argued that the relevant unit of analysis is the household. In our study area, however, some members (or nuclear groups of household members) have individual sources of income and prepare individual meals in addition to sharing the collective meals of the household.[19] Therefore we also estimate the impact of the program on individual nutrtion status. A strength of our analysis lies in the use of objective measures of nutrition, based on anthropometric indicators collected for all household members. Specifically, we estimate the impact of the program on BMI and BMI-for-age and on the prevalence of malnutrition as explained in Section 5.2. We distinguish between adults (19-59) and two age groups for children (0-4 and 5-18). Household-level measures use the average nutritional status for all household members in the relevant age category. Estimates of the impact on nutritional outcomes are reported in Table 6.

The number of observations reported for the ANCOVA estimations (Columns 3 and 4) is again lower than it would be if all individuals had been weighed and measured in both the baseline and endline surveys.[20] This is because a small number of individuals were absent from the village on the day of the survey (PUT NUMBER). In order to verify that the program does not lead to differential attrition between control and treatment villages, we estimate the impact of the intervention on the probability to be weighted and measured. Results are reported in Table 13 (Appendix 3). Reassuringly, we find that the program had no effect on the probability to be weighed and measured. Below we comment the results of the DID estimations at the individual level. Focusing instead on household-level analyses or ANCOVA estimations would not change our conclusions.

[19]This type of household organisation has been described in other contexts in sub-Saharan Africa (CITE CITE CITE).
[20]It would then be exactly half the number reported for DID estimations in Columns 1 and 2.

The intervention has had a large and positive impact on nutritional outcomes for both adults and children. The estimated effect for adults (Panel 1) is positive and significant and corresponds to 0.39 BMI point (Column 2) which, on average, corresponds to about one-kilo difference (CHECK) for an individual with mean BMI. This average impact does not translate into a significant effect on the prevalence of underweights among adults (measured as a BMI lower than 18.5). As for the impact on 5 to 18 years old children, it is large and significant. The size of the effect is 0.20 z-score of BMI-for-age (Column 2). Since the post-treatment mean z-score for this age group in control villages is -1, the effect of the program corresponds to a 20 percent reduction in the existing gap with the well-nourished reference population. For this age group, the program also reduces the prevalence of malnutrition (measured as a BMI-for-age z-score lower than 2) by 4.4 percentage points. Even more important is the impact on children aged 0 to 4. The impact is 0.23 z-score, which corresponds to a 70 percent reduction CHECK in the existing gap between them and the well-nourished reference population. The prevalence of malnutrition among 0 to 4 years-old significantly decreased, by 5.8 percentage points, as a result of the intervention. Because the experience of malnutrition in early childhood is detrimental to both cognitive and physical development, the results for this age group suggests that the program produced a long-term impact on the well-being of the target population group.

Heterogeneous effects on nutrition are presented in Table 14, Appendix 3. The effects of the intervention on nutritional outcomes for both adults and children appear larger the no-road villages, albeit not always significantly.

Taken together, these results reveal that, in line with the predictions of the simple model presented in Section 3, the intervention has improved the nutritional status of the target population group at the end of the lean season. To investigate the pathways to this success, and the nature of the constraints faced by the households in their foodgrain management, we now examine the impact of the program on purchases and consumption.

6.3 Impacts on purchases and consumption

Foodgrain purchase — Panel 1 and 2 of Table 5 provide estimates of the impact of FSGs on the probability that households 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.[21] 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.

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. The second corresponds to the number of months the household holds a stock of foodgrain in the granary located inside the household compound. The third relies on both a binary and a continuous variable that capture purchases made before the depletion of the granary. 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 production is stored on the 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. As a consequence, purchases made before depletion of the granary stock have the effect of extending its duration. It is striking that anticipatory purchases have been made by the majority of households: as many as 65 percent of them started to purchase foodgrain while their granary was not empty (in the control villages CHECK).

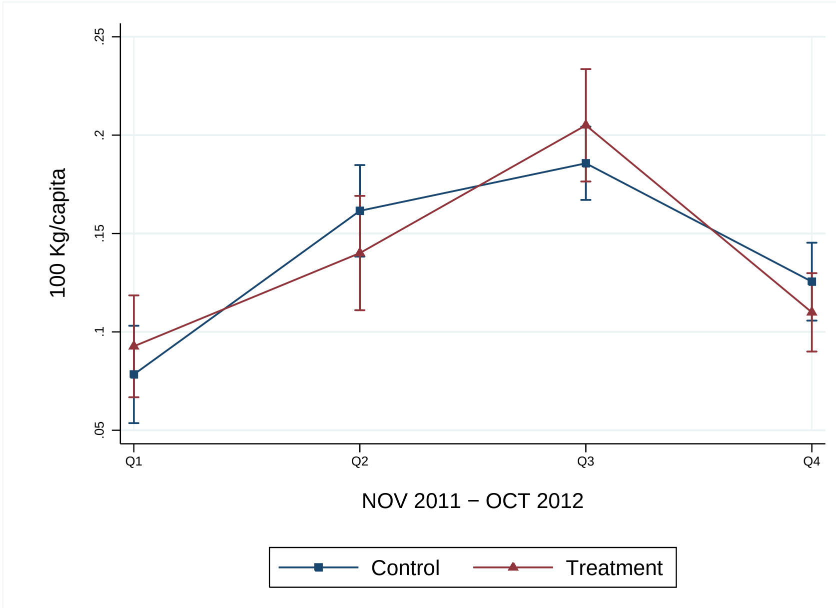
Figure 4 compares quarterly purchases in treatment and control villages. It is based on per capita quantities purchased as have been estimated with the help of a negative binomial regression.[22] It suggests that households in treatment villages bought less in the second but more in the third quarter than households in control villages. This looks as if the former decided to move purchases from the second to the third quarter. The difference between the two purchase time patterns is not statistically significant, though.

Turning to the second measure, we expect that households in treatment areas depleted their own stock faster than control households. This expectation is confirmed in Figure 5. The left panel reports, for all control and treatment households, the cumulative distribution of the duration of own stock, as assessed by th emonth during which the household's own stock was reported to have been depleted. 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

[21] Our reference for the annual requirement is the country's consumption reference level of 190 kilograms of foodgrain per capita per year.

[22] 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 4: FSGs impact on quarterly quantity bought

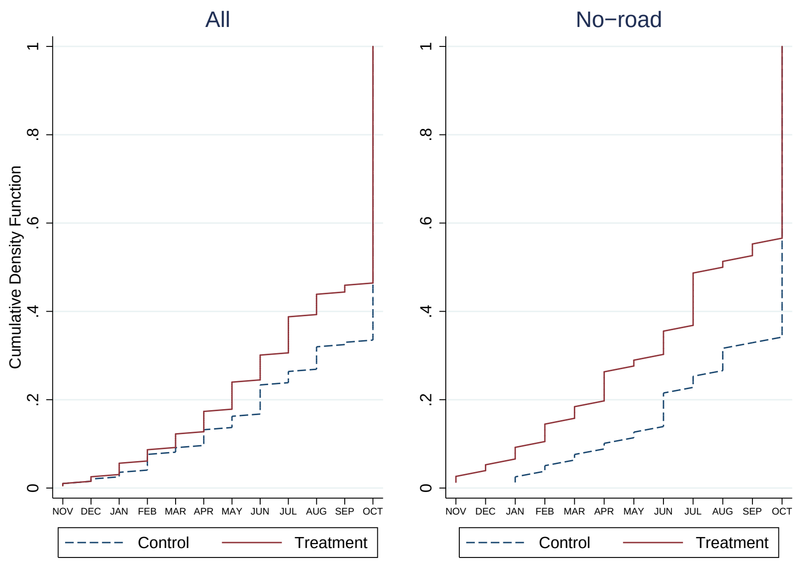


for the control group first-order stochastically dominates the distribution for the treatment group. Kolmogorov-Smirnov tests confirm that the differences across these distributions are statistically significant. The granary of households in the treatment villages was empty at an earlier date (month) than it was for households in the control villages, and this difference persisted throughout the entire year. We also estimate the impact of the program on the duration of own stock in a regression framework. Table 9 reports the results. They indicate that intervention shortens the duration of own stock but the effect is not statistically significant.

Finally, concomitantly to the shortening of the duration of stock, we expect that the intervention had the effect of reducing anticipated purchases understood as purchases made before the depletion of own stock. Table 9 broadly confirms this prediction. On the extensive margin, households in treatment villages were less likely to make anticipated purchases than households in control villages, but the effect is significant only for no-road villages. In the latter, beneficiaries were 20 percent less likely to make any purchase before stock depletion. On the intensive margin, we find that the intervention substantially reduced the quantities bought before own stock depletion: households in treatment villages decreased their anticipated purchases of foodgrain by 9 kg per capita, which represents a 36 percent decrease CHECK. It is noticeable that the impact is nearly twice as large in no-road villages as in the full sample.

Consumption — To measure consumption of foodgrain over the year, we use total disposable

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



foodgrain. This is obtained by adding purchases and gifts received to the quantity produced and then subtracting losses, sales and gifts made.[23] 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. The overall picture that comes out of Table 7 is that there is no clear evidence of an impact of the intervention on food consumption. The intervention does not significantly increase the disposable foodgrain or the probability that the latter exceeds the consumption reference level.

Foodgrain accounts for about 80% of calorie intake in our context, so that total disposable foodgrain provides a good approximation of the calorie intake of targeted households. This measure, however, does not capture the micronutrient adequacy of the diet. It may be argued that, if the program did not increase the quantity of foodgrain consumed, it may have improved the diversity of the diet. This would happen if the increase in purchasing power translated into a greater demand for animal products, vegetables or fruits. We have no complete information about the total consumption of other food items over the year of the intervention but we can construct a diet diversity scores (DDS) for the month preceding the survey. This score corresponds to the number of food groups to which items consumed over this period belong. We also compute a score capturing the diet composition of the

[23]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.

day preceding the survey but this index is less adequate in our context where food diets are very poor (Hoddinott, 1999).[24] Simple difference estimates reported in Table 8 suggest that the impact of the program on diet diversity is small, not significant and even negative.[25] 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 temporary 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.

7 Discussion

The results presented above reveal that the intervention succeeded in lowering foodgrain prices - especially in the lean season - and in increasing local provisioning. As a result, the nutritional status of both children and adults substantially improved. However, neither total foodgrain purchases nor foodgrain consumption increased. While this latter result may appear surprising at first sight, it is consistent with the predictions of the model presented in Section 3. In the presence of storage losses, total purchases may not increase even though foodprices decrease in the lean season (Proposition 1). Furthermore, when we allow for the possibility of body-mass storing, we find that an improved nutrition at the end of the lean season does not require an increase in total food consumption over the year. This is because households can modify the timing of purchase and consumption over the year, and therefore avoid the losses associated with body mass storing.

Unfortunately we do not have data that enables us to track the evolution of nutritional status during the year of the intervention. As a result we are unable to formally establish the program's dampening effect on seasonal nutritional fluctuations. Fortunately, however we have a wealth of experimental and non-experimental evidence confirming that households face constraints when they store foodgrain and engage in body-mass storing. In seeking to understand the nature of storage constraints, we discovered that physical storage losses are not a great concern of the local households. By contrast, losses arising

[24] Following Steyn et al. (2006), we distinguish between nine food groups: (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.

