World Development 161 (2023) 106092

Contents lists available at ScienceDirect

World Development

journal homepage: www.elsevier.com/locate/worlddev

Inventory credit to enhance food security in Burkina Faso

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ARTICLE INFO

Article history:
Accepted 26 August 2022
Available online 24 September 2022

JEL codes:
O12
O13
O16
D14
E21

Keyword:
Inventory credit
Warrantage
Intertemporal price fluctuations
Storage
Savings

ABSTRACT

In many African countries, rural households typically sell their crops immediately after the harvest, and then face severe food shortages during the lean season. This paper explores whether alleviating both credit and storage constraints through an inventory credit (or warrantage) program is associated with improvements in household livelihood. We partnered with a rural bank and a nation-wide organization of farmers to evaluate a warrantage program in seventeen villages in Burkina Faso. In randomly chosen treatment villages, households were offered a loan in exchange for storing a portion of their harvest as a physical collateral in one of the newly-built warehouses of the program. We found that the program has, on average, increased cultivated area in treated villages (mainly cotton and maize), fertilizer use, cattle and grain stock at the end of lean season (millet). Although much less robust, the results of the estimations concerning the direct users of the system further suggest that warrantage may have extended the self-subsistence period of about two weeks and increased dietary diversity, with more fruit consumed weekly.

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1. Introduction

The lean season, defined as the period between the depletion of food stocks and the completion of the new harvest, is particularly crucial in dryland African regions where agricultural production is rain-fed and relies on only one short rain season per year. During this period, rural households must often sell productive assets, rely on food aid or gifts from relatives or borrow from traders at excessive rates in order to satisfy basic consumption needs. Many rural households enter into heavy indebtedness and find themselves unable to invest into agricultural production. Coping with household food insecurity during the lean season is thus a particularly high priority in these areas.

Staple food prices in rural Africa are typically low in the immediate post-harvest period and high in the pre-harvest period. The reason why many smallholder farmers are unable to exploit this opportunity for inter-temporal arbitrage has puzzled economists for some time (Burke, Bergquist, & Miguel, 2018; Stephens & Barrett, 2011). One important reason why farmers do not store their grain may be because they lack access to credit or savings and thus have to sell their grain at low post-harvest prices to meet urgent cash needs like educational fees (Dillon, 2017). Another explanation might be that farmers would store their grain were it not for a lack of adequate storage technologies that would enable them to avoid losses due to mold and pests (Kumar & Kalita, 2017), self-control problems (Ashraf, Karlan, & Yin, 2006; Bauer, Chytilova, & Morduch, 2012; Le Cotty, Matre d'Htel, & Soubeyran, 2019), social pressure to share with kin and neighbours (Platteau, 2000; Barr & Genicot, 2008; Baland, Guirkinger, & Mali, 2011; di & Bulte, 2011; Jakiela & Ozier, 2015; Goldberg, 2017), or a combination of the three (Aggarwal, Francis, & Robinson, 2018). Inventory credit – commonly named warrantage in French speaking developing countries – is designed to solve both the credit problem and the storage problem.

With warrantage, banks typically offer farmers a loan of 80 percent of the market value of the amount of grain that they choose to store in a certified warehouse over a six-month period. Once stored, it is impossible for either the farmer or the bank to recover the grain before the loan matures. Warrantage is therefore both a credit access mechanism and a commitment device to increase grain savings. A major benefit expected from the inventory credit

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https://doi.org/10.1016/j.worlddev.2022.106092
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system is increased food security, for a given level of production. However, since inventory credit increases the value of grain during the storage period, it can also create an incentive to produce more grain. This effect is only likely to occur under certain conditions, which are difficult to anticipate. In this study, we therefore propose an experimental protocol to test the presence of the food security effect and the production effect in the field. Moreover, many theoretically promising storage systems like cereal banks led to ultimately disappointing results after two or three years of implementation, as they probably lacked the commitment effect of inventory credit and the protection against social pressure, two powerful levers for the effectiveness of the warrantage system. Thus, it is important to evaluate system performance (adoption and impact) not only in the first year of its implementation, but also in the longer term.

We partnered with the Reseau des Caisses Populaires du Burkina Faso, a rural bank operating in Burkina Faso, and the Confederation Paysanne du Faso (CPF), a nation-wide organization of farmers, to evaluate a warrantage system with seventeen villages in the western region of the country. In 2013, we ran a baseline survey from a random sample of 933 farmers spread across these villages and randomly selected eight villages that were then provided a warehouse. In November 2013, farmers living in the treatment villages were offered credit in exchange for storing a portion of their harvest as collateral in one of the newly-built warehouses. Farmers were not able to access the stored grain for a period of six months. We ran a final survey from the same sample in 2016, i.e. after three full agricultural seasons. The warrantage system has continued to function in subsequent years.

After three years of warrantage, participation reached 34% in treated villages. First, we found that the program increased cultivated area on average (+1.8 ha or 27%), essentially for cotton and maize cultivation in treated villages, compared to control ones. Moreover, the amount of fertilizers used increased by 163 kg (25%), the cattle size increased by 1.5 head (38%), and the amount of grain available at the end of the hunger season increased by 68 kg of millet. These effects are in line with the purpose of warrantage, which is avoiding the yearly depletion of resources before the season of investment (the lean season). Second, when focusing on the subset of farmers who actually made use of the program, we found again that warrantage significantly increased the size of the farm by an average of one additional hectare of cotton, as well as the fertilizer quantities and the number of cattle. Although much less robust, these results further suggest that warrantage may have extended the self-subsistence period of about two weeks and increased dietary diversity, with more fruit consumed weekly.

Taken together, these results provide evidence that warrantage is likely to perform well in providing farmers with an opportunity to overcome the "sell low buy high" phenomenon, enabling them to adjust their selling activities throughout the year and take advantage of seasonal crop price fluctuations. Our analysis also tends to confirm the results of recent empirical studies that have showed that releasing the credit constraints of households can have important consequences for the improvement in the standard of living in developing countries (Stephens & Barrett, 2011; Basu & Wong, 2015; Fink et al., 2014; Beaman et al., 2014; Burke et al., 2018). In a field experiment in Kenya, Burke et al. (2018) indeed showed that providing timely access to credit allows farmers to buy at lower prices and sell at higher prices, increasing farm revenues and generating a return on investment of about 30 percent. Our findings are also in line with previous papers that have stressed the importance of having a reliable storage technology that protects the grain from potential sources of depletion, including the impulses of the farmer himself and solidarity expenses (giving to friends and family). For example, Aggarwal et al. (2018) showed that providing a communal saving scheme for maize significantly increases both the probability to store and the probability to sell later and at higher prices.

To our knowledge, the number of studies highlighting the effects of a system allowing both access to credit and savings is still very small. The study closest to the one presented here is probably that of Delavallade and Godlonton (2020), which provides evidence of a number of short-term effects of warrantage, that on the use of agricultural inputs in particular. Our study provides field-based evidence of the long-term impacts of warrantage, which include not only production decisions, but also households' standard of living and food security. The article proceeds as follows. Section 2 describes the main features of the warrantage system that we implemented in Burkina Faso. Section 3 presents the specific features of warrantage, including the expected effects of farmers' participation in the system. Section 4 presents the data collected and Section 5 provides the empirical strategy used to estimate the effects of warrantage. Section 6 presents the results and Section 7 provides interpretations. Section 8 concludes.

2. A warrantage program in Burkina Faso

2.1. Context

Warrantage is not yet widespread in Africa. Originally developed in Niger as part of FAO interventions in the 1990's, it was first introduced in Burkina Faso in 2005 via a number of development projects (Tabo et al., 2011; Ouattara et al., 2018). The two oldest inventory credit systems, implemented in the south-west of Burkina Faso, are Union TenTietaa and the Copsac cooperative. These systems were inspired by older warrantage systems in Niger (Coulter & Onumah, 2002; Pender, Abdoulaye, Ndjeunga, & Gerard, 2008) and benefited from the support of the non-governmental organizations SOS-Sahel and CISV, respectively. In the ensuing years, both farmer organizations as well as rural banks have adopted inventory credit devices in Burkina Faso, which has contributed to their expansion and development in the country.

Most inventory credit systems are available in surplus areas where grain production exceeds grain consumption, such as in the Western and South Western regions of the country. In these regions, farmers often produce cotton and a set of cereals, the most common of which are maize, millet and sorghum. In Burkina Faso, cotton cultivation is a fully integrated production. The cotton company, Sofitex, provides farmers with fertilizer for cotton through farmers' organizations at the planting season. However, to minimize the diversion of fertilizer from cotton to maize cultivation, Sofitex also provides maize fertilizer, so that households, who are able to commit to producing a larger area of cotton, receive more fertilizer for cotton but also for maize. New inventory credit experiences are emerging in deficit areas where farmers also tend to store cash crops such as sesame, cowpeas and groundnuts. To our knowledge, none of the projects mentioned above have been rigorously evaluated to date, neither in Burkina Faso nor in other African countries.

