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The Spillover Impact of Index Insurance on Agricultural Investment by Cotton Farmers in Burkina Faso

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Abstract

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

JEL classification: G22, I38, O12, O13, Q12

Keywords: index insurance, Burkina Faso, productive investments, randomized evaluation, mixed-methods

1. Introduction

An increasing amount of evidence suggests that the lack of instruments for risk management plays a major role in limiting poor households' ability to accumulate assets and improve their future well-being.

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Uninsured risk prevents households from perfectly smoothing consumption (Dercon 2002; Kazianga and Udry 2006) and causes adverse shocks to have harmful lifetime consequences (Hoddinott and Kinsey 2001; Alderman, Hoddinott, and Kinsey 2006). Furthermore, exposure to risk also discourages investment in profitable but risky activities, as households seek to smooth income to limit fluctuations in consumption (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 would seem to constitute a promising poverty alleviation tool. By directly offsetting the most deleterious consequences of realized shocks, insurance should indirectly allow rural households to invest more in risky, but high returning agricultural activities. While conventional agricultural insurance is infeasible in most rural areas of Sub-Saharan Africa,[1] 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, so that the protection it provides may be relatively low (an issue described as "basis risk").[2] Despite this weakness of index insurance, and the controversy that sometimes surrounds it (Economist 2018), there is a small, but growing body of evidence showing that insurance protection indeed boosts small-scale farmer investment in protected activity, as discussed below.

The goals of this study are three-fold. We first 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 also 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 reveals the substantial 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 depends on trust and offers infrequent, stochastic benefits.

Despite its compelling logic, index insurance to smallholder farmers is difficult to implement (Jensen and 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 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 company will make the required transfers 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.[3] Failure to address this trust deficit in the case of insurance can result in low uptake and a variant of implementation failure.

In addition to these implementation challenges, index insurance projects also present two evaluation challenges. In contrast to an randomized control trial (RCT) of, say, the health impacts of a biologic

1 The fixed costs of loss verification under conventional insurance make it uneconomic to investigate losses for small-scale producers whose total insurance premiums are small. In practice, this leads 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 and Farrin (2012), Jensen and Barrett (2017), and Carter et al. (2017).

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.

treatment, in an evaluation of social or economic interventions, human cognition and agency intervene between the treatment that is offered and the treatment that is received (Barrett and 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 an untrustworthy effort to defraud them. This heterogeneity in treatment received not only can result in lower compliance, but may also induce an additional layer of impact heterogeneity (or attenuation bias), 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 actually observe the performance and ex post impacts of insurance, that is, 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 RCT. Implementation failures as well as trust deficits are both sensitive topics that are best probed using qualitative methods (see for instance the study of microcredit 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 the opportunity 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 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 minimize their exposure to risk. This "risk rationing" strategy (Boucher, Carter, and Guirkinger 2008) has adverse effects on the entire farming system. Cotton insurance may not only directly boost cotton production, but it may also have spillover effects on farmers' other agricultural activities, 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 an RCT that involved 1,015 households from 80 farmer groups located in the cotton-growing region of Burkina Faso. Half of the groups were randomly selected and offered the insurance product for purchase. Furthermore, 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 that pays farmer groups when their yields fall below a specified level. As

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 and Rosenzweig (2012) and Jensen, Mude, and Barrett (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. An important exception is Janzen and Carter (2018). Their index-based livestock insurance study in Kenya covered seven years, during which one major drought occurred, allowing them to study the ex post impacts of the insurance. Taking a different approach, Boucher et al. (2020) spatially diversified a two-year RCT across multiple regions in two countries, allowing them to observe shocks in some regions and measure their ex post impacts.

described in more detail below, the contract also included a second, audit or disciplining trigger meant to control moral hazard. The product was sold to farmers on credit and provided reliable protection (Elabed et al. 2013 discuss a similar design implemented 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 effects 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 use treatment status and premium subsidies as instruments to estimate the local average treatment effect (LATE) on farmers that did purchase the product.

Overall uptake of the insurance was high (46 percent of treatment group farmers), in contrast to some other studies of index insurance pilot projects. Despite the promising uptake 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 other farm activities: sesame production (a 17 percentage-point increase in the probability of cultivating this cash crop), livestock herding (about 1 tropical livestock unit (TLU)[6] increase in herd size), and cereals production (a 15 percent decrease in this self-insurance activity).

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 and 9 treatment farmer groups, including 3 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 compensate losses in the event of a bad year;
- severe implementation problems in the form of late insurance sales, with some farmers explicitly noting that these timing issues prevented them from investing more in their cotton, but empowered them 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, even the delayed payments allowed farmers to eventually undo most of the damage caused, and most reported continued willingness to purchase the insurance.[7]

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 technology 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.

6 The formula used is TLU = 1 * cattle + 0.4 * calves + 0.3 * (goats + sheep) + 0.01 * (chicken + other poultry) + 0.2 * pigs + 0.5 * (horses + donkeys) (Njuki et al. 2011).

7 All groups that received payouts in fact renewed their contracts the following year, whereas the renewal rate was modest for farmer groups that had not received payouts.

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' portfolios of activities, this section considers the empirical evidence to date on this topic.

