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Buy as you need: Nutrition and food storage imperfections☆

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ABSTRACT

In this paper, we investigate whether and how a more steady supply of foodgrain in local markets impacts the nutritional status (measured with body-mass-indexes) 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 in Burkina Faso, we reach three conclusions. First, especially in remote areas where local markets are thin, the program 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 we argue that it is a change in the timing of food purchases, translated into a change in the timing of consumption, that drives the nutritional improvement. A simple two-period model shows that, once we account for various forms of storage costs, an increase in nutrition does not necessarily require larger quantity of food purchases or even consumption. Our last and unexpected conclusion is that the losses associated with foodgrain storage do not stem from physical losses in household granaries but rather from inefficient seasonal bodymass fluctuations. One plausible mechanism behind this particular storage imperfection rests on the households' urge to consume readily available foodgrain.

1. Introduction

A well-known problem that afflicts many poor and isolated rural areas is seasonal fluctuations in prices, food availability and incomes (Fafchamps, 1992). Due to economic and physical isolation, market integration is weak 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; Renkow et al., 2004; Barrett, 2008). These seasonal fluctuations in prices and food availability have dramatic consequences on health and nutrition, children's nutrition in particular (Behrman, 1988, 1993; Sahn, 1989; Branca et al., 1993; Dercon and Krishnan, 2000; Vaitla et al., 2009; Bhagowalia et al., 2011; Abay and Hirvonen, 2016; Hirvonen et al., 2016; Christian and Dillon, 2018). 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).[1] To the extent that seasonal fluctuations are anticipated by households, the question arises as to why households are unable to smooth their consumption across seasons. A prominent explanation put forward by economists is a lack of liquidity that prevents farmers from exploiting intertemporal arbitrage opportunities (Foster, 1995; Stephens and Barrett, 2011; Burke et al., 2018; Basu and Wong, 2015; Fink et al., 2014). A lack of access to effective savings and storage devices can have the same consequences of hindering consumption smoothing (Fafchamps et al., 1998; Aggarwal et al., 2018).

A recent literature has emerged that evaluates, in randomized-control settings, the relevance of these financial constraints for poor households exposed to seasonal price fluctuations. Specifically various authors have evaluated the impacts of relaxing either credit constraints (Burke et al., 2018; Basu and Wong, 2015) or saving constraints (Aggarwal et al., 2018). Overall they find sizable effects of the improved supply of financial instruments on farm income in contexts where farmers are net food sellers.

In this paper, we analyze the effects of an intervention that tackles the problem more directly and in a context where households are net

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[1] In their paper, Christian and Dillon (2018) explicitly link the children's exposition to seasonal shocks and their adult outcomes.

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foodgrain buyers. It seeks to improve the local supply of foodgrain and to thereby dampen the seasonality of foodgrain availability and prices. Operating through a nationwide farmer organization, it consists in setting up village-level cooperatives in charge of buying grain from outside sources and selling it locally in poor and isolated areas of Burkina Faso. The approach followed is thus to smooth the distribution of foodgrain across the territory by directing foodgrain from surplus areas (where net exports are positive) to deficit areas (where net imports are positive). We take advantage of a randomized extension of the program to evaluate its impacts on people's livelihood. Moreover, the occurrence of a drought caused a severe food stress in the program area during the years 2011–12, that is during the first year following the program's extension. Our initial research plan was to collect data during and after the 2012-13 campaign. To seize the opportunity offered by this adverse shock, however, we decided to move forward the first endline survey to the end of 2011–12. A cost associated with this last minute change of strategy is that we were not able to collect data at mid-year to track changes in consumption and nutrition between seasons.

Three main conclusions emerge from the analysis. First, the program has greatly improved the body-mass-index (BMI) of both adults and children. More precisely, the setting up of a foodgrain selling point in a village enables to considerably reduce the gap between the BMI-for-age z-score of children who belong to beneficiary households, on the one hand, and the WHO standards for a well-nourished population, on the other hand.

Our second result concerns the pathways to these nutritional improvements. We show that rather than increasing the total quantity of foodgrain purchased and consumed as we would have expected, beneficiary households modified the timing of their purchases. Specifically, being better insured against the uncertainty of future food availability and affordability, households delayed their purchases until later in the season. As a consequence, they limited their home storage of food and the associated losses. These findings, which came as a surprise to the program management, are consistent with a two-period model of food purchases and nutrition in which storing food is costly.

Our last result is also unexpected: the losses associated with foodgrain storage do not stem from physical losses in household granaries but rather from seasonal body-mass fluctuations that are inefficient. On the basis of rich, non-experimental evidence, we suggest that households face self-control problems (and to a lesser extent redistributive pressures), which constrain the management of their foodstock. Storing accessible food at home makes immediate consumption tempting and causes body mass storing. A new mechanism to improve nutrition, unintended by the conceivers of the program, is thus uncovered: by postponing food purchases, households are better able to resist the urge to consume food in the post-harvest period. For a given aggregate consumption level, smaller seasonal variations result in heavier weights because individuals save the metabolic cost of storing, maintaining and de-storing body mass (Prentice and Cole, 1994).

This last finding resonates with a recent literature on the effects of community storage programs: it shows that households are willing to pay to store their own foodgrain outside of their dwellings in order to escape kin taxes or self-control problems (Aggarwal et al., 2018; Basu and Wong, 2015; Le Cotty et al., 2019). Relatedly, Dillon et al. (2017) argue that the same type of savings constraints explains why poor households do not take advantage of bulk discounts. In the case of kin taxes, the source of storage costs lies in redistributive pressures originating from outside the household (Platteau, 2000, 2014; Baland et al., 2011; Dupas and Robinson, 2013; Jakiela and Ozier, 2015; Brune et al., 2016). In the case of self-control, the pressure originates from within the household (or within the individual self) and prevents an optimal allocation of consumption across seasons. Interestingly, this issue arises not only in contexts of acute poverty (Ashraf et al., 2006; Banerjee and Mullainathan, 2010; Bernheim et al., 2015), but also in rich economies (see DellaVigna, 2009, for a review, Olafsson and Pagel, 2018, for evidence of "hand-to-mouth" behavior, whereby individuals over-spend when they receive their pay-check).

The outline of the paper is as follows. In Section 2, we provide details about the nature of the intervention and the experimental design. Section 3 presents the data and descriptive statistics. In Section 4, we lay out our empirical strategy before estimating the impacts of the intervention on food access, nutrition, purchases and consumption. In Section 5, we show that our set of results is compatible with the predictions of a simple two-period model where, as in Foster (1995) or Dercon and Krishnan (2000), an individual's utility depends on her nutritional level (a stock) instead of (only) her consumption level (a flow). In this model, food can be stored either in a granary - which entails conventional storage costs - or in the form of body mass, which causes costs associated with metabolic processes. Section 6 proposes further evidence, both quantitative and qualitative, to support our interpretation of the underlying mechanisms. Section 7 discusses the relevance of alternative explanations for our set of results. Section 8 concludes.

2. Program and experimental design

2.1. The Food Security Granaries program

In the late 1970s, in order to mitigate the food access problem, many aid organizations and governments widely promoted the creation of cereal banks. A key objective of these community-based interventions was to reduce market risks understood as availability risk (food supply becomes less reliable in times of need) or price risk (food price rises in times of need). Most of the 4000 cereal banks that were inventoried in Sahelian countries in 1991 collapsed in the late 1990s 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 cereal banks has nonetheless developed over the last two decades. An example of such initiative 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 was aimed at revitalizing a network of about 400 former cereal banks in an area where most households engage in subsistence agriculture and are net food buyers. Food access is critical, especially in the rainy season when people engage in heavy agricultural work, grain stored in family granaries starts to be depleted, food prices tend to increase, and access to villages becomes more difficult because of heavy rain (hence the name lean season to characterize this period of acute stress).

The pillars of the FSG intervention consist of 1) setting up a local, informal storing and marketing organization whose function is to buy foodgrain from surplus areas (in the south of the country), store it, and sell it throughout the agricultural year (to any willing purchaser) at a price that covers costs and includes a predetermined margin[2]; 2) mobilizing a network of pre-existing farmer groups 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.[3]

An important feature of the FSGs is that they are organized as local antennas belonging to a national federation (called FNGN - Fédération

[2] The recommendation of the program is to set the margin at 500 CFA-F per bag, corresponding to a moderate 2.5% markup during the year of the intervention.

[3] 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 inherently complementary.

Nationale des Groupements Naam) in charge of managing the program. At the antenna level, a village assembly (called "coordination villageoise") made of key representatives of the village community appoints and supervises an executive committee (called "comité de gestion") tasked with the daily management of the FSG. Thanks to its network structure, the FSGs can fulfill the first above function effectively. More precisely, economies of scale can be reaped through the pooling of food purchases and the collective organization of transportation from surplus areas. In addition, information regarding local food availability and prices is easily circulated. Because in our whole study area, most households are net buyers of foodgrain, the 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.[4]

The supply of training, monitoring and working capital enhances the effectiveness of FSGs as food sellers on local markets. Importantly, the FSGs are required to sell exclusively against cash, and the funds obtained from the Federation are used only to finance their purchases of foodgrain and tide over the storing period. A commercial interest (8% in 2011–12) is charged on the corresponding loans. During a public meeting organized by the Federation annually, village representatives present and motivate their demand for funds in front of the central "credit committee". Members of the latter then compare this demand to their estimation of the future foodgrain deficit based on production and population information collected at the level of the village.[5] As a result of this comparative excercise, and of consultation of the Federation's grassroot operators, they are able to also assess the management skills of the local executive committee and the monitoring ability of the village assembly. Once the loan is disbursed, the Federation checks 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 perpetrators in court, thus adding external sanctioning to peer pressures. Because of this organizational and financial support, village granaries may possess a comparative advantage over the private sector, thereby enabling them to operate even where and when private merchants are absent.

To ensure that villagers are well informed about the program, several meetings are organized not only during the first year of the intervention but also during each agricultural campaign. The whole village community is invited to participate in these meetings in the course of which the needs of the village and the credit amount requested by the cooperative are discussed. Furthermore, villagers are informed about the quantity and delivery date of each stock of foodgrain purchased.

2.2. 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.[6] In the area targeted for gradual scaling-up of the program, the NGO identified eligible villages that had expressed an interest in 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 become part of the program two years later. Although the number of treated villages is small, our ability to detect impacts of the program (the statistical power of our experiment) is quite satisfactory (see Section 3.2).[7]

The intervention consists in setting up a FSG at the village level with the purpose of storing and selling foodgrain obtained from surplus areas located in the southern (non-Sahelian) part of the country. Because the villages in the study area tend to be isolated and the market share of the FSG is rather small, we do not expect significant spillovers to neighboring villages. We assess these two points quantitatively in Section 4.1.

