The impact of crop insurance on welfare and climate resilience: Experimental evidence from Uzbekistan

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Abstract

As index insurance is often discussed as a promising climate adaptation strategy for agricultural producers, growing literature has examined its effectiveness. Yet, a clearer understanding on the differentiation between *ex-ante* (insured but no damage) and *ex-post* (payout) impacts is often missing. In order to understand the full-scale implications and benefits, entrance points of the impact on the different production stages are fundamental. Therefore, this study uses a framed field experiment to analyze both effects on welfare (risky but profitable fertilizer input, consumption, and farm income) and climate resilience (financial independency) among rainfed wheat farmers in Uzbekistan. Our results suggest that crop index insurance induces *ex-ante* and *ex-post* welfare gains for all related outcomes and strengthens climate resilience after a drought. On the practical side, our results contribute to assessing the efficacy of crop index insurance and its positive implications on rural welfare: First, through the insurance coverage directly, and second, through an adoption stimulating narrative indirectly.

Keywords Crop index insurance; Ex-ante and ex-post impact analysis; Experimental economics; Uzbekistan

JEL codes G22, O12, O13, O33, Q14

1. Introduction

Weather shocks pose production risks for agricultural producers. Evidence predicts devastating effects of uninsured risk to climate-vulnerable farmers: volatile agricultural incomes and household consumption. Intending to smooth income, farmers traditionally decide for farming practices that result in stable but lower crop productivity and they save money for precautionary purposes (e.g., Morduch, 1995). The role of consumption is twofold: In a tradeoff between consumption smoothing and asset sale, it conditions short-term asset endowment. In quantitative and qualitative terms it influences health investments, and thus determines human capital formation, maintenance or destruction (Hoddinott, 2006). Declines in economic growth and wellbeing can be long-term impacts of uninsured weather shocks in developing countries (de Nicola, 2015; Janzen & Carter, 2019; Hill et al., 2019).

Adequate climate adaptations can either enhance productivity directly through input investments such as drought-resilient seeds or irrigation (e.g., Lybbert & Sumner, 2012), or indirectly via improved microfinance services. Such services include credits and insurance programs (Hill et al., 2019). However, access to formal credit and insurance products is usually limited in developing countries due to missing markets and/or capital constraints.

Research and international organizations often tout agricultural index insurance as a potential remedy here. In a nutshell, farmers insured by index-based programs receive a payout if a pre-defined regional or farm-level index (e.g., rainfall) falls below a previously specified threshold. The relevant index is chosen to achieve the highest possible correlation with farm-level or regional yields. This way, index insurance relies on objective information, avoids problems of information asymmetry, and lowers insurance costs. Index insurance protection is expected to solve the productivity and consumption issues of traditional adaptation practices, as it may smooth the consumption of farm households when experiencing insured weather shocks (*ex-post*). Anticipating that, it moreover is expected to induce investments into more risky but higher-return inputs before the shock occurs *ex-ante* (Hazell & Hess, 2010). Yet, one challenge of index insurance is basis risk, which occurs when the index does not correlate with realized and insured on-farm losses (e.g., Carter et al., 2017).

Particularly in the last decade, index insurance (pilot) projects have been implemented in many parts of the world. While most research in the context of agricultural index insurance has focused on exploring its low adoption rate (e.g., Cai et al. 2015), impact analyses are more recently gaining recognition. Its importance is expressed by Cai and Song (2017), who state that individuals only recognize the benefits of index insurance when the shock appears. Embedding the advantages of index insurance into promotion activities may increase its low adoption rate and all its positive synergies, whereas identified disadvantages can foster the creation of index insurance that fulfills the desired welfare outcomes. Within this body of literature, evaluations of insurance effectiveness are primarily addressing either *ex-ante* or *ex-post* impacts, or do not differentiate between those at all. As pointed out by Noritomo and Takahashi (2020), detangling *ex-ante* and *ex-post* effects is essential for truly understanding the implications of index insurance coverage in different time horizons. For this reason, this study examines how marketable crop index insurance influences farmers' investment decisions (a) before experiencing a weather shock, (b) once it occurs, and (c) in the following years of recovery.