2.2. Program implementation

As part of the FARMAF project, we implemented a warrantage system in two administrative districts of Burkina Faso, the Tuy and Mouhoun provinces, in the western region of the country (Fig. 1). We partnered with the CPF, a nationwide farmer organization, to shortlist villages that were eligible to inventory credit

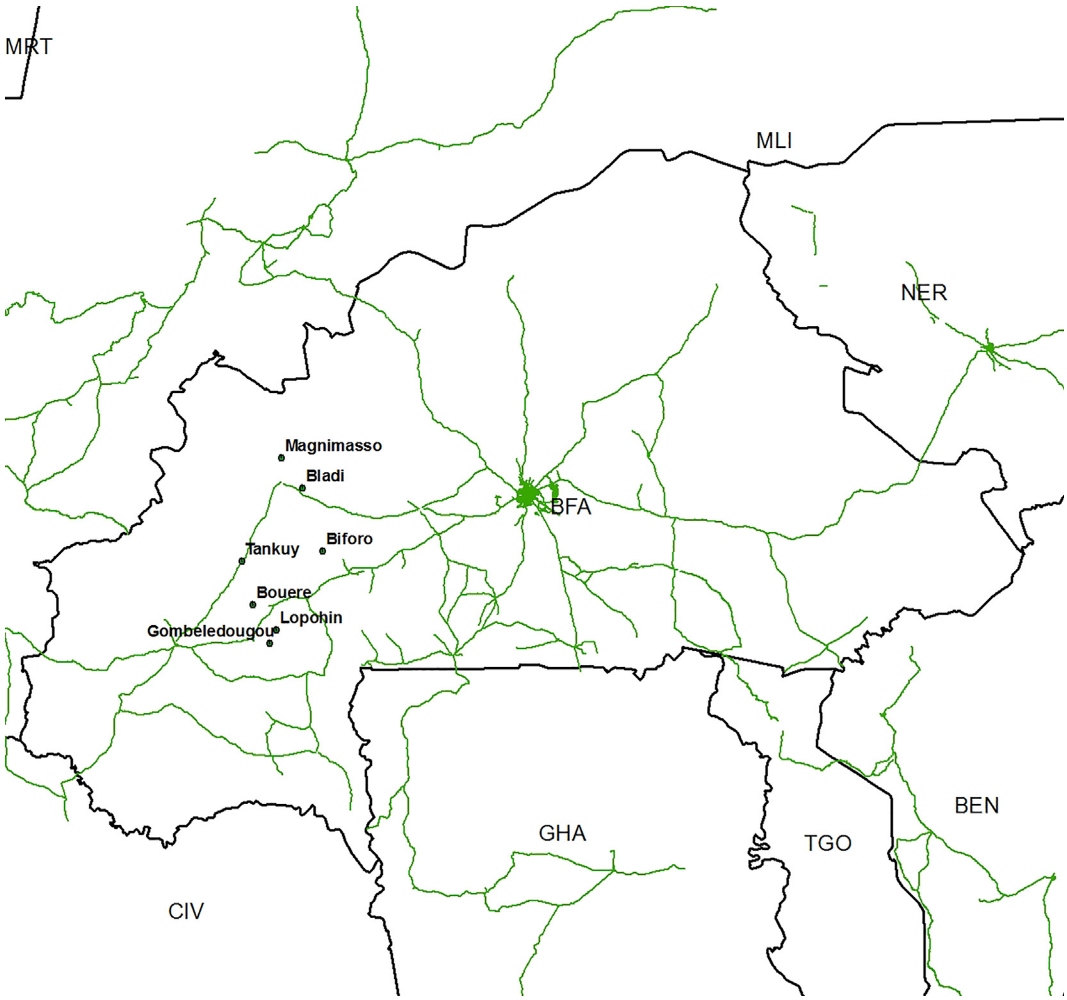

Fig. 1. Location of participant villages.

in these two districts. The selection was made on the basis of four criteria: (i) the farmer organization (FO) represented in the village had to be a member of the CPF; (ii) the FO had to be interested in participating in the warrantage program (whether treated or not); (iii) the village had to be less than 20 km away from a rural bank agency that was a member of the Reseau des Caisses Populaires du Burkina; and (iv) the FO had to have an account at the rural bank with no defaulted payments. Seventeen villages were identified, eight of which were randomly assigned to participate in the warrantage program, which includes the building of a warehouse and a number of training sessions. The random draw was made using a simple urn containing the names of the 17 villages, in the presence of representatives of the CPF.

In West Burkina Faso, most farmers grow maize and cotton, and sell cotton through FOs that are affiliated to the Union Nationale des Producteurs de Coton, an nationwide organisation that is member of the CPF. Although most FOs have an active account in rural banks to receive cotton payments, the proximity of a rural bank remains a restrictive criterion for the implementation of a warrantage system. Thus, our field experiment does not document the effectiveness of inventory credit in the context of remote areas. However, it applies well in contexts where individuals can sell their agricultural products on the market and access rural banks through FOs.

In 2013, warehouses that could hold up to 60 tons of grain were constructed in each of the treatment villages. In November 2015, i.e. after three seasons of warrantage, 85 percent of the storage capacity was reached.[1] The FARMAF project covered 95 percent of the building cost; the remaining 5 percent were paid by the farmers who were members of the local farmer organizations. The warehouses were built in the villages in order to enable farmers to bring their bags themselves on bicycles, motorcycles or donkey-pulled carts. The warehouses are secured with two locks. The key to one of these locks belongs to the rural bank, and the other key belongs to the local farmers' organization. As a result of this dual-lock system, neither party can open the warehouse in the absence of the other. Warehouse control visits by representatives from both the FO and the rural bank take place every month.

In 2013 and throughout the three farming seasons that followed, the CPF organized a major training campaign in all treatment villages, which involved FO representatives, rural bank representatives and farmers. A total of 64 training sessions were carried out. These trainings described the warrantage tool and discussed issues such as quality control management, credit monitoring and collective marketing strategies. In each treatment village, a so-called inventory credit management committee, made up of farmers responsible for the operation of the warrantage system, was elected. Members of these committees followed a collective

[1] This rate is an average. In practice, only three warehouses had reached their maximum capacity by the date of the final survey: Lopohin, Gombeledougou, and Biforo. When performing the impact analysis, we checked whether the effect of warrantage in these villages was different from that observed elsewhere and the results did not show any significant difference.

training internship in Founzan, a village where farmers were already using a similar scheme.

In the first year of implementing the program (September 2013), a large meeting bringing together the committees and representatives of the CPF of each village was organized, just before the grain was stored. Another meeting was then held in rural bank offices to build trust between the farmers and the bank and to agree on a schedule of operations to be carried out between the harvest and the locking of the warehouses. Finally, a meeting was led in each village after the reopening of the warehouse in March 2014 in order to share experiences and improve the procedure for next year.

3. The warrantage system

3.1. Principle

The warrantage system is designed around the agricultural calendar (Fig. 2). Farmers are allowed to store cereals, sesame, and peanuts. Farmers store mainly maize, followed by sorghum and millet, which are characterized by very similar price patterns.[2] In Burkina Faso, the preparation of land and sowing of maize, sorghum and millet typically begin in June. The crops grow during July and August and mature between September and October.[3] Farmers who participate in the warrantage system deposit a portion of their harvest in one of these warehouses in exchange for a 6-month loan in November, which is often used to pay seasonal employees for cotton harvesting. Farmers who are able to repay the loan are returned their collateral in May, at the lean season, when the price of grain is usually high.

It is important to mention that the loan is taken out by the FO, and not by the individual farmers. The loan amount is then redistributed by the organization to each loan applicant in proportion to the collateral provided. The rural bank does not lend more than 80 percent of the value of the inventory at the time of the loan. Should borrowers default, this protects the rural bank even if the price of grain decreases by 20 percent – something that is very unlikely to occur. The monthly interest rate charged by the bank is around 1 percent.[4] The value of the collateral is determined by the rural bank, in agreement with the representatives of the farmers' organization: the price of the grain chosen is that most commonly observed on the local markets after the harvest, ie at the village level. Slight discrepancies may appear between the price offered by the rural fund and that expected by the farmers' organisations. In this case, a discussion is initiated between the two parties until an agreement is reached. During the first season of warrantage, the value of a 100 kg bag of maize or sorghum was around 10,000 CFA, with differences from one village to another indeed, but quite negligible, the minimum value being 9,500 CFA in Tankuy, a village close to a secondary town and the maximum value being 11,000 CFA in Biforo, a remote village.

In the same way, the exact dates of opening and closing of the warehouse for the deposit of the bags of cereals are fixed jointly by the representatives of the FOs and the bank. When they have a sufficiently precise idea of the quantity of cereals to be stored and the progress of threshing, drying and bagging, the FO representative goes to the bank, borrows the keys from the bank and organizes an appointment for the closing of the warehouse. The FOs generally organize the deposit of the bags of cereals over a period of two to three days, and the bank representative comes on the last day to close the warehouse and collect the key. Farmers also have to pay storage costs, which amount to 100 CFA for each 100 kg bag of grain per month. It corresponds to approximately 1% of the value of a bag of maize stored at harvest, which means that over the storage period, the average total cost of storage is approximately 6% of the value of the bag at harvest. This storage fee is determined based on information regarding previous warrantage programs that have been implemented in Burkina Faso and Niger. It includes the costs of warehouse maintenance and the transaction costs incurred in dealing with rural banks (phone calls and travel from village to bank agencies). The borrower's name is written on each bag of grain that is deposited so that each farmer can to identify his deposit thereafter. Farmers also have the opportunity to store grain without taking out a loan.

