NBER WORKING PAPER SERIES

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Working Paper 27564
http://www.nber.org/papers/w27564

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
July 2020

We are very grateful to Karim Pare and his team for excellent data collection efforts. We thank Thomas Barré for useful comments and suggestions, as well as seminar participants at Istanbul Technical University, Bahçeşehir University, Boğaziçi University and various conferences. We also thank Inclusive Guarantee and SOFITEX for their support and for providing access to data. This project was made possible by generous funding from the United States Agency for International Development through the BASIS Assets and Market Access Innovation Lab grant No: EDH-A-00-06-0003-00. Quentin Stoeffler also acknowledges support from Istanbul Technical University's Bilimsel Araştırma Projeleri (BAP) unit, grant number SAB-2018-41143. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 27564
July 2020
JEL No. G22,I38,O12,O13,Q12

ABSTRACT

This paper examines whether agricultural insurance can boost investment by small scale farmers in West Africa. We conduct a randomized evaluation to analyze the impacts of index insurance for cotton farmers in Burkina Faso. We find no impact of insurance on cotton, but, consistent with microeconomic theory, we find significant spillover impacts on investment in other agricultural activities. Furthermore, the effects of insurance payouts on farmers hit by a shock confirm the potential of index insurance as a risk-management tool. However, we uncover important flaws in the implementation of the project that limited its impacts. Overall, this study suggests a promising role of index insurance for stimulating investment, but also draws attention to key challenges for an efficient delivery of insurance to small farmers. Finally, the hybrid, mixed methods RCT design that we employ offers lessons for the evaluation of complex interventions where trust, understanding and timing are all important.

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1 Introduction

An increasing amount of evidence suggests that the lack of instruments for risk management (saving, credit and insurance) plays a major role in limiting poor households' ability to accumulate assets and improve their future well-being. Uninsured risk prevents households from perfectly smoothing consumption (Dercon, 2002; Kazianga & Udry, 2006), and causes adverse shocks to have harmful lifetime consequences (Hoddinott & Kinsey, 2001; Alderman *et al.* , 2006). Besides the impact of realized shocks, exposure to risk also discourages investment in profitable but risky activities, as households smooth income (Morduch, 1995). Farmers in Sub-Saharan Africa for example have been shown to adopt low-risk, low-return portfolio strategies, such as cultivating "safe" crops (Dercon, 1996; Stoeffler, 2016). This situation is striking in the Sahel in general and in Burkina Faso in particular, where levels of risk are high and overall levels of investments in input and productive assets are low.

If risk thus deepens and perpetuates low living standards in Burkina and elsewhere in rural Africa, then insurance or other instruments to transfer risk from farmers would seem to be promising poverty alleviation tools. By directly offsetting the most deleterious consequences of realized shocks, insurance should indirectly allow rural households to prudentially invest more in risky, but high returning agricultural activities. However conventional agricultural insurance is infeasible in most rural areas of sub-Saharan Africa.[1] On the other hand, index insurance has emerged as a promising alternative to traditional insurance contracts. By making indemnity transfers contingent on an index (such as average yields or rainfall within a locality) rather than on an individual outcome, index insurance is immune to moral hazard and eliminates the need for costly individual loss verification. The drawback is that insurance payments based on the index are not perfectly correlated with actual farmers' losses, and that the protection it provides farmers may be relatively low (an issue described as "basis risk").[2] Despite this weaknesses of index insurance, and the controversy that sometimes surrounds it (Economist, December 13), there is a small, but growing body of evidence that insurance protection indeed boosts small-scale farmer investment in protected activity (Mobarak & Rosenzweig, 2012; Karlan *et al.* , 2014; Cai *et al.* , 2015; Cole *et al.* , 2017; Jensen *et al.* , 2017; Elabed & Carter, 2018).

The goals of this study are threefold. In the first instance we aim to increase the evidence base on the impacts of agricultural insurance. Within the framework of a randomized control trial, we examine the impacts of insurance not only on the insured crop but more generally on the whole portfolio of agricultural activities. We also investigate the ex-post effects of insurance on farmers hit by a negative shock that triggered insurance payments. Second, our particular study allows a window into the implementation challenges that stand between index insurance programs and their expected impacts. Third and finally, we illustrate the advantages of using mixed, quantitative and qualitative methods to evaluate a complex intervention like insurance that offers infrequent, stochastic benefits.

Despite its compelling logic, index insurance to smallholder farmers is difficult to implement (Jensen & Barrett, 2017). Two of these challenges are particularly relevant to this study. First, the agricultural calendar is fixed and unforgiving of implementation delays. The "risk reduction dividend" of increased

[1] The fixed costs of loss verification make it uneconomic to investigate losses for small-scale producers whose total insurance premium are small. In practice, this led to poor loss verification, morally hazardous behavior and high loss ratios for insurance companies (see Hazell (1992) for more detail and empirical examples).

[2] Clarke *et al.* (2012) show that weather-based index insurance correlates poorly with farmer losses. More general overviews on this problem are given in the review papers by Miranda & Farrin (2012); Jensen & Barrett (2017) and Carter *et al.* (2017)

investment cannot take place if insurance is delivered late, after key planting decisions have been made. Second, insurance requires substantial trust on the part of the insured farmer that the financial institution company will payoff as required in the event of a bad crop year in the future. Note that the trust requirement under insurance is precisely the opposite of the trust required for a loan, where the institution must trust that the borrowing farmer will repay in the future. Failure to address this trust deficit in the case of insurance can result in low uptake and a variant of implementation failure.[3]

Index insurance projects also present evaluation as well as implementation challenges. In contrast to an RCT of, say, the health impacts of a biologic treatment, in an evaluation of social or economic interventions, human cognition and agency intervene between the the treatment that is offered and the treatment that is received (Barrett & Carter, 2010). The offer of a reliable insurance contract may be received as such by some individuals, even as others may perceive the contract as untrustworthy effort to to defraud them. This heterogeneity in treatment received not only can result in lower compliance, but it may also induce an additional layer of impact heterogeneity, with those fully trusting the contract potentially responding more robustly than those who do not.[4] In short, the fact that the treatment received is itself heterogeneous complicates inference about program efficacy. In addition, index insurance offers what might be termed stochastic benefits, making payments only in the case of relatively infrequent events (*e.g.*, the one in ten year drought). Absent a long-run study, or a geographically diversified research design, it is difficult to actual observe the performance and *ex post* impacts of insurance, i.e. impacts on households that actually received insurance payments.[5]

These myriad implementation and evaluation challenges motivate our reliance on a mixed research design that draws on both quantitative and qualitative methods. As discussed by White (2013), qualitative methods can help parse out the meaning of reduced form findings that emerge from even a well-designed randomized control trial (RCT). Implementation failures as well as trust deficits are both things that can perhaps best be probed using qualitative methods (see for instance the study of micro-credit in Morocco by Morvant-Roux *et al.* 2014). Moreover, as we shall see in the case of this study, the flexibility of qualitative methods allows some opportunities to learn from rare events (like severe crop failure) even when the sample size considerations would doom quantitative methods.

Against this backdrop of methodological challenges, this paper studies the impacts and implementation challenges of an index insurance contract designed for cotton farmers in Burkina Faso. Cotton farming in Burkina Faso, as in other West African countries, is a profitable but risky activity, given the crop's vulnerability to the region's variable weather patterns. Small-scale farmers often forgo this profitable opportunity (or limit the area cultivated and their credit demand for cotton) in order to

[3]Lending institutions manage any trust deficit by requiring collateral from the borrower, whereas there is no similar recourse for the insured farmer to use to bond the behavior of the financial institution that offers insurance.

[4]As discussed below in the specific case of this study, the decision to purchase insurance was a group one, raising the specter that some of those insured may have had no trust in the insurance, while others may not have even known that their group chose to purchase insurance. In addition, index insurance works best for those whose individual losses best track the index, raising the possibility that some members of an insured group may have a pattern of yield loss that is objectively not well correlated with average losses in the group. Mobarak & Rosenzweig (2012) and Jensen *et al.* (2018) discuss the impact of a similar "basis risk" problem on the demand for individually purchased index insurance contracts.

[5]Most studies actually look at *ex ante* investment effects, meaning the impact of the insurance on production decisions (because of the protection it provides) before households know whether they will have a shock and actually receive insurance payments. Exceptions index based livestock insurance study in Kenya that covered 7 years, during which one major drought occurred, allowing Janzen & Carter (2018) to study the *ex post* impacts of the insurance. Taking a different approach, Boucher *et al.* (2020) spatially diversified a 2 year RCT across multiple regions in two countries, allowing them to observe shocks in some regions and observe their *ex post* impacts.

minimize their exposure to risk. This "risk rationing" strategy (Boucher *et al.* , 2008) has adverse effects on the entire farming system, because cultivating cotton is often the only channel for Burkinabe households to obtain agricultural inputs. Specifically, cotton inputs are used for other crops such as maize, and protecting cotton production may also have spillover effects on farmers' other risky agricultural activities (other crops or livestock herding) which are vulnerable to similar shocks. In this context, insuring cotton has the potential to impact not only cotton production but the whole household portfolio and farmers' long-term well-being, creating a "risk reduction dividend" by allowing farmers to prudentially invest more in higher returning opportunities.