In Uzbekistan, crop index insurance for wheat production is planned for wide-scale implementation in the country's pilot region (Jizzakh province). Therefore, a local insurer created a marketable index insurance product to hedge against drought, the region's most dramatic weather shock during summers (IPCC, 2021). Aiming to assess the efficacy of this particular index insurance option, we conducted a framed field experiment (Harrison & List, 2004) with a random sample of 199 (future) Uzbek pilot farmers. In an experimental setting, we introduce the sample farmers to the concept of index insurance and one marketable option in particular. In economic games, farmers then mimic five consecutive farming years, in which they individually allocate financial endowment between different investment options (consumption, fertilizer, marketable index insurance, and savings). Depending on the chosen investment decision and exogenous weather conditions, farmers receive a new endowment that they reinvest into the new hypothetical growing season. Playing this procedure for five consecutive seasons (rounds) allows us to explore the dynamics of index insurance behavior, as well as its *ex-ante* and *ex-post* impacts. Aiming to elicit potential impacts of the real marketable index insurance product, we attempt to include field context as best as possible into a controlled lab experiment. Hence, the game is based on locally averaged farm, market and weather data that approximate the reality of local farmers in an efficient and comprehensible manner. Following Hill and Viceisza (2012), this experiment classification facilitates impact evaluations in an ideal environment that is clear of credit and trust constraints.

The remainder of the paper is structured as follows. After delivering some background in section 2, section 3 describes the data collection process and experimental design. Section 4 discusses the empirical approach, and the main findings are presented and discussed in section 5. The final section concludes.

2. Background

The general insurance idea implies that policyholders pay an insurance premium and receive a payout when experiencing an insured shock. From an individual's perspective, insurance can smooth incomes over states by transferring resources from a good state of nature to the bad one. Related behavioral changes do not only stem from the money transfer per se but also from adjusted preferences. A growing body of literature has concentrated on the impact of index insurance protection for agricultural producers in various developing countries. Existing literature identifies impact through two channels: First, *ex-ante* effects that consider resource allocations of insured households before knowing the accumulated weather condition that may trigger payments. Second, *ex-post* (payout) effects refer to recovery mechanisms when encountering a shock.

There is evidence that sole index insurance coverage (*ex-ante*) stimulates investments devoted to risky but higher-return activities (Cole et al., 2017; de Nicola, 2015; Hill et al., 2019; Hill & Viceisza, 2012; Jensen et al., 2017; Karlan, 2014). These effects seem to hold for index-based livestock, crop, and tobacco insurance in several African and Asian countries. As examples, insured pastoralists reinforce livestock health expenditures in Kenya (Jensen et al., 2017) and insured crop farmers enhance irrigation, hired labor, and fertilizer expenses in Bangladesh (Hill et al., 2019). Moreover, Matsuda et al. (2019) assume *ex-ante* quality investments to cause higher productivity levels.

Other scholars argue that index insurance coverage substitutes alternative precautionary instruments. Examples are lower monetary savings (Matsuda et al., 2019), fewer livestock holdings among pastoralists (Jensen et al., 2017), and decreased stocks of food grain production as self-insurance for cotton farmers (Stoeffler et al., 2020). However, Cai (2016) cannot identify any impact on the amount devoted to savings.

Another strand of literature sheds light on *ex-post* impacts. When suffering insured weather shocks, insurance protection allows farmers to deviate from usual risk coping strategies. In this line of argumentation, Janzen and Carter (2019) find that insurance coverage substitutes traditional coping strategies when encountering a weather shock: poorer farmers no longer reduce their food consumption and richer farmers do not sell livestock holdings as productive assets. This prevents them from devastating economic consequences. Similar, Karlan et al. (2014) and de Nicola (2015) have evidence of improved consumption smoothing impacts, which yet seem to be non-existent in other research (Cole et al., 2017; Matsuda et al., 2019). Empirical studies by Bertram-Huemmer and Kraehnert (2018) in Mongolia as well as Jensen et al. (2017) and Noritomo & Takahashi (2020) in Kenya find that index-based livestock insurance can smooth productive assets (livestock holdings) *ex-post*. Bertram-Huemmer and Kraehnert (2018) even estimate the recovery benefit to prevail for three years post drought. Hill et al. (2019) further report a payout effect on enhanced investments into irrigation and fertilizer, which are associated with higher production levels in Bangladesh. This production impact shows external validity in China (e.g., Cai et al., 2015). Moreover, Cole et al. (2017) have evidence that payouts serve as savings for future shocks or are used to repay remaining credits. Compared to an anti-poverty transfer in Kenya, index-based livestock insurance can further exhibit lower marginal costs and proves to be the more efficient social security program (Jensen et al., 2017). This is similar to a study by Noritomo & Takahashi (2020), who find that the positive income effect can prevent poorer pastoralists to fall into poverty after extreme weather events.

Probably due to data availability, most impact analyses investigate *ex-ante* implications or do not differentiate between *ex-ante* and *ex-post* channels (Cai et al., 2015; Cole et al., 2017; Hill & Viceisza, 2012; Karlan et al., 2014). However, it is important to detangle these two channels to identify the real impact effect in its respective time horizon in a simultaneous estimation (Noritomo & Takahashi, 2020). To our knowledge, there is only one study that causally parses out the two impact effects and they do so for index-based (livestock) insurance (Noritomo & Takahashi, 2020).