Insurance and Farmers' Portfolios 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, Reardon, and Webb 2001). For example, small farmers plant different crops and often combine crop production with livestock-rearing activities in the hope of stabilizing their income in the 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, Udry, and Czukas 1998).[8]

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, Gollier, and Schlesinger 1996; Hennessy 1998; Ramaswami 1993; Chambers and Quiggin 2002; Carter and Barrett 2006), insurance is unambiguously expected to stimulate investment in the insured activity as this investment becomes safer (Yu and Sumner 2018 give a quick review). In contrast, the impact of insurance on investment in other risky activities of farmers' portfolios is less straightforward as many effects are at play. First, insurance may reduce the need for diversification or precautionary low-risk investments and thereby reduce investments 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, and thereby increase a farmer's willingness to invest in the 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 correlated (Eeckhoudt, Gollier, and Schlesinger 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 and 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 is obtained if absolute prudence is decreasing and larger than twice the absolute risk aversion. This assumption is not innocuous, and Gollier (2001) provides examples when the opposite result holds.

The problem of insurance spillovers onto other activities becomes slightly simpler if the farmer is constrained in their ability to modify their investment in the directly insured activity (cotton in our case; see the section Farming Systems and the Role of Cotton). 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, Gollier, and Schlesinger (1996) show that a decrease in an independent background risk increases the demand for risky assets, provided that absolute risk aversion is decreasing and convex. If the background risk is positively correlated with the other risky assets (a likely situation

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

in rainfed agriculture), the result is obtained a fortiori, as the insurance also indirectly insures the other activity (Tsetlin and 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), including cash and in-kind savings.

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 their ability to increase investment in the directly insured crop, they are likely to invest more in other farming activities that correlate positively with the insured activity.

Index Insurance and Investment

Index insurance has the potential to reduce risk faced by poor households (Barnett and Mahul 2007; Barnett, Barrett, and Skees 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). In contrast, index insurance 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, Townsend, and Vickery 2008), on average livestock mortality rate in a region (Bertram-Huemmer and Kraehnert 2017), average crop yields (Elabed et al. 2013), on satellite-based predictions of forage scarcity (Chantarat et al. 2013), or on crop losses (Flatnes, Carter, and Mercovich 2018).[9] Relative to conventional, individual loss-verified insurance, index insurance is substantially cheaper and addresses 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 and Farrin 2012; Clement et al. 2018). The index may trigger payments when the farmers did not experience a negative shock (false positives), or, worse, the index may 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 and Stoeffler 2017). While index insurance has raised enthusiasm among government and development agencies, uptake has often 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, and low financial literacy.[10]

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, Barrett, and Mude (2017) show that livestock insurance stimulates investment in the insured animals, while Janzen and 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 percent, 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

9 Benami et al. (2021) review the evolution of different indices that have been used for index insurance.

10 For comprehensive reviews, see Carter et al. (2017), Jensen and Barrett (2017), and Platteau, De Bock, and Gelade (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 and Carter (2015) show that ambiguity-averse individuals will exhibit excess sensitivity to low-quality, basis-risk-laden contracts compared to expected utility maximizers.

their area cultivated for cotton and their purchase of inputs by approximately 25–40 percent (Elabed and Carter 2018).

The evidence regarding spillover effects on investments 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 education investments in Mexico.[11] 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 cotton production and its relationship with other activities, which is important for framing the potential impacts of index insurance in this setting. In addition, we discuss how the organization of the cotton sector generates both opportunities for designing a high-quality index insurance product, and implementation frictions that may affect the impact of index insurance.

Farming Systems and the Role of Cotton

As stated by Barrett, Reardon, and Webb (2001), "diversification is the norm" in rural Africa. Table 1 shows descriptive statistics from our baseline survey (see the section The RCT Research Design and Surveys) regarding the portfolio of agricultural activities and their profitability. At baseline, the median farmer in our study area cultivated three hectares of cereal grains (split between maize and drought-resistant sorghum and millet), three hectares of cotton, and a mix of secondary crops on another two hectares.[12] 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 livestock constitutes a major productive asset, used for ploughing, or for generating animal products, and for reproduction. As described by Savadogo, Reardon, and Pietola (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, Udry, and Czukas 1998; Kazianga and 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 (Gildemacher 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, the fraction cultivating sesame grew from 20 percent in the 2014 baseline to 39 percent in 2015. Amongst those

11 The authors suggest that the increase may be driven by an income effect.

12 Figures reported in this section are for the median farmer.

Table 1. Baseline Agricultural Portfolio and Profitability

	Mean	Standard deviation	Median	Observations
		Crop area (hectares)		
Total field area	10.0	7.4	8	1,010
Cotton	3.9	3.4	3	1,003
Millet & sorghum	1.7	1.7	1	1,007
Maize	2.8	2.7	2	1,007
Sesame	0.19	0.5	0	1,010
		Value of production ('000 CFA per hectare)		
Cotton	195	81	188	1,003
Millet & sorghum	68.1	42.9	57	764
Maize	163.1	81.1	157.5	1,007
Sesame (2015)[a]	91.3	59	80	396
		Net revenue[b] ('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 and 2015 follow-up surveys.
Note: Market exchange rate over the time of the study averaged 550 West African CFA franc/USD.
[a]Data on 2014 baseline sesame production and inputs were not collected.
[b]Net revenue is the gross value of production minus cash inputs.