While the operational framework is identical in all villages, the level of financial support to the FSGs, in the form of credit, varies across villages and over time, depending on the demand and needs of each village. The mean credit corresponds to 3150 euros while all credits granted to the sampled villages were between 1500 and 5500 euros. This variation in credit amount is not an issue for our identification strategy since we estimate "intent-to-treat" (ITT) impacts. In other words, we answer questions such as "does the set-up of a FSG in the village of residence of a child improve her nutrition?". Answers correspond to average effects over a set of villages that may have responded differently to the new opportunity (some may have seeked/received more credit than others). We are thus following an approach commonly used in the literature dealing with the impacts of microfinance in RCT settings (Banerjee et al., 2015; Ksoll et al., 2016). As long as the randomization was successful, the comparison between treatment and control villages allows to estimate the average causal impacts of the FSG intervention on the local population.

3. Data and descriptive statistics

3.1. Data

Our sample households were surveyed three times during the agricultural years 2010-11 and 2011–12. Fig. 1 presents the timing of the intervention and the surveys. The first survey was undertaken before the 2011 lean season and the second survey at the end of that season. Both took place before the announcement of the program and constitute our baselines. As for the third survey, it was implemented at the end of the 2012 lean season and it coincides with the end of the first year of the intervention. Our impact assessment relies on Rounds 2 (pre-intervention) and 3 (post-intervention). Round 1 data is used exclusively for descriptive purposes and to test the parallel trend assumption. We conducted two additional survey rounds in 2012–13. Unfortunately the renewal of the program turned out to be problematic as the result of embezzlement, complicating the use of this data for impact evaluation.[8]

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. Household attrition is low - less than 3 percent - 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

[4] The funds necessary to purchase foodgrain are typically obtained from livestock rearing and small business activities.

[5] This estimation is reasonably precise because signs of a bad harvest are detectable early: not only irregular (or insufficient) rains but also poorly developed ears of the grain are directly observable by the villagers. In fact, it is the onset of the rainy season that is the most critical determinant of the state of the future harvest.

[6] During the period 2002-10 the program succeeded in reaching as many as 300 villages out of the targeted 400 villages belonging to the semi-arid Northern region of the country. This area had been deliberately chosen by the NGO because of its chronic vulnerability to climate shocks (droughts) and malnutrition. For our impact study we used the opportunity presented by the extension of the program to the 100 remaining villages.

[7] No pre-analysis plan was registered for this randomized control trial.

[8] A grassroot employee of the Federation who was in charge of six villages stole the money entrusted to him to pay back the village loans. As a result, the bank denied these six villages the renewal of their loan and the village cooperatives were asked to pay back their outstanding loan (again). It is noteworthy that some of these cooperatives complied and re-gained access to the program. We nevertheless provide estimates of the program's impacts on nutrition in 2012-13 in the online appendix.

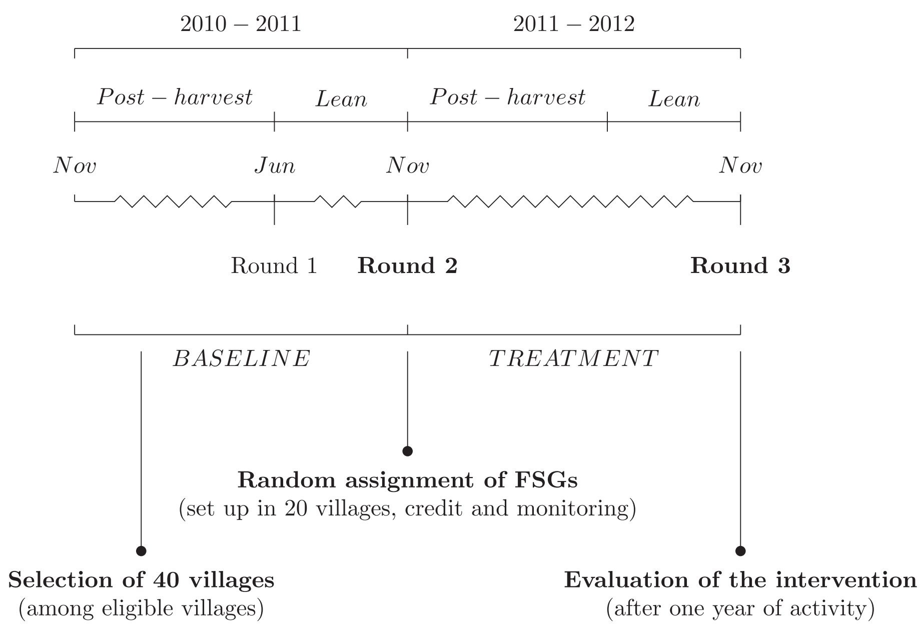

Fig. 1. Timing of the intervention and the surveys.

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: 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-for-age < −2)	0.13	0.33	0.16	0.37	0.18	0.39
= 1 if 0.5-4y children's wasting (BMI-for-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
Panel B: 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 (in village)	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

(1) All figures are calculated on the basis of our sample of 200 households drawn from control villages.

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 (type and location) involved and the transaction motives. Because households purchase foodgrain mainly in bags of 100 kg, they make only a few transactions over the course of one year and remember well the details of each transaction. 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 were particularly cautious in our identification of children. To avoid mistakes between rounds, we relied on detailed information regarding their identity and did not hesitate to use photographs. Age measurement is particularly difficult in contexts where parents do not necessarily know the birth dates of their children. We therefore asked to see birth certificates (the question was repeated at each round if the certificate had not been shown before). By the end of the last round, we were able to obtain exact birth date for 48% of the 0–5 years old children (for the 5–18, the proportion is 38%). The spike plots for weight, height for children confirm that distributions are smooth for weight and height (online appendix, Figs. 1 and 2). As for age, spikes at round ages are modest for the 0 to 5 years-old children but more marked for the 5 to 18 (online appendix, Figs. 1 and 2). Fortunately, while the measures of BMI-for-age are very sensitive to ages (in months) below 5, they are less so for later ages. Furthermore, our estimated impact of the program on nutrition are qualitatively similar if we exclude children for which we do not have an exact birth date (online appendix, Tables 11 and 12).

3.2. Descriptive statistics, balance tests, attrition and power calculations

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 z-score for children. 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. These constitute objective measures that are sensitive to short-term variations in food consumption. Based on weight and height (and controlling for age in the case of children), they measure 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. According to WHO standards, adults with BMI below 18.5 are underweight. Children and adolescents presenting z-score below −2 suffer from wasting. 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". In the case of young children, we verify that our results hold with measures of nutrition based on weight-for-height.[9]

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, 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 three 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).

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). During that same year, purchases amounted to 53 kg per capita, corresponding to about one-third of annual consumption.[10] Tight local market conditions translated into very high prices from the very beginning of the agricultural year (online appendix, Fig. 1). The mean price of foodgrain was almost 50 percent higher in 2011-12 than in the previous year, a rate of increase also observed for other crops (FAO et al., 2012). Clearly, the timing of our program evaluation coincides with a drought year and high local food prices, 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 in the form of 100-kg bags. Sorghum is the most important traded foodgrain, far ahead of millet, maize and rice: in 2010–11, it amounted to 80 percent of all grain bought. Although households emphasize their preference for buying close to their dwelling (more on this later), nearly half of their purchases were made outside their village. In 2011–12, the situation worsened with only 40 percent of the purchased cereals bought inside the village of residence. The timing of purchases is another important dimension of food security. Households buy foodgrain through the agricultural year with a small peak during the lean season (online appendix, Fig. 2). In 2011–12, however, a larger proportion of foodgrain purchased (about two-thirds) was acquired before the lean season. This is because stocks started to deplete earlier and households bought larger quantities before depletion of own stock.

Activity of FSGs — Over the agricultural year 2011–12, each FSG sold an average of 18.1 tons of foodgrain. Our data shows that on average the FSGs more than fully replenished their foodgrain stock during the campaign itself. This is because the loan obtained to finance the purchase of foodgrain by the local cooperative is relatively small compared to local demand. Once the stock initially purchased by the GSA is sold out, the proceeds of the activity are immediately used to buy a new stock. This suggests that local cooperatives do not take full advantage of the

[9] 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. When levels of malnutrition are assessed for a population of children and adolescents, BMI-for-age measures are generally preferred to weight-for-height measures for two main reasons. First, the relationship between weight and height varies with age so that a similar level of the weight-for-height ratio for children of different ages may hide important differences in their nutritional status (Cole et al., 2007 argue that this caveat may explain the poor performance of measures of malnutrition based on weight-for-height when it comes to predict mortality). Measures based on BMI-for-age address this concern since they are based on height and use age-specific benchmarks. Second, the weight-for-height measure is typically used only for children up to 5 (the World Health Organization publishes growth standards based on this measure only up to age 5). This is because, beyond that age, weight continues to increase but height growth slows down, rendering the measure uninformative. In contrast, BMI-for-age can be used to estimate thinness in older children and is therefore the only measure that applies throughout childhood, from age 5 onwards (Flegal et al., 2002; Cole et al., 2007; Mei et. al., 2002). Note however that the results presented in the paper qualitatively hold if we use weight-for-height instead, but they are less significant (online appendix, Tables 10 and 11).

[10] Interestingly, very few households are involved in grain sales while those sales concern negligible quantities (Table 1). This suggests that households prefer relying on storage rather than on market to smooth consumption within and across years.

temporal arbitrage possibilities (buying when the price is the lowest after harvest and selling throughout the season) but instead restock their granary when prices are already rising. When analyzing transaction data, we observe that the FSGs' overall market share was 14 percent but as high as 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.[11] These two pieces of information indicate that, although they have not fully substituted for private suppliers, the village granaries were a significant actor in local food markets during the initial year of their operation, potentially driving down local prices at the village level.