Besides the suggestive positive evaluation of index insurance, there are also possible negative effects to consider. Index insurance participation may imply negative welfare outcomes in the good states of nature because the paid insurance premium without a transfer implies a financial loss. Another issue in this context refers to basis risk. The worst scenario for farmers is to be insured, suffer actually insured losses but not receive an insurance payment (Carter et al., 2017). Fuchs and Wolff (2011) further warn against lacking investments in non-insured crops.

In this vast literature, a remaining question is to decompose the impact of index-based crop insurance into *ex-ante* and *ex-post* effects. Our study attempts to estimate the welfare-enhancing and resilience-increasing *ex-ante* and *ex-post* impacts of crop index insurance in the case of Uzbekistan.

3. Data and experimental design

3.1 Research area and sample selection

Uzbekistan has an established agricultural insurance market that insures roughly 30% of all crops. However, offered insurance products are characterized by high premiums and lacking coverage in times of severe drought predictions (Muradullayev & Bobojonov, 2014). In 2019, the Uzbek government issued a decree to subsidize 20% of the insurance payouts for the two main crops cotton and wheat, but index-based insurance may provide a more sustainable insurance solution in the country (Muradullayev & Bobojonov, 2014). Moreover, there are predictions of more extreme weather conditions in the future: drought during summers and increased precipitation during winters (IPCC, 2021). To increase resilience against these weather shocks, adequate climate adaptations are vital. For this reason, an index insurance pilot is currently under implementation in the Jizzakh province of Uzbekistan. The remaining question is directed towards the efficacy of this marketable crop index insurance in the pilot region.

This study draws on two data collection strategies. First, in March 2019, our local partners interviewed all 696 rainfed wheat farmers in the Jizzakh province, who are also the population of the planned insurance pilot. Second, from this population a random sample of 234 rainfed wheat farmers was selected and invited for an experiment in April 2019. The experiment was then conducted in 12 sessions, each with 7 to 30 participants. All in all, 199 farmers participated. As our experiment simulates five subsequent farming years, we have 993 valid observations for our analysis.[1]

[1] One participant dropped out the experiment after three rounds already: 198*5-3.

3.2 Experimental design

Our experiment is classified as a framed field experiment (Harrison & List, 2004).The experiment started with an intensive introduction to the general concept of index insurance, as well as one marketable option that had been previously developed by a local insurer for forthcoming implementation in the pilot region.[2] This specific index insurance product relies on satellite information and was calibrated with weather station data. Payouts are then triggered in two increments: (1) when the season's accumulated precipitation falls below 65% (*few rainfall*) of what in the local context is considered normal rainfall, and (2) when it remains under 40% (*very few rainfall*). Therefore, the experimental insurance option is an exogenous drought insurance and contains real insurance properties regarding premium, triggers, and payouts. These are kept constant over all participants and experiment sessions. Intending to explore insurance participation under ideal conditions, we neglect the common challenge of basis risk.

After the educational input, we prepared the economic games. For the games, participants were divided into two or three different game groups depending on the attendance size. Within one game group, participants sat in close proximity, shared enumerators, and were randomly assigned to one of three initial endowment levels, each occurring with a 1/3 probability. Based on their individual endowment assignment, participants received game money and were equipped with identical game sheets. Aiming to simulate five consecutive farming years in which participants allocated their endowment to preferred investment strategies, the game sheet displays all available options, their costs, and (weather-dependent) returns.[3] Across all experimental sessions, participants then played their individual game in four steps:

1. As in real life, participants need to pay for fixed farm costs (seeds, labor, machinery, diesel, etc.) and a minimum level of household consumption to cover basic human needs.
2. Optionally, participants could:
    - **a.** spend more money on household consumption[4], and/or
    - **b.** invest into risky but higher-return fertilizer as a production input, and/or
    - **c.** purchase index insurance as protection against the weather risk (drought), and/or
    - **d.** store money on a savings account with an annual deposit rate for precautionary purposes.

[2] In order to have full control over the experimental procedure, one experimenter gave instructions and answered all questions in the local language. In contrast to other similar experiments (e.g., Hill and Viceisza, 2012), time-consuming translations were redundant, and complete awareness regarding participants' understanding granted.

[3] For reasons of simplicity, the game assumes that every farmer cultivates wheat on one hectare of land and has six household members.

[4] While extra consumption payments were not associated with an economic benefit in the game design, it was signaled by golden (chocolate) coins that positively connoted with social prestige. Thus, social rewards and social approval may induce higher consumption spending, if also relevant in real life.

Perfect credit markets allowed participants to take a loan with an annual interest rate, if liquidity constraints prevented them from choosing the preferred investment strategy.