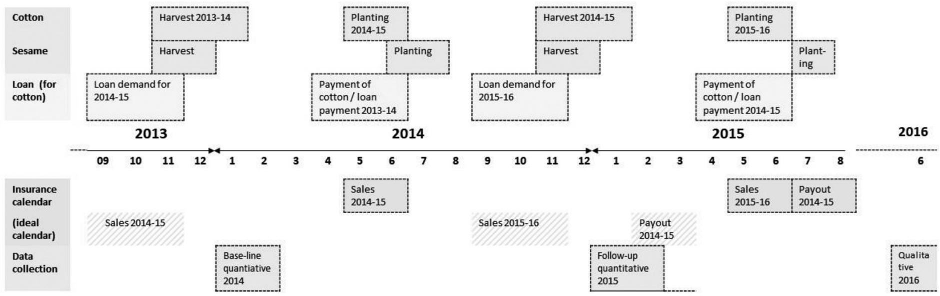
growing sesame in the control group, the average area of sesame cultivated grew from 1 to 1.4 hectares over that same time period.[13]

While our data do not permit a full cost accounting for all crops, table 1 gives an idea of the importance and returns of each of these primary agricultural activities. Sorghum and millet are drought resistant, but net returns to cotton are 50 percent higher than returns to these crops.[14] Net returns 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 percent 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 percent 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 percent of farmers failed to produce even 440 kilograms per hectare, the amount required to fully reimburse principal and interest on the production loan.[15]

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.

13 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/).
14 Net revenue approximates returns to family labor and land.
15 There is also some price uncertainty, reinforced by the length of the production timeline described above. The monopsony 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.

Figure 1. Cotton and Insurance Timeline



SOFITEX, the cotton company in the study area, is highly centralized and enjoys a local monopsony.[16] Each cotton farmer belongs to a farmer group (GPC or *Groupes de Producteurs de Coton*), which are comprised of 10 to 40 farmers from the same community. SOFITEX provides all inputs on credit (seeds, fertilizer, pesticide, etc.) using the group's standing cotton crop as collateral.[17]

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 percent.[18] For most farmers, the cotton company is the only source of formal credit for agricultural 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 the section Index Insurance for Cotton Farmers 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 fig. 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

16 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 percent of its capital. SOFITEX currently controls about 70 percent of the cotton crop in Burkina, with the residual now handled by two smaller companies that operate in well-specified (and separate) geographies.

17 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.

18 The loan is formally held by EcoBank.

insurance is provided).[19] 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 fig. 1). Maize is planted and harvested approximately at the same time as cotton, and cotton inputs are generally used for maize cultivation, but maize can be sold or consumed immediately after harvest.

Finally, while cotton loans are limited liability with no explicit collateral beyond the standing crop, they do entail some 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 their 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 and Guirkinger (2018).[20] Thus, the financial risks that insurance could reduce are both at the individual and at the group level.

First, at the individual level, having insufficient cotton yields to cover their loan implies that a farmer needs to either (a) liquidate savings and/or productive assets to reimburse SOFITEX or (b) suffer a social penalty for having other farmers reimbursing the loan under the joint liability, in addition to reimbursing the 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 low production, it generates tensions in the local community (Gelade and Guirkinger 2018). Our qualitative results provide further evidence of the economic and social costs of defaulting on the entire GPC loan (see the section Ex Post Impacts of Insurance Payments). 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, farmers' 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. While we lack data on savings, we know farmers save in cash and in kind to at least partially protect their consumption and productive assets in the event that the cotton crop fails.[21] 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.[22]

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.[23] The insurance contract is based on a "double trigger" area-yield index (see discussion below) 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

19 These features of the cotton system and timing have been well described theoretically and empirically by Saitone, Sexton, and Malan (2018) and Theriault, Serra, and Sterns (2013).

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

21 Note that a standard portfolio model would imply that individuals would maintain some savings even as they borrowed money under at least partially limited liability credit contracts, which provide some of the same protection as insurance (e.g., see the discussion in Bryan 2019).

22 Elabed and Carter (2018) find exactly this effect in a sister pilot in neighboring Mali.

23 At the time of the study, Inclusive Guarantee was known as PlaNet Guarantee.

purchase the insurance (Casaburi and 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.[24]

Area-yield contracts are relatively easy to understand and generally provide high-quality protection to farmers. Area-yield contracts have long been recognized as a reliable form of index insurance (Miranda 1991). Alternative indexes, such as those based on rainfall levels or vegetation indices measured by satellites, are only *proxies* of what one would like to measure directly, namely yields in a given area. Using area yields directly generally outperforms these proxies.[25] Benami and Carter (2021) provide a recent empirical example using the Tanzanian rice data analyzed by Flatnes, Carter, and Mercovich (2018), showing that while expensive to implement outside of monopsony buyers like SOFITEX, the area yield outperforms rainfall and satellite-based indices and easily passes a well-defined insurance quality standard.