When the loan matures in May, the bank demands the farmers' organization the repayment of the amount borrowed plus interest before authorizing the restitution of farmers' bags. The farmers that are not in capacity of paying back their part of the loan plus interests (the poorest ones presumably) can, on the same day the warehouse is opened, sell part of their bags to a buyer directly at the warehouse, to get the money to repay their loan and collect the remaining bags. In the event that the farmers could not have arrived on the day of the opening of the warehouse accompanied by a buyer, solutions are then sought with the farmers' organization within the village, and finally, if no solution is found internally, the bank can put the farmers' organization in contact with wholesalers to buy the stored cereals, in order to avoid any situation of non-payment.

The loan contract mentions a late payment penalty of 10% of the total debt per day of delay. Since the loans are taken out by the farmers' organisations, in the event of a delay, it is never just one farmer who is late, it is the whole group. This situation never happened in practice between 2013 and 2015, because the farmers collectively commit themselves to meeting the deadlines and in case they cannot individually repay their share of the loans, they almost always have the possibility of finding an arrangement with another member of the FO or to come on the day of reimbursement with a buyer.

3.2. Theoretical mechanisms of the decision to participate

When a farmer decides to participate in warrantage, she makes a tradeoff between the benefits of participating in the system, such as access to credit, to a commitment device or to a protection against social pressure and its direct and indirect costs, such as the opportunity cost of the collateral deposit, the obligation to pay storage costs at the time of deposit, the risk of not being able to reimburse the loan, the risk of misunderstanding how the system functions, and a possible lack of trust in its managers. Cotty et al. (2019) have shown that warrantage may not be profitable every year, nor for every farmer. In particular, they have stressed that, aside the benefits from commitment and social pressure relief, warrantage is profitable only when the increase in the price of grain is sufficiently large compared to the interest rate. They moreover showed that participants in warrantage are likely to fall into three categories, defined according to their preferences for time and risk: those who store grain and borrow the maximum loan amount allowed, those who store grain and borrow less than the maximum amount allowed, and those who store grain without

[2] Farmers may also store cowpeas, but since the pre-storage drying process is much easier for cereals than for cowpeas, farmers tend not to store cowpeas. Another reason why farmers store mainly maize is that maize yields are higher (since maize responds better to fertilizer). Sorghum and millet are preferred for self-consumption and traditional usages including making dolo (a traditional beer), whereas maize is not only consumed but is also a cash crop. Cotton, the main cash crop, is not a possible candidate for warrantage, notably because a parastatal board controls the entire cotton sector.

[3] The length of the cropping cycle is around 100 days for maize and 120 days for millet and sorghum.

[4] In 2013, the monthly interest rate was 0.7 percent in Magnimasso, 0.8 percent in Lopohin, 1 percent in Tankuy, 1.5 percent in Bouéré, and 1.2 percent in Bladi, Biforo, and Gombélédougou.

	June	July	August	Sept	Oct	Nov	Dec	January to April	May
Grain production	Tilling	Sowing Fertilizing	Plant growing Weeding Fertilizing		Harvesting				
Cotton production	Tilling	Sowing Fertilizing	Plant growing Weeding Fertilizing			Harvesting			
Inventory Credit (or warrantage)						Storage Credit delivery			Credit repayment Collateral restitution

Fig. 2. Agricultural Activities and Warrantage Calendar. (*Notes*: Grain production refers to production of maize, millet and sorghum.).

taking out a loan. In this study, we consider all types of participants.

3.3. Expected effects of participation

If a farmer uses the loan for urgent cash needs, instead of selling grain immediately after harvest (when prices are low), the primary interest of warrantage is to help her to take advantage of the seasonal price increase. If grain prices increase significantly in the six months since the grain was stored (which is the general pattern), the farmer will have no difficulty in repaying the bank and will leave with money in hand to satisfy consumption needs during the lean season (when usually financial liquidities are low) and to invest in productive assets such as inputs. If a farmer uses warrantage without taking a loan, or if she invests the loan in husbandry or any non-liquid assets, then an additional benefit of warrantage is that part of the crop is sheltered from the many solicitations from kin and neighbours and (inconsistent) time preferences of farmers themselves.

A variety of additional, possibly longer term, effects would also be expected, the importance of which is difficult to anticipate. For example, participants in warrantage may invest the credit in income-generating activities such as breeding cattle or hiring farm labor. They are also more likely to purchase inputs at the growing season, since they can get their collateral back in May, just before they buy inputs. With warrantage, grain can be sold later, thus at a higher price. Crop production thus becomes more profitable, and investment in general is expected to increase. Finally, warrantage is also expected to improve food security, something that can be observed in farmers' daily diet. However, as underlined previously, the effects of warrantage may not be positive, especially if the price of grain does not increase sufficiently between November and May, or if the returns on investments made are lower than expected. There is thus a need to test empirically whether warrantage can benefit to farmers at the end and if yes to what extent.

4. Data

4.1. Survey data

During the project, we carried out two major surveys: a baseline survey in January 2013, approximately eight months before the first warrantage transaction, and a final survey in August 2016, at the end of the third farming year. In January 2013, 933 farmers were randomly surveyed in the seventeen villages: 681 farmers were located in treatment villages and 252 in control villages. An average of 93 households were interviewed in each treatment village. A total of 28 farmers were interviewed in each control village. We deliberately chose to interview more people from the treatment villages because we did anticipate a low participation rate and we did want to be able to follow a large enough number of participants.

Twenty interviewers and two supervisors were recruited for the data collection. Surveys were conducted in the Dioula language with the heads of households, who were defined as the person responsible for making the farming decisions of the household. Households were randomly selected, by proceeding as follows: the interviewers began their activities at the northernmost household in the village and then walked southeast to the edge of the village, then continued southwest until the opposite edge of the village, and so on until they covered the entire village. For example, if the village had 300 households and they aimed to survey 30 households, they surveyed one household for every ten households that they passed. The number of steps from the northernmost household and the first surveyed household was random. If a household-head was not at home, the interviewers came back later.

We returned to the field in August 2016. We faced a relatively large attrition due to migration, death, or an interviewer's inability to locate the household head, most often because this person has moved and changed his name, which frequently occurs in the event of religious conversion. Locating farmers in August (the rainy season) is also much more difficult than in January because they work all day long in their field, and sometimes sleep there. In our case, however, the main cause of attrition was due to social tensions in one particular village where many farmers did not participate in the final survey. At the end, our sample includes 770 farmers who were surveyed twice: 524 farmers in treatment villages and 246 farmers in control villages. The possible consequences of this attrition are discussed in the next section.

The August 2016 survey included the same questions as the January 2013 survey, as well as additional questions related to food security, which could not be asked in January since the lean season does not start until May. They included questions around food availability and diet: the quantity of maize, sorghum, and millet currently in granaries (in kilograms), a dummy variable taking on the value of one if the farmer states that he still has grain in storage (and zero otherwise), a dummy variable taking on the value of one if the farmer states that the quantity of grain currently stored is large enough to "hold out" until the next harvest (and zero otherwise), and the number of days the household can be self-sufficient.[5]

The 2016 survey also included questions about households' diet. In the survey, farmers were asked "In the last seven days, how many times have you eaten the following foods?". For each food group, we constructed a dummy variable that takes on the value of one if the farmer answered yes to "every day", another dummy variable if the farmer answered yes to "between 3 and 6 times a week", and another dummy variable if the farmer answered yes to "one time a week" or "never".

4.2. Descriptive statistics

4.2.1. Attrition

Table 1 reports mean values for various farmer characteristics collected during the baseline survey in the treated and control villages, as well as the normalized differences between the mean values in the two groups. In the initial sample (i.e. before attrition), almost all normalized differences are below 0.25 standard deviations, which indicates that the randomization procedure was successful in constructing balanced groups (Imbens & Wooldridge, 2009). In the final sample (i.e. after attrition), all normalized differences are still less than 0.25 standard deviation, indicating that attrition ultimately did not significantly upset the balance between the two groups. The main cause of attrition is due to one treated village (Bladi) where many farmers did not participate in the final survey in 2016. These villagers actually left the project because a dispute took place between two farmers' organizations for access to and management of the warehouse, not because of their ability to use the system. We formally assess the extent to which attrition may disturb the impact estimates in Section 6.

4.2.2. Representativeness

In our data, treatment households are on average comprised of 11 members, 6 of whom are employed in farming activities; they own 7 hectares of land and devote about 20 percent of their land to maize, 20 percent to sorghum, and about 40 percent to cotton, as displayed in Table 2. We compared our data with the nationally-representative agricultural survey carried out by the Burkina Faso Ministry of Agriculture in 2013 (Table 3). This survey includes 3,547 rural households that were randomly selected in each of the 45 provinces of Burkina Faso, among which 133 households were located in the Tuy and Mouhoun provinces, where our project was implemented. Table 3 shows that average household characteristics are very similar between our sample and the households from the same geographic area that were included in the national survey. Thus, our sample appears to be quite representative of households located in western Burkina Faso more broadly.