3. After recording individual investment choices, we simulate the season's accumulated weather, which is expressed in normal, few, or very few rainfalls. The season-specific weather condition was predetermined but the probability of the three possible weather events was unknown to participants ex-ante. In fact, they resemble accumulated local precipitation levels of the years preceding the experiment.
4. Finally, individual investment choices as (production) inputs and the exogenous weather event cause hypothetical yields and resulting revenues. This individual revenue translates into new income, which farmers receive for investments into the next season. The game then starts at step 1 again.

Aiming to simulate five subsequent farming years, these steps were rerun for four additional rounds (seasons) that are identical in terms of procedure, choice options and their respective payout structure.

Intending to reveal true preferences, the game incorporates a reward system for the most economically efficient investment behavior per initial endowment group.[5] Generally, the game is designed to approximate reality in an intuitive way for all farmers – independent of their financial literacy level. This is embodied in all numerical values that replicate the average farm reality in the Jizzakh province and the experimental weather sequence relying on historical and locally aggregated precipitation levels. Additionally, farmers within one session could communicate and possibly influence each other, as decision-making in more collective societies may not happen in isolation. In this familiar setting we then introduce a novel and marketable index insurance that could soon be offered to our sample farmers in reality.

In summary, our experiment is a controlled lab experiment that includes field context in a simplified but efficient way and studies behavior of the real target group of the insurance pilot. We argue to gain rich insights into real investment behavior related to index insurance adoption. This follows a strand of literature that argues for framed field experiments/lab-in-the-field experiments to predict real decision-making (e.g. Gneezy & Imas, 2017).

Moreover, our experiment can be considered an extension of a similar experiment conducted by Hill and Viceisza (2012). While the authors use an actually fair insurance product, we offer a marketable option. Substantial differences in the experimental design are further expressed in credit rationing, decision-making in isolation (voting boxes), two stochastic weather events (good and bad) that are drawn without replacement per round, fixed consumption costs, fertilizer as the only investment option, and mandatory index insurance for a random sample in the last two game rounds. Similarities exist in random initial

[5] Since intermediate game performance was not announced, we do not assume the reward element to induce an unrealistic game competition.

endowments, fast insurance payouts, a detailed educational input, and weather as the only production risk. We argue our experimental design to approximate the local farm reality more precisely, and give better insights into possible impacts.

4. Estimation strategy

This study explores *ex-ante* and *ex-post* welfare-enhancing and resilience-increasing impacts of the adoption of marketable crop index insurance in an experimental setting. The outcome variables of interest are household consumption costs, fertilizer input, farm income, savings amount, and the credit amount. The main independent variables are index insurance participation and experienced insurance payouts. Since all sample farmers were offered index insurance and could flexibly opt for it, there is a self-selection into insurance participation. In order to account for the endogenous insurance decision, we apply an instrumental variable approach.

Similar studies usually exploit the random (exogenous) distribution of discount vouchers for insurance participation as an instrument (e.g., Janzen & Carter, 2019; Jensen et al., 2017; Matsuda et al., 2019; Noritomo et al., 2020). However, our experiment offers one marketable index insurance option without any discount or rebate possibilities. In search for a valid instrument we rely on adoption research that finds evidence of peer behavior stimulating individual uptake (e.g., Cai et al, 2015). In this context, we argue that individual farmers imitate the behavior of other participating farmers in the same experimental session. While there is no reason to believe that the average peer behavior directly correlates with individual investment decisions, it is plausible to assume indirect influence through the individual insurance participation choice. Moreover, one's peer's insurance uptake is not correlated with the error term because behavior of all session participants can be regarded as exogenous. Consequently, average peer behavior fulfills the instrumental variable properties of independence and relevance and is a valid instrument in our model.

Further, we exploit the longitudinal structure of our data that consists of five consecutive game rounds played. A test of overidentification restrictions further reveals that the fixed effects model is more appropriate than the random effects model.

We first estimate the effect of peer insurance participation on an individual *i*'s insurance demand in round *t* in the first stage regression:

$$Insurance_{it} = \beta_{10} + \beta_{11} \cdot PeerInsurance_{it} + \beta_{13} \cdot X_{it} + \alpha_{1i} + u_{1it}, \quad (1)$$

where $PeerInsurance$ measures the share of insurance adopters in one's game session (oneself excluded). The vector X_{it} captures time-variant investment decisions (consumption, endowment lost,[6] fertilizer input, savings amount, credit amount),[7] α_i represents unobserved individual heterogeneity and u_{it} is the error term. Standard errors are clustered on the individual level.