[25] We rely on simple differences because we do not have information about diet diversity in the baseline survey.

from self-control problems (and to a lesser extent, redistributive presures) may be far more challenging. We now carefully review this evidence.

Physical storage losses in household granaries

Physical 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). ADD EVIDENCE FROM THE MONTHLY SURVEY?

The timing of purchase, the timing of consumption and body-mass variations

As shown in Figures 12 and 13, households in the study area suffer from substantial seasonal variations in their body-mass. We have non-experimental evidence showing that the timing of purchase is correlated with body-mass fluctuations. While we visited household only once the year of the intervention, we made two visits in 2010-11 and 2012-13. This data reveals 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 16 in Appendix 3 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 smoothen the food consumption pattern over the year and, hence, to dampen body mass fluctuations. 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 they made a purchase (Table 17, Appendix 3). Postponing purchases until the need arises in the lean season may thus help stabilize nutrition.

To confirm this interpretation of the results, we returned to the field to conduct follow-up workshops in both treatment and control villages (June 2015). In a first step, we devised visual tools to summarize our quantitative findings in an easily understandable manner (see Figures 9 to Figure 18, 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 21).[26] 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 then asked to allocate these cards month by month so as to allow us to visualize the timing of their purchases. Afterwards, participants were invited 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 19, 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 households who purchased earlier also tended to consume greater quantities during the months of purchase. Figure 20 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.

Explaining the recourse to body-mass variation in the absence of physical storage losses

Body mass storing involves costs associated with storing and de-storing and also with the maintenance of a larger body mass (Dugdale and Payne, 1987, Branca et al., 1993, IFPRI, 2015).[27] If physical

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

[27] 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

storage losses are limited, why would households engage in body-mass storing? We investigated this question during our follow up workshops. Participants mentioned that large stocks are difficult to protect from the demands of visitors or of household members themselves. In the first instance, the source of storage costs lies in redistributive pressures originating from outside the household (Platteau, 2000; Baland et al., 2011; Dupas and Robinson, 2013; Platteau, 2014; Jakiela and Ozier, 2015). As is evident from our interviews with sample villagers, large household stocks signal abundance and attract solicitations. In particular, visitors are likely to stay longer.

In the second instance, costs are caused by an inability to withstand the pressure to consume quickly the foodgrain purchased, an inability akin to a present-bias (or self-control) problem (Ashraf et al., 2006; Bernheim et al., 2015).[28] The idea here 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 present-bias problem, in this case the urge to eat when food is plentiful. As a solution to this problem, households might use delayed purchases as a commitment device to avoid "overconsumption" in the post-harvest season. In an extension of our basic model (presented in Appendix 2), we show not only that the expected effects of the program on nutrition do not change when we allow for present-bias, and also that a decrease in the lean-period price is more likely to induce a decrease in total consumption and total purchase of foodgrain among present-biased than among time-consistent households.

What evidence do we have that the program may help households to resist redistributive pressure or overcome self-control problems? Starting with the former, we note that while treatment households received fewer visits of people staying and eating in the household, the effect is not quantitatively important (Table 15, Appendix 3). In our empirical analysis, we have actually accounted for these visits when computing the quantity of grain consumed by household members. As we know, we did not find a significant effect of the program on the quantity of food consumed per capita (see Table 7). Besides hosting hungry visitors, 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 and it indeed appears that there is a significant difference in such transfers between households in the treatment and

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.

[28] The context in which the self-control problem arises here is different from the context of the study by Duflo et. al. (2008). While in the latter, the farmers anticipate the purchase of fertilizers for fear of running out of cash when they will actually need it, our villagers are wary of purchasing food too quickly because of the difficulty of refraining from consuming it when it is readily available at home.

control villages. However, the quantities concerned are small (Table 15, Appendix 3), and they have again been taken into account when computing the total foodgrain disposable. We therefore conclude that even though there may exist a mitigating impact of FSGs on redistributive pressures, it is not significant enough to explain our results.[29]

Turning to self-control, during in-depth individual interviews conducted after our workshops, interviewees 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 children when they are hungry: “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 go against 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

[29] A possible worry is that we implicitly assume that visitors are opportunistic consumers who free ride on the abundant stock of fellow villagers. The reality may be more complex as the visitors may also be consumers under stress who want to benefit from informal insurance through their social network. To test for the latter, we have estimated the impact of the program on the probability to receive a food transfer when a negative shock has occurred. Although the sign of the interaction between treatment and the shock binary variable is negative, the coefficient is not significantly different from zero.

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, thus refraining from anticipated purchases and avoiding 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.

8 Alternative stories

The Giffen effect probably constitutes the most straightforward explanation for our central findings, namely improved nutrition despite constant (or declining) consumption. 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, in the sense that households are poor and obtain most of their calories from the consumption of staple grains (Jensen and Miller, 2008). On the other hand, improved nutrition is also 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 XX, 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 absorbtion of nutrients (Duh and Spears, 2016). 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 having recourse to medical treatment (conventional or traditional) only as a last resort solution. The data confirm that health expenditures are very small (2 percent of total cash expenditures). 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 rather than the quantity of foodgrain consumed. 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 though they do not increase the quantity purchased. Again, our evidence does not support this 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 zero impact of the program for households who did not purchase cereals in the FSGs. Table 18 in Appendix 3 indicates that this is not the case, however.

Finally, the impact of the program on nutrition is unlikely 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.

9 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 nu-

[30]Results available upon request.

[31]There is no effect of the program on production, on the propensity of treated individuals to engage in income generating activities or on the income generated by these activities (see Table 15, Appendix 3). There is no difference either in the variation of the herd owned by treatment and control households.

tritional 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 undernutrition (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: Total consumption and total purchases as a function of P_2 in the absence of body mass storing ($\varepsilon = 0$)

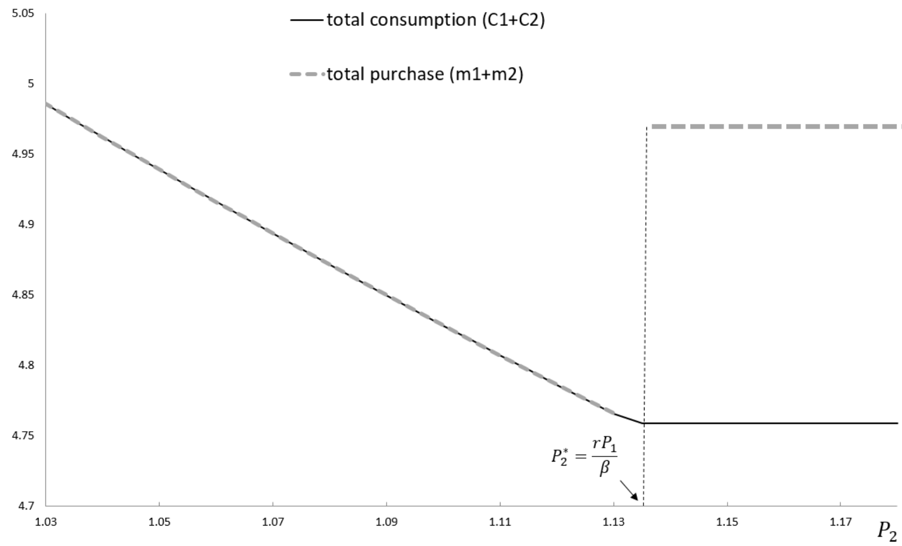


Figure 7: Nutrition in each period as a function of P_2 in the absence of body mass storing ($\varepsilon = 0$)

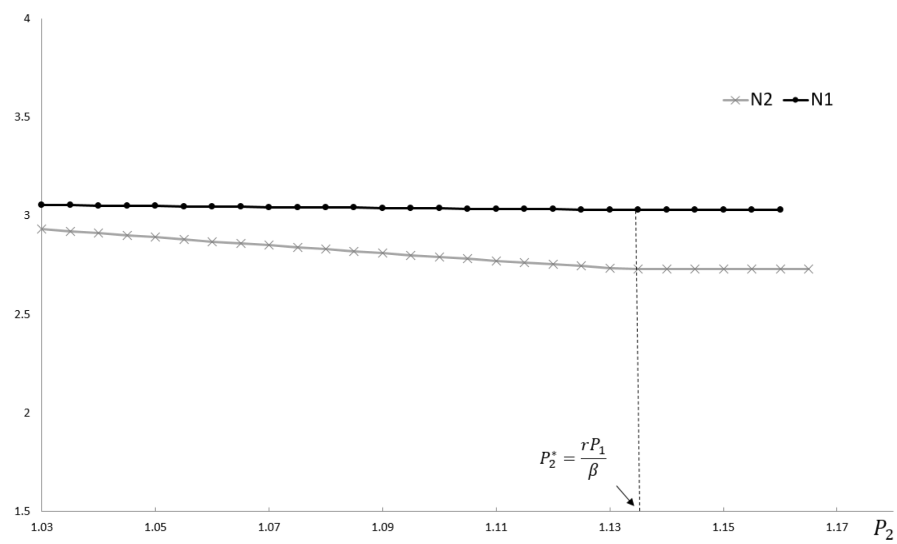


Figure 8: Total consumption and total purchases as a function of P_2 in the presence of body mass storing ($\varepsilon > 0$)

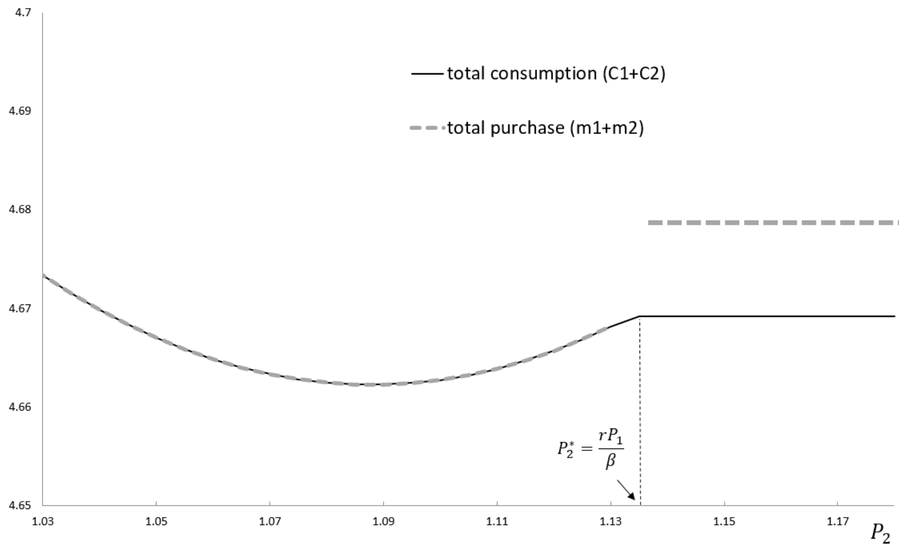


Figure 9: Nutrition in each period as a function of P_2 in the presence of body mass storing ($\varepsilon > 0$)