Balance tests — Tables 2 and 3 present balance tests on baseline characteristics and outcomes, respectively. The online appendix (Tables 1 and 2) present the same for the sample of "no-road villages" for which heterogenous effects will be observed. A total of 16 villages fall into this category and they are equally distributed across treatment and control.[12] The tables reveal that there is no significant difference between treatment and control villages on a large set of village and household characteristics and that for most outcomes there is no pre-existing difference between them either.[13] It remains that some differences, albeit not statistically significant, are relatively large. This is most notably the case for the share of grain purchased locally, which is not surprising since only a small proportion of households was concerned (recall that the baseline was collected after a good harvest). In the case of no-road villages, however, two food access variables exhibit statistically significant differences, suggesting more precarious food access in the treatment villages (online appendix, Table 1). The same villages also experienced a worse season in terms of rainfall, as measured by an end-of-season harvest indicator (online appendix, Table 2). As a robustness check, we verify that our results stand when we systematically control for pre-existing differences in exogenous time-varying characteristics, such as indicators of the quality of the agricultural campaign (see Section 4.1). Finally, because anthropometric indicators were collected twice before the intervention, we verify that changes in nutritional status across time are not systematically different between the two types of villages: in other words, we test the "parallel trend assumption". We present the results of this test after introducing our methodology in the next section.

Attrition — While household attrition is very low (see Section 3.1), at each survey round some individual members of the surveyed households were absent from the village on the day of the survey. 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 (online appendix, Table 3). Reassuringly, we find that the program had no effect on the probability to be weighed and measured.

Power calculation — Despite a limited number of control and treatment villages (a total of 40), power calculations suggest that the experiment allows us to detect economically significant impacts on the main outcomes of interest. Thus the power to detect an improvement of 0.2 standard deviation in BMI measures is above 80% for all age categories (online appendix, Table 4). For the other main outcomes of interest (market and consumption related outcomes), power levels are close to 1.00 for an effect of 0.5 standard deviation (but lower for an effect of 0.2 standard deviation). The comparison of these levels of power with the sizes of the effects we estimate (Section 4.2) indicates that our experiment is well powered for nutrition and market-related outcomes. As for consumption and purchases, our point estimates are typically negative, enabling us to safely rule out even modest increases in these dimensions.

4. Methodology and results

Before investigating the impact of the intervention on various market outcomes and components of wellbeing, we describe the methodology used to assess it.

4.1. Methodology

Our main 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).[14] Specifically, the model we estimate for individual outcomes is:

$$y_{ijt} = \beta_1 P_t + \beta_2 T_j P_t + \tau_j + \varepsilon_{ijt} \tag{1}$$

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 intervention. This is done with respect to the anthropometric indicators for which we have two observations prior to the intervention. Reassuringly, we fail to reject that the treatment and the control groups follow the same trend (online appendix, Tables 5 and 6).

Another important assumption for the DID to capture the full impact of the program is the absence of spillover effects from treatment to control villages. In particular, we could worry about a general equilibrium effect going through the foodgrain market: if local markets in control villages are affected by the FSG operated in the treatment villages, foodgrain prices would be expected to decrease not only in the latter but also in the former villages. Note that if this were true, the impacts we calculate would be underestimated. However, the spillover effect from treatment to control villages is unlikely in our case.

[11] FSGs purchases represent 4.5 percent of total annual consumption in treatment villages.

[12] There are 8 no-road villages in the treatment group (77 households) and 8 in the control group (80 households). As for villages served by a road practicable during the rainy season, they number 12 in the treatment group (119 households) and 12 in the control group (117 households).

[13] If we compare the distributions of baseline household characteristics using Kolmogorov Smirnov tests, we can reject differences for 29 out of 33 variables. We also test for the joint orthogonality of baseline characteristics in regressions where the treatment is explained by all baseline characteristics. We find that village characteristics are jointly orthogonal to the treatment status. However, 6 out of 23 household variables are significantly correlated with the treatment, leading to a rejection of joint orthogonality of household characteristics. Note, however, that since our empirical strategy is based on difference-in-difference estimates, we implicitly control for these differences at baseline.

[14] 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 and more appropriate to control for the past outcome of each observation. It appears that, for our main outcomes of interest, i.e. anthropometric measures of nutrition, autocorrelation is notably important, thus reducing the advantage of the technique. Furthermore, when, for some households, a specific outcome is observed for one time period only, these households do not contribute to the estimation of the program's effect. This is patently the case for purchase transactions: a significant number of households did not engage in any food purchase in the initial year. For the sake of testing the robustness of our results, we have nevertheless estimated ANCOVA specifications. As expected, our main results with DID are confirmed, particularly regarding nutrition effects. For outcomes related to purchases, results are confirmed but are less significant.

Table 2
Descriptive statistics and balance tests on baseline characteristics.

	Treatment (T)			Control (C)			(T) - (C)	
	N	MEAN	SD	N	MEAN	SD	DIFF	P-VAL
Village-level characteristics								
Village population (# individuals)	20	2735.20	3018.77	20	3793.55(4)	6619.97	−1058.35	0.60
Distance to the nearest community health center (km)	20	2.35	3.75	20	3.25	3.60	−0.90	0.43
Distance to the nearest town (km)	20	17.00	7.58	20	15.35	9.68	1.65	0.49
= 1 if no road passing through the village	20	0.40	0.50	20	0.40	0.50	−0.00	1.00
Distance to the nearest road (km)	20	3.15	4.76	20	4.25	6.53	−1.10	0.51
= 1 if no market place in the village	20	0.50	0.51	20	0.50	0.51	0.00	1.00
Distance to the nearest market place (km)	20	3.50	4.14	20	3.35	4.70	0.15	0.94
= 1 if no permanent cereal trader in the village	20	0.70	0.47	20	0.65	0.49	0.05	1.00
Transport cost city-village (in CFA-F/bag of grain)	20	642.50	408.23	20	655.00	377.28	−12.50	0.94
End-of-season harvest indicator (2011 WRSI for sorghum (5))	20	84.35	9.21	20	87.15	11.12	−2.80	0.36
= 1 if 2011 rain started late (in july)	20	0.55	0.51	20	0.50	0.51	0.05	1.00
= 1 if 2011 precipitations were less abundant than usual	20	0.95	0.22	20	1.00	0.00	−0.05	1.00
Household-level characteristics								
Household (HH) size (# HH members)	200	11.98	5.36	200	11.94	5.92	0.05	0.97
Number of HH members below 14	200	6.18	3.17	200	6.18	3.92	0.00	1.00
= 1 if polygamous HH	200	0.62	0.49	200	0.56	0.50	0.06	0.37
= 1 if male household-head (HH-H)	200	0.98	0.12	200	0.98	0.12	0.00	1.00
Age of HH-H	200	54.73	13.84	200	54.51	14.34	0.21	0.94
= 1 if HH-H native from village	200	0.95	0.22	200	0.92	0.28	0.03	0.27
= 1 if HH-H Mossi (main ethnic group)	200	0.90	0.30	200	0.74	0.44	0.15	0.18
= 1 if HH-H Muslim (main religious group)	200	0.81	0.40	200	0.79	0.41	0.02	0.89
= 1 if HH-H close relative of a village leader	200	0.47	0.50	200	0.43	0.50	0.04	0.57
= 1 if HH-H went to formal school	200	0.36	0.48	200	0.38	0.49	−0.01	0.95
= 1 if HH-H part of a village organisation	200	0.20	0.40	200	0.20	0.40	0.01	0.93
= 1 if house made of concrete wall	200	0.05	0.22	200	0.04	0.20	0.01	0.83
= 1 if HH owns a motorcycle	200	0.38	0.49	200	0.45	0.50	−0.07	0.15
= 1 if any small business	200	0.54	0.50	200	0.63	0.48	−0.09	0.21
= 1 if HH owns some livestock	200	0.97	0.16	200	0.95	0.22	0.03	0.29
Cattle herd size (# of head)	200	20.27	21.14	200	18.63	18.98	1.64	0.47
Surface of land cultivated (Ha/cap)	199	0.28	0.16	192	0.29	0.16	−0.00	0.86
= 1 if self-sufficient in cereals over the last 3 years	199	0.39	0.49	198	0.38	0.49	0.00	1.00
2011 cereal production (kg/cap)	196	107.51	118.51	194	107.49	96.11	0.02	1.00
PPI consumption index (6)	200	20.43	6.12	200	21.54	7.25	−1.10	0.30
Annual total expenditures (in 1000 CFA-F/cap)	200	73.84	38.11	200	81.51	39.37	−7.67*	0.08
Share of food expenditures	200	0.73	0.14	200	0.72	0.16	0.01	0.77
Share of health expenditures	200	0.02	0.03	200	0.02	0.07	−0.00	0.67

(1) Missing values are due either to the absence of the respondant or to unavailable information.
(2) P-values reported in the last column are calculated using randomization inference.
(3) Level of significance: *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.
(4) Higher population size in controls is explained by the presence of a small city in this subsample. Village sizes are about the same in the two groups - on average 2500 inhabitants.
(5) WRSI is a water balance indicator that is used by Food and Agricultural Organization (FAO) and FEWS NET scientists to provide crop yield assessments (for more details, see Verdin and Klaver, 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, 2012).

Households from control villages do not purchase foodgrain in treatment villages (no household from the control group bought any foodgrain from a FSG), 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.

Because the intervention is implemented at the village level and our number of villages is limited to 40, we estimate wild-bootstrap standard errors at the village level (Bertrand et al., 2004; MacKinnon and Webb, 2017). In addition, we systematically provide randomization inference standard errors, clustered at the village level (Bloom, 2005; Athey and Imbens, 2017). Given the large number of outcomes we also explore the robustness of our results through multiple hypotheses tests (Christensen and Miguel, 2018). Specifically, we build composite indexes by family of outcomes, distinguishing between food access outcomes, nutrition outcomes, purchases and consumption outcomes. These are defined as equally weighted averages of the standardized corresponding outcomes (using control group averages and standard deviations to standardize). We estimate the overall impact of the intervention on these indexes (online appendix, Table 7). Finally, we verify that our results stand when we control for pre-existing differences across treatment and control groups in time-varying (exogenous) characteristics.[15]

In the following, we start by looking at the impact of the intervention on food access, measured in terms of local availability and affordability of foodgrain.

4.2. Proximate impacts: food access

Table 4 (first two columns) and 5 (first two columns) report the impact of the intervention on availability and affordability using DID estimations. In both tables, column (2) reports the estimates, allowing for an heterogenous effect by village remoteness as measured by the availability of road connections. Because of their isolation, the “no-road

[15] Controls include an end-of-season harvest indicator (the water requirement satisfaction index, WRSI) which is based on rainfall characteristics available at geo-localized weather stations (the measure is village and time specific) and a set of dummy variables on self-reported agricultural shocks (drought, flood and pest attacks). Results barely change (Tables 8 and 9, online appendix).