The index insurance contract developed for this study took advantage of SOFITEX monopsony status and the fact that SOFITEX measures cotton production and area planted for each of its farmer groups in order to make loans and issue payments to farmers. Given this rich data source, there were two fundamental design questions. The first concerned the spatial scale over which area yields would be defined (see (Benami and Carter 2021) for a general discussion of this issue). Farmers wanted the index defined at the level of their GPC (if not at the level of their own farm). Insurers wanted a wider spatial scale, such as an agglomeration of villages, across which it would be difficult for farmers to coordinate to mutually reduce yields in order to obtain insurance payoffs. As a compromise, the contract developed here followed Elabed et al. (2013) and proposed a dual trigger contract. The primary trigger was farmers' preferred GPC-level trigger, meaning that the contract would in principal trigger any time GPC yields were low enough to threaten group loan repayment problems. However, to manage the morally hazardous behavior that could potentially be organized at the scale of the individual farmer group, the contract included a second disciplining or audit trigger based on yields averaged across the four or five GPCs closest to the primary GPC. This second trigger was set at about 100 percent of average yields in the neighborhood, meaning a single GPC with losses would always receive compensation as long as their neighboring farmer groups were not having an above-average year. In their analysis of cotton production in Mali, Elabed et al. (2013) show that this second or audit trigger has only a modest effect on the probability that the contract will not pay when the original GPC has experienced losses.[26] Additional details on the double trigger design in Burkina is given in the supplementary online appendix S1.

24 The newspaper Lefaso.net (Sidiber 2018) reports on SOFITEX's plan to roll out the cotton insurance nationwide. Stoeffler and Opuz (2020) analyze data from this expansion of the insurance program and from the pilot project to study demand for the product. They exploit experimental and quasi-experimental variations in price, information, and quality of the product available to farmers in order to measure the impact of these factors on index insurance uptake. They find that price subsidies and information games play an important role in explaining the high demand found during the pilot stage. However, farmers do not appear to react to the quasi-experimental variation in product quality (introduced by the fixed levels of yield-based insurance triggers), and uptake rates were much lower during the scale-up phase (2018) when subsidies and behavioral games were absent and project implementation efforts were lower.

25 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, Barrett, and Mude 2016; Carter et al. 2017; Binswanger-Mkhize 2012; Benami et al. 2021). 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.

26 Elabed et al. (2013) compare the performance of the double trigger contract with single trigger contract where the zone is defined as the broader neighborhood. Using data from the cotton company in Mali, they estimate that the single trigger, lower resolution contract has a 45 percent chance of failing to pay farmers in a GPC even when their GPC has an insurable loss. In contrast, the double trigger contract failure rate was only 15 percent.

The second design issue concerned the exact strike points and indemnity function. The final contract provided three levels of payment.[27] When GPC yields are below the 12th percentile of the GPC yield distribution (a one-in-eight-year event), farmers receive a "small payout" of 11,200 CFA per hectare insured (subject to the audit trigger).[28] This insurance payment was designed to correspond to the full market value of the insurance premium (so that the premium is in effect reimbursed to farmers in case of a small shock in practice). When yields fall below the 8th percentile of the yield distribution, the insurance provides a "medium payout" of 34,000 CFA. Finally, in case of yields falling below the 4th percentile (a one-in-twenty-five-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 prevent them from defaulting on their loan. The commercial price of the insurance product after all mark-ups and taxes was set at 11,200 CFA per hectare, or about 12 percent of the loan amount per hectare. Supplementary online appendix S1 discusses further details on estimation of yield distributions and pricing.

Despite these attractive design features, the implementation of the insurance suffered from a major drawback: the timing of insurance sales. As described in the section Index Insurance for Cotton Farmers, under SOFITEX rules, cotton input demand had 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 fig. 1 shows the timing related to the index insurance product. Ideally, insurance sales would have occurred in October, when cotton input demand occurred, so that farmers can easily adjust 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 limited farmers' ability to adjust their cotton production based on their insurance status.

Given these constraints, but under the assumption that insured farmers felt well protected by a high-quality product (an 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 the section Risk, Investment, and Insurance.

- *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 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.
- *Staple food crops and buffer savings*
  If staple food crops play a self-insurance role, we expect insurance to decrease investment in these buffer activities. Low return in-kind and cash savings would also be expected to diminish, potentially freeing up resources for more productive investment.
- *Other risky crops and activities*
  Theory suggests that being constrained in their ability to adjust cotton production, insured farmers would invest more in other risky and profitable activities. We thus expect insurance to positively impact sesame cultivation and livestock investment.[29]

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

27 These payment levels can be seen as a stepwise approximation to a linear indemnity function. Prior experience had suggested this approach was more easily understood by farmers with limited numeracy. Despite some disadvantages (e.g., small differences in measured area yields can make a big difference in payouts), this approach avoids making tiny payouts when yields fall just below trigger values.