This paper tests for such a risk reduction dividend following the introduction of cotton insurance in Burkina Faso using what White (2013) calls a mixed methods RCT. Working with commercial partners, the research team implemented a randomized control trial that involved 1000 households in 80 farmer groups located in the cotton-growing Houndé region, in southwestern Burkina Faso. Half of the groups were randomly selected and offered the insurance product for purchase. Further, premium price subsidies were used as part of an encouragement design and were randomly distributed within groups that were offered the insurance. The insurance product is an area-yield insurance which pays farmer groups when their yields fall below a specified level. The product was sold to farmers on credit and provided reliable protection (see the discussion in Elabed *et al.* 2013 who implemented a similar design in neighboring Mali).

We measure the impact of being insured on farmers' cotton production and other agricultural investments. We consider area cultivated, input use and yields for cotton, the directly insured crop. In addition, we measure the spillover effect of being insured on food crops, sesame and livestock, which are likely to be affected by the risk reduction provided by the index insurance. We first estimate the Intention-to-treat (ITT) effect in the treatment group (all farmers who were offered the product). Second, we use premium subsidies as an instrument to estimate the Average treatment effect (ATE) on farmers that did purchased the product. The premium subsidy was efficient at boosting demand, and can thus be used as a relevant instrument.

Overall uptake of the insurance was high (46% of treatment group farmers), in contrast to some other studies of index insurance pilot projects. Despite the promising take-up of the cotton insurance, we find that the insurance had no detectable impact on investment in cotton, the directly insured activity. We estimate a relatively precise 0 effect on cotton area, input use, credit and yield. On the other hand, we find large impacts on sesame production (17 percentage point) and livestock herding (about 1 Tropical Livestock Unit).

Our mixed methods approach allows us to unpack this seemingly puzzling configuration of results, with null direct, but positive spillover impacts. We followed up the quantitative data collection with qualitative research in 11 of the 80 farmer groups that comprise the quantitative study (2 control farmer groups, 9 treatment farmer groups, including the three that suffered severe yield losses in the last year of the RCT). We find:

- High, but incomplete levels of trust that the insurance company would indeed return and compensate losses in the event of a bad year;
- Severe implementation problems in the form of a late insurance sales, with some farmers explicitly noting that these timing issues prevented them from investing more in their cotton, but

empowered to invest in other agricultural activities that take place on a later calendar;

- A mixed message on the reliability of the insurance in the three farmer groups that experienced shocks. Payouts did eventually occur as promised, but late, and only after many farmers had engaged in costly coping strategies to repay loan liabilities. Fortunately, the delayed payments allowed farmers to eventually undo most of the damage caused by costly coping strategies, and most reported continued willingness to purchase the insurance.[6]

While the time horizon of this study was a modest two years, these findings indicate the layers of implementation challenges that must be overcome if a trust-intensive instrument like insurance is to really work over the longer term.

The remainder of this paper is organized as follows. Section 2 briefly reviews the literature on risk and agricultural insurance in developing countries, focusing on spillover effects of insurance on the full portfolio of activities. Section 3 zooms in on agriculture and cotton in Burkina Faso and introduces the cotton insurance pilot project developed for this study. Section 4 presents the research design and methods, as well as tests for baseline balance between treatment and control households. Section 5 presents results from our mixed-method approach regarding cotton production, other crops and activities, and the impact of insurance payments. Section 6 concludes with reflections on the pitfalls and opportunities for agricultural index insurance.

2 Risk, investment and insurance

One of the objectives of index insurance is to stimulate smallholder farmers' investments in income-generating activities. However, insuring one crop or activity is likely to have complex, spillover effects on farmers' other activities. After a brief review of what economic theory suggests will be the impact of insurance on farmers' portfolio of activities, this section considers the empirical evidence to date on this topic.

2.1 Insurance and farmers' portfolio of activities

Risk and uncertainty play key roles in farmers' management decisions. First, most farm activities imply risk-return trade-offs so that risk preferences and the availability of insurance influence farmers' willingness to invest in a given activity (Dercon, 1998). Second farmers typically invest in different activities and when choosing the composition of their portfolio of activities, they balance risk exposure and expected income (Barrett *et al.* , 2001). For example, small farmers plant different crops and often combine crop production with livestock rearing activities in the hope to stabilize their income in a context of severe liquidity constraints and market failures (Dercon, 1996, 1998). Furthermore, livestock herds frequently include different species of animals for the same risk diversification purpose (Fafchamps *et al.* , 1998).[7]

[6] All groups that received payouts in fact renewed their contracts the following year, whereas the renewal rate was modest for farmer groups that had no received payouts.

[7] Other factors may play a role in the diversification of farm activities. The smoothing of labour demand over time is an example: planting crops that require labour at different moment in time allows farmers to optimize the use of their time.

In this context, insuring one activity is likely to influence a farmer's entire portfolio of investments. Under a range of models of decision making under risk (Eeckhoudt *et al.* 1996; Hennessy 1998; Ramaswami 1993; Chambers & Quiggin 2002; Carter & Barrett 2006), insurance is unambiguously expected to stimulate investment in the insured activity as this investment becomes safer (Yu & Sumner, 2018 give a quick review). In contrast, the impact of insurance on investment in other risky activities in farmers portfolios is less straightforward as many effects are at play. First insurance may reduce the need for diversification, and thereby investment in other activities. At the same time, insuring one crop may indirectly protect another crop's returns if returns across the insured and uninsured crops are positively correlated, increasing a farmer's willingness to invest in the directly uninsured crop as well. Finally, the reduction in the riskiness of the portfolio may increase the farmer's willingness to take risks in general, including in activities not directly insured.

Several strands of the literature on decision making under risk provide formalizations of this problem. Standard portfolio theory (following a mean-variance approach) suggests that insuring one activity would affect investments in another risky activity, but only if returns across these activities are positively correlated (Eeckhoudt *et al.* , 2005). In a more general expected utility framework, insuring one activity would change the levels of investment in other activities, even if returns are not correlated across activities. Gollier & Kimball (1996) explore the conditions for independent investments to be substitute (implying that insurance would decrease investment in the non-insured activity). They show that substitutability obtains if absolute prudence is decreasing and larger than twice the absolute risk aversion. This assumption is not, however innocuous, and Gollier (2004) provides examples when the opposite result will hold.

The problem of insurance spillover on to other activities becomes slightly simpler if the farmer is constrained in her ability to modify her investment in the directly insured activity (cotton in our case; see Section 3.1). In the presence of such a constraint, insurance reduces the "additive background risk" that the farmer faces when deciding how much to invest in other risky activities. Eeckhoudt *et al.* (1996) show that a decrease in an independent background risk increases the demand for risky assets, provided absolute risk aversion is decreasing and convex. If the background risk is positively correlated with the other risky assets (a likely situation in rainfed agriculture), the result obtains *a fortiori*, as the insurance also indirectly insures the other activity (Tsetlin & Winkler, 2005).

Finally, the impact of insurance on investment in a risk-free component of the portfolio is more straightforward. As insurance reduces the need for hedging, farmers are expected to decrease their investment in risk-free hedging activities (Karlan *et al.* , 2014).

In short, theory suggests that insuring one crop will decrease investments in risk-free activities and affect investments in other risky activities in directions that are not clear *a priori* (and will depend on risk preferences and correlation in returns between the activities). In the specific case where a farmer is constrained in her ability to increase investment in the directly insured crop, she is likely to invest more in other farming activities that correlate positively with the insured activity.

2.2 Index insurance and investment

Index insurance has emerged as a policy option to reduce risk faced by poor households (Barnett & Mahul, 2007; Barnett *et al.* , 2008). Classic insurance products that require individual loss verification are extremely expensive to manage due to pervasive problems of moral-hazard, adverse selection and long implementation delays (Hazell, 1992). Index insurance on the other hand eliminates the need for assessing individual losses as payouts depend on the value of an index correlated with the shocks faced by farmers. The index can be based on weather events (Gine *et al.* , 2008), on average livestock mortality rate in a region (Bertram-Huemmer & Kraehnert, 2017), average crop yields (Elabed *et al.* , 2013), or on satellite-based prediction of forage scarcity (Chantarat *et al.* , 2013) or crop losses (Flatnes *et al.* , 2018).[8] Relative to conventional, individual loss-verified insurance, index insurance can result in substantial savings and address issues of adverse selection and moral hazard, if it is based on an index that is easily measurable and impossible to manipulate by the insured or the insurer (Miranda, 1991).