The second impact of interest concerns the receipt of an insurance payout. Receiving a payout depends on (exogenous) previous weather conditions and the (endogenous) insurance status. Therefore, we assume payout to also be endogenous and instrument it with one's peer's insurance choice in a rain-deficit event in the previous season. The resulting second first stage regression is:

$$Payout_{it} = \beta_{20} + \beta_{21} \cdot PeerInsurance_{it} + \beta_{23} \cdot X_{it} + \alpha_{2i} + u_{2it}. \quad (2)$$

In a second stage regression, we next estimate the impact of the predicted insurance coverage $\widehat{Insurance}_{it}$ (*ex-ante* effect) and predicted payout $\widehat{Payout}_{it}$ (*ex-post* effect), both obtained from their respective first stage regressions, on welfare-enhancing consumption costs, fertilizer input, farm income and savings, and resilience-increasing credit uptake respectively:

$$Y_{it} = \gamma_0 + \gamma_1 \widehat{Insurance}_{it} + \gamma_2 \widehat{Payout}_{it} + \gamma_3 X_{it} + \delta_i + \epsilon_{it}, \quad (3)$$

where δ_i includes individual heterogeneity and ϵ_{it} is the error term. All standard errors are again clustered on the individual level.

Following ideas by Noritomo & Takahashi (2020), this model specification allows to distinguish between *ex-ante* and *ex-post* impacts of insurance participation. While $\gamma_1$can be interpreted as a behavioral or preference-related change once being insured, γ_2 expresses the sole indemnity payment for insured farmers after experiencing drought in the last season.

5. Results and discussion

5.1 Descriptive results

Table 1 presents the share of insurance adopting farmers per game round. In the first round, 56% demand agricultural index insurance. Relatively, participants seem a bit initially reluctant towards the innovative agricultural insurance concept.[8] In the following rounds, the adoption share reaches 85-89% and decreases in the season after a severe drought (round 4) that is associated with liquidity constraints. We assume that after experiencing mild drought in round 2, more skeptical farmers could observe the immediate payout and build trust

[6] Due to multicollinearity problems the *ex-ante* and *ex-post* analysis cannot estimate the isolated effects of endowment, weather and payout. Hence, we controls for endowment lost and payout instead.

[7] The specific list of time-variant investment decisions depends on the outcome variable of interest – all investment decisions are also outcome variables. In this case, the specific investment variable moves from the right to the left side of the regression equation.

[8] It should be noted that farmers in Uzbekistan are familiar with indemnity-based agricultural insurance. However, related trust deficits may stem from the fact that the traditional insurance does not insure production in seasons with severe drought predictions (see section 3).

towards this agricultural insurance concept. To better protect from climate shocks, the share of adopters then slightly grows. With an average demand of 77%, farmers seem very interested in index insurance and adopt it as a climate adaptation strategy if they are not budget constrained.

Table 1
Round-specific share insurance adopters

Game round	Rainfall event	Insurance adopters (%)	N
1	Normal	56.28	199
2	Few	85.43	199
3	Very few	88.94	199
4	Normal	71.21	198
5	Normal	84.85	198

The resulting question concerns the determinants of individual uptake behavior. Besides personal, household, and farm characteristics favoring index insurance demand, we assume that the behavior of surrounding peers further influences individual decision-making. Figure 1 descriptively shows how the share of insurance adopters in one's peer (i.e. other session participants – own behavior excluded) positively affects individual participation. Thus, higher peer uptake rates translate into a higher probability for the individual to follow suit in the same game round. We conclude peer behavior to be a relevant determinant for individual adoption.

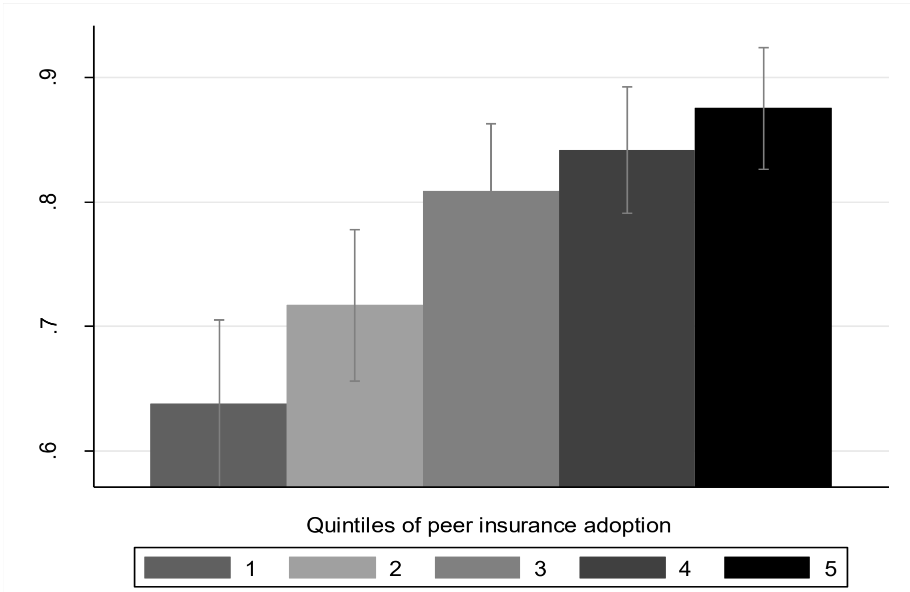

Figure 1. Individual insurance adoption and peer decision. ***Note***: Quintiles of peer insurance adoption are calculated as: (1) ≤ 65%, 65 < (2) ≤ 76%, 76% < (3) ≤ 85%, 85% < (4) ≤ 90% and (5) > 90%.