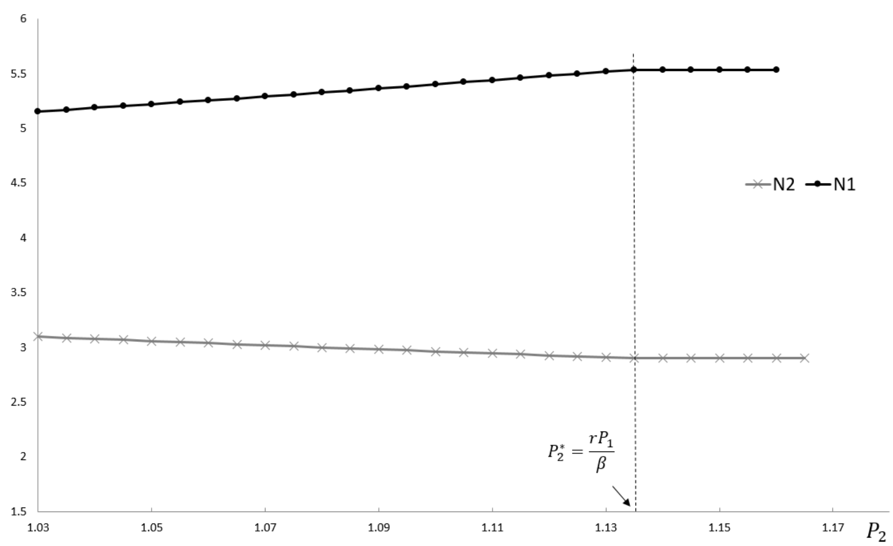


Figure 10: Seasonal variations in adults BMI (2016 subsample)

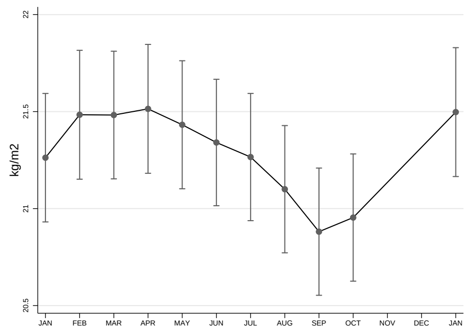


Figure 11: Seasonal variations in daily per capita foodgrain ration (2016 subsample)

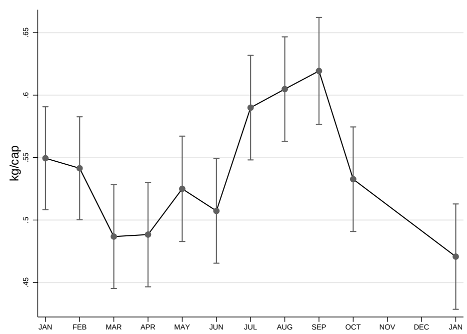


Figure 12: Seasonal variations in BMI-for-age for children age 5 to18 (2016 subsample)

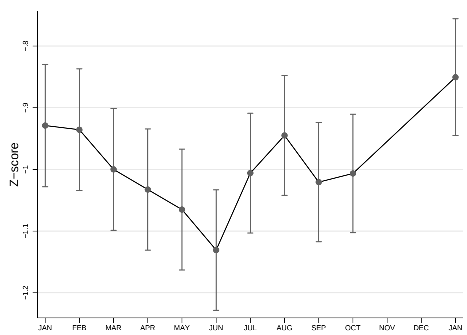


Figure 13: Seasonal variations in BMI-for-age for children below 5, by remoteness (2016 subsample)

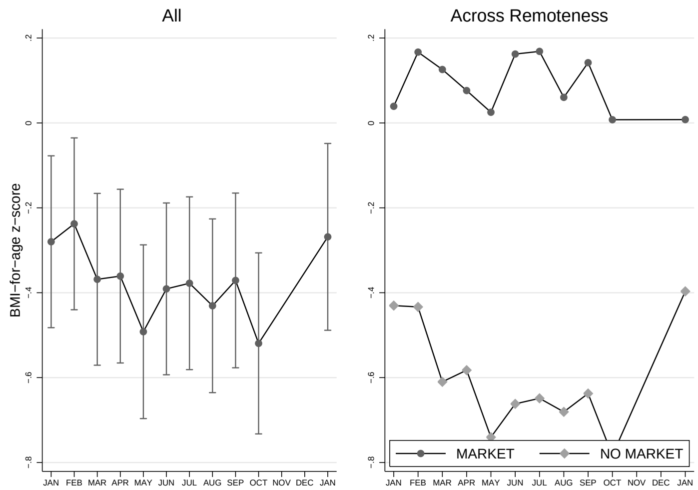


Table 1: Nutritional outcomes and foodgrain consumption across agricultural cycles (in control villages)

	2010-2011		2011-2012		2012-2013	
	MEAN	SD	MEAN	SD	MEAN	SD
Panel A : Foodgrain production, transactions and consumption (Household level)						
Foodgrain production (Kg/cap)	242.47	145.38	104.66	102.47	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
Share of sorghum in foodgrain purchases	0.80	0.40	0.68	0.37	0.65	0.45
Share of foodgrain purchased locally	0.55	0.50	0.40	0.44	0.56	0.49
Annual distance travelled to purchase foodgrain (walking min/bag)	65.11	32.79	95.91	57.90	67.67	59.78
Share of foodgrain purchased to a particular seller because of proximity	0.72	0.45	0.40	0.44	0.48	0.49
Share of foodgrain purchased to a particular seller because of availability	0.23	0.42	0.33	0.42	0.43	0.49
Share of foodgrain purchased to a particular seller because of price	0.03	0.17	0.19	0.33	0.07	0.24
Nominal price paid for 100 kg of foodgrain (in 1000 CFA)	13.98	2.04	19.14	3.36	16.18	2.70
Nominal price paid in post-harvest season	15.64	0.90	19.26	3.13	15.41	2.66
Nominal price paid in lean season	14.01	2.07	19.26	3.97	16.61	2.54
Total expenditures on foodgrain (in 1000 CFA/cap)	1.43	2.90	8.59	8.45	2.87	5.73
Real annual foodgrain disposable (kg/cap)	259.95	179.08	162.08	101.04	167.52	103.64
=1 if real annual foodgrain disposable >190 kg/year	0.63	0.49	0.28	0.45	0.31	0.46
Panel B : Nutritional Outcomes (Individual level)						
19-49 years old adult's BMI	20.78	2.40	20.59	2.37	20.71	2.53
5-18 years old children BMI-for-Age z-score	-0.96	0.92	-1.04	0.93	-1.06	0.98
0.5-4 years old children BMI-for-Age z-score	-0.18	0.98	-0.44	0.98	-0.50	1.09
=1 if adults malnutrition (BMI <18.5)	0.15	0.36	0.16	0.37	0.17	0.38
=1 if 5-18y children's wasting (BMI-f-age <-2)	0.13	0.33	0.16	0.37	0.18	0.39
=1 if 0.5-4y children's wasting (BMI-f-age <-2)	0.03	0.16	0.06	0.23	0.07	0.25
Difference (after-before lean season) in adult's BMI	0.08	1.47	-	-	-0.74	1.28
Difference in 5-18y children's BMI-for-age	-0.97	0.99	-	-	-0.83	0.90
Difference in 0.5-4y children's BMI-for-age	-0.14	1.08	-	-	-0.37	1.01

(1) All figures are drawn from the sample of 200 households from contol villages.
(2) Foodgrain retail purchases were not investigated in depth at baseline. This explains why bulk purchases correspond to total purchases in 2010-2011.

Table 2: Descriptive statistics and balance tests on baseline characteristics

	Treatment (T)			Control (C)			(T) - (C)	
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	0.04	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 3: Balance test on outcomes

	TREATMENT (T)			CONTROL (C)			(T) - (C)	
	N	MEAN	SD	N	MEAN	SD	DIFF	SE
Food access								
Share of foodgrain purchased locally	59	0.37	0.48	62	0.55	0.50	-0.18	0.15
Annual distance travelled to purchase grain (walking min/bag)	59	76.13	35.65	62	65.11	32.79	11.02	9.13
Nominal price paid for 100 kg of foodgrain	56	14.22	1.74	60	13.98	2.04	0.25	0.40
Nutrition								
19-49 years old adult's BMI	444	20.70	2.28	469	20.78	2.40	-0.08	0.22
5-19 years old children's BMI-for-Age	827	-1.06	0.84	739	-0.96	0.90	-0.10	0.08
0-4 years old children's BMI-for-Age	323	-0.24	0.97	342	-0.16	0.96	-0.08	0.11
=1 if adult's BMI <18.5	444	0.15	0.36	469	0.15	0.36	-0.00	0.04
=1 if 5-19 children BMI-for-age <-2	827	0.13	0.34	739	0.13	0.33	0.01	0.02
=1 if 0-4 children BMI-for-age <-2	323	0.04	0.20	342	0.02	0.14	0.02**	0.01
Food purchases and consumption								
=1 if HH purchased any foodgrain	199	0.31	0.46	199	0.33	0.47	-0.02	0.06
Total quantity of foodgrain purchased (in 100 kg/cap)	199	0.10	0.18	199	0.10	0.20	-0.00	0.03
Total expenditures on foodgrain (in 1000 CFA/cap)	199	1.34	2.46	199	1.43	2.90	-0.09	0.34
Real annual foodgrain disposable (ln of kg/cap)	198	5.46	0.51	190	5.38	0.63	0.09	0.08
=1 if real annual foodgrain disposable >190 kg/year	198	0.67	0.47	190	0.63	0.49	0.05	0.07

(1) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
(2) Standard errors correspond to village-level Cluster-Robust-Standard-Errors (CRSE)

Table 4: Changes in nutritional outcomes before the intervention (test of the parallel trend assumption)

	DID		**ANCOVA**	
	HOUSEHOLD	INDIVIDUAL	HOUSEHOLD	INDIVIDUAL
	(1)	(2)	(3)	(4)
I. Level of nutritional outcomes				
	19-49 years old adult's BMI			
TREAT	-0.153 [0.196]	-0.114 [0.190]	-0.159 [0.186]	-0.063 [0.167]
Observations	1105	2990	350	796
	5-18 years old children's BMI-for-age			
TREAT	-0.076 [0.071]	-0.060 [0.078]	-0.098 [0.073]	-0.112 [0.070]
Observations	1119	4579	362	1349
	0-4 years old children's BMI-for-age			
TREAT	-0.009 [0.128]	-0.025 [0.108]	0.030 [0.124]	-0.004 [0.115]
Observations	967	2197	293	577
II. Prevalence of moderate or acute malnutrition (MAM)				
	= 1 if 19-49 years old adult's BMI <18.5			
TREAT	0.005 [0.036]	0.010 [0.035]	-0.006 [0.038]	-0.003 [0.028]
Observations	1105	2990	350	796
	= 1 if 5-18 years old children's BMI-for-age <-2			
TREAT	0.023 [0.028]	-0.002 [0.030]	0.022 [0.023]	0.017 [0.021]
Observations	1119	4579	362	1349
	= 1 if 0-4 years old children's BMI-for-age <-2			
TREAT	0.030 [0.029]	0.009 [0.025]	0.015 [0.016]	0.005 [0.018]
Observations	967	2197	293	577