The major drawback of index insurance is that it imperfectly correlates with a farmer's losses, implying that the insured farmer faces uncovered or "basis risk" (Miranda & Farrin, 2012; Clement *et al.* , 2018). The index may trigger payments when the farmer's did not experience a negative shock (false positives), or, worse, the index does not trigger a payment when the farmer experiences losses (false negatives). The extent of basis risk depends on the quality and granularity of the index, and the value of the protection offered to farmers varies greatly across index insurance products (Carter *et al.* , 2017; Clarke *et al.* , 2012; Barre & Stoeffler, 2017). While index insurance has raised enthusiasm among government and development agencies, take-up has sometimes been disappointingly low (Binswanger-Mkhize, 2012). Many factors contribute to explain this outcome, including low quality of the products offered, high costs, lack of trust in the provider, low financial literacy.[9]

When successfully implemented, index products have been shown to help farmers cope with *ex-post* shocks and to manage *ex-ante* risk. Cai *et al.* (2015) and Jensen *et al.* (2017) show that livestock insurance stimulated investment in the insured animals, while Janzen & Carter (2018) provide evidence that it protects consumption and livestock holding when shocks occur. With respect to crop index insurance, Karlan *et al.* (2014) find that insured maize farmers in Ghana increased investment in maize by 13-17%, and that their ability to absorb shocks improved. Similarly, results from a study in Mali indicate that, once offered area-yield insurance for cotton production, cotton farmers increased their area cultivated for cotton and their purchase of input by approximatively 25-40% (Elabed & Carter, 2018).

The evidence regarding spillover effects on investment in non-insured activities is thinner but suggests that, in line with theory, these effects may be negative or positive. Karlan *et al.* (2014) found that insured farmers reduce their investments in low risk/low return "hedging" activities such as non-farm labor and mango harvesting. In contrast, the Cai *et al.* (2015) study of sow insurance in China finds that if spillover exists on other livestock (besides the insured sows), they are positive. In a different context, Gehrke (2019) shows that providing employment guarantees (through the NREGS program in India) induces farmers to shift their production towards riskier and more profitable crops. Finally Alcaraz *et al.* (2017) find strong evidence for health insurance to trigger substantial increases in edu-

[8] Benami *et al.* (2020) review the evolution of different indices that have been used for index insurance.

[9] For comprehensive reviews, see Carter *et al.* (2017), Jensen & Barrett (2017) and Platteau *et al.* (2017). See Clarke (2016) for a theoretical discussion of the relationship between index insurance quality and demand from a conventional, expected utility perspective. Building on insights from the behavioral economics literature, Elabed & Carter (2015) show that ambiguity avers individuals will exhibit excess sensitivity to low quality, basis risk-laden contracts compared to expected utility maximizers.

cation investments in Mexico.[10] Our study contributes to this emerging literature on index insurance impacts, and in particular on the changes in the allocation of investments among insured farmers.

3 Cotton, risk and the index insurance pilot in Burkina Faso

While index insurance has been promoted as an answer to risk in developing countries in general, the actual success of each product depends on a series of factors related to its context and design. This section describes how the organization of the cotton sector in Burkina Faso allows the design of a promising index insurance product, while posing some specific implementation challenges. Moreover, understanding cotton production and its relationship with other activities is important for framing the potential impacts of index insurance in this setting.

3.1 Farming systems and the role of cotton

As stated by Barrett *et al.* (2001), "diversification is the norm" in rural Africa. Table 1 shows descriptive statistics from our baseline survey (see section 4.1) regarding the portfolio of agricultural activities and their profitability. At baseline, the median farmer in our study area cultivated 3 hectares of cereal grains (split between maize and drought-resistant sorghum and millet), 3 hectares of cotton and a mix of secondary crop on another 2 hectares.[11] On these two hectares, farmers cultivated crops such as peanut, beans and sesame (on which more below). Markets for selling grain are relatively thin and localized, as food crop production goes primarily to home consumption. In addition to crop cultivation, livestock herding is an important part of farmers' livelihoods and a major productive assets, used as a plough animal, or for generating animal product and for reproduction. As described by Savadogo *et al.* (1998), animal traction greatly improves land and labor productivity in Burkina Faso. However, some farmers have been found to limit their investments in livestock due to lump-sum costs and high levels of risk, focusing in lower-risk, lower-return activities (Dercon, 1998). In Burkina Faso as well, all these activities are vulnerable to common, correlated covariate shocks such as low rainfall (Fafchamps *et al.* , 1998; Kazianga & Udry, 2006).

In Burkina Faso and other Sahelian countries, sesame has become an attractive cash alternative to cotton as sesame requires lower input and time investments, and can be sold rapidly after harvest (Mangnus *et al.* , 2015; Stoeffler, 2016; Dossa *et al.* , 2017). The emerging importance of sesame seed as a secondary cash crop is visible in our data. Among the control group farmers in our study (those not offered insurance), the fraction cultivating sesame grew from 20% in the 2014 baseline to 39% in 2015. Amongst those growing sesame in the control group, the average area of sesame cultivated grew from 1 to 1.4 hectares over that same time period.[12]

While our data do not permit a full cost accounting for all crops, Table 1 gives an idea of the importance and returns to each of these primary agricultural activities. Sorghum and millet are drought resistant, but net returns to cotton are 50% higher than returns to these crops.[13] Net returns

[10] The authors suggest that the increase may be driven by an income effect.
[11] Figures reported in this section are for the median farmer.
[12] The increasing trend in sesame cultivation over the period is consistent with other sources such as the national figures from the FAO (http://www.fao.org/faostat/).
[13] Net revenue approximates returns to family labor and land.

Table 1: Baseline Agricultural portfolio and profitability

	Mean	Standard Deviation	Median	Observations
	Crop Area (hectares)			
Total field area	10.0	7.4	8	1010
Cotton	3.9	3.4	3	1003
Millet & Sorghum	1.7	1.7	1	1007
Maize	2.8	2.7	2	1007
Sesame	0.19	0.5	0	1010
	Value of Production ('000 CFA)			
Cotton	819.6	916.4	517.0	1003
Millet & Sorghum	106.9	134.8	68.4	1007
Maize	458.5	525.1	294.0	1007
Sesame (2015)*	34.7	70.8	0	1010
	*Net Revenue** ('000 CFA per-hectare)*			
Cotton	99.0	83.4	93.9	993
Millet & Sorghum	62.6	42.7	53.2	764
Maize	96.5	103.4	94.4	953
Sesame	81.7	56.9	72.0	396

Source: 2014 baseline survey.
Market exchange rate over the time of the study averaged 550 CFA/USD
* Data on 2014 baseline sesame production and inputs were not collected.
** Net Revenue is the gross value of production minus cash inputs

to maize compare favorably to those for cotton, but the market for maize and other grains is thin and highly localized. Comparing cotton to sesame, the other cash crop alternative, we see that net revenues per-hectare are about 25% higher for cotton. At the same time, cotton has substantially higher cash exposure than sesame as its cash costs per-hectare are roughly 10-times higher than those for sesame. Elabed *et al.* (2013) report that in neighboring Mali, cotton farmers find it difficult to repay loans and manage family obligations once yields fall below 750 kilogram per-hectare. Long-term data from the Burkina study area show that there is a 20% chance that average yields in a village farmer group will fall below this critical level. Individual risk exposure is more pronounced as individual farmer yields fluctuate more than their village average. In the 2014 baseline study year, fully 9% of farmers failed to produce even the 440 kilograms per-hectare, the amount required to fully reimburse principal and interest on the production loan.[14]

This risk-return profile makes cotton a promising target for insurance coverage. The well-organized cotton value chain facilitates the development of area-yield index products and its delivery to farmers. SOFITEX, the cotton company in the study area is highly centralized and enjoys a local monopsony.[15] Each cotton farmer belongs to a farmer group (GPC or *Groupes de Producteurs de Cotton*), which are comprised of ten to forty farmers from the same community. SOFITEX provides all inputs on credit

[14]There is also a certain price uncertainty, reinforced by the length of the production timeline described above. The monosony cotton processing company, SOFITEX, guarantees a minimum price at the beginning of the cotton season, but this "floor price" is low and the final price fluctuates. Food crops are "safe" in that they are mostly cultivated for self-consumption and isolate farmers from market price risk as producers and as consumers.

[15]SOFITEX began as a parastatal national monopoly. Other West African countries had a similar model, although most countries have not privatized their cotton company. SOFITEX is now a private company, with the government of Burkina Faso owning 49% of its capital. SOFITEX currently controls about 70% of the cotton crop in Burkina, with the residual now handled by two smaller companies that operate in well-specified (and separate) geographies.

(seeds, fertilizer, pesticide, *etc.*) using the group's standing cotton crop as collateral.[16]

The SOFITEX input package consists of a fixed quantity of seeds, fertilizers and pesticides per hectare. The cost of the input package for farmers is about 90,000 CFA per-hectare, and the annual interest rate is between 6 and 10%.[17] In fact, the cotton company is the only source of formal credit for inputs, and is the main source of input purchased by farmers. In theory, farmers are not allowed to use these inputs on other crops, and input diversion is monitored by the company's agents (*Agents Techniques de Coton, ATCs*). In practice, it is widely known and accepted by SOFITEX that part of the inputs obtained on credit are applied to other crops, by decreasing fertilizer usage per hectare below technical recommendations for cotton. This makes cotton production central for farmers' entire crop portfolio. In particular, fertilizer is used to produce maize, the primary food crop in the region (Traore 2020).