28 For reference, 656.07 CFA = 1 euro (fixed exchange rate).

29 If livestock serves as precautionary saving instead of as a profitable investment, the opposite result would obtain (as for staple food crops, we would expect insurance to decrease investment in livestock). However, there is evidence from Burkina Faso that livestock is not used as a buffer stock when shocks occur (Fafchamps, Udry, and Czukas 1998;

4. Research Methods and Design

This section reviews the hybrid, mixed methods RCT implemented to evaluate the impacts of the insurance contract introduced above.[30]

The RCT Research Design and Surveys

The quantitative portion of this paper is based on baseline and endline surveys of 1,015 cotton farming households, divided among 80 cotton groups (GPC) in the Houndé region in southwestern 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 group comprises 40 GPCs, whereas the 40 control GPCs could not purchase the insurance (insurance contracts were not generated for these groups). Second, an encouragement design was generated among the treatment group by randomly distributing insurance subsidy coupons to farmer groups. Of the GPCs, 10 received no subsidy, 10 a 25 percent subsidy, 10 a 50 percent subsidy, and 10 a 75 percent subsidy. Given that the market price of the insurance was some 78 percent 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 (see supplementary online appendix S1 and Barre and 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 in a baseline and a follow-up survey. A total of 1,015 households were thus surveyed first in January 2014, before the first insurance sales that took place in May–June 2014 (see the timeline in fig. 1 above). The follow-up survey was conducted in January 2015 following the cotton harvest. Attrition was very low between baseline and endline (0.5 percent). The main purpose of the survey was to measure the ex ante impact of the insurance, that is, the actual changes in production induced by the insurance because of the protection provided. Questionnaire modules included detailed information on 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.[31] An insignificant F-statistic 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.). 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 and have average livestock holdings of 6.4 TLU (see note 6 above). 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

Kazianga and Udry 2006), suggesting it has an important role to play as a productive asset, as further analyzed by Carter and Lybbert (2012).

30 The history of this study is less linear than this section might suggest. It began life as a boilerplate RCT, with qualitative methods introduced as the research team realized that such methods were needed to 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.

31 While treated as a continuous variable, this measure takes on only the discrete values of 0, 25, 50, and 75 percent.

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%	$1.86e{-}11^{***}$	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
Cereal production (kg)	5,490	5,309	0.58	0.635
Sesame cultivated (1 = yes)	21%	17%	0.25	0.168
Tropical livestock unit (TLU)	10.9	9.54	0.10	0.049^{*}
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 observations	508	507	1,015	1,015

Source: 2014 baseline and 2015 follow-up surveys.

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: (a) the treatment status; (b) the percentage subsidy variable. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

baseline and rented more land. Later econometric analysis will control for GMO cultivation in an effort to mitigate this imbalance. 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 percent of households in that year. As discussed earlier, the rarity of these events challenges the ability of a short-term quantitative study to obtain reliable estimates of the ex post impacts of insurance.

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), households have a poverty likelihood of 17 percent using the national poverty line (Schreiner 2011). As can be seen, both treatment and control households have 10 members on average, and household heads average only 1.2 years of education.

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

Qualitative Research Methods

In addition to the quantitative data collection efforts in 2014 and 2015, we conducted qualitative fieldwork in the study area in June 2016 as shown in the fig. 1 timeline. While their use is 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 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, Carter, and May 2006; Kanbur and Shaffer 2007).

Another strength of qualitative work is its ability to shed light on "implementation gaps," which is the mismatch between the design of the program on paper and its actual implementation (de Sardan and Hamani 2018; Ridde et al. 2013). Mixed methods, which combine qualitative study with a randomized experiment, have proven to generate important insights for understanding the demand for microfinancial 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).

The first objective of our qualitative fieldwork was to better understand the quantitative results (as in Morvant-Roux et al. 2014 and White 2013). We explored in particular the details of the project implementation on 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 that were affected by shocks. The endline household survey was conducted *before* the first insurance payments and therefore does not allow measurement of the effect of shocks and the potential mitigating effect of the insurance.[32]

In total, we conducted 14 focus groups, including 2 focus groups with farmers who were never insured, 2 focus groups with small producers, 2 focus groups with women, 4 focus groups with producers who received an insurance payment, and 2 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 experiences with the insurance contract. While there exists 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 two to six focus groups by subpopulation tend to be sufficient (Guest, Namey, and McKenna 2017). We also supplemented the focus group discussions with semistructured 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.[34]

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 1 group a "small" payment).

33 Most focus groups had 10 participants (the maximum that we allowed), but the groups with women and groups that never purchased the insurance had fewer participants.

34 A caveat is that information was collected in 2016, two years after the product was initially sold to farmers (see the timeline in fig. 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 generated a bias in their answers. That being said, farmers remembered their experience with the insurance very well (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, they openly discussed both positive and negative aspects of their experience with the index insurance project.

5. Impact of Insurance on the Farm Portfolio

The section Index Insurance for Cotton Farmers above presented 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, 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 whether 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 the following:

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 percent, 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 SOFITEX farmers in Burkina Faso (see footnote 24), Stoeffler and 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 trusted the insurance.[35] As stressed above, one of the complexities that confronts 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 the following:

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)

The contrast between those who did and did not trust the insurance suggests that ex ante response to the insurance will likely be heterogeneous. Farmers confident in the reliability of the insurance might feel empowered to invest more, while farmers who were not confident would be unlikely to invest more. Econometrically, as we discuss below, this kind of heterogeneity would be expected to create an attenuation bias, with average treatment effects (identified by a mix of those who did and did not have confidence in the insurance) pushed towards zero, relative to estimates that would emerge if everyone trusted the product.