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

Table 5: Impact of FSGs on foodgrain local availability and affordability

			ACROSS NO ROAD	
	DID	ANCOVA	DID	ANCOVA
	(1)	(2)	(3)	(4)
I. Availability-related outcomes				
	Share of grain bags bought locally			
TREAT	0.247* [0.138]	0.238** [0.093]	-0.024 [0.179]	0.264* [0.135]
TREAT x NO ROAD	-	-	0.614** [0.273]	-0.077 [0.217]
Observations	406	105	406	105
	Total distance travelled per bag (in minutes)			
TREAT	-31.256** [12.879]	-37.814*** [12.221]	-7.858 [13.941]	-31.796*** [11.737]
TREAT x NO ROAD	-	-	-52.477** [23.399]	-12.547 [29.364]
Observations	406	105	406	105
II. Affordability-related outcomes				
	Mean price of 100kg food grain bags (in 1000 CFA) (3)			
TREAT	-1.168* [0.701]	-1.002 [0.827]	-0.069 [0.911]	0.039 [0.926]
TREAT x NO ROAD	-	-	-2.510* [1.339]	-2.347 [2.029]
Observations	399	100	399	100
	Post-harvest season mean price of 100kg food grain bags (in 1000 CFA)			
TREAT	0.877 [1.761]	-0.428 [2.899]	-0.399 [4.995]	1.132 [47.794]
TREAT x NO ROAD	-	-	2.843 [4.717]	-7.169 [8.652]
Observations	202	12	202	12
	Lean season mean price of 100kg food grain bags (in 1000 CFA)			
TREAT	-1.403* [0.894]	-1.505 [1.213]	0.054 [0.949]	-0.348 [1.088]
TREAT x NO ROAD	-	-	-3.386* [1.783]	-2.638 [2.785]
Observations	351	83	351	83

(1) Standard-Errors in brackets are village-level Wild-Cluster-Boostrapped Standard-Errors.
(2) Level of significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
(3) Mean price paid per bag is taken at the household level and includes 3 different types of grain consumed locally - sorghum, millet and maize. Sorghum is by far the most important grain consumed - two-third of total purchases - but the nutritional content and the price pattern are very similar across grain. We thus group prices of all grain purchased and control for whether the household has purchased any other grain than sorghum. Results hold when we restrict the analysis to sorghum only or when we control more specifically for grain type in a bag-level regression.

Table 6: Impact of FSGs on nutrition

	DID		ANCOVA	
	HOUSEHOLD	INDIVIDUAL	HOUSEHOLD	INDIVIDUAL
	(1)	(2)	(3)	(4)
I. Level of nutritional outcomes				
	19-49 years old adult's BMI			
TREAT	0.307*	0.389**	0.313*	0.135
	[0.178]	[0.162]	[0.190]	[0.150]
Observations	736	1818	351	716
	5-18 years old children's BMI-for-age			
TREAT	0.175**	0.196***	0.150**	0.132**
	[0.064]	[0.053]	[0.062]	[0.056]
Observations	747	2941	360	1174
	0-4 years old children's BMI-for-age			
TREAT	0.192*	0.227**	0.228***	0.155*
	[0.105]	[0.104]	[0.084]	[0.079]
Observations	635	1402	289	562
II. Prevalence of moderate or acute malnutrition (MAM)				
	= 1 if 19-49 years old adult's BMI <18.5			
TREAT	-0.007	-0.012	-0.024	0.000
	[0.032]	[0.026]	[0.028]	[0.028]
Observations	736	1818	351	716
	= 1 if 5-18 years old children's BMI-for-age <-2			
TREAT	-0.051*	-0.044*	-0.041*	-0.033
	[0.026]	[0.025]	[0.024]	[0.026]
Observations	747	2941	360	1174
	= 1 if 0-4 years old children's BMI-for-age <-2			
TREAT	-0.080***	-0.058**	-0.044*	-0.031*
	[0.025]	[0.020]	[0.023]	[0.018]
Observations	635	1402	289	562

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

Table 7: Impact of FSGs on foodgrain purchase and consumption

			ACROSS NO ROAD	
	DID	ANCOVA	DID	ANCOVA
	(1)	(2)	(3)	(4)
I. Purchases				
	=1 if any foodgrain purchase			
TREAT	0.026 [0.060]	0.008 [0.046]	0.020 [0.068]	0.026 [0.065]
TREAT x NO ROAD	-	-	0.017 [0.129]	-0.044 [0.097]
Observations	791	391	791	391
	Total quantity of foodgrain purchased (in 100 kg/cap)			
TREAT	-0.040 [0.061]	-0.045 [0.065]	-0.046 [0.085]	-0.042 [0.090]
TREAT x NO ROAD	-	-	0.015 [0.138]	-0.008 [0.145]
Observations	791	391	791	391
	Total expenditures on foodgrain (in 1000 CFA/cap) (3)			
TREAT	-0.828 [1.198]	-0.997 [0.980]	-0.493 [1.684]	-0.493 [1.709]
TREAT x NO ROAD	-	-	-0.841 [2.544]	-1.021 [2.679]
Observations	791	391	791	391
II. Consumption				
	Real annual foodgrain disposable (ln of kg/cap) (3)			
TREAT	-0.127 [0.090]	-0.079 [0.067]	-0.181 [0.139]	-0.093 [0.086]
TREAT x NO ROAD	-	-	0.131 [0.171]	0.034 [0.152]
Observations	780	381	780	381
	=1 if real annual foodgrain disposable >190 kg/year (4)			
TREAT	-0.083 [0.070]	-0.057 [0.059]	-0.111 [0.105]	-0.029 [0.077]
TREAT x NO ROAD	-	-	0.067 [0.142]	-0.067 [0.119]
Observations	780	381	780	381

(1) Standard-Errors in brackets are village-level Wild-Cluster-Boostrapped Standard-Errors.
(2) Level of significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
(3) Real grain disposable corresponds to (production + purchases + gifts in - losses - sales - gifts out).
(4) The consumption standard in Burkina Faso corresponds to 190 kg/capita/year or, equivalently, 0.520 kg/cap/day.

Table 8: Impact of FSGs on diet diversity

	SIMPLE DIFFERENCE	**ACROSS NO ROAD**
	(1)	(2)
	Hoddinott's dietary diversity score	
TREAT	-15.248	-5.470
	[9.630]	[13.692]
TREAT x NO ROAD	-	-24.692
		[17.372]
Observations	393	393
	IFPRI's dietary diversity score	
TREAT	-0.005	-0.025
	[0.071]	[0.076]
TREAT x NO ROAD	-	0.047
		[0.169]
Observations	393	393

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

Table 9: Impact of FSGs on anticipated purchases

	SIMPLE DIFFERENCE	ACROSS NO ROAD
	(1)	(2)
Timing of food storage		
	Number of months before own stock depletion	
TREAT	-0.626	-0.028
	[0.460]	[0.441]
TREAT x NO ROAD	-	-1.510
		[1.141]
Observations	393	393
Timing of food purchases		
	=1 if any foodgrain purchased before own stock depletion	
TREAT	-0.058	0.023
	[0.062]	[0.082]
TREAT x NO ROAD	-	-0.204*
		[0.120]
Observations	393	393
	Quantity of foodgrain purchased before own stock depletion (100kg/cap)	
TREAT	-0.093*	-0.028
	[0.054]	[0.069]
TREAT x NO ROAD	-	-0.165
		[0.103]
Observations	393	393

(1) Standard-Errors in brackets are village-level Wild-Cluster-Boostrapped Standard-Errors.
(2) Level of significance: * $p < 0.10$, ** $p \leq 0.05$, *** $p < 0.01$.

Appendix 1 : Resolution of the two-period allocation model

We derive first general expressions for the main variables of interest before exploring the effects of a decrease of P_2 for the case $\varepsilon = 0$ (no body mass storing) and for the case $\varepsilon > 0$.

Lagrangian and first-order conditions

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:

$$
\begin{aligned}
L = U(N_1) + V(O_1) + \delta U(N_2) + V(O_2) - \lambda_1 (N_1 - \varepsilon N_0 - C_1) - \lambda_2 (N_2 - \varepsilon N_1 - C_2) \\
- \lambda_3 (rP_1 m_1 + rO_1 + P_2 m_2 + O_2 - rY) - \lambda_4 (\alpha C_1 + C_2 - \alpha m_1 - m_2) \\
- \lambda_5 (C_1 - m_1) + \nu_1 m_1 + +\nu_2 m_2
\end{aligned}
$$

The first-order conditions are:

$$
\begin{aligned}
\frac{dL}{dO_1} &= V_O(O_1) - \lambda_3 r = 0 && (10) \\
\frac{dL}{dO_2} &= \delta V_O(O_2) - \lambda_3 = 0 && (11) \\
\frac{dL}{dN_1} &= U_N(N_1) - \lambda_1 + \lambda_2 \varepsilon = 0 && (12) \\
\frac{dL}{dN_2} &= \delta U_N(N_2) - \lambda_2 = 0 && (13) \\
\frac{dL}{dC_1} &= \lambda_1 - \lambda_4 \alpha - \lambda_5 = 0 && (14) \\
\frac{dL}{dC_2} &= \lambda_2 - \lambda_4 = 0 && (15) \\
\frac{dL}{dm_1} &= -\lambda_3 r P_1 + \lambda_4 \alpha + \lambda_5 + \nu_1 = 0 && (16) \\
\frac{dL}{dm_2} &= -\lambda_3 P_2 + \lambda_4 + \nu_2 = 0 && (17)
\end{aligned}
$$

Depending on the relative price of buying food in period 2 versus storing, two cases arise: the corner solution $m_2 = 0$, and the interior solution $m_2 > 0$. To restrict attention to $C_2 > 0$, we assume that one of the following two conditions hold: $\varepsilon < \alpha$, or $\varepsilon < \frac{rP_1}{P_2}$. Intuitively, if the body mass carry-over were very efficient (high ε), the household would be able to just rely on the body mass stored in the first period, making consumption in the second period unnecessary (which is obviously unrealistic).