The tight value chain for cotton in Burkina creates the opportunity for an index insurance product. Because SOFITEX purchases the entire production from farmer groups, it has detailed information on annual production and yields at the group level. As discussed in section 3.2 below, the availability of these data permits the low cost implementation of a reliable area yield-based index insurance. However, a disadvantage of this well-structured value chain is its rigidity. Farmer groups need to aggregate and communicate their demand for cotton credit (the number of hectares to be planted) 7-8 months before cotton is actually planted. The top half of Figure 1 shows the timeline of agricultural activities. Credit demands are made as early as September, for sowing in May/June of the following year. Harvesting takes place between November and January, with farmers only receiving payment for their crop in April (*i.e.*, 18 months after the farmers arranged for credit). The rigidity of the cotton value chain, combined with its risks, pushes farmers to be conservative in their input requests from SOFITEX, and limits their capacity to invest when conditions change in the short term (*e.g.* when insurance is provided).[18] In contrast, the agricultural calendar for sesame is more favorable: farmers do not need to purchase inputs in advance, planting occurs later during the rainy season, and sales are made right after the harvest (see Figure 1).

Finally the financing scheme also entails risk for farmers who are jointly liable for the GPC cotton loan. If the production of one farmer in the GPC is not sufficient to cover her debt, other producers' revenues are reduced to reimburse the entire GPC loan. Farmers are thus not only exposed to weather risk, but also to the morally hazardous behavior of their neighbors, a feature discussed in detail by Gelade & Guirkinger (2018).[19] Thus, the financial risks that insurance could reduce is both at the individual and at the group level.

First, at the individual level, having insufficient cotton yields to cover her loan implies that a farmer needs to either (i) liquidate productive assets to reimburse SOFITEX; or (ii) suffer a social penalty for having other farmers reimbursing her loan under the joint-liability, in addition to reimbursing the

[16] Specifically, SOFITEX provides inputs in kind to farmers at the beginning of the agricultural season. When it purchases the harvest, SOFITEX pays farmers for the value of the production but deducts the value of the input package. Because SOFITEX is the only buyer (selling elsewhere is illegal and not observed in practice) it uses *de facto* cotton as a collateral and perfectly enforces the reimbursement of the loan, as long as the yields of the GPC are sufficient.

[17] The loan is formally held by EcoBank.

[18] These features of the cotton system and timing have been well described theoretically and empirically by Saitone *et al.* (2018) and Theriault *et al.* (2013).

[19] Flatnes & Carter (2019) suggest adding individual collateral into joint liability contracts in order to control this intra-group moral hazard problem.

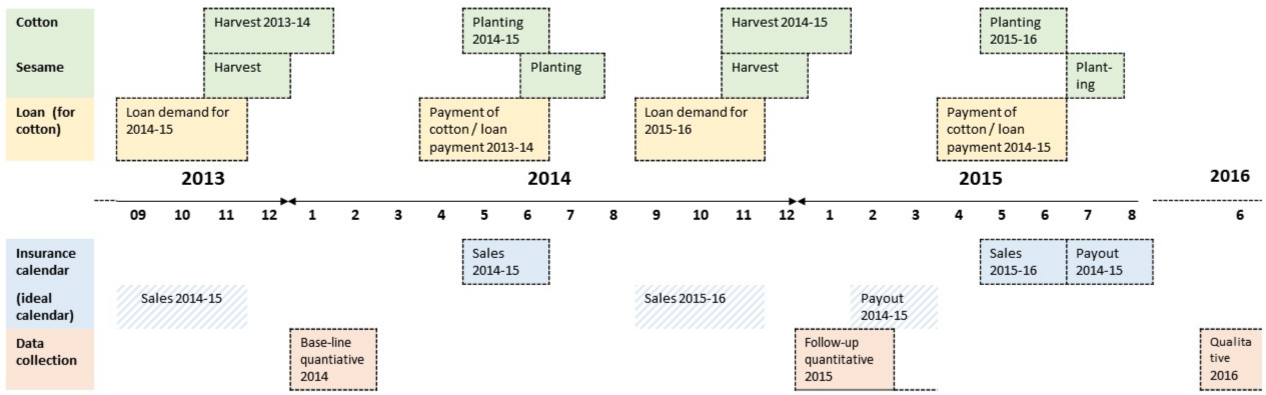

Figure 1: Cotton and insurance timeline

jointly-liable farmers in a future year.

Second, at the group level, while defaulting is a rare event, it has severe economic costs. Indeed, SOFITEX bans the farmers of a defaulting group from borrowing in the future. Such a ban means losing access for several years both to cotton production and to input for other crops. In this context, when a group experiences a bad year and a low production, it generates great tensions in its local community (Gelade & Guirkinger, 2018). Our qualitative results provide further evidence of the economic and social costs of defaulting on the entire GPC loan (see section 5.3). In fact, farmers tend to be eager to pay back their loans for avoiding the costs associated with default, and liquidate productive assets or reduce consumption to do so, with important potential adverse consequences for their long-term well-being.

In this highly risky context, farmers ration their demand for credit. Indeed, farmer's risk exposure has a negative *ex-ante* impact on cotton production at the intensive and at the extensive margin: it pushes some cotton farmers to take smaller loans to decrease their exposure to defaults, and it discourages or excludes some farmers from entering the cotton sector at all. As a result, financial instruments that would reduce the group exposure to covariate risk are potentially in high demand, and might enable farmers to borrow more, produce more and increase their agricultural income.[20]

In sum, the organization of the cotton sectors generates both opportunities for designing a high-quality index insurance product, and implementation frictions that may affect the impact of index insurance.

[20] Elabed & Carter (2018) find exactly this effect in sister pilot in neighboring Mali.

3.2 Index insurance for cotton farmers

The pilot insurance project analyzed in this paper started in Burkina Faso in 2014 in the Houndé region. It was implemented by Inclusive Guarantee, in collaboration with SOFITEX and other commercial partners.[21] The insurance contract is based on a area-yield index (modeled on the contract described in Elabed *et al.* , 2013), and is sold as part of the cotton credit package by the cotton company, SOFITEX, eliminating the need for farmers to finance the premium payment up-front. This feature not only eliminates liquidity constraints to the purchase of insurance, but also makes it easier for farmers with time inconsistent preferences to purchase the insurance (Casaburi & Willis, 2018). Farmer groups had to collectively decide whether or not to purchase the insurance. Given the joint liability nature of the cotton loan contract, individuals were not allowed to deviate from the collective decision and if the farmer group decided to buy coverage, then the entire cotton area cultivated by every group member was insured and each individual was liable for their share of the premium. In 2018, SOFITEX decided to scale-up the contract nationwide and to offer it to all its affiliated farmer groups in seven cotton production regions.[22]

Area yield contracts are both easy to understand and generally provide high quality protection to farmers. Area yield contracts have long been recognized to be a reliable form of index insurance (Miranda, 1991). Indeed, alternative indexes to construct insurance products, such as those based on rainfall levels or vegetation indices measured from satellites, are only *proxies* of what one would like to measure directly, which is yields in a given area. Using area-yields directly outperforms, in theory, these proxies.[23] Carter & Chiu (2018) provide a recent empirical example using the Tanzanian rice data analyzed by Flatnes *et al.* (2018), showing that while expensive to implement outside of monopsony buyers like SOFITEX, the area-yield product easily passes well-defined insurance quality standards.

The Burkina Faso index insurance product is based on the yields obtained from the entire farmer group, and measured accurately by SOFITEX (which pays farmers based on this measurement). The cotton insurance contract provides three levels of payment. When group yields are below 20% of the yield distribution (a one in five years event), farmers receive a "small payout" of 11,200 CFA per-hectare insured.[24] This insurance payment was designed to correspond to the value of the insurance premium (so that the premium is reimbursed to farmers in case of small shock in practice). When yields fall below 8% of the yield distribution, the insurance provides a "medium payout" of 34,000 CFA. Finally, in case of yields falling below 4% of the distribution (a 1 in 25 year event), the farmers receive a "big payout" of 90,000 CFA per hectare, which corresponds to the value of the input loan per-hectare. As such, the payments do not cover a farmer's full income (the value of the production lost because of shocks), but prevents them from defaulting on their loan. The commercial price of the insurance product was set to 11,200 CFA per hectare, or about 12% of the loan volume.[25]

[21] At the time of the study, Inclusive Guarantee was known as PlaNet Guarantee.

[22] The newspaper Lefaso.net (Sidiber, 2018) reports on SOFITEX's plan to roll out the cotton insurance nationwide . Stoeffler & Opuz (2020) analyze data from this expansion of the insurance program.

[23] For examples of low quality insurance products based on rainfall levels, see for instance Clarke *et al.* (2012).

[24] For reference, 656.07 CFA = 1 euro (fixed exchange rate).