These skeptical comments also raise the issue of how trust evolves over time as farmers gather information on the actual performance of the contract. In their multi-year study of a combined insurance/drought-tolerant seed intervention, Boucher et al. (2020) find that farmers who experienced drought events and observed the efficacy of the stochastic technologies subsequently intensified their investment in the technology. Those who did not observe the technology subsequently walked away from it. Cai, de Janvry, and Sadoulet (2020) similarly find that the personal experience of insurance payouts boosts subsequent uptake. In the section Ex Post Impacts of Insurance Payments, we take advantage of payouts that occurred following the 2015–16 season to learn about how trust evolves over time, especially in the face of the implementation challenges surrounding insurance.

35 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. A formal vote was rare, but the insurance purchase decision was typically described as consensual during qualitative interviews.

In the remainder of this section, we first investigate investment effects on cotton production, at both the extensive and the intensive margins. We then turn to impacts on other activities in the farmers' portfolios.

Results on Cotton Production

To estimate the impact of area-yield insurance, we estimate an ANCOVA treatment on the treated model:[36]

$$y_{i1} = \delta \hat{I}_{i1} + \alpha_0 y_{i0} + \beta_0 + \beta_1 X_{i0} + \varepsilon_{i1}, \tag{1}$$

where y_{i1} is the endline value of the outcome variable of interest, y_{io} is the baseline measure of the outcome variable, and X_{i0} is a vector of baseline control variables, which includes district fixed effects, baseline measures of household economic status, and a binary indicator of whether or not the household cultivated GMO cotton varieties in baseline.[37] Finally, $\hat{I}_{i1}$ is the estimated uptake of insurance derived from the following linear probability model of insurance uptake:

$$I_i = \gamma_0 + \gamma_1 T_i + \gamma_2 S_i + [\psi_0 y_{i0} + \psi_1 X_{i0}] + \nu_i, \tag{2}$$

where $I_i = 1$ if individual i's GPC purchased insurance and the identifying instruments are T_i which is assignment to treatment and S_i which is the subsidy level offered to the GPC. Both treatment assignment and especially subsidy levels are strong and statistically significant predictors of insurance uptake. The R^2 for these first stage regressions is approximately 0.37 and the regression passes Sargan and Basmann over-identification tests in all the two-stage-least-square regressions with p-values above 0.05 (supplementary online appendix S2 presents these first stage results). As described above, the subsidy encouragement varies across GPCs, ranging from a subsidy of 0 to one of 75 percent. Because higher subsidy rates were effective in encouraging insurance uptake, we anticipate substantial efficiency gains from this treatment on the treated estimation strategy as compared to a simpler ITT approach.

The top panel of table 3 displays the local average treatment effect estimates of the impact of insurance on cotton investment and production estimated using equation (1). 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 point estimates of the impact of being insured are all economically small relative to the baseline control group mean and statistically insignificant. For example, the point estimate on the amount borrowed implies only a 1 percent change relative to the control group mean.[38]

These null findings of the impact of insurance on cotton investment could reflect attenuation bias created by the fact that farmers were a mix of those who did and did not trust the insurance, as discussed earlier. However, this trust problem is certainly not unique to this study, and the estimated lack of impact on investment in the insured activity stands in contrast to other findings in the literature summarized in the introduction. While this contrast suggests that other mechanisms are at play in our study, we cannot definitively rule out attenuation bias based on the econometric evidence. It is here that our qualitative evidence can help us unpack the mechanisms underlying our reduced-form econometric results, as suggested by White (2013). As detailed in the section Cotton, Risk, and the Index Insurance Pilot in Burkina Faso,

36 As has long been appreciated (e.g., see Van Bruekelen (2006) on the bio-medical literature and McKenzie (2012) for the economics literature), ANCOVA estimations give more precise estimates than either single difference or difference-in-difference estimates under a wide range of assumptions about the dependent variable's degree of autocorrelation (assuming the data are generated by an RCT that is asymptotically balanced).

37 As discussed earlier, GMO cultivation was statistically unbalanced at baseline.

38 The ANCOVA ITT estimates for all regressions displayed in table 1 are similar to the LATE estimates, except that the ITT estimates are smaller in magnitude (as expected given partial compliance with the treatment) and relatively noisier (as expected given that we have varying, randomly distributed insurance subsidies that effectively encouraged differential uptake across treated units).