4.2.3. Participation in warrantage over the three years

Participation in the system has been steadily increasing over the three seasons, reaching more than 30 percent in November 2015. Our final sample includes 180 farmers who participated in 2015 and possibly during previous years as well, as illustrated in Fig. 3. As Table 4 shows, the farmers electing to engage in warrantage stored a large portion of harvested crops – about 34 percent in 2015. The average number of bags stored per farmers declined over the years, which reflects the success of the device and the fact that village committees had to fix maximum amounts stored to ensure the participation of the greatest number given the 60 metrics tons storage capacity. Storage was comprised mainly of maize versus other staple food crops such as sorghum and millet. We found that the average amount of credit was higher in 2013 than in 2014 or 2015. This is mainly due to the fact that the proportion of those who chose to store without taking out a loan was also much lower in 2013 than in 2014 or 2015. The increasing adoption of warrantage over time is probably linked to people's increasing trust in the system and in its governance. The decrease over time in the demand for credit can be due either to a progressive participation of the less financially constrained farmers, or to a progressive understanding that the system offers benefits that go beyond access to credit, the commitment effect and the protection against social pressure in particular.

5. Empirical strategy

5.1. Parameters of interest

We first evaluated the impact of the program by running an Intention-to-Treat (ITT) analysis. Such analysis includes every farmer who was randomized according to the randomized controlled trial, user or not of the warrantage system. The ITT is defined as ITT$= E(y^1 - y^0)$, where y^1 denotes the outcome level in the presence of the program and y^0 denotes the outcome level in the absence of the program. In the absence of spillover effects within treatment villages, it can be difficult to detect a significant effect of the program, all the more so if the participation rate is low and the effects of the program on the participants are small. In our case, however, there is reason to believe that the warrantage system was able to benefit households other than those that actively participated. First, farmers may have taken credit in their name, for the purpose of sharing it with other households in informal arrangements. Typically, a farmer can store grain and take credit in the process on behalf of another farmer. This type of arrangement being informal, our data do not allow us to spot those "hidden users" of the system among those we designate as non-participants in our sample (Fig. 3). Second, participants who became wealthier because of warrantage may have decided to give their family and neighbours some of their earnings, typically in the form of donations of grain during the lean season.

We then aimed to estimate the Average Treatment effect on the Treated (ATT), i.e. the effect of the program on those households that actually used the warrantage scheme in 2015 (and possibly during previous years as well), which includes not only those who received credit but also those who chose to store without taking out a loan (Fig. 3). The ATT is defined as ATT$= E(y^1 - y^0 | D = 1)$, where D is a dummy variable that takes on the value of one when the farmer is a warrantage user and zero otherwise.

The key assumption for the validity of the estimates, called the Stable Unit Treatment Value Assumption (SUTVA), is that the treatment received by one farmer does not affect the outcome of another farmer located in a control village (Rubin, 1978). It should be noted that, in the event that an individual from a control village requested permission to participate in the proposed program in the nearest treated village, he would have been refused by the committee. Direct contamination of the control group is therefore unlikely. However, other phenomena, such as general equilibrium effects, are likely to occur, although connections between villages are extremely limited due to the poor quality of transport infrastructure. We discuss them at the end of our analysis.

5.2. Estimators

Regarding the ITT, we performed an OLS regression that includes a set of covariates as controls in the event that some

[5] In the survey, the farmer was asked: "How many days do you think your current stock will allow you to satisfy the basic consumption needs of the household?"

Table 1
Survey attrition.

	Initial sample (N = 933)					Final sample (N = 770)				
	Treated (n = 681)		Controls (n = 252)			Treated (n = 524)		Controls (n = 246)		
Baseline variables	Mean	SD	Mean	SD	ND	Mean	SD	Mean	S	ND
Total cultivated area (ha)	7.2	5.8	9.5	8.6	−0.216	7.4	5.9	9.4	8.5	−0.198
Cotton area (ha)	3.1	3.4	4.3	4.6	−0.222	3	3.4	4.3	4.6	−0.227
Maize area (ha)	1.5	2.4	2.3	3.1	−0.198	1.7	2.7	2.3	3.1	−0.130
Sorghum area (ha)	1.8	1.7	2.1	3.1	−0.101	1.8	1.8	2.1	2.9	−0.092
All cattle (number)	5.5	19	7.9	12.6	−0.105	5.5	20.7	7.8	12.5	−0.092
Draft cattle (number)	1.8	2	2.6	2.4	−0.262*	1.9	2.1	2.6	2.3	−0.225
Poultry (number)	16.4	20.9	26.1	35.5	−0.234	17.1	21.7	25.9	35.5	−0.212

Note: Treated group refers to the households living in the villages where the warehouses were built in 2013. Control group refers to the households living in the villages that were not offered to participate in the project. The normalized difference (ND) is the difference in means divided by the square root of the sum of variances for both groups. The * indicates that the ND exceeds one quarter.

Table 2
Household characteristics (Baseline survey).

	Intervention group			Comparison group			
Variables	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	ND
Literate (yes = 1)	524	0.35	0.48	246	0.45	0.5	−0.139
Family size (number)	524	11.25	7.68	246	13.89	10.2	−0.206
Ploughs (number)	524	1.76	1.46	246	2.2	1.76	−0.192
Labor force (number)	524	6.16	4.48	246	8.12	6.34	−0.252
All cattle (number)	524	5.53	20.7	246	7.76	12.49	−0.092
Draft cattle (number)	524	1.89	2.08	246	2.59	2.27	−0.225
Poultry (number)	524	17.1	21.71	246	25.92	35.54	−0.212
Sheep (number)	524	3.41	7.02	246	4.53	6.59	−0.117
Fertilizer use (kg)	524	594.06	705.45	246	914.29	1081.7	−0.248*
Credit (yes = 1)	524	0.63	0.48	246	0.69	0.46	−0.086
Total cultivated area (ha)	524	7.38	5.93	246	9.43	8.45	−0.198
Cotton area (ha)	524	3.05	3.35	246	4.34	4.6	−0.227
Maize area (ha)	524	1.74	2.66	246	2.27	3.07	−0.130
Sorghum area (ha)	524	1.76	1.78	246	2.07	2.94	−0.092
Cotton harvest (kg)	521	3,475.7	9,467.02	245	4,376.93	4,948.71	−0.084
Maize harvest (kg)	520	2,890.39	5,196.58	246	3,867.53	6,654.59	−0.116
Sorghum harvest (kg)	523	1,313.25	1,826.95	246	1,378.49	1,656.56	−0.026

Note: Intervention group refers to the households living in the villages where the warehouses were built in 2013. Comparison group refers to the households living in the villages that were not offered to participate in the project. The normalized difference (ND) is the difference in means divided by the square root of the sum of variances for both groups. The * indicates that the normalized difference exceeds one quarter.

Table 3
Representativeness of the sample

	Sample (N = 770)		National survey (N = 133)		
Baseline survey	Mean	Std. Dev.	Mean	Std. Dev.	ND
Total cultivated area (ha)	8.04	6.9	6.98	6.98	0.108
Cotton area (ha)	3.46	3.84	3.61	4.71	−0.025
Maize area (ha)	1.91	2.81	1.82	2.04	0.026
Sorghum area (ha)	1.86	2.22	1.98	2.29	−0.038
Draft cattle (number)	2.11	2.16	3.05	4.62	−0.183
Family size (number)	12.10	8.65	10.58	6.29	0.142

Note: This table displays summary statistics for main characteristics of farmers. The second column displays an extraction from a national agricultural survey led in 2013 by the Ministry of Agriculture of Burkina Faso. This sample is representative of the Tuy and Mouhoun regions. The normalized difference (ND) is the difference in means divided by the square root of the sum of variances for both groups. The * indicates that the normalized difference exceeds one quarter.

imbalances remain across the two groups despite the randomization procedure:

$$y_i = \alpha + \beta T_i + \gamma X_i + \epsilon_i \quad (1)$$

where y_i denotes the 2016 level of (or the change between 2013 and 2016 in) the outcome variable for household i, T_i is a binary variable that takes on the value of one when the household lives in a treated village and zero elsewhere, ϵ is an error term. The set of covariates X includes the total cultivated area (in ha), the cotton area (in ha), the maize area (in ha), the sorghum area (in ha), the education level of the head of the family (literate= 1), the family size (number), the number of ploughs, the labor force (number of active members), the cattle (number), the draft cattle (number), poultry (number), fertilizer use (in kg), credit access (yes= 1) and the existence of another warehouse in the village (yes= 1). It is important that the observable factors, X, are not affected by the project (Imbens, 2004), which is why we use pre-treatment values from the 2013 baseline survey. We clustered standard errors at the village level.