Case a $\frac{rP_1}{\alpha} \geq P_2$

If $\frac{rP_1}{\alpha} \geq P_2$, equations (16) and (17) imply $\frac{\lambda_5+\nu_1}{\alpha} > \nu_2$ (we obtain this expression by multiplying equation (17) by $\frac{1}{\alpha}$ and substracting it from (16)). 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 $m_1 > 0$, hence $\nu_1 = 0$ 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 (12) and (13) then imply:

$$\frac{U_N(N_1, O_1)}{\delta U_N(N_2, O_2)} = \frac{\lambda_1 - \lambda_2 \varepsilon}{\lambda_2}$$

The multipliers λ_1 and λ_2 can be easily be written as functions of λ_4. Note, first, that (16) and (17) imply $\lambda_5 = \lambda_4 \left(\frac{rP_1}{P_2} - \alpha\right)$. Then, (14) implies $\lambda_1 = \lambda_4 \frac{rP_1}{P_2}$. Since $\lambda_2 = \lambda_4$, from (15) it follows that $\frac{\lambda_1}{\lambda_2} = \frac{rP_1}{P_2}$ and

$$\frac{U_N(N_1, O_1)}{\delta U_N(N_2, O_2)} = \frac{rP_1 - \varepsilon P_2}{P_2}$$

Bearing in bind that $U(N) = \frac{N^{-\rho+1}}{-\rho+1}$, it comes that:

$$N_1 = N_2 \left(\delta \frac{rP_1 - \varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}} \tag{18}$$

Using the explicit form of $V(O)$, and (10) and (11), we write likewise: $O_1 = (\delta r)^{-\frac{1}{\rho}} O_2$. Equations (11) and (13) then yields:

$$\frac{V_O(O_2)}{U_N(N_2)} = \frac{\frac{\lambda_3}{\delta}}{\frac{\lambda_2}{\delta}} = \frac{\lambda_3}{\lambda_2}.$$

Using (17) and (15), we can express both λ_3 and λ_2 as a function of λ_4, and we obtain the following expression: $\frac{V_O(O_2)}{U_N(N_2)} = \frac{1}{P_2}$ or $O_2 = N_2 P_2^{\frac{1}{\rho}}$. As foodgrain is purchased in both periods, we know that $C_1 = m_1$ and $C_2 = m_2$. The budget constraint can thus be written as: $rP_1C_1 + rO_1 + P_2C_2 + O_2 = rY$. 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:

$$
\begin{aligned}
rP_1(N_1-\varepsilon N_0)+rO_1+P_2(N_2-\varepsilon N_1)+O_2 &= rY \\
N_1(rP_1-\varepsilon P_2)+rO_1+P_2N_2+O_2 &= rY+rP_1\varepsilon N_0 \\
N_2\left(\left(\delta\frac{rP_1-\varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}}(rP_1-\varepsilon P_2)+r(\delta r)^{-\frac{1}{\rho}}P_2^{\frac{1}{\rho}}+P_2+P_2^{\frac{1}{\rho}}\right) &= rY+rP_1\varepsilon N_0 \\
\frac{rY+rP_1\varepsilon N_0}{\left(\delta\frac{rP_1-\varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}}(rP_1-\varepsilon P_2)+\left(r(\delta r)^{-\frac{1}{\rho}}+1\right)P_2^{\frac{1}{\rho}}+P_2} &= N_2 \qquad (19)
\end{aligned}
$$

We can then solve for all other variables (recalling $C_2 = N_2 - \varepsilon N_1$ and $C_1 = N_1 - \varepsilon N_0$):

$$
\begin{aligned}
N_1 &= \frac{rY+rP_1\varepsilon N_0}{\left(\delta\frac{rP_1-\varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}}(rP_1-\varepsilon P_2)+\left(r(\delta r)^{-\frac{1}{\rho}}+1\right)P_2^{\frac{1}{\rho}}+P_2}\left(\delta\frac{rP_1-\varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}} \qquad (20)\\
C_2 &= \left(1-\varepsilon\left(\delta\frac{rP_1-\varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}}\right)\frac{rY+rP_1\varepsilon N_0}{\left(\delta\frac{rP_1-\varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}}(rP_1-\varepsilon P_2)+\left(r(\delta r)^{-\frac{1}{\rho}}+1\right)P_2^{\frac{1}{\rho}}+P_2} \qquad (21)\\
C_1 &= \frac{rY+rP_1\varepsilon N_0}{\left(\delta\frac{rP_1-\varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}}(rP_1-\varepsilon P_2)+\left(r(\delta r)^{-\frac{1}{\rho}}+1\right)P_2^{\frac{1}{\rho}}+P_2}\left(\delta\frac{rP_1-\varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}}-\varepsilon N_0 \qquad (22)
\end{aligned}
$$

Case b $\frac{rP_1}{\alpha} < P_2$

If $\frac{rP_1}{\alpha} < P_2$, equations (16) and (17) imply $\frac{\lambda_5+\nu_1}{\alpha} < \nu_2$. 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 (14) and (15) imply $\lambda_2 = \frac{\lambda_1}{\alpha}$. Plugging this expression in (12), we get $U_N(N_1, O_1) = \lambda_1\left(1 - \frac{\varepsilon}{\alpha}\right)$. Plugging the same expresion in (13) yields $\delta U_N(N_2, O_2) = \frac{\lambda_1}{\alpha}$. We can therefore write the following expression:

$$
\frac{U_N(N_1,O_1)}{\delta U_N(N_2,O_2)} = \alpha - \varepsilon
$$

Using the explicit form of utility, Equation (7) implies $N_1 = N_2\left(\delta(\alpha-\varepsilon)\right)^{-\frac{1}{\rho}}$. On the other hand,

$$
\frac{V_O(O_2)}{U_N(N_2)} = \frac{\lambda_4\frac{\alpha}{rP_1}}{\lambda_4} = \frac{\alpha}{rP_1}
$$

It follows that $O_2 = \left(\frac{\alpha}{rP_1}\right)^{-\frac{1}{\rho}} N_2$, and the total quantity purchased is $m_1 = C_1 + \frac{1}{\alpha}C_2$. The budget constraint is then:

$$\begin{aligned}
rP_1\left(N_1 - \varepsilon N_0 + \frac{1}{\alpha}(N_2 - \varepsilon N_1)\right) + rO_1 + O_2 &= rY \\
N_1 rP_1\left(1 - \frac{\varepsilon}{\alpha}\right) + N_2\frac{rP_1}{\alpha} + rO_1 + O_2 &= rY + \varepsilon N_0 rP_1 \\
N_2\left((\delta(\alpha-\varepsilon))^{-\frac{1}{\rho}} rP_1\left(1 - \frac{\varepsilon}{\alpha}\right) + \frac{rP_1}{\alpha} + r(\delta r)^{-\frac{1}{\rho}}\left(\frac{rP_1}{\alpha}\right)^{\frac{1}{\rho}} + \left(\frac{rP_1}{\alpha}\right)^{\frac{1}{\rho}}\right) &= rY + \varepsilon N_0 rP_1 \\
\frac{rY + \varepsilon N_0 rP_1}{(\delta(\alpha-\varepsilon))^{-\frac{1}{\rho}} rP_1\left(1 - \frac{\varepsilon}{\alpha}\right) + \frac{rP_1}{\alpha} + \left(r(\delta r)^{-\frac{1}{\rho}} + 1\right)\left(\frac{rP_1}{\alpha}\right)^{\frac{1}{\rho}}} &= N_2 \qquad (23)
\end{aligned}$$

Expressions for the other variables can be deduced from the above:

$$N_1 = \frac{rY + \varepsilon N_0 rP_1}{(\delta(\alpha-\varepsilon))^{-\frac{1}{\rho}} rP_1\left(1 - \frac{\varepsilon}{\alpha}\right) + \frac{rP_1}{\alpha} + \left(r(\delta r)^{-\frac{1}{\rho}} + 1\right)\left(\frac{rP_1}{\alpha}\right)^{\frac{1}{\rho}}}(\delta(\alpha-\varepsilon))^{-\frac{1}{\rho}} \qquad (24)$$

$$C_2 = \left(1 - \varepsilon(\delta(\alpha-\varepsilon))^{-\frac{1}{\rho}}\right)\frac{rY + rP_1\varepsilon N_0}{(\delta(\alpha-\varepsilon))^{-\frac{1}{\rho}} rP_1\left(1 - \frac{\varepsilon}{\alpha}\right) + \frac{rP_1}{\alpha} + \left(r(\delta r)^{-\frac{1}{\rho}} + 1\right)\left(\frac{rP_1}{\alpha}\right)^{\frac{1}{\rho}}} \qquad (25)$$

$$C_1 = \frac{rY + \varepsilon N_0 rP_1}{(\delta(\alpha-\varepsilon))^{-\frac{1}{\rho}} rP_1\left(1 - \frac{\varepsilon}{\alpha}\right) + \frac{rP_1}{\alpha} + \left(r(\delta r)^{-\frac{1}{\rho}} + 1\right)\left(\frac{rP_1}{\alpha}\right)^{\frac{1}{\rho}}}(\delta(\alpha-\varepsilon))^{-\frac{1}{\rho}} - \varepsilon N_0 \qquad (26)$$

We now turn to exploring the effects of a decrease of P_2 on nutrition, consumption and purchase behavior. We first show that $\frac{dN_2}{dP_2} \leq 0$ and $\frac{dm_2}{dP_2} \leq 0$, in other words, a decrease in P_2 is expected to increase nutrition and food purchase in period 2. We then explore the impact of a decrease of P_2 on total consumption and purchase and distinguish between two cases, $\varepsilon = 0$ (no body mass storing), and $\varepsilon > 0$.

Effect of a decrease in P_2 on N_2 and m_2 (for both $\varepsilon = 0$ and $\varepsilon > 0$)

For high second period-prices $P_2 >> \frac{rP_1}{\alpha}$, the household does not buy food in the period 2 ($m_2 = 0$) and the level of nutrition N_2 is independent of P_2 (see Equation 23). Hence a marginal decrease in P_2 does not affect household behavior. However, as prices further decrease, the condition for positive purchase, $P_2 < \frac{rP_1}{\alpha}$, becomes easier to satisfy. Furthermore, provided the household buys food in the second period, $\frac{dN_2}{dP_2} < 0$ and $\frac{dm_2}{dP_2} < 0$. To see this, consider Equation 19:

$N_2 = \frac{rY + rP_1\varepsilon N_0}{\left(\delta\frac{rP_1-\varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}}(rP_1-\varepsilon P_2)+\left(r(\delta r)^{-\frac{1}{\rho}}+1\right)P_2^{\frac{1}{\rho}}+P_2}$. The numerator of this ratio is independent of P_2, the derivative of the denominator with respect to P_2 is:

$$\left(-\frac{1}{\rho}\left(-\delta\frac{rP_1}{P_2^2}\right)\left(\delta\frac{rP_1-\varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}-1}(rP_1-\varepsilon P_2)-\varepsilon\left(\delta\frac{rP_1-\varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}}+\frac{1}{\rho}\left(r(\delta r)^{-\frac{1}{\rho}}+1\right)P_2^{\frac{1}{\rho}-1}+1\right)$$

Thus:

$$\frac{dN_2}{dP_2} = -N_2\frac{\left(\delta\frac{rP_1-\varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}}\left(\frac{rP_1}{\rho P_2}-\varepsilon\right)+\frac{1}{\rho}\left(r(\delta r)^{-\frac{1}{\rho}}+1\right)P_2^{\frac{1}{\rho}-1}+1}{\left(\delta\frac{rP_1-\varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}}(rP_1-\varepsilon P_2)+r\left(r(\delta r)^{-\frac{1}{\rho}}+1\right)P_2^{\frac{1}{\rho}}+P_2} \tag{27}$$

Let us now show $\frac{dN_2}{dP_2} \leq 0$. All terms of the fraction are unambiguously positive except $\frac{1}{\rho}\left(\frac{rP_1}{P_2}\right)-\varepsilon$. The condition for positive consumption in the second period (the case to which we restrict attention) is $\varepsilon < \frac{rP_1}{P_2}$. Since $\rho > 1$, the term $\frac{1}{\rho}\left(\frac{rP_1}{P_2}\right)-\varepsilon$ may be negative, but we can show that the numerator of the fraction is positive (and $\frac{dN_2}{dP_2}$is negative). To see it, first note that all terms in the numerator are decreasing in ρ. This implies that if the limit of this numerator is positive when ρ tends to $+\infty$, it is always positive. This limit is $-\varepsilon + 1 > 0$.