Table 3
Balance test on outcomes.

	TREATMENT (T)			CONTROL (C)			(T) - (C)	
	N	MEAN	SD	N	MEAN	SD	DIFF	P-VAL
Food access								
Share of foodgrain purchased locally	57	0.33	0.48	62	0.55	0.50	−0.22	0.14
Annual distance travelled to purchase foodgrain (walking min/bag)	57	79.02	35.70	62	65.11	32.79	13.91	0.11
Nominal price paid for 100 kg of foodgrain	54	14.19	1.74	60	13.98	2.09	0.21	0.63
Nutrition								
19–49 years old adult's BMI	444	20.70	2.28	469	20.78	2.40	−0.08	0.76
5–19 years old children's BMI-for-Age	827	−1.06	0.84	739	−0.96	0.90	−0.10	0.20
0.5–4 years old children's BMI-for-Age	323	−0.24	0.97	342	−0.16	0.96	−0.08	0.41
= 1 if adult's BMI < 18.5	444	0.15	0.36	469	0.15	0.36	−0.00	0.99
= 1 if 5–19 children BMI-for-age < −2	827	0.13	0.34	739	0.13	0.33	0.01	0.76
= 1 if 0.5–4 children BMI-for-age < −2	323	0.04	0.20	342	0.02	0.14	0.02*	0.06
Food purchases and consumption								
= 1 if HH purchased any foodgrain	199	0.31	0.46	199	0.33	0.47	−0.02	0.86
Total quantity of foodgrain purchased (in 100 kg/cap)	199	0.03	0.05	199	0.03	0.05	−0.00	0.58
Total expenditures on foodgrain (in 1000 CFA/cap)	199	1.34	2.46	199	1.43	2.90	−0.09	0.88
Real annual foodgrain disposable (ln of kg/cap)	198	267.12	136.76	190	259.95	179.08	7.17	0.74
= 1 if real annual foodgrain disposable > 190 kg/year	198	0.33	0.47	190	0.37	0.49	−0.05	0.47

(1) P-values reported in the last column are calculated using randomization inference.
(2) Level of significance: $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

Table 4
Impact of FSGs on the local availability of foodgrain, consumption and diet diversity.

	Availability		Consumption		Diet diversity	
	(1)	(2)	(3)	(4)	(5)	(6)
	Share of grain bags bought locally		**Real annual foodgrain disposable in kg/cap**		**Hoddinott's dietary diversity score**	
TREAT	0.247*	−0.024	−18.771	−34.270	−15.248*	−5.470
p-value Wild	[0.075]	[0.885]	[0.292]	[0.168]	[0.097]	[0.667]
p-value RI	[0.060]	[0.930]	[0.260]	[0.120]	[0.090]	[0.700]
TREAT x NO ROAD	–	0.614**	–	37.800	–	−24.692
p-value Wild		[0.020]		[0.300]		[0.154]
p-value RI		[0.050]		[0.320]		[0.180]
Mean in control group	0.40	0.40	162.08	162.08	187.35	187.35
Observations	406	406	780	780	393	393
	Total distance travelled per bag (in minutes)		**=1 if real annual foodgrain disposable >190 kg/cap/year**		**IFPRI's dietary diversity score**	
TREAT	−31.256**	−7.858	0.083	0.111	−0.005	−0.025
p-value Wild	[0.019]	[0.543]	[0.215]	[0.251]	[0.959]	[0.803]
p-value RI	[0.000]	[0.550]	[0.210]	[0.240]	[0.910]	[0.780]
TREAT x NO ROAD	–	−52.477**	–	−0.067	–	0.047
p-value Wild		[0.027]		[0.624]		[0.772]
p-value RI		[0.070]		[0.590]		[0.720]
Mean in control group	95.91	95.91	0.72	0.72	3.96	3.96
Observations	406	406	780	780	393	393

(1) Outcomes in columns (1) and (2) are computed using data on all foodgrain transactions made by the household over the agricultural cycle. Real grain disposable - column (3) - corresponds to: production + purchases + gifts in - losses - sales - gifts out. The 190 kg/capita/year threshold used for outcome in column (3) corresponds to the consumption standard for an adequate diet in Burkina Faso. Outcomes in columns (5) and (6) correspond to food diet diversity scores.
(2) Except in columns (5) and (6) corresponding to simple difference estimations, all other results are obtained through differences-in-differences estimations (using rounds 2 and 3). P-values reported into brackets correspond to (i) Wild clustered SE and (ii) Randomization inference-based clustered SE.
(3) TREAT corresponds to the interaction between T_j and P_t in Equation (1). The coefficient on TREAT captures the impact of the intervention (β_2).
(4) Level of significance based on p-value Wild: $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.
(5) Mean in control group corresponds to the mean outcome for control group in round 3.

villages" are more vulnerable to supply scarcities and significant price increases in times of stress (De Janvry et al., 1991; Newbery, 1991).

Regarding foodgrain local availability, Table 4 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 in the village increased by 24.7 percentage points (column 1). As shown in column (2), the impact is mainly driven by villages that are not accessible by road, and where availability of foodgrain for local purchases is critically important.

The second reported outcome is the average walking distance (in minutes) per 100 kg bag of foodgrain purchased (columns 1 and 2, panel 2). 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 min walk per bag, which corresponds to 167 min for the average household: this represents a 36 percent reduction of the annual distance travelled by control households.[16] Again the effect is significantly larger in no-road villages, with a decrease of 52 min per bag.

The intervention of the FSGs has clearly achieved one of its main goals, which is to bring food closer to rural buyers. That local availability of foodgrain is a critical concern for households is evident from the fact that, when asked to motivate their choice of a particular seller during the year of the intervention, 40 percent of (control) households cited proximity as the main reason (Table 1, panel B). The second most important reason (33 percent of the cases) is a strong confidence in the actual availability of foodgrain at the selling point. Interestingly, lower prices come only third and are cited by as few as 19 percent of households. Focus group discussions confirmed that households prefer to buy foodgrain closer to their dwelling, because of the gain in time and effort and also the reduced risk of an unsuccessful transaction. This risk arises when a villager moves to a nearby market or town to buy foodgrain but returns empty-handed owing to unavailability of foodgrain or excessive price.

We now turn to the impact of the program on foodgrain affordability, as reflected in prices (Table 5, first two columns). The dependent variable in the regressions reported in the first panel is the average price paid by households for a bag of foodgrain. Foodgrain includes sorghum, millet and maize. The nutritional content and price pattern are very similar for the three cereals. Our results hold if we restrict attention to the main foodgrain consumed (sorghum). In treatment villages, the intervention is responsible for a significant reduction of the price of foodgrain (1168 CFA-F), corresponding to a 6 percent cut.[17] Again, we expect that the price-reducing impact of the intervention is especially large in remote villages. This is because remoteness has the effect of isolating a village from price-dampening market forces in times of supply stress. Evidence reported in column (2) confirms this expectation: the price reduction observed in no-road villages is twice as large as in the other villages.

We also consider purchases made in the post-harvest and the lean seasons separately (columns 1 and 2, panels 2 and 3). 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 foodgrain is more uncertain. This expectation is confirmed and, in fact, it is only during the lean season that prices are lower in villages where the program is in place (by 1403 CFA-F, with p-values of 0.108 with wild bootstrapped standard errors and 0.100 with randomized inference). Furthermore, the price effect in remote villages is 2.5 times larger than in the whole sample during that season.

In short, the program appears to have stimulated local grain purchases and decreased the price of foodgrain for the local population, especially during the lean season. This is further confirmed by the impact of the program on the household-level composite index of market-access (online appendix, Table 7). A word of caution is nevertheless needed insofar as our sample is rather small and only a low proportion of households purchased grain in the initial year, yielding some imbalances in this outcome at baseline.

Table 5
Impact of FSGs on the local affordability of foodgrain and on purchases.

	(1)	(2)	(3)	(4)
	Mean price of 100 kg foodgrain bags (in 1000 CFA)		= 1 if any foodgrain purchase	
TREAT	−1.168*	−0.069	0.026	0.020
p-value Wild	[0.076]	[0.911]	[0.646]	[0.770]
p-value RI	[0.060]	[0.930]	[0.650]	[0.760]
TREAT x NO ROAD	–	−2.510*	–	0.017
p-value Wild		[0.062]		[0.897]
p-value RI		[0.140]		[0.940]
Mean in control group	19.14	19.14	0.82	0.82
Observations	399	399	791	791
	Post-harvest season mean price of 100kg foodgrain bags (in 1000 CFA)		Total quantity of foodgrain purchased (in 100 kg/cap)	
TREAT	0.877	−0.399	−0.040	−0.046
p-value Wild	[0.452]	[0.568]	[0.513]	[0.575]
p-value RI	[0.350]	[0.620]	[0.540]	[0.550]
TREAT x NO ROAD	–	2.843	–	0.015
p-value Wild		[0.215]		[0.903]
p-value RI		[0.250]		[0.900]
Mean in control group	19.26	19.26	0.53	0.53
Observations	202	202	791	791
	Lean season mean price of 100 kg foodgrain bags (in 1000 CFA)		Total expenditures on foodgrain (in 1000 CFA/cap)	
TREAT	−1.403	0.054	−0.828	−0.493
p-value Wild	[0.108]	[0.946]	[0.475]	[0.734]
p-value RI	[0.100]	[0.990]	[0.470]	[0.720]
TREAT x NO ROAD	–	−3.386*	–	−0.841
p-value Wild		[0.055]		[0.728]
p-value RI		[0.120]		[0.720]
Mean in control group	19.26	19.26	8.59	8.59
Observations	351	351	791	791

(1) All outcomes are computed using data on all foodgrain transactions made by the household over the agricultural cycle. Mean price paid per bag is aggregated at the household level and across the types of grain consumed locally - sorghum, millet and maize. The three grains are similar in their nutritional content and price patterns.
(2) All results are obtained through differences-in-differences estimations (using rounds 2 and 3). P-values reported into brackets correspond to (i) Wild clustered SE and (ii) Randomization inference-based clustered SE.
(3) TREAT corresponds to the interaction between T_j and P_t in Equation (1). The coefficient on TREAT captures the impact of the intervention (β_2).
(4) Level of significance based on p-value Wild: $*p<0.10$, $**p<0.05$, $***p<0.01$.
(5) Mean in control group corresponds to the mean outcome for control group in round 3.
(6) Post-harvest months are December to April, lean-season months are May to August.