Regarding the ATT, we turned to quasi-experimental approaches. The main concern when evaluating the effects of a

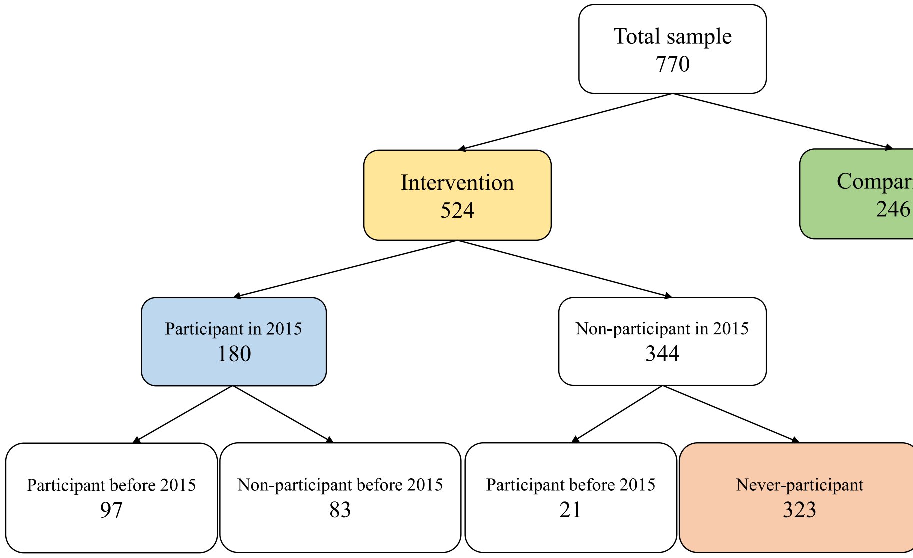

Fig. 3. Sample composition.

Table 4
Participation in warrantage: summary statistics.

Characteristics	2013	2014	2015
Number of farmers	60	105	180
Adoption rate	0.11	0.20	0.34
Average nb of maize bags stored	14.5	11.5	10.4
Average nb of sorghum bags stored	2.2	1.3	1.0
Average nb of millet bags stored	0.8	0.5	0.3
Average share of harvest stored (%)	0.28	0.23	0.34
Average amount of credit (CFA)	106,998	66,492	84,328

Note: The amount of credits is expressed in nominal value. Inflation over the period was close to zero.

voluntary program arises from the fact that the participants in intervention communities self-selected into the program. To deal with this issue, we used four estimators often used for impact analysis: the 2-Nearest Neighbor Matching (NNM) estimator which matches each participant to the two closest farmers from the comparison villages according to pretreatment covariates X, the Inverse Probability Weighted Regression Adjustment (IPWRA) estimator (Cattaneo, 2010), an OLS regression that includes the set of X and an IV regression that includes as well the same set of X, using the random allocation of the warrantage program as an instrument.[6] In practice, we thus compared participants in warrantage to their (matched) counterparts from the comparison villages (Fig. 3). Applied to the outcome variables for which we have collected data both in 2013 and 2016, this identification strategy consists of comparing the change in users' outcomes between 2013 and 2016 with the change in outcomes among matched untreated farmers from the comparison villages. We clustered standard errors at the village level using a bootstrap procedure based on 500 replications when applying non-parametric estimators (NNM and IPWRA). In the OLS and the IV regressions, clustered standard errors are obtained using the clustered sandwich estimator (as computed by STATA software).

[6] Note that in our setting where the only farmers who actually use the warrantage system are those who were randomly assigned to have access to the warrantage system, the IV estimator gives the ATT (while it gives the effect of the program on compliers in other cases) (Imbens & Rubin, 2015).

6. Results

6.1. ITT analysis results

Main results of the ITT analysis are provided in Table 5 and Table 6. Looking first at the total cultivated land area (in hectares), the area under cotton farming (in hectares), the area under maize farming (in hectares), the area under sorghum farming (in hectares), the amount of fertilizer used for maize (in kilograms), and the number of cattle, plows, poultry, and sheep, we found evidence that living in a treatment village had improved farmers' productive investment and capital accumulation (Table 5). First, we found that, after three years of warrantage, farmers in treated villages cultivated on average a larger area (+1.8 ha, i.e. a 27% increase), devoted to growing cotton and maize. We also found that on-farm fertilizer use (NPK) increased by an average of 167 kg (25%) compared to the control group. Finally, we found that the herd size increased significantly, averaging 1.5 head (38%) more than in the control group.

Looking then at food security outcomes, i.e. the probability of having grain in stock at the time of the survey, the probability that the quantity of grain in stock is sufficient to satisfy basic consumption needs until the next harvest, the number of days of self-sufficiency, and the quantity of maize, sorghum and millet in stock, we ended up with impact estimates that lack precision most of the time (Table 6). The findings however suggest that living in a treatment village may have improved farmers' food security by increasing millet stock (85 kg of millet in stock in the treated group compared to only 15 kg in the absence of warrantage).[7]

In order to assess the extent to which attrition may have disturbed our estimates, we estimated the Lee bounds (Lee, 2009; Tauchmann, 2014). The results indicate that the bounds are ranging from −0.66 to a +1.75-ha increase in farmland. Taking standard

[7] Although warrantage is not designed to favour one type of farmer over others, we tested for the presence of heterogeneous effects in the main regression that gives the difference between treated villages and control ones. We included an interactive variable in the model, which crosses the treatment and a variable measuring the level of wealth of the farmer, measured by the farm size, the area cultivated under cotton, the cattle size or access to credit through a formal institution. In all three cases, the results do not allow us to conclude that there is a more pronounced effect of access to warrantage for the farmers who were initially better endowed.

Table 5
Impact on land use and farming activities (ITT estimates).

Outcome	(1) sample mean y_1	(2) ITT regression coef.	s.e.	N	R^2
Total cultivated area (ha)	8.56	1.82 ***	0.54	770	0.20
Cotton area (ha)	4.16	1.22 *	0.58	770	0.22
Maize area (ha)	2.09	0.46 ***	0.14	770	0.25
Sorghum area (ha)	1.58	0.32	0.22	770	0.26
All cattle (number)	5.63	1.47 *	0.78	770	0.71
Draft cattle (number)	2.01	−0.3	0.20	770	0.36
Poultry (number)	14.36	−2.65	3.65	770	0.56
Sheep (number)	3.8	0.30	0.34	770	0.05
Fertilizer use (kg)	811	167.47 *	81.37	770	0.22
Cotton harvest (kg)	3,758	916.81 *	483.82	765	0.11
Maize harvest (kg)	2,947	272.65	170.84	766	0.10
Sorghum harvest (kg)	1,039	−281.40	239.57	769	0.13

Note: This table presents ITT estimates. Column 1 gives the mean value of the outcome level (y_1) in 2016 amongst households living in treated villages. Column 2 gives the ITT using an OLS regression that includes a set of pretreatment covariates as controls: the total cultivated area (in ha), the cotton area (in ha), the maize area (in ha), the sorghum area (in ha), the education level of the head of the family (literate = 1), the family size (number), the number of ploughs, the labor force (number of active members), the cattle (number), the draft cattle (number), poultry (number), fertilizer use (in kg), credit access (yes = 1) and the existence of another warehouse in the village (yes = 1). Robust standard errors are adjusted for village clusters. The ***, ** and * indicate that the estimated coefficients are statistically significant at the 1%, 5%, and 10% levels, respectively.

Table 6
Impact on food security (ITT estimates).

Outcome	(1) sample mean y_1	(2) ITT regression coef.	s.e.	N	R^2
Cereals still in stock (yes = 1)	0.84	0.02	0.047	770	0.08
Cereals in sufficient quantities (yes = 1)	0.08	0.02	0.063	770	0.13
Self-sufficiency (days)	79	9.84	8.62	769	0.13
Quantity of maize in stock (kg)	477	25.22	166.34	766	0.28
Quantity of sorghum in stock (kg)	244	50.16	113.23	770	0.25
Quantity of millet in stock (kg)	85	68.68 **	25.82	770	0.08

Note: This table presents ITT estimates. Column 1 gives the mean value of the outcome level (y_1) in 2016 amongst households living in treated villages. Column 2 gives the ITT using an OLS regression that includes a set of pretreatment covariates as controls: the total cultivated area (in ha), the cotton area (in ha), the maize area (in ha), the sorghum area (in ha), the education level of the head of the family (literate = 1), the family size (number), the number of ploughs, the labor force (number of active members), the cattle (number), the draft cattle (number), poultry (number), fertilizer use (in kg), credit access (yes = 1) and the existence of another warehouse in the village (yes = 1). Robust standard errors are adjusted for village clusters. The ***, ** and * indicate that the estimated coefficients are statistically significant at the 1%, 5%, and 10% levels, respectively.

errors into account, the lower bound does not significantly deviate from zero. This indicates that although the impact is more likely positive, we cannot rule out that it is zero.

6.2. ATT analysis results

6.2.1. Self-selection of warrantage users

The program was offered to all households living in treatment villages. Farmers were invited to participate in informational meetings and decided whether they would like to participate. This self-selection process have led to a particular profile of participants that distinguishes them from those who never chose to participate in the scheme. Table 7 shows that the subset of surveyed farmers who decided to store crops in the warrantage system indeed differ in some respects from farmers who did not. In particular, we found that participants have larger farms, larger areas of land under cotton farming, larger areas under sorghum farming and they use larger quantities of fertilizer.

6.2.2. Matching procedure

To estimate the impact of the program on actual warrantage users, we applied the aforementioned estimators to the group of users, using those who were not offered the warrantage program to estimate the counterfactual level of outcomes (see Fig. 3). This requires computing conditional probabilities for being warrantage users (or propensity scores)[8] and for determining whether the matching procedure performed well. Table 8 compares the extent of balancing between the user and control groups before and after the matching procedure. All normalized differences after matching are well below the suggested criteria of 0.25 standard deviations (Rubin, 2001; Imbens & Wooldridge, 2009), which indicates that the matching procedure was successful in constructing a valid control group. Fig. 4.