Table 2 displays the average investment decisions of interests conditional on the insurance status over all rounds, as well as the payout receipt in the post-drought seasons. We have two groups that are compared to each other: (1) uninsured vs. insured, and (2) no payout recipients vs. payout recipients. Table 2 reveals a positive effect of insurance coverage on household consumption spending, fertilizer use, precautionary savings, financial independency (lower credit amounts), and consequently net farm income.[9] We observe a similar positive influence regarding insurance compensation during climate-related harvest defaults. Insurance payout recipients can dedicate more money into household consumption and self-insuring savings, are more likely to fertilize, require less credit amounts, and hence have higher farm net incomes. A two-sample t-test calculates all group differences to be highly significant (p<0.0001). One exception constitutes the credit difference among (un)insured farmers.

Table 2
Average investment decisions dependent on insurance status

	Insured			Received payout		
	No	Yes	Diff	No	Yes	Diff
Consumption (UZS)	822,000	851,000	+29,000***	811,000	850,000	+39,000***
Fertilizer (%)	0.6756	0.8906	+0.2150***	0.520	0.8646	+0.3446***
Savings (UZS)	121,000	173,000	+52,000***	77,000	151,000	+74,000***
Farm income (UZS)	1,482,000	1,650,000	+168,000***	955,000	1,558,000	+603,000***
Credit amount (UZS)	51,000	47,000	-4,000	276,000	33,000	-243,000***
N	225	768		50	347	

Notes: The payout comparison only captures the post-drought seasons with lag 1. *p<0.10, **p<0.05, ***p<0.01.

5.2 Estimation results

The first stage regression for all outcome variables of interest shows that more insurance adopters in one's game session per round induce the individual decision-maker to also formally insure (p<0.0001). This is in accordance to former results on peer imitation influences in agricultural technology adoption (e.g., Matuschke & Qaim, 2009) and shows the relevance of our main instrument.

Table 3 then presents the average *ex-ante* and *ex-post* impacts of index insurance participation (over all game rounds) in the second stage regression. Since the identification of *ex-ante* impacts requires the simultaneous control for *ex-post* impacts, this model specification includes *ex-post* impacts over all rounds. However, since the first climate shock only appears in the second round, actual payout impacts can only occur from round three onwards. Therefore, we neglect the interpretation of the payout effects here and shed light on it in later specifications.

Column (1) displays the insurance impacts on household consumption. On average and ceteris paribus, insured farmers have 29.98 percentages higher consumption levels relative to the uninsured counterparts (p<0.0001). Upon inquiry, sample farmers reported an association between higher consumption costs and investments into children's education, household's health status, and social events of prestige like weddings. Insurance coverage may boost consumption because it substitutes the necessity of saving current income to compensate future income shocks. This is in line with findings by de Nicola (2015).

[9] Net farm income denotes the end-season income subtracted by all credit-related costs (credit amount and accumulated credit interest).

Further, column (2) shows that insurance participation has a positive relation with the decision to fertilize by 36.0 percentage points ($p<0.0001$).[10] The return on fertilizer investment is weather-dependent and is most profitable in the good state of nature. Fertilizer can be regarded as a risky but higher-return production input (Karlan et al., 2014). Yet, insuring the bad states of nature also insures the fertilizer-related risk by design, and stimulates sample farmers to decide for more risky but profitable agricultural investments. This corroborates former research (de Nicola, 2015; Hill et al., 2019; Hill & Viceisza, 2012; Jensen et al, 2017; Stoeffler et al., 2020).

Possibly unexpected is the positive *ex-ante* effect on savings in column (3). The money dedicated to precautionary savings is 818,716 UZS ($p<0.0001$) higher among policyholders on average when compared to the uninsured. This contradicts results from Matsuda et al. (2019). With a constant level of consumption, insured farmers build up an informal financial buffer stock. From a neoclassical perspective, rational business farmers strive for investments that maximize profits. Different to investments into a greater expected income (formal insurance and fertilizer), storing money in a savings account with an annual deposit rate augments one's future incomes with certainty, and may be strictly favored by risk-averse individuals or regarded as a mean of diversification or a complement to other investments.