Table 3. Impact of Insurance on Agricultural Activities

	Panel A: Cotton				
	Loans ('000 CFA)	Area cultivated (hectares)	Fertilizer use (bags/hectare)	Yields (kg/hectare)	
Insured (instrumented)	−7.0	−0.23	0.06	−69.7	
[Standard error]	[34.3]	[0.23]	[0.14]	[59.01]	
Baseline dependent variable	0.28***	0.85***	0.16***	0.29**	
[Standard error]	[0.08]	[0.06]	[0.03]	[0.03]	
Other controls[a]			*Included*		
Observations	913	927	927	927	
Baseline Control Group Mean	448.1	4.2	2.3	849	
	Panel B: Other activities				
	Cereal production (kg)	Sesame cultivation (1, if cultivate)	TLU (#)	Rent-in land (1, if rent-in)	Infrastructure investment ('000 CFA)
Insured (instrumented)	−778**	0.15**	1.63*	0.15**	2.4
[Standard error]	[336.5]	[0.0619]	[0.991]	[0.0624]	[2.4]
Baseline dependent variable	0.61***	0.30***	0.92***	0.28***	0.31
[Standard error]	[0.07]	[0.04]	[0.05]	[0.04]	[0.24]
Other controls[a]			*Included*		
Observations	922	927	927	927	927
Baseline control mean	5,739	0.21	11.0	0.34	3.9

Source: 2014 baseline and 2015 follow-up surveys.
Note: [a]Included control variables are the progress out of poverty index, land stock, baseline cultivation of GMO cotton, and subregional (district) dummy variables. Standard errors are clustered at the village level. $^{*}p < 10$ percent, $^{**}p < 5$ percent, $^{***}p < 1$ percent.

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 fig. 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.

These implementation flaws during the 2014 experimental trial raise the possibility that farmers learned about the insurance and may have responded in the subsequent 2015–16 cropping season. Indeed, as can be seen from fig. 1, input demand for the 2015–16 cotton occurred in October–November 2014, only a few months after farmers had the possibility to purchase insurance in June 2014. While we did not collect farmer data for the 2015–16 season, we were able to recover administrative data on cotton area planted, cotton production, and number of cotton-growing farmers for 79 out of the 80 farmer groups that were included in the RCT. From these data, we estimate the impact of being insured in 2014 on area

Table 4. Post-Experiment Impacts of Insurance as Seen through GPC Administrative Data

	2015–16 cotton outcomes	
	Area cultivated per farmer (hectares)	Production per farmer (kilograms)
Insured (instrumented)	0.32	367
[Standard error]	[0.428]	[0.226]
2014–15 dependent variable	0.79^{***}	0.74^{***}
[Standard error]	[0.00]	[0.00]
Observations	79	79
Baseline control group mean	3.9	3,383

Source: Administrative data provided by SOFITEX (cotton variables) and Inclusive Guarantee (insurance variables).
Note: $^{***}p < 1$ percent.

cultivated and production using the two-stage least-squares strategy described above in equations (1) and (2).

Table 4 reports the results from a two-stage least squares analysis of this administrative data. As can be seen, the point estimates imply that insured farmers boosted area cultivated by about a third of a hectare (just under a 10 percent increase), with production rising in step by 367 kilograms (or approximately a 10 percent increase). These point estimates are in line with other findings in the literature on the impact of insurance on the insured crop (see the section Index Insurance and Investment above). However, with p-values of 0.43 and 0.23, respectively, we cannot reject the hypothesis of zero impact at any conventional level of statistical significance. We should also note that for farmers to have expanded their cultivation, they would have had to have believed that the insurance agents would eventually return to make insurance available (in June 2015) after they already committed to larger loan amounts and area cultivated.[39]

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 fig. 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 portfolios of agricultural activities. In particular, given the qualitative evidence that farmers largely trusted the insurance at baseline, we expect farmers to increase sesame cultivation as well as investment in livestock and other forms of on-farm investment. In addition, we might also expect to see a reduction in buffer savings and cereals cultivation, which is a low-risk, low-return investment and a form of self-insurance (see the section Cotton, Risk, and the Index Insurance Pilot in Burkina Faso). Note that a reduction in the need for buffer savings would free up liquidity that could be used to finance these other investments.

Using the same econometric approach employed to analyze the cotton variables, the bottom panel of table 3 presents the LATE estimates of the impact of the cotton area-yield insurance on the agricultural activities that could be indirectly influenced by the provision of cotton insurance: cereals production, cultivation of sesame seeds (a cash crop), and livestock rearing. We also investigate the

39 The second season of insurance sales (2015) was again subject to significant delays, along with other implementation issues. Only six farmer groups purchased the insurance, all within the original treatment group: among these, three had received a large insurance payout and three had obtained a 70 percent random subsidy in 2016. This low uptake does not provide us with sufficient statistical power to test the impact of 2015 insurance purchase on cotton cultivation in future years.

impact of insurance on two indicators of overall farm investment over the 12 months preceding the endline survey: land rentals[40] and infrastructure investment (fences, small dams, and small-scale irrigation).

The parameter estimates in table 3 reveal an impact pattern for cereal production, sesame seed cultivation, and livestock rearing that is consistent with the hypotheses about the spillover impacts of cotton insurance described earlier. The estimates imply that insured farmers produce 778 kg less of cereals, about a 14 percent drop. The estimates also show a 15 percentage point increase in the cultivation of the cash crop sesame and an increase of 1.63 TLU (roughly a cow and a half). In addition, insured farmers are estimated to increase their propensity to rent-in land by 15 percentage points. As noted in the section Risk, Investment, and Insurance, insurance would also be expected to reduce farmers' need for buffer savings. Release of these funds would provide a second source of liquidity (beyond reduced spending on cereals) for the estimated livestock and sesame investment. We do not, however, see any statistically significant change in the amount of investment in farm infrastructure.[41]

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 directly covered by the product and perhaps a decrease in cereals cultivation which 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. In other words, as discussed earlier, the estimated effects are data-weighted averages of the responses of those who did and did not trust the insurance (i.e., the estimates are subject to attenuation bias). 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 us to investigate these issues, as the next section now discusses.