Turning to the effect of P_2 on m_2, recall that $m_2 = C_2 = N_2 - \varepsilon N_1 = N_2 - \varepsilon N_2\left(\delta\frac{rP_1-\varepsilon P_2}{P_2}\right)^{-\frac{1}{\rho}}$, so that $m_2 = N_2\left(1-\varepsilon\left(\frac{P_2}{\delta(rP_1-\varepsilon P_2)}\right)^{\frac{1}{\rho}}\right)$. It is clear that $\frac{d\left(1-\varepsilon\left(\frac{P_2}{\delta(rP_1-\varepsilon P_2)}\right)^{\frac{1}{\rho}}\right)}{dP_2} < 0$, and since $\frac{dN_2}{dP_2} \leq 0$, we have $\frac{dm_2}{dP_2} \leq 0$.

Effect of a decrease in P_2 on $C_1 + C_2$ and $m_1 + m_2$

Case 1: $\varepsilon = 0$

We consider the case of no body mass storing. We show first that a decrease in P_2 would increase the total quantity of grain consumed $\frac{d(C_1+C_2)}{dP_2} < 0$, and second that the total quantity of grain purchased may go down. When $\varepsilon = 0$, $C_2 = N_2$ and $C_1 = N_1$. If there is no purchase in the second period $\left(P_2 > \frac{rP_1}{\alpha}\right)$, a marginal decrease in P_2 leaves consumption and purchase unchanged. If there are purchases in the second period, then we have shown above that $\frac{dN_2}{dP_2} = \frac{dC_2}{dP_2} < 0$. Let us now examine the sign of $\frac{dC_1}{dP_2}$. In that case, $C_1 = N_1 = N_2\left(\delta\frac{rP_1}{P_2}\right)^{-\frac{1}{\rho}}$ (using Equation 18) and:

$$\frac{dC_1}{dP_2} = \frac{dN_2}{dP_2}\left(\delta\frac{rP_1}{P_2}\right)^{-\frac{1}{\rho}} + \frac{1}{\rho P_2}\left(\delta\frac{rP_1}{P_2}\right)^{-\frac{1}{\rho}}N_2$$

Using Equation 27, we can rewrite this expression as:

$$\frac{dC_1}{dP_2} = -\frac{1}{\rho P_2}\left(\delta\frac{rP_1}{P_2}\right)^{-\frac{1}{\rho}} N_2 \frac{\left(\delta\frac{rP_1}{P_2}\right)^{-\frac{1}{\rho}}(rP_1) + \left(r(\delta r)^{-\frac{1}{\rho}}+1\right)P_2^{\frac{1}{\rho}} + \rho P_2}{\left(\delta\frac{rP_1}{P_2}\right)^{-\frac{1}{\rho}}(rP_1) + \left(r(\delta r)^{-\frac{1}{\rho}}+1\right)P_2^{\frac{1}{\rho}} + P_2} + \frac{1}{\rho P_2}\left(\delta\frac{rP_1}{P_2}\right)^{-\frac{1}{\rho}} N_2$$

Given $\rho > 1$, the fraction $\frac{\left(\delta\frac{rP_1}{P_2}\right)^{-\frac{1}{\rho}}(rP_1)+\left(r(\delta r)^{-\frac{1}{\rho}}+1\right)P_2^{\frac{1}{\rho}}+\rho P_2}{\left(\delta\frac{rP_1}{P_2}\right)^{-\frac{1}{\rho}}(rP_1)+\left(r(\delta r)^{-\frac{1}{\rho}}+1\right)P_2^{\frac{1}{\rho}}+P_2}$ is larger than 1, implying $\frac{dC_1}{dP_2} < 0$, and $\frac{d(C_1+C_2)}{dP_2} < 0$. Since there is no discontinuity in N_2 at the threshold price ($\liminf_{P_2 \to \frac{rP_1}{\alpha}}(N_2) = \limsup_{P_2 \to \frac{rP_1}{\alpha}}(N_2)$), there is no discontinuity either in the total quantity consumed. We have therefore proven that, in the absence of body mass storing, a decrease in the second period price increases the total quantity consumed (and strictly increases it in the domain below the threshold).

We now turn to the impact of a decrease in P_2 on the total quantity purchased. If the household purchases foodgrain in the second period, the total quantity purchased is always equal to the total quantity consumed (there is no storage and therefore no loss) and: $\frac{d(C_1+C_2)}{dP_2} < 0 \Rightarrow \frac{d(m_1+m_2)}{dP_2} < 0$. If the household does not buy foodgrain in the second period, we have $m_1 + m_2 = m_1$ and the quantity purchased is insensitive to a marginal change in the second-period price. However, because of physical storage losses, there is a discontinuity in the total quantity purchased at the threshold price, $\liminf_{P_2 \to \frac{rP_1}{\alpha}}(m_1+m_2) > \limsup_{P_2 \to \frac{rP_1}{\alpha}}(m_1+m_2)$, implying that the total quantity purchased may go down as a result of a decrease in the lean period price. This occurs when the price decrease induces the household to delay its purchases until the second period. To see this, note that if $P_2 > \frac{rP_1}{\alpha}$, $m_1 + m_2 = m_1 = C_1 + \frac{1}{\alpha}C_2$, while if $P_2 < \frac{rP_1}{\alpha}$, $m_1 + m_2 = C_1 + C_2$. Since there is no discontinuity in consumption at the threshold, $\alpha < 1$ implies that the total quantity purchased goes down when the household switches from buying only in the first period to buying in both periods. This is because the household economizes on storage losses. Figures 6 and 7 present the effect of a change of P_2 (holding other prices constant) on total consumption, total purchases and nutrition levels in periods 1 and 2. The parameters are set to the following values: $r = 1.02$, $\rho = 1.5$, $\delta = 0.95$, $Y = 11$, $N_0 = 2$, $\varepsilon = 0$, $\alpha = 0.9$.

Case 2: $\varepsilon > 0$

In the presence of body mass storing, a decrease in P_2 may decrease the total quantity of grain consumed. This is because the expression for $\frac{dC_1}{dP_2}$ includes ε and consumption in the first period may go down as a result of a decrease in P_2. We show that this may be the case with the help of simulation. Figures 8 and 9 present the effect of a change of P_2 (holding other prices constant) on total consumption, total purchases and nutrition levels in each period. The parameters are set to the following values: $r = 1.02$, $\rho = 1.5$, $\delta = 0.95$, $Y = 11$, $N_0 = 2$, $\varepsilon = 0.5$, $\alpha = 0.9$.

Appendix 2: Extensions to the simple model

Storage, consumption and nutrition in the presence of price risk

In the presence of price risk, households take their storage decision not knowing the lean period price. While they anticipate a seasonal increase in the price, uncertainty about its exact level may be an important determinant of storage for risk-averse households. In fact the intervention that we consider 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.[32] Denoting by $\tilde{P}_2$ the stochastic lean period price (and using the same notations as above), a risk-neutral household stores food if $P_1 < \frac{\alpha}{r} E\tilde{P}_2$, 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 $P_1 < \frac{\alpha}{r} \frac{E[\tilde{P}_2 V_P(P_2)]}{E\tilde{P}_2}$, 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 widen 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.

[32] 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).

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

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 XXX), we now discuss how our 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.[33] In period 1P, the household maximizes the same expected utility as the time-consistent household of Section 2.1: $U(N_1, O_1) + \delta U(N_2, O_2)$. In contrast, in period 1C the household is tempted to consume more than what was deemed optimal in period 1P. It now maximizes:

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

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

Let's assume that the household is sophisticated in the way defined by O'Donoghue and Rabin (1999): the household anticipates the urge to consume readily available food. It can then decide to postpone the purchase of the food intended for consumption in period 2 so as to avoid storage. This strategy serves as a 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

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

in 1C.[34] We implicitly assume an asymmetry between cash and physical food stocks: the household cannot use cash to satisfy an urge to consume foodgrain in period 1C and, therefore, there is no self-control problem affecting savings. There are two practical reasons justifying this asymmetry. First, because of an indivisibility of the foodgrain unit offered for sale on the market (100 kg bags), households cannot respond instantaneously to a felt need to consume minute additional quantities of food. Second, different actors inside the household make decisions about destocking foodgrain and using cash for purchasing food. While the latter belongs to the household head, the former may be forced on the head by other household members, women in particular, who are sensitive to the hunger stress of children (see Section 7 for anecdotal evidence).

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, $P_2^* = \frac{rP_1}{\alpha}$. In other words, a household with present bias will want to continue to purchase foodgrain in period 2 at price P_2^* and beyond. This is illustrated by Figure 14: while households with no present bias start storing at $P_2^* = \frac{rP_1}{\alpha}$, households with a present bias (dashed line) purchase foodgrain in period 2 until $P_2 = P_2^{**} > P_2^*$.[35] 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.

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 now, as Figure 14 indicates, the decrease in total consumption caused by a fall in the lean period price occurs over a larger price range.

Storage, consumption and nutrition in the presence of self-control: resolution and simulations

We assume that the household is sophisticated and perfectly anticipates that, while in 1P preferences are described by $U(N_1, O_1) + \delta U(N_2, O_2)$, present bias arises in 1C (his expected utility becomes

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

[35] Parameters used for the simulations and the resolution method are provided in Appendix 1.

$U(N_1, O_1) + \beta\delta U(N_2, O_2))$. 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 its 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 the former.