The basic idea of an insurance decision is to redistribute income from a good state to a bad one. Therefore, it is not surprising that column (4) shows 583,710 UZS lower average end-season farm incomes (over all rounds) among policyholders. Simulating weather conditions of the five seasons prior the experiment, we have 3/5 good rain events where farmers only pay a premium without receiving a payout. This finding is vital and signals the basic insurance-related decision challenge: Agricultural insurance is most profitable for farmers when they experience more climate shocks. Yet, the true frequency of detrimental weather events is ex-ante unknown.

Lastly, column (5) presents the relation between insurance and credits. Farmers that decide for an insurance coverage, on average, decide for credits that have a 642,844 UZS lower credit sum. In order to interpret this effect, we note an average credit sum of 48,000 UZS for all sample farmers. Hence, insured farmers are generally less likely to borrow any money,[11] which supports former evidence of relieved budget constraints (e.g., Jensen et al., 2017). We constitute insurance to induce financial independency during changing weather events, which signals improved climate resilience.

[10] In this study we only control for fertilizer as a dichotomous investment decision – for reasons of efficiency, the experimental setting neglects the amount of purchased fertilizer.

[11] Estimating the same independent variables on binary credit uptake confirms that insured farmers are generally less likely to borrow money ($p=0.0001$).

Table 3
Insurance effects on other agricultural investment decisions

	(1) Consumption costs (ln)	(2) Fertilizer (0/1)	(3) Savings (in 1000 UZS)	(4) Net income (in 1000 UZS)	(5) Credit amount (in 1000 UZS)
Insurance adoption (0/1)	0.2622***	0.3600***	818.7162***	-583.7099***	-642.8437***
	(0.0395)	(0.1393)	(119.7398)	(118.4509)	(167.9202)
Payout previous round (0/1)	-0.0109	-0.0382	-72.8278***	-130.9477***	21.7278
	(0.0120)	(0.0289)	(23.3864)	(23.7877)	(29.7839)
Endowment lost (in 1000 UZS)	-5.27e-06	-0.0002**	-0.0526	-0.2798***	0.2899**
	(4.31e-05)	(0.0001)	(0.0731)	(0.0874)	(0.1213)
Consumption costs (ln)		-0.1896	-546.2836***	204.8422	511.9945***
		(0.1836)	(155.3041)	(177.7290)	(184.3953)
Fertilizer input (0/1)	-0.0090		-94.5580*	146.6509***	89.1650*
	(0.0155)		(50.2834)	(37.6796)	(48.9175)
Savings amount (in 1000 UZS)	-3.30e-05	-0.0003***		0.5087***	0.3048***
	(3.17e-05)	(0.0001)		(0.1114)	(0.0999)
Credit amount (in 1000 UZS)	-0.0001	0.0001	-0.0713	-0.0606	
	(4.30e-05)	(0.0001)	(0.1139)	(0.1024)	
Observations	993	993	993	993	993
Individuals	199	199	199	199	199

Notes: Serial correlation robust standard errors in parentheses: ***p<0.01, **p<0.05, *p<0.1. Endowment lost refers to current endowment relative to endowment in the last round.

Table 3 estimates average payout effects in damaging and normal events. We assume the respective payout estimates to be downward biased as a proper analysis of payout effects only includes post-drought seasons. However, in such a model our instruments are no longer valid and we apply the OLS approach. Since insurance decisions are still endogenous, we cannot rule out potential biases in the OLS estimation but argue it to be less biased than the two-stage least-squares alternative. Findings are presented in Table 4, but require a cautious interpretation. In the two post-drought seasons, insurance payouts seem to increase consumption spending, fertilizer investments, and net incomes, whereas it asserts a negative influence on credits amounts. This follows research by Janzen et al., (2019), Jensen et al. (2017) and Noritomo & Takahashi (2020). Additionally, payouts may induce a higher savings volume after the mild shock, which seems vice versa after severe drought – after an insured heavy drought, farmers rather invest into (risky) welfare-increasing activities (consumption and fertilizer) and not store it. We conclude Table 4 to hint at positive *payout* effects that are larger when encountering a massive income shock. In the post-drought seasons, the insurance participation *ex-ante* may have a positive effect on fertilizer investments and net income after mild drought, but may be associated with higher credit sums after heavy drought. The latter implies that farmers adopt index insurance, even if it requires a credit uptake.