[25] As the basis for designing insurance contracts, SOFITEX provided historical yield information for all farmer groups in the study area. Farmer groups were clustered in five categories, depending on their historical average yield. The yield distribution was estimated separately for each category, and each category was offered a different contract based on the estimated distribution. The index insurance is built on a double trigger mechanism following the design by Elabed *et al.*

The literature on index insurance emphasizes the problems associated with providing low quality products to farmers, such as those plagued by high levels of basis risk and by a poor design in general (see for example Clarke 2016; Jensen *et al.* 2016; Carter *et al.* 2017; Binswanger-Mkhize 2012). Clarke *et al.* (2012) describe an index insurance product that provides almost random payouts to farmers, rather than providing support when shocks occur. In contrast, the product sold to cotton farmers in Burkina Faso protects their income relatively well. As Elabed *et al.* (2013) show for the same insurance product in Mali, this area-yield contract performs well in terms of providing payments to farmer groups with low yields: when yields are below the critical level of 750 kg/ha, farmers receive payouts with a probability of 85%. The relatively high quality of the protection is due to the small scale of the "area" (the farmer group) considered by the area-yield design. Were the contract designed at a larger geographic scale, the false negative rate would be 45% instead. Analyzing the Burkina Faso contract, Barre & Stoeffler (2017) show that the product is relatively efficient at stabilizing farmers' cotton income, and passes some normative tests of index insurance quality.

Despite these attractive design features, the implementation of the project suffered from a major drawback: the timing of insurance sales. As described in section 3.2, cotton input demand have to be made early in the season (October-November 2013). On the other hand, insurance sales for the same season occurred late, when the agricultural activities were starting (May-June 2014). The bottom part of Figure 1 shows the timing related to the index insurance product. Ideally, insurance sales would have occurred much earlier, when cotton input demand occurred, so that farmers can adjust easily the area cultivated and their input obtained from SOFITEX. Thus, the implementation issue (late sales) combined with the rigidity of the cotton input provision chain constitute a constraint for obtaining an impact on cotton production.

Given these constraints, but under the assumption that insured farmers felt well protected by a high quality product (as assumption queried later), what impacts could we expect on agricultural outcomes and investment? We formulate three hypotheses in light of the framework and evidence discussed in section 2.

- *Cotton area, inputs and yields:*

  While theory suggests that insured farmers should increase their investment in the insured activity the timing of insurance sales largely constrained farmers from adjusting in their loan demand and investment in cotton. Except to the extent that farmers may have reduced the diversion of cotton inputs to other crops, we expect little impact of the insurance on cotton area, inputs or yields.

- *Other risky crops and activities*:

  Theory suggests that being constrained in their ability to adjust cotton production, insured

(2013) in Mali. Farmers receive payments under two conditions. First, the farmer group yield needs to be below a given threshold corresponding to its category of yields (*e.g.*, yields below 800 kg/ha). Second, the other farmer groups in the neighborhood need to be below a "neighborhood threshold" as well. This means that the other groups located in the same area (same village or neighboring villages) need to have somewhat low yields as well. The neighborhood condition was designed to avoid potential moral hazard issues, while still conditioning the payment on each group's yield. Since farmers of a GPC live in the same village and are usually members of the same family, ethnic group or religious community, there were concerns of potential coordination within one farmer group. The neighborhood condition prevents such coordination by ensuring that yields are not particularly good in other groups in the area as well. The "neighborhood threshold" is higher than the own farmer group threshold (*e.g.*, yields in the neighborhood needs to be below 1000 kg/ha).

farmers would invest more in other risky and profitable activities. We thus expect insurance to positively impact sesame cultivation and livestock investment.

- *Staple food crops*:
  If staple food crops play a self insurance role, we expect insurance to to decrease investment in these buffer activities.

The next section presents the research design employed to test these hypotheses.

4 Research methods and design

As discussed in the introduction, the implementation and evaluation of index insurance faces a number of challenges that are rooted in the reality of agriculture and the nature of insurance itself. This section reviews the hybrid, mixed methods RCT implemented to meet these challenges and carry out this study.[26]

4.1 The RCT research design and surveys

The quantitative portion of this paper is based on baseline and endline surveys of just over 1000 cotton farming households, divided among 80 cotton groups (GPC) in the Houndé region of Burkina Faso. None of these farmers had prior experience with agricultural insurance. The insurance intervention studied was randomized in two steps. First, half of the GPCs were randomly selected to be offered the insurance. Thus, the treatment area comprises 40 farmer groups, whereas the 40 farmer groups in the control area could not purchase the insurance (insurance contracts were not generated for these groups to prevent from contamination entirely). Second, an encouragement design was generated among the treatment group by randomly distributing insurance subsidy coupons to farmer groups. Ten GPCs received no subsidy, ten a 25% subsidy, ten a 50% subsidy and ten a 75% subsidy. Given that the market price of the insurance was some 60% above the actuarially fair price, the first two groups of GPCs faced prices well above the actuarially fair price, while the latter two enjoyed discounts below that level (Barre & Stoeffler, 2017). Each GPC decided whether or not to subscribe to the insurance during a general assembly meeting.

Around 13 farmers per GPC were randomly selected to participate to a baseline and a follow-up survey. A total of 1015 households were thus surveyed first in January 2014, before the first insurance sales that took place in May-June 2014 (see the timeline in Figure 1 above). The follow-up survey was conducted in January 2015 following the cotton harvest. Attrition was very low between baseline and endline (only 5 households, i.e. 0.5%). The main purpose of the survey was to measure the *ex-ante* impact of the insurance, i.e. the actual changes in production induced by the insurance because of the protection provided, but regardless of future insurance payments. Indeed, at endline farmers did not know yet whether they would receive an insurance payment, but had been protected by the insurance during a whole agricultural season (see 1). Questionnaire modules included detailed information on

[26]The history of this study is less linear than this section might suggest. It began life as a boiler plate RCT, with qualitative methods introduced as the research team realized that such methods were needed to parse untangle what was happening as well as to learn from the experience of the smallish subset of farmers who suffered yield losses and experienced insurance payouts.

Table 2: Baseline Summary Statistics and Balance Tests

	Control Group	**Treatment Group**	***t*-Test (p-value)**	***F*-Test (p-value)**
		Agricultural Variables		
Cotton area cultivated (ha)	4.03	3.77	0.23	0.862
Cotton yields (kg/ha)	829.4	829.3	1	0.437
Cultivates GMO cotton (1=yes)	63%	42%	0.0***	0.166
Cotton credit (CFA)	424,281	407,484	0.60	0.773
NPK fertilizer (bags/ha)	2.29	2.38	0.17	0.752
Total area cultivated (ha)	10.1	9.8	0.55	0.911
Rented a field	34%	27%	0.015*	0.317
Cereals cultivated (ha)	4.59	4.43	0.44	0.905
Sesame cultivated (1 = yes)	21%	17%	0.25	0.168
Number of cows	2.88	2.13	0.10	0.016*
Drought Shock, 2013/14	13%	17%	0.080	0.257
Livestock Shock, 2013/14	4%	5%	0.35	0.329
		Household Living Standards		
Progress out of Poverty Index	36.3	36.8	0.55	0.671
Roof of dwelling is solid	47%	51%	0.12	0.467
Household Diet Diversity Score	7.83	7.84	0.91	0.942
Number of food coping strategies	0.47	0.4	0.19	0.542
		Household Demographics		
Age of household head	44	43.6	0.66	0.23
Household size	10.4	10.4	0.98	0.004***
Household head education (years)	1.2	1.2	0.66	0.95
		Insurance Uptake		
Covered by Insurance	0%	46%	-	-
Number of Farm Observations	508	507	1015	1015

Note: Variable averages and p-value of the difference of means between treatment and control groups. The F-test is the joint test of significance of the coefficients for a regression of each variable on the two randomized variables: (1) the treatment status; (2) the % subsidy variable.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

agricultural production and investments at the plot level, as well as detailed household information. In addition to the household survey, local leaders answered a separate questionnaire on the functioning of the GPC.

Table 2 presents descriptive statistics for the treatment and control groups. To test for balance between these groups, column 3 of the table presents the p-value for the t-test of equality of means between the two groups. The fourth column reports the p-value for the F-test for joint significance of the regression of the baseline characteristic on the treatment indicator plus a single variable measuring the discount offered to the farmer.[27] An insignificant F-statistics indicates that we cannot reject the hypothesis that the baseline characteristic is unrelated to treatment and discount assignment.

The first panel of the table contains key agricultural indicators. As can be seen, the average area cultivated is about 10 ha, with approximately 4.5 ha devoted to staple food crops (maize, sorghum, millet and rice), 4 ha of cotton and 1.5 ha to other food and cash crops (sesame, groundnut, bean, *etc.*).

[27]While treated as a continuous variable, this measure takes on only the discrete values of 0, 25%, 50% and 75%.