6.2.3. ATT estimates

Our estimates of the effects of warrantage on land use and farming activities among warrantage users are presented in Table 9. Column (1) gives the mean value of the outcome in 2016 among users, while Columns (2)-(5) provide the impact of warrantage, that is, the difference between the value given in Column (1) and the estimated counterfactual value. For a number of outcomes,

[8] We compute propensity scores for users and controls by estimating a probit model, using the sample of individuals living in treatment villages, where the dependent variable is a dummy variable which takes on the value of one if the farmer is a user and zero otherwise. The explanatory variables include all of the pretreatment covariates presented in Table 7. From the estimated parameters of this model, we then computed the conditional probabilities of participating in the program for both users and controls. Fig. 4 shows that densities in both groups are high enough for a wide range of propensity scores, meaning that the matching procedure is likely to perform well.

Table 7
Participants vs Never-participants: Summary statistics.

	Never-participants (N = 323)		Participants (N = 180)		
Baseline survey	Mean	Std. Dev.	Mean	Std. Dev.	ND
Literate (yes = 1)	0.31	0.46	0.43	0.5	−0.19
Family size (number)	10	7	12	9	−0.19
Ploughs (number)	1.63	1.41	1.91	1.49	−0.14
Labor force (number)	5.75	3.76	6.68	5.35	−0.14
All cattle (number)	5.76	25.76	4.85	7.21	−0.03
Draft cattle (number)	1.69	2.04	2.14	1.99	−0.16
Poultry (number)	15	19	20	25	−0.15
Fertilizer use (kg)	458	524	771	843	−0.31*
Credit (yes = 1)	0.61	0.49	0.66	0.47	−0.08
Total cultivated area (ha)	6.17	4.58	8.96	6.93	−0.34*
Cotton area (ha)	2.5	2.83	3.76	3.82	−0.27*
Maize area (ha)	1.54	2.18	1.85	2.89	−0.08
Sorghum area (ha)	1.49	1.49	2.21	2.12	−0.28*

Note: Participants are the households living in the villages where the warehouses were built in 2013, who actually used the warrantage scheme in 2015 and possibly in the years before. Never-participants refer to the households living in the villages where the warehouses were built in 2013, who decided not to use the warrantage scheme (neither in 2015 nor before). The normalized difference (ND) is the difference in means divided by the square root of the sum of variances for both groups. The * indicates that the normalized difference is significant since it exceeds one quarter.

Table 8
Balancing tests before and after matching.

Variables in 2013	Treated	Control (ipwra)	Control (2-nn)	SD before ipwra	SD after ipwra	SD before 2-nn	SD after 2-nn
Total land area (ha)	10.9	10.1	9.8	−0.10	−0.01	−0.14	−0.04
Cotton area (ha)	4.3	3.8	3.7	−0.14	0.00	−0.16	0.01
Maize area (ha)	2.3	1.8	1.9	−0.14	−0.01	−0.13	−0.03
Sorghum area (ha)	2.1	2.2	2.1	0.05	−0.05	0.00	−0.07
Literate (yes = 1)	0.5	0.4	0.4	−0.04	−0.02	−0.02	−0.14
Family size (number)	13.9	12.5	11.8	−0.15	0.00	−0.23	−0.07
Ploughs (number)	2.2	1.9	1.9	−0.18	−0.03	−0.19	−0.01
Labor force (number)	8.1	6.7	6.7	−0.24	−0.03	−0.25	−0.08
All cattle (number)	7.8	4.9	4.5	−0.29	−0.02	−0.32	−0.05
Draft cattle (number)	2.6	2.1	2.1	−0.21	−0.03	−0.24	−0.01
Poultry (number)	25.9	19.8	20.0	−0.20	−0.02	−0.19	0.02
Fertilizer use (kg)	914.3	770.7	754.5	−0.15	0.01	−0.16	0.00
Credit (yes = 1)	0.7	0.7	0.7	−0.06	−0.01	−0.04	0.02

Note: This table provides mean values of pre-treatment covariates in both treated and control groups as constructed using the 2-NNM and the IPWRAestimators. It moreover provides the standardized difference (SD) in means of the two groups. SD in means is considered negligible when it is below the suggested rule of thumb of 0.25 standard deviations (Rubin, 2001; Imbens andWooldridge, 2009).

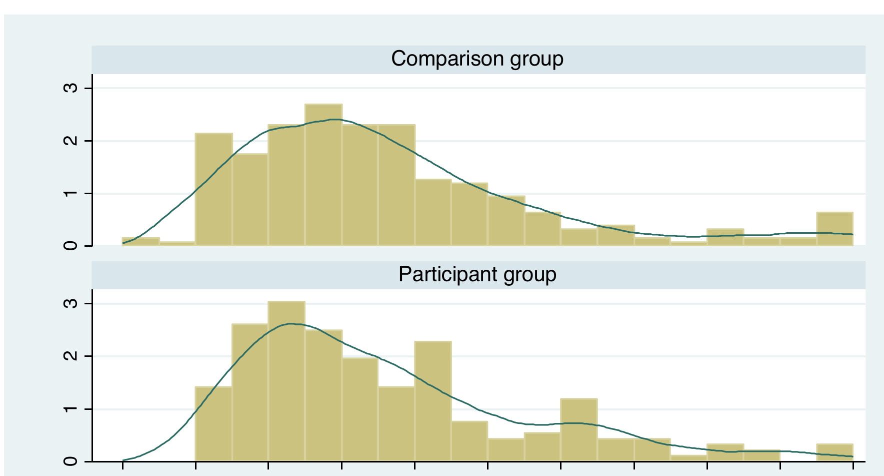

Fig. 4. Distribution of propensity scores by groups. (*Note*: The participant group includes the 180 households that actually used the warrantage scheme. The comparison group includes the 246 households that were not offered to participate in the program.).

the impact is estimated with precision. The impact on the total cultivated area varies from 1.1 ha (according to the IPWRA estimator) to 2.41 ha (according to the IV estimator). As the warrantage users have an average of 10.7 hectares, the mean relative impact varies from 10 and 30 percent. In line with ITT estimates, the results also suggest that warrantage increased the area of land used to grow

Table 9
Impact on land use and farming activities (ATT estimates).

	(1) sample mean	(2) 2-nearest-neighbor matching		(3) ipwr adjustment		(4) OLS regression		(5) IV regression	
Dependent variable	y_1	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.
Total cultivated area (ha)	10.71	1.55 *	*0.83*	1.10 ◆	*0.77*	1.36 **	*0.64*	2.41 ◆	*1.62*
Cotton area (ha)	5.57	1.42 **	*0.69*	1.10 **	*0.49*	1.29 **	*0.51*	1.84 ◆	*1.29*
Maize area (ha)	2.41	0.35	*0.28*	0.25	*0.21*	0.28 *	*0.14*	0.64	*0.48*
Sorghum area (ha)	1.78	−0.08	*0.33*	−0.03	*0.39*	0.06	*0.26*	0.74	*0.59*
All cattle (number)	6.33	1.26 ◆	*0.79*	1.27 *	*0.76*	1.54 **	*0.66*	2.77	*2.11*
Draft cattle (number)	2.53	0.10	*0.31*	0.10	*0.24*	0.10	*0.16*	−0.36	*0.50*
Poultry (number)	18.43	1.41	*3.15*	−0.99	*3.38*	0.70	*3.04*	−3.76	*7.00*
Sheep (number)	4.50	0.55	*0.65*	1.19 **	*0.62*	1.15 **	0.48	1.36 *	*0.78*
Fertilizer use (kg)	1,125.28	192.04 ***	*140.15*	187.36 **	*92.40*	202.09 **	*77.67*	230.04	*174.10*
Cotton harvest (kg)	5,321.49	847.58	*800.21*	760.53	*717.48*	913.68 ◆	*548.41*	781.65	*1275.0*
Maize harvest (kg)	3,732.01	655.11 ◆	*430.69*	567.45 ◆	*373.32*	529.51	*328.86*	321.95	*517.14*
Sorghum harvest (kg)	1,219.51	−79.15	*286.20*	−102.30	*159.58*	−142.85	*296.42*	−177.05	*603.07*

Note: This table presents ATT estimates. Column 1 gives the mean value of the outcome level (y_1) in 2016 amongst treated households. Column 2 gives the ATT using the 2-NNM estimator. Column 3 gives the ATT using the IPWRA estimator. Column 4 gives the ATT using an OLS regression. Column 5 gives the ATT using an IV regression taking the random location of warehouses as an instrument for participation in warrantage. Robust standard errors are adjusted for village clusters. The ***, **, * and ◆ indicate that the estimated coefficients are statistically significant at the 1%, 5%, 10% and 15% levels, respectively.

cotton, as well as the quantity of fertilizer. Finally, we also found that the warrantage users ended up with a number of heads of cattle higher than that of their matched counterparts (more than one head on average).

Table 10 displays the estimates of the ATT for various food security variables. Just like in Table 9, Column (1) gives the mean value of the outcome in 2016 among warrantage users, while Columns (2)-(5) provide the impact of warrantage, that is, the difference between the value given in Column (1) and the estimated value in the counterfactual scenario. Here the results are much less robust. The NNM estimator suggests that warrantage may have increased the probability of having grain in stock and the probability that the quantity of grain in stock is sufficient to satisfy basic consumption needs until the next harvest. However, the results are not supported by other estimators. The IPWRA and the OLS estimators suggest also that warrantage may have increased the number of days of self-sufficiency (about 16 or 17 additional days on average), but again this results remains fragile.