The present-biased household thus chooses to buy food in period 2 at a rising price as long as the second-period price exceeds a threshold P_2^{**} strictly above P_2^*: $P_2 > P_2^{**} > P_2^*$. Once the present-biased household stores food, it allocates its nutrition across time periods so as to maximize $U(N_1, O_1) + \beta\delta U(N_2, O_2)$, resulting in the following expression for the marginal rate of substitution between N_1 and N_2:

$$\frac{U_N(N_1)}{U_N(N_2)} = \beta\delta(\alpha - \varepsilon).$$

For the simulations, the parameter for present bias is $\beta = 0.99$, while 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, we obtain $N_1 = N_2\left(\delta\beta(\alpha - \varepsilon)\right)^{-\frac{1}{\rho}}$. Furthermore, the following three equations link nutrition, consumption and the quantity purchased: $N_1 = \varepsilon N_0 + C_1$, $N_2 = \varepsilon^2 N_0 + \varepsilon C_1 + C_2$ and $m_1 = C_1 + \frac{1}{\alpha}C_2$. Combining these expressions, we obtain a second equation linking $N_1(m_1)$ and $N_2(m_1)$: $m_1 = N_1(1 - \frac{\varepsilon}{\alpha}) - \varepsilon N_0(1 - \frac{\varepsilon}{\alpha}) + \frac{1}{\alpha}N_2 - \frac{1}{\alpha}\varepsilon^2 N_0$. We thus obtain the following expression for $N_2(m_1)$ and $N_1(m_1)$:

$$N_2 = \frac{m_1 + \varepsilon N_0(1 - \frac{\varepsilon}{\alpha}) + \frac{1}{\alpha}\varepsilon^2 N_0}{(\delta\beta(\alpha - \varepsilon))^{-\frac{1}{\rho}}(1 - \frac{\varepsilon}{\alpha}) + \frac{1}{\alpha}}$$

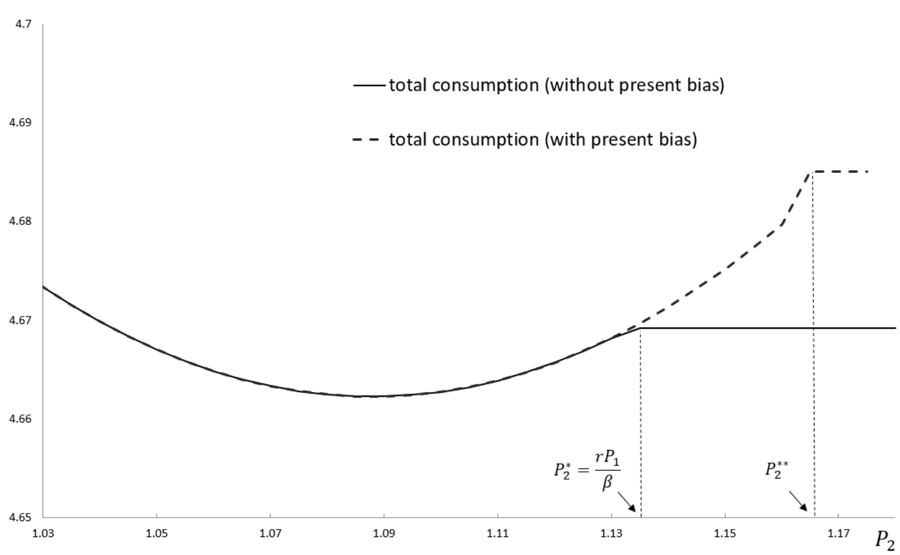
$$N_1 = \frac{m_1 + \varepsilon N_0(1 - \frac{\varepsilon}{\alpha}) + \frac{1}{\alpha}\varepsilon^2 N_0}{(\delta\beta(\alpha - \varepsilon))^{-\frac{1}{\rho}}(1 - \frac{\varepsilon}{\alpha}) + \frac{1}{\alpha}}(\delta\beta(\alpha - \varepsilon))^{-\frac{1}{\rho}}$$

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 $U(N_1, O_1) + \delta U(N_2, O_2)$, given $N_1(m_1)$ and $N_2(m_1)$ (and the budget constraint). As above, we have $O_1 = (\delta r)^{-\frac{1}{\rho}}O_2$ and the budget constraint becomes $rP_1 m_1 + O_2\left(1 + r(\delta r)^{-\frac{1}{\rho}}\right) = rR$, implying $O_2 = \frac{rR - rP_1 m_1}{1 + r(\delta r)^{-\frac{1}{\rho}}}$. 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^{**}.

Figure 14: Total consumption as a function of P_2 ($\varepsilon > 0$): comparison without and with present bias ($\beta > 0$)



Appendix 3: Additional empirical results

Table 10: Balance tests on baseline characteristics: No-road sample

	TREATMENT (T)			CONTROL (C)			(T) - (C)	
	N	MEAN	SD	N	MEAN	SD	DIFF	SE
Village-level characteristics								
Village population (# individuals)	8	1896.75	940.13	8	2318.75 (4)	994.64	-422.00	483.88
Distance to the nearest community health center (km)	8	3.38	4.00	8	4.38	3.96	-1.00	1.99
Distance to the nearest town (km)	8	18.25	5.70	8	19.50	10.13	-1.25	4.11
=1 if no road passing through the village	8	1.00	0.00	8	1.00	0.00	0.00	0.00
Distance to the nearest road (km)	8	7.88	4.36	8	10.62	6.19	-2.75	2.68
=1 if no market place in the village	8	0.75	0.46	8	0.62	0.52	0.12	0.25
Distance to the nearest market place (km)	8	5.50	3.96	8	4.12	6.13	1.38	2.58
=1 if no permanent cereal trader in the village	8	0.75	0.46	8	0.88	0.35	-0.12	0.21
Transport cost city-village (in CFA-F/sack of grain)	8	825.00	539.84	8	825.00	377.02	0.00	232.80
End-of-season harvest indicators (2011 WRSI for sorghum (5))	8	82.00	9.44	8	90.62	8.11	-8.62**	4.40
=1 if 2011 rain started late (in july)	8	0.62	0.52	8	0.38	0.52	0.25	0.26
=1 if 2011 precipitations were less abundant than usual	8	1.00	0.00	8	1.00	0.00	0.00	0.00
Household-level characteristics								
Household (HH) size (# HH members)	80	12.35	5.12	80	11.55	5.88	0.80	0.87
Number of HH members below 14	80	6.60	3.27	80	6.05	3.89	0.55	0.55
=1 if polygamous HH	80	0.65	0.48	80	0.53	0.50	0.12	0.10
=1 if male household-head (HH-H)	80	0.99	0.11	80	1.00	0.00	-0.01	0.01
Age of HH-H	80	53.45	12.19	80	52.73	13.42	0.73	2.71
=1 if HH-H native from village	80	0.96	0.19	80	0.97	0.16	-0.01	0.03
=1 if HH-H Mossi (main ethnic group)	80	0.93	0.27	80	0.74	0.44	0.19	0.15
=1 if HH-H muslim (main religious group)	80	0.91	0.28	80	0.90	0.30	0.01	0.06
=1 if HH-H close relative of a village leader	80	0.55	0.50	80	0.50	0.50	0.05	0.08
=1 if HH-H went to formal school	80	0.34	0.48	80	0.41	0.50	-0.08	0.10
=1 if HH-H part of a village organisation	80	0.14	0.35	80	0.16	0.37	-0.03	0.05
=1 if house made of concrete wall	80	0.03	0.16	80	0.03	0.16	-0.00	0.02
=1 if HH owns a motorcycle	80	0.38	0.49	80	0.46	0.50	-0.09	0.07
=1 if any small business	80	0.50	0.50	80	0.62	0.49	-0.13	0.11
=1 if HH owns some livestock	80	0.99	0.11	80	0.96	0.19	0.02	0.03
Cattle size (# of head)	80	21.35	23.56	80	22.56	25.26	-1.21	4.56
Surface of land cultivated (Ha/cap)	80	0.28	0.18	76	0.29	0.16	-0.01	0.03
=1 if self-sufficient in cereals over the last 3 years	80	0.31	0.47	79	0.38	0.49	-0.07	0.11
2011 cereal production (kg/cap)	77	102.53	104.12	80	111.68	97.67	-9.15	28.73
PPI consumption index (6)	80	19.57	5.98	80	21.20	6.93	-1.63	1.38
Annual total expenditures (in 1000 CFA-F/cap)	80	69.16	43.87	80	79.54	34.79	-10.38	7.97
Share of food expenditures	80	0.75	0.14	80	0.72	0.16	0.03	0.04
Share of health expenditures	80	0.02	0.05	80	0.01	0.02	0.01**	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 11: Balance test on outcomes, no-road villages

	TREATMENT (T)			**CONTROL (C)**			**(T) - (C)**	
	N	MEAN	SD	N	MEAN	SD	DIFF	SE
Food access								
Share of foodgrain purchased locally	27	0.11	0.32	29	0.66	0.48	-0.54***	0.19
Annual distance travelled to purchase grain (walking min/bag)	27	87.30	31.20	29	56.04	28.68	31.25***	8.49
Nominal price paid for 100 kg of foodgrain	25	14.12	1.69	28	13.74	1.66	0.37	0.61
Nutrition								
19-49 years old adult's BMI	190	20.45	2.14	180	20.49	2.60	-0.03	0.36
5-19 years old children's BMI-for-Age	326	-1.09	0.88	266	-0.98	0.97	-0.10	0.16
0-4 years old children's BMI-for-Age	149	-0.26	0.95	139	-0.18	0.98	-0.08	0.18
=1 if adult's BMI <18.5	190	0.18	0.38	180	0.21	0.41	-0.03	0.06
=1 if 5-19 children BMI-for-age <-2	326	0.16	0.37	266	0.15	0.36	0.01	0.03
=1 if 0-4 children BMI-for-age <-2	149	0.03	0.16	139	0.02	0.15	0.01	0.01
Food purchases and consumption								
=1 if HH purchased any foodgrain	80	0.34	0.48	79	0.39	0.49	-0.05	0.11
Total quantity of foodgrain purchased (in 100 kg/cap)	80	0.10	0.19	79	0.14	0.26	-0.03	0.05
Total expenditures on foodgrain (in 1000 CFA/cap)	80	1.38	2.43	79	1.84	3.78	-0.46	0.71
Real annual foodgrain disposable (ln of kg/cap)	79	5.47	0.49	78	5.49	0.57	-0.01	0.11
=1 if real annual foodgrain disposable >190 kg/year	79	0.65	0.48	78	0.71	0.46	-0.06	0.09

(1) Level of significance : * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
(2) Standard errors correspond to village-level Cluster-Robust-Standard-Errors (CRSE)

Table 12: Changes in nutritional outcomes before the intervention (test of the parallel trend assumption), no-road villages

	DID		ANCOVA	
	HOUSEHOLD	INDIVIDUAL	HOUSEHOLD	INDIVIDUAL
	(1)	(2)	(3)	(4)
I. Level of nutritional outcomes				
	19-49 years old adult's BMI			
TREAT	-0.087 [0.294]	-0.001 [0.273]	-0.155 [0.290]	-0.017 [0.232]
TREAT x NO ROAD	-0.166 [0.363]	-0.257 [0.358]	-0.007 [0.341]	-0.097 [0.269]
Observations	1105	2990	350	796
	5-18 years old children's BMI-for-age			
TREAT	-0.085 [0.080]	-0.045 [0.106]	-0.114 [0.078]	-0.114 [0.092]
TREAT x NO ROAD	0.021 [0.162]	-0.041 [0.166]	0.042 [0.164]	0.008 [0.165]
Observations	1119	4579	362	1349
	0-4 years old children's BMI-for-age			
TREAT	-0.057 [0.161]	-0.030 [0.125]	-0.011 [0.154]	-0.033 [0.141]
TREAT x NO ROAD	0.117 [0.273]	0.011 [0.253]	0.097 [0.269]	0.068 [0.264]
Observations	967	2197	293	577
II. Prevalence of moderate or acute malnutrition (MAM)				
	= 1 if 19-49 years old adult's BMI <18.5			
TREAT	0.004 [0.054]	0.006 [0.054]	-0.001 [0.054]	0.009 [0.037]
TREAT x NO ROAD	0.002 [0.069]	0.006 [0.071]	-0.012 [0.075]	-0.033 [0.056]
Observations	1105	2990	350	796
	= 1 if 5-18 years old children's BMI-for-age <-2			
TREAT	0.024 [0.033]	0.003 [0.042]	0.020 [0.022]	0.016 [0.028]
TREAT x NO ROAD	-0.004 [0.057]	-0.016 [0.060]	0.007 [0.046]	-0.002 [0.042]
Observations	1119	4579	362	1349
	= 1 if 0-4 years old children's BMI-for-age <-2			
TREAT	0.054 [0.038]	0.028 [0.030]	0.039* [0.022]	0.033* [0.018]
TREAT x NO ROAD	-0.056 [0.060]	-0.042 [0.053]	-0.056 [0.035]	-0.063* [0.038]
Observations	967	2197	293	577