Baseline average cotton yields are relatively low (829 kg/ha) and fertilizer usage on cotton is below the level recommended by the cotton company (farmers use an average 115 kg/ha, or 2.1 bags instead of the recommended level of 3 bags or 150 kg/ha). Most households raise animals, with an average livestock size of 2.5 cows and 6.4 Tropical Livestock Units (TLU).[28] As can be seen, most of the indicators are well-balanced across treatment groups, except that the control group farmers had planted substantially more GMO cotton at baseline and rented-in more land. Later econometric analysis will control for GMO cultivation in an effort to mitigate this imbalance.[29] Finally the data on drought and livestock shocks were measured retrospectively in 2015 for the 2013-14 season. Statistically similar numbers of households in treatment and control groups suffered shocks. As can be seen, drought events are relatively rare, affecting only 13-17% of households in that year. As discussed earlier, the rarity of these events challenge the ability of a short-term quantitative study to obtain reliable estimates of the *ex post* impacts of insurance.[30]

As the second two panels of Table 2 show, treatment and control households appear quite similar in terms of basic living standard and demographic indicators. Based on the Progress Out of Poverty index (PPI), household have a poverty likelihood of 17% using the national poverty line (Schreiner, 2011). As can be seen, both treatment and control households are large (10 members on average) and most household heads have a low level of education (1.2 years on average).

As shown in the final panel of the Table, take-up was high in the research area: 18 out of the 40 GPC (45%) purchased the insurance product. This corresponds to 233 out of the 506 households to whom the insurance was offered in our sample (46%), a take-up rate substantially above levels usually observed in index insurance pilots projects (Hazell, 2010; Binswanger-Mkhize, 2012). As mentioned above, GPCs were randomly selected to receive discounts, ranging from 0 to 75%. For those GPCs offered no subsidy, the uptake rate was 20%. The uptake rate increased to 50% for the GPC offered a 25% discount, 30% for the 50% discount, and 80% for the 75% discount.

4.2 Qualitative research methods

In addition to the quantitative data collection effort in 2014 and 2015, we conducted qualitative fieldwork in the study area in June 2016 as shown in the Figure 1 timeline. While its use is still marginal in the economics literature, qualitative methods are increasingly used by development economists and practitioners for understanding the mechanisms generating impacts, testing the robustness of quantitative findings, exploring the generalization of results, or addressing questions that quantitative work left unanswered (Kanbur, 2003; Morvant-Roux *et al.* , 2014). In particular, qualitative studies can be extremely valuable for assessing the external validity of results in the case of complex development interventions (Woolcock, 2013), as well as for the analysis of poverty (Narayan, 2000; Adato *et al.* , 2006; Kanbur & Shaffer, 2007).

Another strength of qualitative work is to shed light on "implementation gaps", which is the

[28] The formula used is: TLU = 0.7 * cattle + 0.35 * calves + 0.1 * (goats + sheeps) + 0.01 * (chicken + other poultry) + 0.2 * pigs + 0.5 * horses + 0.3 * donkeys.

[29] Our results are not sensitive to the set of control variables that we use. We show results controlling for GMO cultivation in the instrumented specification because GMO cultivation is likely to have an impact on the input purchased.Thus, including this variable is likely to makes our estimates more precise.

[30] With very few exceptions (*e.g.*, Janzen & Carter 2018, which benefitted from a 6-year study), quantitative impact studies of insurance have only been able to focus on the *ex ante* effects of insurance.

mismatch between the design of the program on paper and its actual implementation (de Sardan & Hamani, 2018; Ridde *et al.* , 2013). Also particularly relevant for our objectives, mixed-methods (combining a qualitative study to a randomized experiment) have proven to generate important insights for understanding the demand for micro-financial products among poor rural households (Morvant-Roux *et al.* , 2014). However, very few academic studies have tried to analyze the *impact* of an intervention through qualitative research, especially on productive investments of rural households (Daidone *et al.* , 2015). Our qualitative fieldwork proved to provide a much better understanding of the demand *and* impacts of the insurance program that we studied.[31]

In terms of impacts, the first objective of the qualitative fieldwork was to better understand our quantitative results (as in Morvant-Roux *et al.* , 2014 and White 2013). We explored in particular the details of the project implementation in the ground, the timing of farmers' investment decisions and their initial trust in the product. The second objective was to explore the *ex-post* impacts of the program on groups which were affected by shocks. The endline household survey was conducted *before* the first insurance payments and therefore does not allow to measure the effect of shocks and the potential mitigating effect of the insurance.[32]

In total, we conducted fourteen focus groups: two focus groups with farmers who were never insured, two focus groups with small producers, two focus groups with women, four focus groups with producers who received an insurance payment and two focus groups with farmers who renewed their insurance (without having received a payment).[33] The rationale behind these group compositions was to elicit information from farmers that had a range of experience with the insurance contract. While there exist little guidance regarding the required number of focus groups to reach saturation (after which additional focus groups bring little additional information), recent research indicates that 2 to 6 focus groups by sub-population tend to be sufficient (Guest *et al.* , 2017). We also supplemented the focus group discussions with semi-structured individual interviews with farmers, farmer group leaders, and SOFITEX employees. Each focus group or interview was conducted by one or two local enumerators, in the presence of one author, and then transcribed. The report that summarizes these transcriptions is available upon request.

5 Impact of insurance on the farm portfolio

Section 3.2 above derived a set of hypotheses about the potential impacts of cotton insurance on agricultural investment, conditional on the assumption that farmers felt genuinely protected by the insurance relative to their uninsured state. Before turning to the evidence on these investment impacts,

[31] A caveat is that information was collected in 2016, two years after the product was initially sold to farmers (see the timeline in Figure 1). By that time, farmers had experienced the product, various implementation issues, and the delivery or lack of delivery of insurance payments. This experience may have influenced positively or negatively their attitude towards the cotton insurance, and generate a bias in their answers. That being said, farmers remembered very well their experience with the insurance project and product (especially those who purchased the product), referring for instance to their initial meetings with our surveyors and to the initiation games that they played back in January-February 2014. Moreover, their answers openly discuss both positive and negative aspects of their experience with the index insurance project.

[32] As discussed earlier, shocks are also relatively rare events. In our treatment group, only 3 farmer groups out of 40 received a "large" insurance payment (and one group a "small" payment).

[33] Most focus groups had ten participants (the maximum that we allowed), but women groups and groups which never purchased the insurance had fewer participants.

we first consider information gathered from 2016 focus group interviews on the extent to which farmers indeed trusted the novel insurance product when it was introduced for the 2014/15 cotton season.

Focus group sessions began asking the assembled farmers if they felt protected and had confidence in the insurance product when it was introduced. Nearly all groups comprised farmers who answered affirmatively with comments such as:

I felt protected and I trusted the insurance (1, FG7)

We trusted the insurance, this is why we purchased it again (5, FG6)

I believe in the insurance (5, FG14)

These expressions of trust are consistent with the relatively robust uptake rate of 46%, and give confidence that our tests for investment impacts are grounded in a reality where many farmers at least perceived that the insurance would assist them in time of need. In a recent analysis that compares insurance uptake in this pilot year with uptake in 2018 when the insurance was offered to all the SOFITEX farmers in Burkina Faso (see footnote 22), Stoeffler & Opuz (2020) show that many of the farmers in the study area were well-trained (especially through insurance games that had been used to explain the product), understood the features of the contract and felt relatively well protected by it.

Despite these indications that the contract was largely well-received by cotton farmers, it is also clear that not all farmers did trust the insurance.[34] As stressed above, one of the complexities that confront insurance and other interventions where human beliefs and perception stands between the treatment that was delivered and the treatment that was received, is that we can expect substantial heterogeneity of impact. Notable comments from skeptical focus group participants include:

Since it was something new, we cannot say that we trusted it. (1, FG8)

In addition, we did not have proof that it would really pay people in case of shock (1, FG9)

In addition to their skeptical attitude toward the insurance, these comments also raise the issue of how trust evolves over time as farmers gather information on the actual performance of the contract. In Section 5.3, we take advantage of payouts that occurred following the 2015-16 season to learn about how trust in insurance evolves over time, especially in the face of the implementation challenges surrounding insurance.

In the remainder of this section, we first exploit the quantitative and qualitative data for evidence on investment effects at the extensive and intensive margins of cotton production in section 5.1. Section 5.2 then examines impacts on other activities in the farmers' portfolios.

5.1 Results on cotton production

The top panel of Table 3 estimation results for the following standard difference-in-difference intention-to-treat (ITT) model:

$$\Delta y_i = \beta_0 + \beta_1 T_i + \beta_2 G_i + \varepsilon_i \tag{1}$$

[34] The decision on whether or not to purchase insurance was made during a meeting of the GPC. While not all farmers participated in the meeting, among those who participated, nearly all agreed with the insurance purchase. Formal vote was rare, but the insurance purchase decision was typically described as consensual during qualitative interviews.