We next examined the diversity of the food consumed by households on a weekly basis. Table 11 displays the impact of warrantage on dietary diversity for the two outcomes for which we obtained some statistically significant results, namely the probability of consuming certain food items several times a week and the probability of consuming them daily. Both OLS and IV regressions suggest that warrantage may have increased the probability of consuming fruit several times a week or on a daily basis. However, non-parametric estimators remain inconclusive on this point.

7. Discussion

7.1. Participation rates in warrantage

We observed that average participation in the warrantage program increased steadily over the three seasons, starting at 11 percent in 2013 and reaching 34 percent in 2015. This take up rate may seem low as compared to one other experimental project led in Burkina Faso by Delavallade and Godlonton (2020) that reached around 90 percent. In that study, however, households eligible for warrantage were those who had clearly expressed an interest in participating in the program before its launch. It is therefore not surprising that the participation rate within this sample was high. In our case, on the contrary, the program was offered to all farmers living in the treated villages, including those who were unwilling to participate given their economic status. For instance, the poorest net buyers, those households that grow grain to meet their immediate consumer needs simply cannot afford to store the grain for the duration of the warrantage period. They eat their grain and work as agricultural workers on other farms or engage in non-agricultural activities to supplement their income. These households cannot participate in warrantage, even if they are offered to do so.

Table 10
Impact on food security (ATT estimates).

	(1) sample mean	(2) 2-nearest-neighbor matching		(3) ipwr adjustment		(4) OLS		(5) IV	
Dependent variable	y_1	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.
Cereals still in stock (yes = 1)	0.94	0.09 ◆	*0.06*	0.06	*0.05*	0.06	*0.04*	−0.03	*0.101*
Cereals stored in sufficient quantities (yes = 1)	0.81	0.14 *	*0.07*	0.07	*0.08*	0.065	*0.062*	−0.004	*0.145*
Self-sufficiency (days)	95.4	16.3	*12.46*	15.94 ◆	*10.02*	17.1 *	*8.5*	21.3	*19.07*
Quantity of maize in stock (kg)	746.0	141.33	*200.39*	63.54	*256.95*	216.5	*177.96*	67.5	*350.39*
Quantity of sorghum in stock (kg)	318.8	−110.80	*189.53*	18.57	*112.40*	−71.6	*205.3*	−124.1	*331.17*
Quantity of millet in stock (kg)	94.81	52.05	*49.66*	37.37	*50.41*	33.6	*47.6*	137.5 **	*61.46*

Note: This table presents ATT estimates. Column 1 gives the mean value of the outcome level in 2016 (y_1) amongst treated households. Column 2 gives the ATT using the 2-NNM estimator. Column 3 gives the ATT using the IPWRA estimator. Column 4 gives the ATT using an OLS regression. Column 5 gives the ATT using an IV regression taking the random location of warehouses as an instrument for participation in warrantage. Robust standard errors are adjusted for village clusters. The ***, **, * and ◆ indicate that the estimated coefficients are statistically significant at the 1%, 5%, 10% and 15% levels, respectively.

Table 11
Impact on diet (ATT estimates).

Food group consumed	(1) mean	(2) 2-nn		(3) ipwr		(4) probit		(5) IV	
Several times a week (yes= 1)	y_1	coef.	s.e.	coef.	s.e.	coef.		coef.	
leguminous	0.05	−0.04	*0.03*	−0.03	*0.02*	−0.03		−0.01	
oleaginous	0.20	0.01	*0.05*	0.04	*0.04*	0.03		−0.04	
meat	0.20	0.03	*0.04*	−0.01	*0.04*	−0.01		−0.11	
fish	0.66	0.13	*0.06*	0.15	*0.05*	0.14		0.20	
dairy products	0.07	−0.01	*0.03*	0.00	*0.02*	0.00		0.03	
eggs	0.05	0.03	*0.02*	0.03	*0.02*	0.02		0.09	
oil	0.88	0.09	*0.04*	0.10	*0.04*	0.08		0.12	
vegetables	0.25	−0.05		−0.04	*0.04*	−0.02		−0.11	
fruits	0.05	0.03	*0.00*	0.04	*0.02*	0.04	*	0.16	**
sugars	0.85	−0.01	*0.02*	−0.04	*0.03*	−0.04		−0.13	
sauce and condiment	0.99	0.03	*0.02*	0.02	*0.14*	0.02		0.02	
Daily (yes= 1)									
leguminous	0.01	0.00	*0.01*	0.00	*0.01*	0.00		0.03	
oleaginous	0.06	−0.04	*0.04*	−0.01	*0.02*	−0.01		−0.04	
meat	0.03	0.02	*0.02*	0.00	*0.02*	0.00		−0.02	
fish	0.38	0.08	*0.06*	0.10	*0.05*	0.08		0.04	
dairy products	0.04	0.00	*0.03*	0.00	*0.02*	0.00		0.01	
eggs	0.01	0.01	*0.01*	0.01	*0.01*	0.00		0.00	
oil	0.68	0.07	*0.06*	0.08	*0.05*	0.06		0.08	
vegetables	0.18	−0.03	*0.05*	0.01	*0.04*	0.02		−0.05	
fruits	0.03	0.02	*0.02*	0.03	*0.01*	0.03	◆	0.03	◆
sugars	0.73	−0.03	*0.05*	−0.05	*0.04*	−0.04		−0.13	
sauce and condiment	0.98	0.10	*0.08*	0.09	*0.03*	0.08		0.11	

Note: This table presents ATT estimates. A food group is said to be consumed "several times a week" (resp. "daily") if the respondent stated that he consumed this food group 3 or 4 times (resp. 5 times or more) the week before he was surveyed. Column 1 gives the mean value of the outcome level (y_1) in 2016 amongst treated households. Column 2 gives the ATT using the 2-NNM estimator. Column 3 gives the ATT using the IPWRA estimator. Column 4 gives the ATT using a probit regression. Column 5 gives the ATT using an IV probit regression. (a) For binary dependent variables, Columns (4) and (5) provide marginal effects; in those cases, standard errors are not provided; significance refers to the estimated coefficients. The ***, **, * and ◆ indicate that the estimated coefficients are statistically significant at the 1%, 5%, 10% and 15% levels, respectively.

7.2. Main effects on households

One of our main findings is that warrantage increased the cultivated area, in particular the cotton area and to a lesser extent, that of maize. This result is in line with qualitative information collected in the field, which indicates that many warrantage users chose to use their loan to hire farm workers to harvest more cotton. In the Tuy and Mouhoun regions, the main factor limiting cotton cultivation is not the availability of land but rather the liquidity constraint to hire seasonal workers for the harvest. As the maize harvest takes place in October-November, the grain can be used by households as collateral to obtain the loan offered in the warrantage system. The loan is then granted in December, at the start of the cotton harvest period. It can thus be used to hire seasonal workers. In this way, warrantage provides a loan to relax the liquidity constraint and promotes the expansion of cotton.

Additionally, warrantage is likely to increase the expected gains associated with growing maize: higher maize prices due to later sales, increased food security due to later release of stocks, increased livestock size and a decrease in expected losses of maize through social taxation. Due to this increase in expected profitability, the optimum maize acreage increases and the amounts of fertilizer used on the maize acreage increase too. Since direct access to fertilizers is limited and most farmers obtain fertilizers through the cultivation of cotton (the fertilizers made available by Sofitex for the cultivation of maize are proportional to the area of cotton), the optimal cotton acreage increases with the expected profitability of maize.

Another important finding is that warrantage may encourage farmers to invest in productive assets, such as livestock. This may suggest that participants in warrantage used the loan, or the earnings generated through warrantage during previous seasons, to buy cattle and sheep. It may also mean that warrantage has prevented certain families from decapitalizing, i.e. selling an animal after the grain stock is finished. In all cases, this is an important effect because livestock can serve as a buffer for smoothing consumption, as well as a generator of additional income. Our results thus suggest that warrantage could generate at least two types of effects: an increase in investment in factors of production (labor and land) whose returns will materialize from the next harvest; and an increase in investment in productive assets that play a role of financial safety net.

7.3. Price effects in treated villages

An alternative or complementary explanation for the impacts of warrantage on food security that we found is that warrantage has modified the prices in treated villages. Warrantage reduces the amount of grain sold in the village at harvest time, thus avoiding the drop in food prices typically observed in the absence of a storage warehouse. Releasing collateral stocks at the start of the lean season also increases the amount of grain available in the village, thus avoiding the rise in food prices typical of the lean season. To assess to what extent warrantage could have modified the evolution of prices in the treated villages, we calculated the average monthly prices of maize from the data collected during the final survey. Maize prices were computed from the sales of maize carried out by the respondents between February 2012 and January 2013, in treated and control villages (Fig. 5). We did the same using data on maize prices between February 2015 and January 2016, obtained through the baseline survey, i.e. before the implementation of the warrantage program (Fig. 6).

Fig. 5 shows that the price dynamics in treated and control villages before the warrantage was set up, are quite similar in both groups, meaning that the potential gains from participating in the warrantage system were indeed independent of the treatment. It moreover shows a quite strong seasonality, around 45 percent, i.e. large enough to motivate the use of warrantage in both groups.