4.3. Impacts on the nutrition of children and adults

We now turn to the impact of the program on nutrition. We use measures of nutritional status at both household and individual levels. If all household members face the same budget and food availability constraints, 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.[18] Therefore we also estimate the impact of the program on individuals. A strength of our analysis lies in the use of objective measures of nutrition based on anthropometric indicators available for all household members. Specifically, we estimate the impact of the program on BMI and BMI-for-age (Table 6) and on the prevalence of malnutrition (Table 7), as explained in Section 3.2. We distinguish between adults (19–59) and two age groups for children (5–18 and 0–4). Household-level measures use the average nutritional

[16] We obtain this figure by multiplying the time gained per bag and the average quantity of foodgrain bought by control households (5.4 bags).

[17] As local purchases are associated with smaller transaction costs (including transport cost) the net price difference between treatment and control villages is higher.

[18] See Kazianga and Wahhaj (2017) for a description of household organization in Burkina Faso.

Table 6
Impact of FSGs on BMI levels.

	HOUSEHOLD		INDIVIDUAL	
	(1)	(2)	(3)	(4)
	19–49 years old adult's BMI level			
TREAT	0.307*	0.078	0.389**	0.108
p-value Wild	[0.077]	[0.704]	[0.018]	[0.526]
p-value RI	[0.030]	[0.700]	[0.010]	[0.500]
TREAT x NO ROAD	–	0.573	–	0.681**
p-value Wild		[0.101]		[0.048]
p-value RI		[0.110]		[0.080]
Mean control group	20.58	20.58	20.59	20.59
Observations	736	736	1818	1818
	5–18 years old children's BMI-for-age z-score			
TREAT	0.175**	0.101	0.196***	0.150**
p-value Wild	[0.011]	[0.220]	[0.000]	[0.034]
p-value RI	[0.000]	[0.190]	[0.000]	[0.040]
TREAT x NO ROAD	–	0.191	–	0.117
p-value Wild		[0.135]		[0.241]
p-value RI		[0.200]		[0.370]
Mean control group	−1.05	−1.05	−1.03	−1.03
Observations	747	747	2941	2941
	0.5–4 years old children's BMI-for-age z-score			
TREAT	0.192*	0.085	0.227**	0.093
p-value Wild	[0.061]	[0.578]	[0.031]	[0.518]
p-value RI	[0.030]	[0.560]	[0.010]	[0.480]
TREAT x NO ROAD	–	0.252	–	0.303
p-value Wild		[0.212]		[0.126]
p-value RI		[0.300]		[0.180]
Mean control group	−0.40	−0.40	−0.44	−0.44
Observations	635	635	1402	1402

(1) Nutritional outcomes are based on individual anthropometric measures (weight and height). The dependent variables in columns (1) and (2) correspond to household averages for the relevant age category.
(2) All results are obtained through differences-in-differences estimations (using rounds 2 and 3). P-values reported into brackets correspond to (i) Wild clustered SE and (ii) Randomization inference-based clustered SE.
(3) TREAT corresponds to the interaction between T_j and P_t in Equation (1). The coefficient on TREAT captures the impact of the intervention (β_2).
(4) Level of significance based on p-value Wild: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.
(5) Mean in control group corresponds to the mean outcome for control group in round 3.

Table 7
Impact of FSGs on the prevalence of malnutrition.

	HOUSEHOLD		INDIVIDUAL	
	(1)	(2)	(3)	(4)
	=1 if 19–49 years old adult's BMI < 18.5			
TREAT	−0.007	0.041	−0.012	0.034
p-value Wild	[0.811]	[0.268]	[0.647]	[0.250]
p-value RI	[0.880]	[0.180]	[0.620]	[0.170]
TREAT x NO ROAD	–	−0.121**	–	−0.108**
p-value Wild		[0.046]		[0.010]
p-value RI		[0.030]		[0.010]
Mean control group	0.18	0.18	0.16	0.16
Observations	736	736	1818	1818
	= 1 **if 5–18 years old children**'s BMI-for-age < −2			
TREAT	−0.051*	−0.058	−0.044	−0.050
p-value Wild	[0.063]	[0.146]	[0.104]	[0.180]
p-value RI	[0.090]	[0.130]	[0.140]	[0.150]
TREAT x NO ROAD	–	0.015	–	0.017
p-value Wild		[0.752]		[0.696]
p-value RI		[0.770]		[0.710]
Mean control group	0.16	0.16	0.16	0.16
Observations	747	747	2941	2941
	= 1 if 0.5–4 years old children's BMI-for-age < −2			
TREAT	−0.080***	−0.079**	−0.058***	−0.050**
p-value Wild	[0.002]	[0.015]	[0.006]	[0.048]
p-value RI	[0.000]	[0.040]	[0.020]	[0.090]
TREAT x NO ROAD	–	−0.003	–	−0.018
p-value Wild		[0.959]		[0.687]
p-value RI		[0.950]		[0.640]
Mean control group	0.08	0.08	0.07	0.07
Observations	635	635	1402	1402

(1) Nutritional outcomes are based on individual anthropometric measures (weight and height). The dependent variables in columns (1) and (2) correspond to household averages for the relevant age category.
(2) All results are obtained through differences-in-differences estimations (using round 2 and 3). P-values reported into brackets correspond to (i) Wild clustered SE and (ii) Randomization inference-based clustered SE.
(3) TREAT corresponds to the interaction between T_j and P_t in Equation (1). The coefficient on TREAT captures the impact of the intervention (β_2).
(4) Level of significance based on p-value Wild: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.
(5) Mean in control group corresponds to the mean outcome for control group in round 3.

status for all household members in the relevant age category. Below we comment on the results of the DID estimations at the individual level. Using household-level measures does not change the conclusions.

The intervention has had a large and positive impact on nutritional outcomes for both adults and children. The estimated effect for adults (Table 6, Panel 1) is positive and significant and amounts to 0.39 BMI point (column 3) which, on average, corresponds to about one-kilo difference for an individual with mean BMI. Results reported in Table 7 indicate that 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 5–18 years old children, it is large and significant. The size of the effect is 0.20 z-score of BMI-for-age (Table 6, Panel 2, column 3). 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. Even more important is the impact on children aged 0 to 4. The impact is 0.23 z-score (Table 6, Panel 3, column 3), which corresponds to a 50 percent reduction 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 (Table 7, Panel 3, column 3).[19]

Because experiencing 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. It is possible to check the robustness of this central finding by using our 2012-13 data, keeping in mind that a number of villages had been dropped from the program. It is reassuring that even with this limitation and despite the fact that the year 2012-13 was less climatically adverse than the year 2011-12 year, we find that the program's intervention has improved the nutrition status of children.

[19] As discussed in Section 3.2, for this age group we may use weight-for-height z-scores instead of BMI-for-age z-scores. The results obtained are not very different in magnitude but they loose their statistical significance (online appendix, Table 10).

More precisely, this improvement is evident for children between 5 and 18 years when the BMI measures are considered, and for both these children and those between 0.5 and 4 years when the incidence of malnutrition is considered (online appendix, Tables 13 and 14). As for heterogeneous effects on nutrition, they are presented in columns 2 and 4 of Tables 6 and 7. The effects of the intervention on nutritional outcomes for both adults and children appear larger for the no-road villages, albeit not always significantly.

Taken together, these results reveal that the intervention has improved the nutritional status of the target population group at the end of the lean season. This is confirmed by our assessment of the program's impact on the household-level nutrition index (online appendix, Table 7). 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 behavior.

4.4. Impacts on purchases and consumption

Foodgrain purchases — Table 5 (columns 3 and 4) provides estimates of the impact of FSGs on the probability that households buy any foodgrain, on the annual foodgrain quantities purchased, and on total foodgrain expenditure.[20] 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. Thus, despite a decrease in prices, households did not increase the total quantity of foodgrain purchased. This result is especially surprising because the program improved anthropometric indicators of nutrition. Before providing explanations for this apparent paradox, we estimate the effects of the program on foodgrain consumption.

Consumption — To measure consumption of foodgrain over the year, we use total disposable foodgrain. This is obtained by adding purchases and gifts received to the quantity produced and then subtracting losses, sales and gifts made.[21] We also compare the disposable foodgrain to the consumption reference level of 190 kg 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 4 (columns 3 and 4) 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. In fact, point estimates are clearly negative, allowing us to rule out even small increases in consumption levels in treatment villages.

Since foodgrain accounts for about 80% of calorie intake in our context, total disposable foodgrain provides a good approximation of the calorie intake of targeted households (Cheyns, 1996). 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 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 day preceding the survey but this index is less adequate in our context where food diets are very poor (Hoddinott, 1999).[22] Simple difference estimates reported in Table 4 (columns 5 and 6) suggest that the impact of the program on diet diversity is negative, if anything.[23] 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, a monthly survey that we conducted in 2016 for a sub-sample of the households 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 leads to a similar conclusion: we do not detect any positive effect of the FSGs on consumption outcomes.

5. Household food allocation decision in a two-period model

The objective of the intervention was to increase the availability of foodgrain for sale in the targeted villages and spark a decrease in local prices, particularly during the lean season. According to this logic, the program management expected the program to lead to increases in food purchase, food consumption and the nutritional level of the villagers. While the impact evaluation confirms that the program had the expected effects on prices and nutrition, it indicates that food purchase and total consumption did not increase over the year following the intervention.

Although this set of results may appear puzzling at first sight, microeconomic theory does not unambiguously predict that total purchase and consumption increase as a result of a price decrease, when the possibility of intertemporal household storage and the associated costs are allowed for. Thus, if households take advantage of lower prices during the lean season to delay their foodgrain purchases, household storage losses may be reduced and nutrition may be improved in the absence of purchases increases.

To illustrate this possibility, we develop a simple two-period model, where, as in Foster (1995) or Dercon and Krishnan (2000), an individual's utility depends on her nutritional level (a stock) instead of (only) her consumption level (a flow). Within this framework, we investigate the effect of the program on household's nutrition, consumption and purchasing behavior. We perform a basic 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 was discussed in Section 2. The mode of the intervention on food markets is represented by a decrease in the food price during the lean season. While in this simple version of the model there is no uncertainty, we discuss the effect of introducing price risk in the online appendix. Finally, because survey respondents repeatedly mentioned the "pressure to consume readily available food" as an important constraint on food stock management, we also analyze the effect of time-inconsistent preferences arising from a self-control problem (online appendix). Both extensions complicate the basic model but strengthen the predictions obtained below.

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

[20] Recall that the 2011-12 cycle followed a bad harvest. As many as 80 percent of the households purchased foodgrain and quantity purchased represented one-third of annual consumption.