Table 3: Impacts on cotton

	(1)	(2)	**(3)**	(4)
	Loans	**Area Cultivated**	**Fertilizer Use**	**Yields**
	('000 CFA)	*(Hectares)*	*(Bags/hectare)*	*(Kg/hectare)*
		Intention to Treat Estimates		
Constant	13.0	0.411**	0.0277	139.3***
Treated (offered insurance)	3.8	-0.05	0.02	-34.0
95% Confidence Interval	[-79 → 71]	[-0.4 → 0.3]	[-0.2 → 0.2]	[-113 → 45]
Cultivated GMO	-43.5	-0.154	0.158*	27.09
R^2	0.001	0.004	0.004	0.042
		Treatment on the Treated IV Estimates		
Constant	2.5	0.4**	0.03	127***
Insured (instrumented)	25	-0.05	0.03	-27
95% Confidence Interval	[-108 → 158]	[-0.7 → 0.6]	[-0.3 → 0.4]	[-165 → 111]
Cultivated GMO	-38	-0.2	0.16	30
R^2	0.004	0.001	0.004	0.004
Number of Farms Observed	923	928	928	928
Baseline Control Group Mean	448.1	4.2	2.3	849

Errors clustered at the village level.
$*p < 10\%, **p < 5\%, ***p < 1\%$

where Δy_i is the change from baseline to endline in the value of outcome variable y_i, T_i is a binary variable that equals one for households in the insurance treatment group, and G_i is an indicator variable signaling baseline use of GMO cotton, which, as noted above, was unbalanced between treatment and control groups at baseline.

The outcome variables of interest include two measures of investment at the extensive margin (amount borrowed to cultivate cotton and area cultivated of cotton), and two measures of investment at the intensive margin (bags of fertilizer applied to cotton per hectare and cotton yields). As can be seen, the ITT point estimates of the impact of being offered insurance are all economically tiny and statistically insignificant. The 95% confidence interval estimates cover values that are roughly 10 to 20% of the control group baseline mean, signaling that the zero impact estimates are relatively precise.

With a net rate of compliance with treatment assignment of 46%, a simple treatment on the treated (TOT) estimate is not going to change the qualitative character of these results. However, in addition to treatment, we also have the randomly generated discount coupons that may allow us to obtain sharper treatment on the treated estimates. Table 4 shows results from the first stage linear probability regression that predicts insurance uptake using treatment assignment (T_i) and subsidy amount (S_i):

$$I_i = \gamma_0 + \gamma_1 T_i + \gamma_2 S_i + \gamma_3 G_i + \nu_i \tag{2}$$

As can be seen in the table, treatment assignment and subsidy levels are strong predictors of insurance uptake. The R^2 is 0.37 and the regression passes Sargan and Basmann overidentification tests in all the two-stage-least-square regressions with p-values above 0.05.

Using equation 2 to predict insurance uptake, $\hat{I}_i$, we can now re-estimate equation 1, replacing the treatment variable with the predicted insured variable. Results are showed in the bottom half of Table 3. As expected the magnitude of these LATE treatment on the treated estimates are larger

Table 4: Insurance Take-up First-stage Regression

	Insured
Constant	0.0
Treat, γ_1	0.205*
Subsidy Level, γ_2	0.00595**
Baseline GMO, γ_3	-0.0868
Observations	928
R^2	0.37

t-statistics in parentheses.
** p < 0.10, ** p < 0.05, *** p < 0.01*

than the ITT estimates in the top half of Table 3, but they remain economically small and statistically insignificant.[35]

The lack of impact on investment in the insured activity stands in contrast to other findings in the literature summarized in Section 1. However, as detailed in Section 3, given the rigidity of the input loan calendar and the delays in the sale of insurance, we did not expect a strong impact of the insurance on loan and area planted in cotton. In 10 of the 11 focus groups where farmers had had the opportunity to purchase insurance, it was noted that insurance sales occurred too late (end of May, beginning of June) for farmers to adjust their cotton input demand (see Figure 1). By the times insurance sales occurred, farmers were already sowing their fields. In the words of one focus group participant:

> *For me, it is April to May; after that, it becomes complicated [to change production plans for cotton]* (4, FG1)

Farmers may nevertheless have adjusted the quantity of input effectively applied to cotton after the delivery of insurance. For example, if they routinely divert large quantities of fertilizer towards other crops, once insured, they may apply more fertilizer and labor input to cotton, thereby increasing yield. At most, we might have expected either a moderately positive impact of insurance on input application and yield, depending on whether farmers have some margin of adjustments once seeds, fertilizer and pesticides have been distributed by the cotton company. However, as shown above, the impacts, if any, are too modest to be reliably detected given the sample size and economically very small.

5.2 Spillover impacts of cotton insurance on other farm activities

While the qualitative evidence reveals that implementation delays made it difficult for farmers to expand their borrowing and investment in cotton following the purchase of insurance, the calendar in Figure 1 shows that initiation of a second cash crop activity, sesame, took place after insurance had been purchased. We now turn to testing our other hypotheses concerning the impact of cotton insurance on farmers' general portfolio of agricultural activities. In particular, given the qualitative evidence that farmers largely trusted the insurance at baseline, we expect farmers to increase sesame

[35] In an effort to improve the efficiency of these estimates, both ITT and IV equations were re-estimated using an ANCOVA approach (McKenzie, 2012). While the coefficient estimates on the baseline levels of the dependent variable are well below one, the overall character of the results are the same as the difference in difference estimates reported in Table 3. ANCOVA results are available from the authors.

cultivation as well as investment in livestock and other forms of on-farm investment. In addition, if farmers do invest in riskier, profitable activities, we expect to see a reduction in cereal cultivation, which a low-risk, low-return investment and a form of self-insurance (see section 3).

Using the same econometric approach employed to analyze the cotton variables, we estimate the intent-to-treat and treatment-on-the-treated impacts of cotton insurance on three non-cotton activities: cereal production (mostly for subsistence purposes), cultivation of sesame seeds (a cash crop) and livestock rearing. We also investigate the impact of insurance on two indicators of overall farm investment: land rentals and infrastructure investment.[36] The parameter estimates reported in Table 5 reveal a consistent pattern for cereal production, sesame seed cultivation and livestock rearing. Insurance has a zero to negative impact on cereals production (column 1) and positive impacts on both sesame cultivation (column 2) and herd size (column 3). Focussing on the TOT estimates, estimated insurance impacts are a 17 percentage point increase in sesame cultivation (an 80% increase relative to the baseline level); and, a one unit, or 35%, increase in livestock holdings.

In addition insured farmers increased their propensity to rent land in and their level of farm infrastructure investment (only the TOT is statistically significant for rented land). They suggest a 21 percentage point increase in land rentals (a 66% increase off the baseline level) and a 7,824 CFA ($US 14) increase in infrastructure investment (a doubling of the baseline level).[37]

Table 5: Impacts on other investments

	(1) **Cereal Production** *(kg)*	(2) **Sesame Cultivation** *(1, if cultivate)*	(3) **Cows Owned** *(#)*	(4) **Rent-in Land** *(1, if rent-in)*	(5) **Infrastructure Investment** *('000 CFA)*
Intention to Treat Estimates					
Constant	391.1*	0.145***	-0.0628	0.0316	-2.7
Treated (offered insurance)	-377.7*	0.08*	0.49**	0.07	3.7*
95% Confidence Interval	[-829→74]	[-0.01→0.18]	[0.05→0.93]	[-0.02→0.15]	[-0.7→8.1]
Cultivated GMO	15.25	0.0182	0.0193	-0.0282	4.4**
R^2	0.002	0.006	0.01	0.002	0.005
Observations	923	928	928	928	928
Treatment on the Treated IV Estimates					
Constant	302	0.14***	-0.7	0.00	-2.9
Insured (instrumented)	-464	0.17*	0.99*	0.21***	7.8*
95% Confidence Interval	[-1165→238]	[-0.01→0.36]	[-0.05→2.02]	[0.06→0.36]	[-1.3→16.9]
Cultivated GMO	23	0.03	0.08	0.00	4.9**
R^2	0.004	0.004	0.001	0.008	0.003
Observations	923	928	928	928	928
Baseline Control Mean	5739	0.21	2.89	0.34	3.9

Errors clustered at the village level.
$*p < 10\%, **p < 5\%, ***p < 1\%$

In short, the quantitative evidence indicates that cotton insurance, even when imperfectly implemented, triggers significant behavioral changes towards greater investment in risky farm activities not

[36] In a context where land sales' markets are virtually absent, investment in agricultural activities are often realized by renting land.

[37] As with the cotton results, ANCOVA estimates are again available from the authors and tell the same story as the difference in difference estimates.

directly covered by the product, and perhaps a decrease in cereals cultivation that plays a self-insurance role in the farming system. Focus group participants mentioned these spillover effects into their general portfolio of agricultural activities:

> *I also invested in livestock and sesame thanks to the insurance, even though the insurance only regards cotton, because I felt that my cotton was protected* (II2)
>
> *We really thought that we were protected. This is why we increased the area that we cultivated.* (7, FG12)

These quotes confirm that farmers trusted the insurance and were willing to take on additional risks based on the insurance protection and generate a positive average treatment effect. However, farmers, such as those quoted earlier, who expressed this distrust in the insurance are unlikely to have responded by increasing their farm investments. To the extent that farmers build trust in the insurance product over time, we might expect impacts to become even larger after several years of coverage. However the building of trust crucially depends on a farmer's actual experience with the insurance and its reliability. Our qualitative data enable to investigate these issues, as the next section now discusses.