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

Table 13: Analysis of attrition (nutritional outcomes)

	DID
	(1)
Individual attrition	
	=1 if 19-49 years old adults measured
TREAT	0.024
	[0.035]
Observations	2409
	=1 if 5-18 years old children measured
TREAT	-0.051
	[0.053]
Observations	3844
	=1 if 0-4 years old children measured
TREAT	-0.033
	[0.043]
Observations	1708

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

Table 14: Heterogeneous effects on nutrition

	DID		ANCOVA	
	HOUSEHOLD	INDIVIDUAL	HOUSEHOLD	INDIVIDUAL
	(1)	(2)	(3)	(4)
I. Level of nutritional outcomes				
	19-49 years old adult's BMI			
TREAT	0.078 [0.219]	0.108 [0.188]	-0.002 [0.227]	-0.076 [0.169]
TREAT x NO ROAD	0.573 [0.376]	0.681** [0.344]	0.792* [0.399]	0.517 [0.331]
Observations	736	1818	351	716
	5-18 years old children's BMI-for-age			
TREAT	0.101 [0.078]	0.150** [0.067]	0.075 [0.075]	0.050 [0.078]
TREAT x NO ROAD	0.191 [0.124]	0.117 [0.100]	0.190* [0.115]	0.207* [0.110]
Observations	747	2941	360	1174
	0-4 years old children's BMI-for-age			
TREAT	0.085 [0.155]	0.093 [0.140]	0.146 [0.124]	0.052 [0.105]
TREAT x NO ROAD	0.252 [0.213]	0.303 [0.196]	0.193 [0.169]	0.232 [0.163]
Observations	635	1402	289	562
II. Prevalence of moderate or acute malnutrition (MAM)				
	= 1 if 19-49 years old adult's BMI <18.5			
TREAT	0.041 [0.036]	0.034 [0.028]	0.037 [0.033]	0.060* [0.033]
TREAT x NO ROAD	-0.121** [0.057]	-0.108** [0.043]	-0.154*** [0.052]	-0.146** [0.057]
Observations	736	1818	351	716
	= 1 if 5-18 years old children's BMI-for-age <-2			
TREAT	-0.058 [0.039]	-0.050 [0.037]	-0.047 [0.037]	-0.024 [0.039]
TREAT x NO ROAD	0.015 [0.052]	0.017 [0.048]	0.014 [0.048]	-0.023 [0.052]
Observations	747	2941	360	1174
	= 1 if 0-4 years old children's BMI-for-age <-2			
TREAT	-0.079** [0.031]	-0.050** [0.025]	-0.025 [0.023]	-0.017 [0.020]
TREAT x NO ROAD	-0.003 [0.055]	-0.018 [0.046]	-0.045 [0.053]	-0.033 [0.042]
Observations	635	1402	289	562

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

Table 15: Impacts of FSGs on production, income generating activities and visits to the household

	SIMPLE DIFFERENCE	
		ACROSS NO ROAD
	(1)	(2)
	if any non-member stay	
TREAT	-0.052	-0.007
	[0.065]	[0.073]
TREAT x NO ROAD	-	-0.114
		[0.132]
Observations	389	389
	Annual stays of non-member (in man/day)	
TREAT	-0.890	-0.596
	[0.826]	[1.143]
TREAT x NO ROAD	-	-0.776
		[1.724]
Observations	389	389
	Annual cereal transfer (in kg/cap)	
TREAT	-1.817*	-2.249*
	[0.981]	[1.289]
TREAT x NO ROAD	-	1.104
		[2.078]
Observations	388	388
	=1 if any member involved in IGA	
TREAT	-0.025	0.011
	[0.037]	[0.049]
TREAT x NO ROAD	-	-0.090
		[0.078]
Observations	391	391
	Annual total income from IGA (in 1000 CFA)	
TREAT	-56.694	-47.727
	[43.892]	[67.903]
TREAT x NO ROAD	-	-24.393
		[82.150]
Observations	391	391
	2012 cereal production (in kg/cap)	
TREAT	12.415	9.363
	[13.396]	[16.617]
TREAT x NO ROAD	-	7.905
		[29.857]
Observations	387	387

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

Table 16: Effects of anticipated purchases on adult nutrition, before and after the lean season (years 2010-2011 and 2012-2013 pooled together)

	19-49 YEARS ADULT'S BMI	
	HH FE	**IND FE**
	(1)	(2)
BEFORE LEAN SEASON (B)		
=1 if any foodgrain purchased before own stock depletion	0.336** [0.151]	0.304* [0.161]
Quantity of foodgrain purchased before stock depletion	0.088** [0.035]	0.100** [0.042]
Observations	2122	2122
AFTER LEAN SEASON (B)		
=1 if any foodgrain purchased before own stock depletion	0.042 [0.147]	-0.017 [0.117]
Quantity of foodgrain purchased before stock depletion	0.025 [0.022]	0.012 [0.019]
Observations	2047	2047
VARIATION OVER LEAN SEASON (A-B)		
=1 if any foodgrain purchased before own stock depletion	-0.422** [0.181]	-0.394** [0.192]
Quantity of foodgrain purchased before stock depletion	-0.073* [0.042]	-0.064 [0.044]
Observations	1888	1888

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

Table 17: Daily foodgrain ration and the timing of purchase using monthly data

	SIMPLE DIFFERENCE	ACROSS NO ROAD
	(1)	(2)
Timing of food storage		
	Number of months before own stock depletion	
TREAT	-0.626 [0.460]	-0.028 [0.441]
TREAT x NO ROAD	-	-1.510 [1.141]
Observations	393	393
Timing of food purchases		
	=1 if any foodgrain purchased before own stock depletion	
TREAT	-0.058 [0.062]	0.023 [0.082]
TREAT x NO ROAD	-	-0.204* [0.120]
Observations	393	393
	Quantity of foodgrain purchased before own stock depletion (100kg/cap)	
TREAT	-0.093* [0.054]	-0.028 [0.069]
TREAT x NO ROAD	-	-0.165 [0.103]
Observations	393	393

(1) Standard-Errors in brackets are village-level Wild-Cluster-Boostrapped Standard-Errors.
(2) Level of significance: * $p < 0.10$, ** $p \leq 0.05$, *** $p < 0.01$.

Table 18: Heterogeneous effects on nutrition for households who did not use FSGs

	DID		ANCOVA	
	HOUSEHOLD	INDIVIDUAL	HOUSEHOLD	INDIVIDUAL
	(1)	(2)	(3)	(4)
I. Level of nutritional outcomes				
	19-49 years old adult's BMI			
TREAT	0.230	0.369^{**}	0.222	0.120
	[0.185]	[0.168]	[0.192]	[0.155]
Observations	652	1623	311	641
	5-18 years old children's BMI-for-age			
TREAT	0.186^{***}	0.206^{***}	0.165^{***}	0.138^{**}
	[0.061]	[0.052]	[0.058]	[0.058]
Observations	658	2588	317	1030
	0-4 years old children's BMI-for-age			
TREAT	0.239^{**}	0.252^{**}	0.248^{***}	0.189^{**}
	[0.112]	[0.105]	[0.088]	[0.086]
Observations	564	1245	256	499
II. Prevalence of moderate or acute malnutrition (MAM)				
	= 1 if 19-49 years old adult's BMI <18.5			
TREAT	-0.022	-0.021	-0.029	-0.003
	[0.036]	[0.031]	[0.033]	[0.032]
Observations	652	1623	311	641
	= 1 if 5-18 years old children's BMI-for-age <-2			
TREAT	-0.056^{*}	-0.049^{*}	-0.046^{*}	-0.035
	[0.028]	[0.027]	[0.026]	[0.028]
Observations	658	2588	317	1030
	= 1 if 0-4 years old children's BMI-for-age <-2			
TREAT	-0.085^{***}	-0.058^{**}	-0.044^{*}	-0.033^{*}
	[0.026]	[0.022]	[0.023]	[0.018]
Observations	564	1245	256	499

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

Appendix 4: Figures and pictures used in focus groups discussions

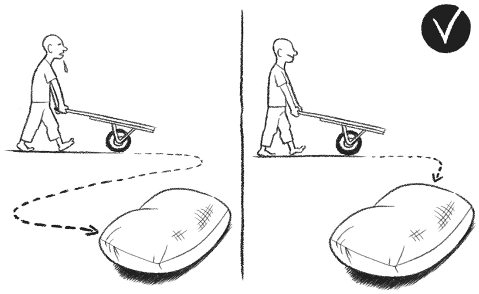


Figure 15: Visual aid example "Households bought foodgrain at lower prices in FSG villages"

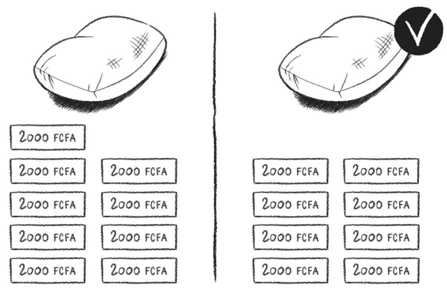


Figure 16: Visual aid example "Households did not consume more or better food in FSG villages"

Figure 17: Visual aid example “Households had a better nutritional status after the drought in FSG villages”

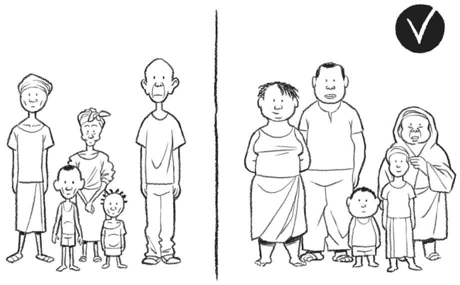


Figure 18: Visual aid example “The paradox”

Figure 19: Canonical patterns of timing of purchases

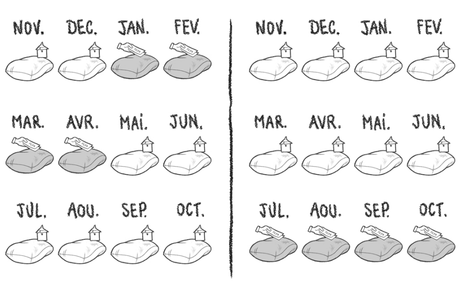


Figure 20: Canonical patterns of timing of purchases and consumption

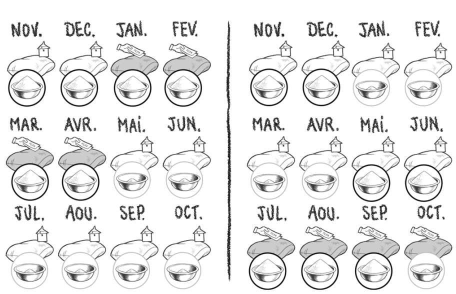


Figure 21: Example of board and cards