[21] 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.

[22] 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.

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

and Krishnan, 2000a).[24] 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 Foster (1995) (and Dercon and Krishnan, 2000) by modelling the nutritional status as a stock or durable, and specifying the nutritional status in period $t \in \{1, 2\}$ as:

$$N_t = \varepsilon N_{t-1} + C_t \tag{2}$$

This equation indicates 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.[25] 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:

$$\alpha C_1 + C_2 = \alpha m_1 + m_2 \tag{3}$$

$$C_1 \leq m_1 \tag{4}$$

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.[26] 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):

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

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 period 2.

Case 1: low second-period price, $P_2 \leq \frac{rP_1}{\alpha}$.

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 features the role of the carryover effect from nutrition in period 1 (the body mass storing effect). This effect reduces 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 carryover effect must not be too large.[27]

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

When $P_2 > \frac{rP_1}{\alpha}$, it follows that $m_2 = 0$. At equilibrium, the intertemporal allocation of nutrition becomes (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 purchases in period 2, the relevant cost of consuming in period 1 rather than waiting until period 2 is the retention coefficient diminished by the carryover effect. If storage losses increase relative to the effectiveness of body mass storing, the marginal utility of nutrition must decrease in period 1 relative to period 2. This implies that the nutrition level will be boosted in period 1 compared to period 2.

Let us now look at the effects 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 increases the nutrition level in period 2 while the nutrition level in period 1 may decrease. The total quantity consumed across the two periods may also decrease: the household resorts less to body mass storing and more to immediate purchases in order to boost nutrition. Because "losses" incurred in the process of body mass storing ($\varepsilon < 1$) are saved, the total quantity consumed and purchased (across the two periods) 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 purchases in the same period, m_2.*
3. *Produces ambiguous effects on the total quantity of food purchased, $m_1 + m_2$, and the total quantity of food consumed, $C_1 + C_2$. These effects depend on the storage technology:*
   (a) *In the absence of body mass storing (current nutrition depends on current consumption only, $\varepsilon = 0$), total food consumption*

[24] 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 $\rho > 1$.

[25] Introducing foodgrain production would not bring additional insights as long as we would restrict attention to net grain buyers (the vast majority of households in our study area) and consider consumption and production decisions to be separable. Obviously predictions may change if we use a non-separable household model instead. We choose to abstract from the production side of the story because of the timing of our evaluation: since we analyze only short-term impacts, 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).

[26] 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.

[27] 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 two following conditions must hold: $\varepsilon < r\frac{P_1}{P_2}$ or $\varepsilon < \alpha$.

unambiguously increases but total food purchases 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 purchases and total food consumption may decrease and these effects may happen even with zero physical storage losses.*

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. In the presence of physical storage losses in the granary, increased purchase in the second relative to the first period allows the household to reduce the quantity of food wasted in storage. 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, and the household can decrease its reliance on body mass storing and the associated losses. In this case, the total quantity of food consumed - as well as total food purchases - may fall despite an improvement in N_2 (Fig. 5 in the online appendix illustrates this possibility). To the left of $P_2^* = \frac{rP_1}{\alpha}$, a decrease in the lean period price causes total food consumption (and total food purchases) to initially decline and, beyond a point, to increase.[28] 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 purchases, $m_1 + m_2$, and an 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.

6. Discussion

The predictions of the two-period model presented above are consistent with our empirical results. 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 nutrition may be improved at the end of the lean season even though total food *consumption* has not increased (Proposition 1). This is because households can modify the timing of purchases and consumption over the year, and therefore avoid the losses associated with body mass storing.

As mentioned in the introduction, the opportunity of a severe drought motivated our decision to move forward the first endline survey, at the cost of preventing us from collecting seasonal data on consumption and nutrition. Hence our inability to formally establish the program's dampening effect on seasonal nutritional fluctuations. Furtunately, however, we can estimate the impact of the program on the timing of purchases and 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 these constraints, we discovered that physical storage losses are not a great concern among the local households whereas losses arising from self-control problems (and to a lesser extent, redistributive presures) appear to be more serious. We now review this evidence in detail.

6.1. Impact of the intervention on the timing of purchases

The model predicts that a decrease in foodgrain price during the lean season prompts households to increase purchases during that season (and to decrease purchases during the post-harvest period). 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

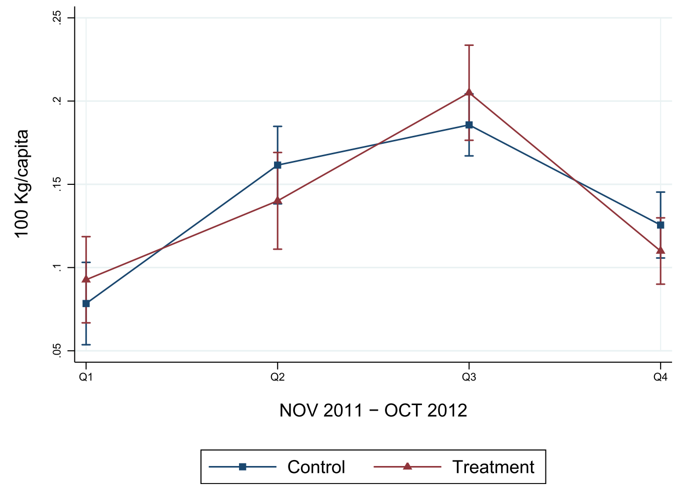

Fig. 2. Impact of FSGs on quarterly foodgrain purchases.

corresponds to the number of months during which a household holds a stock of self-produced foodgrain in the granary located inside its compound. The third relies on two variables, one binary and the other continuous, that capture purchases made before the depletion of self-produced grain. These two variables measure the extent to which households delay the purchase of foodgrain. Indeed, foodgrain purchased is always consumed first so that, if a household makes purchases before the depletion of its self-produced grain stock, it extends the duration of this stock. 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. Because grain deteriorates faster than ears, the foodgrain purchased is always consumed first, thereby making own stock last longer. A critical observation is 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 yet empty (in the control villages).

Fig. 2 compares quarterly purchases in treatment and control villages, reporting the results of a negative binomial regression on the per capita quantities purchased by quarter.[29] We see that households in treatment villages bought less in the second but more in the third quarter than households in control villages. It looks as if the former decided to shift purchases from the second to the third quarter. The difference between the two purchasing 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 (and delayed their purchases). This expectation is confirmed in Fig. 3. For all control and treatment households, the left panel reports the cumulative distribution of the duration of own stock, as assessed by the month 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 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. Compared to households in control villages, the granary of households in treatment villages was emptied at an earlier date (month), 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 8 (panel 1) reports the results, which indicate that the intervention appears to have shortened the duration of own stock, yet not in a statistically significant way.

[28] The corresponding levels of nutrition, N_1 and N_2 are plotted on Fig. 6 in the online appendix.

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

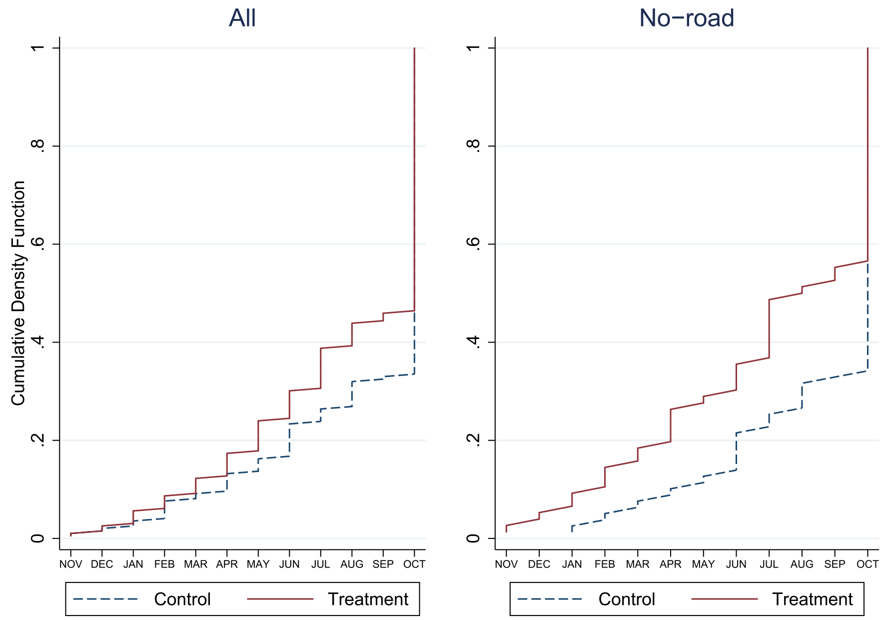

Fig. 3. Impact of FSGs on the cumulative distribution of own stock depletion.

Finally, concomitantly to a shorter 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 8 (panels 2 and 3) broadly confirms this prediction. On the extensive margin, households in treatment villages appear less likely to make anticipated purchases than households in control villages, but the effect is only statistically significant in no-road villages. On the intensive margin, the intervention substantially and significantly 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 29 percent decrease. It is noticeable that the impact is nearly twice as large in no-road villages as in the full sample.

6.2. *The timing of purchases, the timing of consumption, and body mass variations*

As pointed out earlier, while we have measures of the timing of purchases, we have no indicator of fluctuations in consumption or body mass over the year. However, we can provide non-experimental evidence showing that the timing of purchases is correlated with body mass fluctuations. For a reason already explained, we visited the households only once during the year of the intervention. However, we made two visits during the previous and the following years (2010-11 and 2012–13). These data reveal 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. We find that anticipated purchases (made before stock depletion) are associated with higher body mass indices before the lean season but similar body mass indices after the lean season, implying a higher variation in body mass compared to the other households (online appendix, Table 15). These findings suggest that because it induced households to limit their anticipated purchases, the program may have caused a reduction in body mass fluctuations. Following this line, a better timing of cereal purchases appears as an effective way to smooth 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 purchases and the quantity of food prepared at home in the subsample of households surveyed monthly in 2016. Controlling for the annual foodgrain disposable, households prepare significantly more food right after they made a purchase (online appendix, Table 16). In short, postponing purchases until the need arises in the lean season helps stabilize nutrition.[30]

To test this interpretation the best way possible, we returned to the field to conduct follow-up workshops in both treatment and control villages (with a total of 15 individuals during June 2015). We used boards to allow individual participants to illustrate their stock management and consumption strategies (online appendix, Fig. 8). 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 (online appendix, Fig. 9). Revealingly, 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.