Ex Post Impacts of Insurance Payments

Unlike the January 2015 endline household survey, the June 2016 focus group discussions occurred after insurance payments had been made based on yield shortfalls in the 2014–15 cotton cropping season (see fig. 1). While information from these focus groups necessarily lacks the statistical representativeness of quantitative data, it does allow insight on the ex post impacts of insurance and how it changes farmers coping strategies in the wake of a drought. As such, we gain insight on the mechanisms that underlie the investment and other effects that more representative econometric studies have confirmed. In addition, as

40 In a context where land sales' markets are virtually absent, investments in agricultural activities are often realized by renting land.

41 As suggested by an anonymous referee, these impacts suggest exploring whether insurance affected child labor and school attendance. Note that we might expect a mix of income and substitution effects on child labor and education from the estimated insurance-induced behavioral changes, with further ambiguity based on increased sesame but decreased cereals production. Using the same regression strategy employed for other outcome variables, we find that insurance induces a statistically significant 2.5 percentage point increase in agricultural labor for older girls (ages 12–17). However, insurance has no statistically significant impact on school attendance of these girls, and in fact has a statistically significant 9 percentage point positive impact on school enrollment for boys ages 6–11. Further discussion and results are reported in supplementary online appendix S3.

mentioned in footnote 5, few quantitative studies have been able to observe the impacts of insurance on risk coping strategies. While imperfect, our qualitative data enable a more complete picture of the impacts of insurance.

The farmer 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 first place. Typical comments include the following:

> *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 seen as deceptive. All point towards issues 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 and Barrett 2017; Platteau, De Bock, and Gelade 2017), actors in the field still face difficulties in conveying the concept of insurance in general and index insurance in particular.[42]

Focus group respondents from the groups that received insurance payouts reported that they encountered important losses because their fields had been attacked by pests 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 for 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 group was 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 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, due to the agricultural shock, caused serious economic and social stress in the communities. Farmers had to deplete their productive

42 Arguably, this kind of misunderstanding of novel insurance technologies makes the case for some kind of learning subsidy, akin to the case for temporary subsidies for improved agricultural inputs discussed by Carter, Laajaj, and Yang (2021) and as suggested by Cai, de Janvry, and Sadoulet (2020) for microinsurance.

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)

The insurance payments, on the other hand, mitigated the damage (both social and economic):

> *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) [43]

Insurance payments 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 on purchasing 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 oxen that we had to sell to pay back SOFITEX and the bank.* (3, FG8)

While the delay in insurance payments was clearly damaging to farmers, the focus group participants testify to the great potential of a well-implemented insurance scheme to avoid the costly coping strategies and social disruption that farmers reported prior to the receipt of the payout. Less clear is the long-term attitude of these farmers towards the purchase of insurance. In the short term, all three groups that received a large payout purchased the insurance again in 2015, matching work by Boucher et al. (2020) and Cai, de Janvry, and Sadoulet (2020) that indicates that payouts lead to further insurance purchase and intensification of investment.

6. Conclusion: Opportunities for Index Insurance?

This paper has analyzed the impact of a cotton index insurance pilot program on cotton growers in Burkina Faso, combining a rigorous randomized control trial evaluation with careful qualitative work. 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 75 percent increase in the fraction of farmers growing sesame and a 35 percent increase in livestock holding. Similarly, there is also evidence that insurance caused a reduction in the production of food grains, which functions 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,

43 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 live their own counterfactual, uninsured 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 oversold, as Binswanger-Mkhize (2012) and others have argued, these results suggest that there 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. The tight-knit value chain for cotton in Burkina Faso solves many of the barriers that confront 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 reliable insurance protection compared to other types of insurance indices. And yet, even given these advantageous circumstances, the complexities of implementing agricultural insurance in a difficult rural environment limited the impacts of the insurance.

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 were assuring timely marketing, education, and sales of insurance contracts. Timely delivery of indemnity payments also proved difficult. While farmers in our study area who suffered severe shocks ultimately benefited substantially from insurance payouts, payment delays resulted in harmful stress and at least temporary farm decapitalization. Finally, in the year following the study, renewal rates were high for those few farmer groups that had received payouts, but dipped for those groups that did not receive payouts (this pattern resonates with the finding of Stein 2018 on the repurchasing rate for index insurance in India). Learning about a technology that offers only stochastic benefits (e.g., see Lybbert and Bell 2010) remains a challenge and would seem to require development of innovative educational tools that reinforce the learning and trust that can develop following insurance payouts (Cai, de Janvry, and Sadoulet 2020).

A final lesson that 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 1990, and more recently Morvant-Roux et al. 2014 or de Sardan and 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 other 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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