5.3 Ex-post impacts of insurance payments

Unlike the January 2015 endline household survey, the June 2016 focus groups discussions occurred after insurance payments had been made based on yield shortfalls in the 2014-15 cotton cropping season (see figure 1). Focus group discussions were held with the three insured farmer groups in our research area received the "large" payouts after the 2014-15 seasons, as well as with groups who did not receive any payments. These data enables us to draw a more complete picture of the impacts of insurance after a one-year experience.

The groups that had near normal yields and did not receive any payments reveal a pattern that suggests that they may decrease their demand in the future and perhaps did not fully understand or accept the concept of insurance in the firsts place. Typical comments include:

> *It is good to be insured, but it is difficult for farmers to throw away money. We bought the insurance in 2014-15 but it did not bring us anything in return* (6, FG2)
>
> *We thought that individual cases would be considered. But it was not like that, so we stopped our collaboration [with the insurance]* (6, FG11)
>
> *Their [Sale agents'] attitude shows that they just want to make profit on us. It is not to help us* (8, FG12)

These quotes show the critical role of the first experience with the product and point to several common problems encountered in the distribution of microinsurance products. The first quote reveals an incomplete understanding of how insurance in general operates as it seems to reflect frustration at having paid a premium while getting nothing tangible in return in a season without crop losses. The second of these comments points to some confusion between index and individual insurance. The third quote indicates that the aggressive marketing put in place by the insurance company was misleading, and that the product was deceptive. All point towards issue of distrust and misunderstanding that would be expected to undercut future insurance purchases. While these points have been repeatedly made in the literature (*e.g.*, see Carter *et al.* 2017; Jensen & Barrett 2017; Platteau *et al.* 2017), actors in the field still face a lot of difficulty in conveying the concept of insurance in general and index insurance in particular.[38]

Focus group respondents from the groups that received insurance payouts reported that they encountered important losses because their fields had been attacked by parasites in the middle of the season, after a "dry pocket" (relatively long period without rains in the middle of the rainy season). They spent additional time and money to try to save their crops from the worms but the products they used were ineffective:

> *In the entire village, only 10 people were able to reimburse their loan. The shock was huge. The lack of rain and the insects ruined all the cotton* (1, FG6)
>
> *We even sold our livestock to pay the insecticide to kill the worms* (6, FG6)

However, while their yields were very low, they did not receive payments immediately (nor were they promised payments). Instead, farmers were asked to reimburse their loans in June 2015, since the production of their groups were insufficient to cover their credit. Insurance payouts were eventually made in August, although farmers had all but given up on ever receiving indemnification for their losses.

From a research perspective, this payment delay allows us to observe insured farmers in something akin to their counterfactual, uninsured state. That is, the same individuals reported about their situation without insurance (in June) and their situation with (delayed) insurance payments (in August). Farmers' accounts reveal both the traumas caused by the negative agricultural shock and the positive ex-post impact of the (eventual) insurance payments.

As the focus group discussions revealed, debt repayment to SOFITEX/EcoBank, due to the agricultural shock, caused serious economic and social stress in the communities. Farmers had to deplete their productive assets to pay back their loan:

> *We did not know that we would receive insurance payments. Since we had already sold our livestock, our cereals and other things to pay our debt, we were living in misery until the insurance payments arrived* (3, FG7)
>
> *I was working [as a day laborer] for other people in order to get food for my family. I had only a few goats so I did not want to sell them* (5, FG7)
>
> *[Without the insurance] we would not have been able to continue farming. We sold almost everything even the food [stocks]* (1, FG8)

In addition, the situation generated tensions and social conflicts in the affected villages, especially directed towards the GPC leadership that had decided to purchase the insurance in the first place:

> *It was very tense, we sold our livestock to pay back the credit to EcoBank and SOFITEX. Some refused and left the farmer group* (4, FG6)

[38] Arguably, this kind of misunderstanding of novel insurance technologies make the case for some kind of learning subsidy, akin to the case for temporary subsidies for improved agricultural inputs discussed by (Carter *et al.* , forthcoming).

The insurance payments, on the other hand, reverted the situation (both socially and economically):

> *The insurance prevented us from the worst, otherwise I would have left the village* (6, FG7)
>
> *When considering what happened in 2014-15, if the insurance had not been there, we would not be here to talk with you today* (5, FG6) [39]

They allowed them to buy back the livestock that they had sold (although at higher prices), to feed their families for the year to come, and to continue farming. Farmers declared that they spent the insurance money to purchase livestock, food, agricultural input, durables, to pay school fees, cultivate new crops (*e.g.*, rice), increase cotton area, pay back credit and even marry:

> *With the insurance money, I bought an ox, a cart, and the tiles for the roof of my new house* (8, FG8)
>
> *We bought a plow and a few ox that we had to sell to pay back SOFITEX and the bank* (3, FG8)

While the delay in insurance payments was extremely damaging to farmers, the focus group material gives powerful testimony of the great potential of a well implemented insurance scheme to avoid the costly coping strategies and social disruption that farmers reported prior to receipt of the payout. Less clear is the future attitude of these farmers toward the purchase of insurance.

6 Conclusion: opportunities for index insurance?

This paper analyzes the impacts of a cotton index insurance pilot program on cotton growers in Burkina Faso, combining a rigorous randomized control trial evaluation with careful qualitative work. We argue that this kind of hybrid, mixed methods RCT approach is likely to be especially useful for complex and to some extent unforgiving interventions like insurance that confront both implementation and evaluation challenges. This approach allows us to address issues that Miranda & Farrin (2012) identify as important knowledge gaps in their review article, regarding the spillover effects and the *ex-post* impacts of index insurance.

The quantitative evidence reveals that the insurance had no impact on farmers' investment in cotton, a lucrative but risky cash crop. The qualitative work reveals that this finding reflects implementation problems rather than farmers' lack of trust or interest in the insurance product itself. Corroborating this finding, the quantitative work shows that insurance led to substantial increases in investment in other income earning activities, including a an 75% increase in land devoted to sesame production and a 35% increase in livestock holding. There is also statistically weak evidence (ITT estimates significant at the 10% level) that insurance caused a reduction in the production of food grains, which arguably function as a self-insurance activity in the cotton farming system. The qualitative evidence again corroborates this quantitative evidence that insurance created spillover investment impacts in activities other than cotton.

Finally, the qualitative data allow us to gain some insights on the impact of insurance on coping strategies in the wake of a yield shock that influenced only a small fraction of the overall sample,

[39] Farmers also gave examples of serious individual conflicts, as well as risks of suicide.

rendering quantitative analysis infeasible. Implementation challenges again weakened the effectiveness of the insurance (payouts were delivered several months late), but this problem effectively allowed each farmer to provide their own counterfactual as the delay allowed us to observe their coping strategies prior to the late receipt of the insurance payment. We could then observe their at least partial recovery after receiving the insurance payments.

While index insurance has sometimes been over-hyped (as Binswanger-Mkhize, 2012 and others have argued), these results suggest that they are several good reasons to remain optimistic about the prospects for index insurance to alter investment by small-scale farmers in the risk-prone environments of West Africa and elsewhere. At the same time, the tight knit value chain for cotton in Burkina Faso solves many of the barriers that have confronted index insurance elsewhere, including constraints posed by liquidity and perhaps by time inconsistent preferences. The value chain also made it possible to implement at low cost an area yield index that provides relatively reliable insurance protection compared to other families of insurance indices. And yet, even given these advantageous circumstances, the complexities of implementing agricultural insurance in a difficult rural environment had a fundamental effect on the investment effects that did and did not occur.

More specifically, flaws in the insurance delivery systems may have detrimental consequences for farming households and the future of insurance projects. Chief among the challenges are assuring timely marketing, education and sales of insurance contract, but also timely indemnity payments. While farmers in our study area who suffered sever shocks ultimately benefited substantially from insurance payouts, payment delays resulted in harmful stress and at least temporary farm decapitalization. The qualitative interviews uncovered may elements of dissatisfaction related to implementation of the insurance project and also complaints about a number of features of the insurance product, not all of which are simple or inexpensive to resolve. Finally, in the year following the study, renewal rates were high for those few farmer groups that received had received payouts, but dipped for those groups that did not receive payouts (this pattern resonates with the finding of Stein, 2018, on repurchasing rate for index insurance in India). Learning about a technology that offers only stochastic benefits (e.g., see Lybbert & Bell 2010) remains a challenge and would seem to require development of innovative educational tools.

A last lesson we draw from our study is methodological and advocates for a more systematic use of mixed methods to evaluate and interpret the impacts of development interventions. While there is a long tradition of studying implementation challenges (and failures) in development interventions in the qualitative social sciences (see for instance the seminal book from Ferguson, 1994, and more recently Morvant-Roux *et al.* , 2014 or de Sardan & Hamani, 2018), our study is original in that it presents jointly econometric findings on impacts and qualitative findings on both impacts and implementation. We find that the two approaches complement each others in very relevant manners in the case of a complex intervention likely to yield stochastic and heterogeneous benefits. Our study highlights the power of mixed-method approaches, often promoted by researchers and policy makers (White, 2013), but still rarely conducted in economics research.

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