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

Table 8
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
p-value Wild	[0.177]	[0.945]
p-value RI	[0.130]	[0.950]
TREAT x NO ROAD	–	−1.510
p-value Wild		[0.180]
p-value RI		[0.130]
Observations	393	393
Timing of food purchases		
	=1 if any foodgrain purchased before own stock depletion	
TREAT	−0.058	0.023
p-value Wild	[0.347]	[0.779]
p-value RI	[0.360]	[0.730]
TREAT x NO ROAD	–	−0.204*
p-value Wild		[0.090]
p-value RI		[0.130]
Observations	393	393
	Quantity of foodgrain purchased before own stock depletion (100kg/cap)	
TREAT	−0.093*	−0.028
p-value Wild	[0.079]	[0.779]
p-value RI	[0.070]	[0.730]
TREAT x NO ROAD	–	−0.165
p-value Wild		[0.122]
p-value RI		[0.130]
Observations	393	393

(1) All results are obtained through simple difference estimations (using round 3). P-values reported into brackets correspond to (i) Wild clustered SE and (ii) Randomization inference-based clustered SE.
(2) Level of significance based on p-value Wild: $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

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 purchases.[31]

6.3. The nature of storage losses

The model introduced in Section 5 suggests that the storage technology plays a critical role in the household intertemporal allocation of nutrition. If storing in granaries is costly, body mass accumulation may be an attractive alternative. Yet physical losses in household granaries 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 echoes the findings of a recent World Bank Report (World Bank, 2011) and the evidence reported in Kaminski and Christiaensen (2014) and Burke et al. (2018), according to which losses in household granaries are very limited in dry climates.

Body mass storing involves costs associated with storing and destoring and also with the maintenance of a larger body mass (Dugdale and Payne, 1987; Branca et al., 1993; IFPRI, 2015; Prentice and Cole, 1994). If physical storage losses are limited, why would households engage in body mass storing? While investigating this question during our follow-up workshops, we received an answer stressing the fact that large stocks are difficult to protect from the demands of visitors or household members themselves. Regarding the first type of demand, they indicated that large household stocks signal abundance and attract solicitations. In particular, visitors are likely to stay longer where stocks are larger. How strong is this effect is a question we can handle with our data: while treatment households did indeed receive fewer visits of people staying and eating in the household, the effect is not quantitatively important (online appendix, Table 17, panel 1). 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 4, columns 3 and 4). 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.[32]

Let us now turn to the second type of demand, that arising from within the household itself. More specifically, if household members find it difficult to refrain from consuming food that is readily accessible and in apparent (albeit temporary) abundance, body mass storing results from a present-bias (or self-control) problem. The problem is expected to be especially acute when people go hungry. As a solution to this "urge-to-consume" problem, households may use delayed purchases as a commitment device to avoid "overconsumption" in the post-harvest season. Interestingly, by extending our basic model (online appendix), we show that in the presence of present bias a decrease in the lean-period price is actually more likely to induce a decrease in total consumption and total purchase of foodgrain. During in-depth individual interviews conducted after our workshops, interviewees recurrently mentioned and documented how the temptation to quickly consume foodgrain within easy reach drives their consumption time pattern. Such temptation appears to be especially strong among mothers who cannot bear the sight of their children going 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 in such circumstances it is hard for them to oppose their wife (wives). Limiting household storage by delaying purchase helps avoid this form of self-control. Indeed, buying at a GSA typically involves large quantities (bags of 100 kg) of foodgrain and a planning of purchases (the GSA is opened only during a few hours per week). By contrast, the urge to consume in times of acute needs operates through the withdrawal of marginal quantities of foodgrain that are almost instantaneously consumed.

Similar explanations have been recently advanced to explain the behavior of farmers when an intervention provides them with outside-of-the-home storage facilities. A striking illustration is found in the aforementioned study of Aggarwal et al. (2018) who have conducted a randomized impact evaluation of such an intervention in Kenya. They

[31] Fig. 10 in the online appendix 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.

[32] 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 (negative shock is a binary variable equal to 1 if the village is in the bottom quartile of the end-of-season indicator). Although the sign of the interaction between treatment and the shock binary variable is negative, the coefficient is not significantly different from zero.

conclude that escaping both redistributive pressures and present-bias is a major consideration behind the strong impact that they find.[33] In the specific context of Burkina Faso, a directly relevant literature concerns inventory credit programs (warrantage). Providing credit against the deposit of cereals in community granaries, these programs aim at relaxing the farmers' liquidity constraint and avoiding the costly "sell low, buy high" behavior. However, pressure-to-consume and redistributive pressure appear to be major issues. The study of Le Cotty et al. (2019) precisely concludes that present-biased farmers in Burkina Faso use inventory credit as a commitment device to avoid over-consumption during the post-harvest season. Recent technical reports from various other programs point to the same interpretation. Ghione et al. (2013) note that 17 percent of bags stored in community granaries belong to producers who did not request a loan yet paid for the storage. It is therefore the ability to store food outside of the compound that seems to enable households not only to reduce the quantity of food consumed by the family itself but also to escape the social pressure from other members of the community.[34] Finally, for Coulter (2014), 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. The same interpretation comes out of a report by Garrido and Sanchez (2015).

Let us 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. 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 and indirect. In particular, they may reduce bodymass accumulation, which is a second-best strategy in a context of food shortage.

7. Alternative explanations

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 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. 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 already seen in Table 4 (columns 5 and 6), 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 improve nutrition to the extent that healthier individuals have a more efficient metabolism and better absorption 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.

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 accord with 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. This is not the case, however (online appendix, Tables 18 and 19).

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 the amount of agricultural production in the post-intervention campaign.[35] If anything, yields have slightly improved.

8. Conclusion

This paper makes three important contributions. First, it confirms that, especially in remote areas where local markets are thin, deepening food market integration has the effect of improving nutrition. 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. Microeconomic theory nevertheless shows 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 pattern 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, and thereby 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 the foodgrain purchased before the lean season (before the stocks are depleted). The main problem appears to be one of pressure-to-consume.

[33] In their study, two-thirds of respondents agree with the statement "if I have maize at home, my household is tempted to eat more than we need", while half of them agree with the statement "if a friend or relative comes to me to ask for maize, and if I have maize at home, I am obligated to give him/her some".

[34] 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".

[35] 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 (online appendix, Table 14). There is no difference either in the variation of the herd owned by treatment and control households.

This explanation is compatible with the mechanism behind our two-period model: the possibility that total consumption does not increase when the lean-period price decreases is actually enhanced in the presence of a self-control problem. Interestingly, self-control in food (or alcohol) consumption and the disciplining role of controlled purchases have received increasing attention in the context of advanced economies. Obesity (or addiction) instead of under-nutrition is then the problem that needs to be overcome (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 labeled "food-deserts" (Lee, 2012; Leung et al., 2011), thus offering a parallel to the predicament of remote areas in our setup.

Finally, storage imperfections as understood above have begun to receive attention in the literature dealing with storing and selling behavior in poor economies. The originality of our own endeavor lies in the emphasis put on body mass accumulation as a form of storage in a context of nutritional stress. The important role of losses stemming from a sub-optimal timing of food consumption is a rather unexpected finding of our investigation. This explains why our research 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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jdeveco.2020.102444.