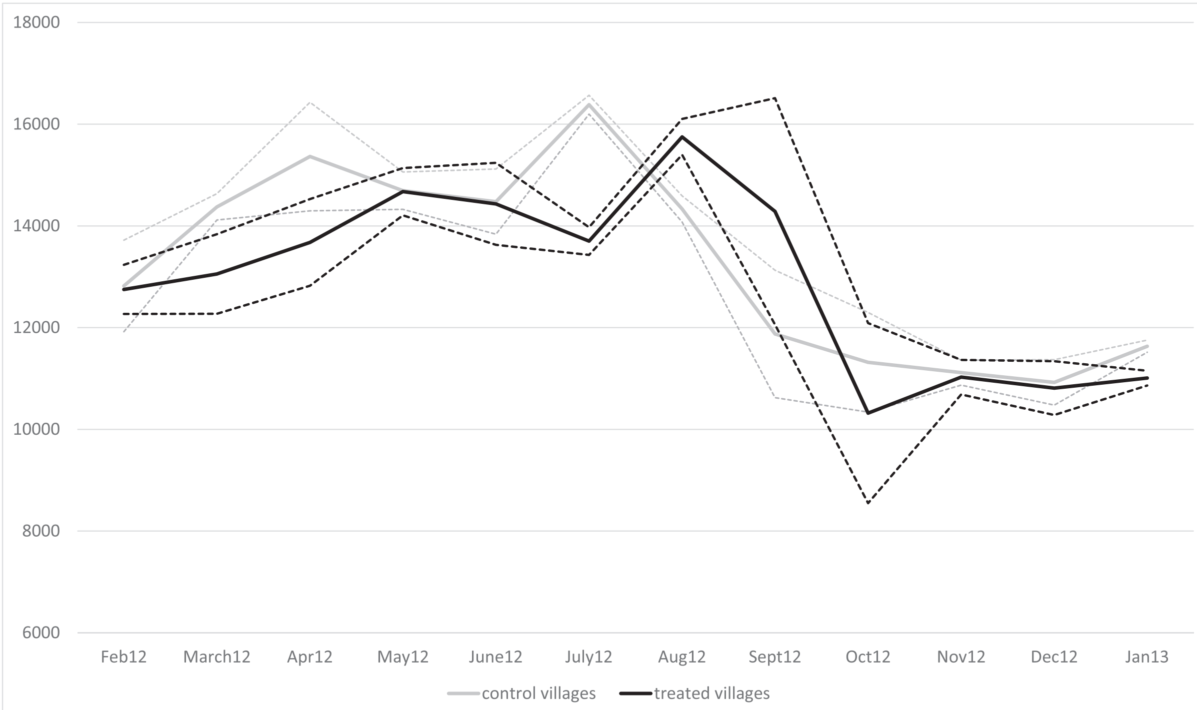

Fig. 5. Evolution of maize prices in treated and control villages in 2012 (in CFA francs).

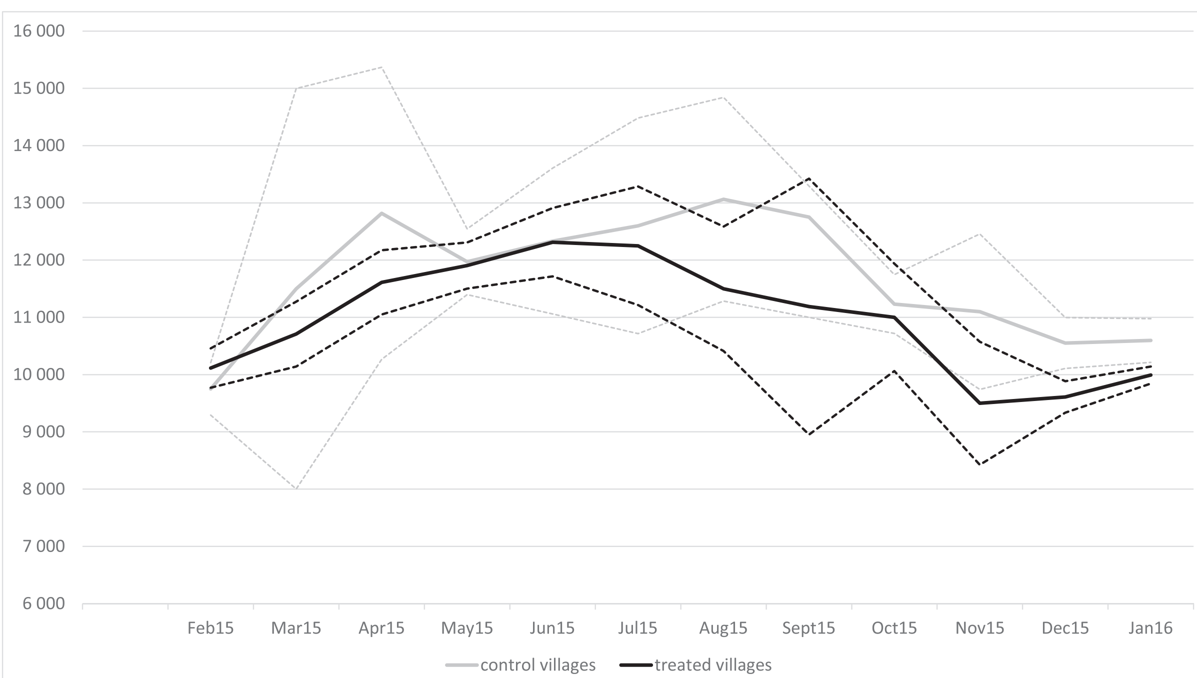

Fig. 6. Evolution of maize prices in treated and control villages in 2015 (in CFA francs).

By contrast, Fig. 6 shows that the price dynamics in treated and control villages appear to have changed after the warrantage was set up. We did not find clear evidence of price smoothing at harvest time in treated villages. On the contrary, the evolution of the price of cereals in treated villages is compatible with a smoothing of prices in the lean season. One possible reason for this is that the amount of grain stored in the warehouse represents a much larger share of the total grain available in the village during the lean season than during the harvest season. Therefore, we cannot exclude that warrantage had an impact on food security also because food was cheaper during the lean season in the treated villages.

This price effect is likely to have also benefited non-users of the warrantage system. To verify this, we estimated the impact of the program on the subset of households located in the treated villages but not having been registered as users of the system. They are called non-participants in Fig. 3. We applied the same identification strategy as for users. The results are not conclusive and do not show any spillover effect of warrantage among non-users.[9] Moreover, this result suggests that non-participants have not benefited from the system through informal arrangements with users either, as we had envisioned, or that the effects are not large enough for us to highlight with our data.

7.4. Price effects in control villages

A concern with the analysis is that the warrantage carried out in the treated villages has affected the price of cereals in the control villages. This would likely happen if the quantities stored in warehouses in the treated villages immediately after harvest, as well as the quantities released during the lean season, could significantly affect regional prices. However, the evolution of local prices in both groups suggests rather that the quantities traded were too small to influence the region as a whole. Fig. 6 indeed suggests an effect of warrantage on the local price of cereals in the treated villages (during the lean season only) but nothing similar in control villages. This tends to support the validity of SUTVA.

8. Conclusion

Inventory credit systems have been celebrated for giving farmers access to credit and, in doing so, providing them with an opportunity to overcome the "sell low buy high" phenomenon, notably because providing access to credit enables farmers to adjust their selling activities throughout the year and take advantage of seasonal price fluctuations. In this paper, we quantified the effects of one of the first warrantage systems implemented in Burkina Faso. Our results suggest that such a system is likely to generate strong and long-term effects on production, savings, and food security.

As in many empirical studies, our findings are to some extent specific to the study area and/or the period analysed. As such, it is difficult to determine whether the effects we estimate can be generalized to other situations. For example, the long-term on-the-ground presence of the project proponent – the CPF – and the trust that characterized the relationship between farmers, the CPF and the rural bank in the study areas probably contributed to such encouraging results. In a less favorable context, many households may have been reluctant to entrust their grain to a farmer organization. It must also be recognized that the efficiency of the system can be significantly reduced when the state intervenes in the marketplace via price stabilization, as occurred in 2013.

We nevertheless believe there are several takeaways from our main findings. In particular, we show that warrantage is likely to increase investment in factors of production (labor and land) and in productive assets that also play a safety net role (cattle). We further provide evidence that warrantage can improve food security, with more grain in stock at the lean season. Overall, these results suggest that warrantage is a promising development tool for African countries. Additional investigations are needed to provide evidence of spillover effects within villages and to show which of the two features of the system (access to credit or access to storage or a combination of both) has led to the effects we estimated. We keep this for future research.

CRediT authorship contribution statement

Tristan Le Cotty: Conceptualization, Investigation, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Elodie Maître d'Hôtel:** Funding acquisition, Conceptualization, Investigation, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Julie Subervie:** Conceptualization, Investigation, Methodology, Formal analysis, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This research would not have been possible without the full cooperation of the Confederation Paysanne du Faso. Funding for this research was provided by the European Union with additional funding from AGRINATURA for the Farm Risk Management for Africa project, coordinated by CIRAD.

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[9] Results are available from authors upon request.

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