References

Abay, K., Hirvonen, K., 2016. Does market access mitigate the impact of seasonality on child growth? panel data evidence from northern Ethiopia. J. Dev. Stud. 1–16.
Aggarwal, S., Francis, E., Robinson, J., 2018. Grain today, gain tomorrow: evidence from a storage experiment with savings clubs in Kenya. J. Dev. Econ. 134, 1–15.
Alderman, H., Hoddinott, J., Kinsey, B., 2006. Long term consequences of early childhood malnutrition. Oxf. Econ. Pap. 58 (3), 450–474.
Ashraf, N., Karlan, D., Yin, W., 2006. Tying odysseus to the mast: evidence from a commitment savings product in the Philippines. Q. J. Econ. 121 (2), 635–672.
Athey, S., Imbens, G.W., 2017. The econometrics of randomized experiments. In: Handbook of Economic Field Experiments, volume 1. Elsevier, pp. 73–140.
Baland, J.-M., Guirkinger, C., Mali, C., 2011. Pretending to be poor: borrowing to escape forced solidarity in Cameroon. Econ. Dev. Cult. Change 60 (1), 1–16.
Banerjee, A., Duflo, E., Glennerster, R., Kinnan, C., 2015. The miracle of microfinance? evidence from a randomized evaluation. Am. Econ. J. Appl. Econ. 7 (1), 22–53.
Banerjee, A., Mullainathan, S., 2010. The shape of temptation: Implications for the economic lives of the poor. National Bureau of Economic Research. Technical report.
Barrett, C.B., 2008. Smallholder market participation: concepts and evidence from eastern and southern africa. Food Pol. 33 (4), 299–317.
Basu, K., Wong, M., 2015. Evaluating seasonal food storage and credit programs in East Indonesia. J. Dev. Econ. (115), 200–216.
Behrman, J.R., 1988. Nutrition, health, birth order and seasonality: intrahousehold allocation among children in rural India. J. Dev. Econ. 28 (1), 43–62.
Behrman, J.R., 1993. The economic rationale for investing in nutrition in developing countries. World Dev. 21 (11), 1749–1771.
Berg, G.J., Pinger, P.R., Schoch, J., 2016. Instrumental variable estimation of the causal effect of hunger early in life on health later in life. Econ. J. 126 (591), 465–506.
Bernheim, B.D., Meer, J., Novarro, N.K., 2016. Do consumers exploit commitment opportunities? evidence from natural experiments involving liquor consumption. Am. Econ. J. Econ. Pol. 8 (4), 41–69.
Bernheim, B.D., Ray, D., Yeltekin, Ş., 2015. Poverty and self-control. Econometrica 83 (5), 1877–1911.
Bertrand, M., Duflo, E., Mullainathan, S., 2004. How much should we trust differences-in-differences estimates? Q. J. Econ. 119 (1), 249–275.
Bhagowalia, P., Chen, S.E., Masters, W.A., 2011. Effects and determinants of mild underweight among preschool children across countries and over time. Econ. Hum. Biol. 9 (1), 66–77.
Bloom, H.S., 2005. Randomizing groups to evaluate place-based programs. In: Bloom, H.S. (Ed.), Learning more from social experiments: Evolving analytic approaches. Russell Sage Foundation, pp. 115–172.
Branca, F., Pastore, G., Demissie, T., Ferro-Luzzi, A., 1993. The nutritional impact of seasonality in children and adults of rural Ethiopia. Eur. J. Clin. Nutr. 47 (12), 840–850.
Brune, L., Gine, X., Goldberg, J., Yang, D., 2016. Facilitating savings for agriculture: field experimental evidence from Malawi. Econ. Dev. Cult. Change 64 (2), 187–220.
Burke, M., Bergquist, L.F., Miguel, E., 2018. Sell Low and Buy High: Arbitrage and Local Price Effects in Kenyan Markets. Technical report. NBER-24476.
Cheyns, E., 1996. Étude de cas sur les pratiques d'approvisionnement alimentaire des consommateurs de Ouagadougou. Approvisionnement et distribution alimentaires des villes de l'afrique francophone. FAO, CIRAD.
Christensen, E.G.B., Nafziger, J., 2016. Packaging of sin goods–commitment or exploitation? J. Econ. Behav. Organ. 122, 62–74.
Christensen, G., Miguel, E., 2018. Transparency, reproducibility, and the credibility of economics research. J. Econ. Lit. 56 (3), 920–980.
Christian, P., Dillon, B., 2018. Growing and learning when consumption is seasonal: long-term evidence from Tanzania. Demography 55 (3), 1091–1118.
Cole, T.J., Flegal, K.M., Nicholls, D., Jackson, A.A., 2007. Body mass index cut offs to define thinness in children and adolescents: international survey. BMJ 335 (7612), 194.
Coulter, J., 2014. Study on Appropriate Warehousing and Collateral Management Systems in SSA. AFD - CTA - IFAD. Technical country reports.
De Janvry, A., Fafchamps, M., Sadoulet, E., 1991. Peasant household behaviour with missing markets: some paradoxes explained. Econ. J. 101 (409), 1400–1417.
DellaVigna, S., 2009. Psychology and economics: evidence from the field. J. Econ. Lit. 47 (2), 315–372.
Dercon, S., Krishnan, P., 2000. Vulnerability, seasonality and poverty in Ethiopia. J. Dev. Stud. 36 (6), 25–53.
Dillon, B., De Weerdt, J., O'Donoghue, T., 2017. Paying more for less: why don't households in Tanzania take advantage of bulk discounts? LICOS Discussion Paper Series. Discussion Paper 396/2017.
Dinkelman, T., 2017. Long-run health repercussions of drought shocks: evidence from south african homelands. Econ. J.
Dugdale, A., Payne, P., 1987. A model of seasonal changes in energy balance. Ecol. Food Nutr. 231–245.
Duh, J., Spears, D., 2016. Health and hunger: disease, energy needs, and the Indian calorie consumption puzzle. Econ. J.
Dupas, P., Robinson, J., 2013. Why don't the poor save more? evidence from health savings experiments. Am. Econ. Rev. 103 (4), 1138–1171.
Fafchamps, M., 1992. Cash crop production, food price volatility, and rural market integration in the third world. Am. J. Agric. Econ. 74 (1), 90–99.
Fafchamps, M., Udry, C., Czukas, K., 1998. Drought and saving in West Africa: are livestock a buffer stock? J. Dev. Econ. 55 (2), 273–305.
FAO, 2001. Human energy requirements. Food and Nutrition Technical Report Series 1. FAO, Rome.
FAO, CILSS, PAM, 2012. Note conjointe sur l'evaluation des marchés et la situation alimentaire au Sahel. FAO, CILSS and FEWS-NET PAM. Technical report.
Fink, G., Jack, B.K., Masiye, F., 2014. Seasonal credit constraints and agricultural labor supply: evidence from Zambia. National Bureau of Economic Research.
Flegal, K.M., Wei, R., Ogden, C., 2002. Weight-for-stature compared with body mass index–for-age growth charts for the United States from the centers for disease control and prevention. Am. J. Clin. Nutr. 75 (4), 761–766.
Foster, A.D., 1995. Prices, credit markets and child growth in low-income rural areas. Econ. J. 105 (430), 551–570.
Garrido, E.S., Sánchez, I.S., 2015. Warrantage paysan au Burkina Faso: Accès au crédit par le biais des stocks de proximité. Rapports de recherche Oxfam, Burkina Faso.
Ghione, A., Kambou, F., Le Cotty, T., Maître d'Hôtel, E., Malnoury, G., 2013. Le warrantage paysan, un outil de protection des ressources. Grain de Sel 59–62. Inter-Reseaux.
Glennerster, R., Takavarasha, K., 2013. Running randomized evaluations: A practical guide. Princeton University Press.
Glewwe, P., Jacoby, H.G., King, E.M., 2001. Early childhood nutrition and academic achievement: a longitudinal analysis. J. Publ. Econ. 81 (3), 345–368.
Hirvonen, K., Taffesse, A.S., Hassen, I.W., 2016. Seasonality and household diets in Ethiopia. Publ. Health Nutr. 19 (10), 1723–1730.
Hoddinott, J., 1999. Choosing outcome indicators of household food security, p. IFPRI. Technical Guide.
Hoddinott, J., Maluccio, J.A., Behrman, J.R., Flores, R., Martorell, R., 2008. Effect of a nutrition intervention during early childhood on economic productivity in Guatemalan adults. Lancet 371 (9610), 411–416.
IFPRI, 2015. Global Nutrition Report 2015: Actions and accountability to advance nutrition and sustainable development. International Food Policy Research Institute, Washington, DC. Global nutrition report.
Jakiela, P., Ozier, O., 2015. Does Africa need a rotten kin theorem? Experimental evidence from village economies. The Review of Economic Studies rdv033.
Jensen, R.T., Miller, N.H., 2008. Giffen behavior and subsistence consumption. Am. Econ. Rev. 98 (4), 1553.
Kaminski, J., Christiaensen, L., 2014. Post-harvest loss in sub-Saharan Africa—what do farmers say? Glob. Food Secur. (3), 149–158.
Kazianga, H., Wahhaj, Z., 2017. Intra-household resource allocation and familial ties. J. Dev. Econ. 127, 109–132.
Ksoll, C., Lilleør, H.B., Lønborg, J.H., Rasmussen, O.D., 2016. Impact of village savings and loan associations: evidence from a cluster randomized trial. J. Dev. Econ. 120, 70–85.
Le Cotty, T., Maître d'Hôtel, E., Soubeyran, R., Subervie, J., 2019. Inventory credit as a commitment device to save grain until the hunger season. Am. J. Agric. Econ. 101 (4), 1115–1139.
Burke, Marshall, Lauren Falcao Bergquist, Edward Miguel, 2019. "Sell low and buy high: arbitrage and local price effects in Kenyan markets." The Quarterly Journal of Economics 134 (2), 785–842.
Lee, H., 2012. The role of local food availability in explaining obesity risk among young school-aged children. Soc. Sci. Med. 74 (8), 1193–1203.

Leung, C.W., Laraia, B.A., Kelly, M., Nickleach, D., Adler, N.E., Kushi, L.H., Yen, I.H., 2011. The influence of neighborhood food stores on change in young girls' body mass index. Am. J. Prev. Med. 41 (1), 43–51.
MacKinnon, J.G., Webb, M.D., 2017. Wild bootstrap inference for wildly different cluster sizes. J. Appl. Econom. 32 (2), 233–254.
Maluccio, J.A., Hoddinott, J., Behrman, J.R., Martorell, R., Quisumbing, A.R., Stein, A.D., 2009. The impact of improving nutrition during early childhood on education among Guatemalan adults. Econ. J. 119 (537), 734–763.
Mei, Z., Grummer-Strawn, L.M., Pietrobelli, A., Goulding, A., Goran, M.I., Dietz, W.H., 2002. Validity of body mass index compared with other body-composition screening indexes for the assessment of body fatness in children and adolescents. Am. J. Clin. Nutr. 75 (6), 978–985.
McKenzie, D., 2012. Beyond baseline and follow-up: the case for more t in experiments. Journal of Development Economics 99 (2), 210–221.
Newbery, D.M., 1991. Agricultural Institutions for Insurance and Stabilization. Oxford University Press.
Olafsson, A., Pagel, M., 2018. The liquid hand-to-mouth: Evidence from personal finance management software. Rev. Financ. Stud. 31 (11), 4398–4446.
Platteau, J.-P., 2000. Institutions, social norms, and economic development, vol. 1. Routledge, London.
Platteau, J.-P., 2014. Redistributive pressures in sub-saharan africa: causes, consequences, and coping strategies. In: Akyeampong, E., Bates, R., Nunn, N., Robinson, J. (Eds.), Africa's development in historical perspective. Cambridge University Press, pp. 153–207.
Prentice, A.M., Cole, T.J., 1994. Seasonal changes in growth and energy status in the Third World. Proc. Nutr. Soc. 53, 509–519.
Renkow, M., Hallstrom, D.G., Karanja, D.D., 2004. Rural infrastructure, transactions costs and market participation in Kenya. J. Dev. Econ. 73 (1), 349–367.
Sahn, D.E. (Ed.), 1989. Seasonal variability in third world agriculture: the consequences for food security. The Johns Hopkins University Press.
Savy, M., Martin-Prével, Y., Traissac, P., Eymard-Duvernay, S., Delpeuch, F., 2006. Dietary diversity scores and nutritional status of women change during the seasonal food shortage in rural Burkina Faso. J. Nutr. 136 (10), 2625–2632.
Schreiner, M., 2012. Une carte de score de pauvreté au Burkina Faso (Technical Report).
Stephens, E.C., Barrett, C.B., 2011. Incomplete credit markets and commodity marketing behaviour. J. Agric. Econ. 62 (1), 1–24.
Steyn, N., Nel, J., Nantel, G., Kennedy, G., Labadarios, D., 2006. Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? Publ. Health Nutr. 9 (5), 644–650.
Vaitla, B., Devereux, S., Swan, S.H., 2009. Seasonal hunger: a neglected problem with proven solutions. PLoS Med. 6 (6).
Verdin, J., Klaver, R., 2002. Grid-cell-based crop water accounting for the famine early warning system. Hydrol. Process. 16 (8), 1617–1630.
Wertenbroch, K., 1998. Consumption self-control by rationing purchase quantities of virtue and vice. Market. Sci. 17 (4), 317–337.
WHO, 1995. Physical Status: the Use and Interpretation of Anthropometry. World Health Organization, Geneva. Technical report.
World Bank, 2011. Missing Food: the Case of Postharvest Grain Losses in Sub-saharan Africa. World Bank Group, Washington. Report No. 60371-AFR.