Table 4

Insurance effects in post-drought seasons

	(1) Consumption costs (ln)	(2) Fertilizer (0/1)	(3) Savings (in 1000 UZS)	(4) Net income (in 1000 UZS)	(5) Credit amount (in 1000 UZS)
Post mild drought					
Insurance adoption (0/1)	-0.0033	0.2542**	-23.6335	647.6263***	19.4331
	(0.0174)	(0.1214)	(28.0844)	(26.3033)	(19.9386)
Payout previous round	0.0673***	0.2637**	117.5048***	50.5739*	-85.0026***
(0/1)	(0.0153)	(0.1033)	(26.8706)	(29.8630)	(26.4509)
Observations	196	196	196	196	196
R-squared	0.5092	0.2700	0.4790	0.7580	0.5642
Post severe drought					
Insurance adoption (0/1)	-0.0137	0.1464*	-19.6805	-15.6734	56.8050***
	(0.0184)	(0.0778)	(19.3942)	(32.8409)	(17.0226)
Payout previous round	0.1465**	0.6394**	-189.1504***	250.2019*	-508.3995***
(0/1)	(0.0576)	(0.2784)	(59.7121)	(130.4711)	(60.1124)
Observations	195	195	195	195	195
R-squared	0.3217	0.2390	0.3997	0.8494	0.8153
Other investment decisions	YES	YES	YES	YES	YES
Session fixed effects	YES	YES	YES	YES	YES
Individual and farm characteristics	YES	YES	YES	YES	YES

Notes: Serial correlation robust standard errors in parentheses: ***p<0.01, **p<0.05, *p<0.1. Other investment decisions include: consumption costs, fertilizer input, savings and credit amount. Individual and farm characteristics cover: endowment group, age, education, risk aversion, rainfed land size, share agricultural income, average yield lost.

Aiming to learn more about payout effects, we next extend our list of independent variables by the payout received the round before the last one (lag 2) in Table 5. This allows estimating the impact in two subsequent seasons post drought in the last two game rounds. *Ex-ante* effects resemble those in the first time lag of severe drought, and thus remain for two time lags. In this model, consumption costs increase in two periods after the insured heavy drought event. Yet, the positive *ex-post* effect on fertilizer, net income, and financial independency (expressed in credit sum) seems to hold for two seasons post drought with decreasing returns. Savings as informal insurance may gain relevance again in lag 2. In summary, Table 5 indicates the positive effect of index insurance not only for the post-shock season but also the one following. This in line with Bertram-Huemmer and Kraehnert (2018), who find prevailing recovery benefits for three years post drought.

Table 5

Insurance effects after two time lags

	(1) Consumption costs (ln)	(2) Fertilizer (0/1)	(3) Savings (in 1000 UZS)	(4) Net income (in 1000 UZS)	(5) Credit amount (in 1000 UZS)
Insurance adoption (0/1)	0.0040	0.1615**	-2.5777	25.4037	55.1769***
	(0.0134)	(0.0664)	(28.5367)	(42.2131)	(16.6839)
Payout lag1 (0/1)	-0.0137	0.2976*	-221.8907***	365.6858***	-445.9141***
	(0.0537)	(0.1734)	(65.2691)	(126.8129)	(51.6876)
Payout lag2 (0/1)	0.0493***	0.1908**	104.6774***	276.3379***	-90.1679**
	(0.0138)	(0.0848)	(24.5539)	(65.6695)	(38.3579)

Table 5 continued on next page

Table 5 continued

Other investment decisions	YES	YES	YES	YES	YES
Round fixed effects	YES	YES	YES	YES	YES
Session fixed effects	YES	YES	YES	YES	YES
Individual & farm characteristics	YES	YES	YES	YES	YES
Observations	390	390	390	390	390
Individuals	199	199	199	199	199
R-squared	0.2389	0.1681	0.4251	0.7307	0.6013

Notes: Serial correlation robust standard errors in parentheses: ***p<0.01, **p<0.05, *p<0.1. Other investment decisions include: consumption costs, fertilizer input, savings and credit amount. Individual and farm characteristics cover: endowment group, age, education, risk aversion, rainfed land size, %agricultural income, average yield lost.

6. Conclusion

Index insurance has been regarded as a promising climate adaptation for farmers in the developing world. Within its growing impact literature, there is clear evidence of positive *ex-ante* effects on risky but profitable farm activities (e.g., Jensen et al., 2017) and increased fertilizer investments *ex-post* (e.g., Hill et al., 2019). However, these studies cannot empirically distinguish between the two impact channels and produce misleading policy implications. One exception is the study by Noritomo and Takahashi (2020) that explores *ex-ante* and *ex-post* impacts of index-based livestock insurance in Kenya. To our knowledge, its external validity in other geographical settings or analogous research on crop index insurance is missing so far. In this context, we conducted a framed field experiment that offers drought index insurance to crop farmers in Uzbekistan and aim to empirically examine impacts in different time horizons.

Our results suggest that index insurance (*ex-ante* and *ex-post*) stimulates investments in household consumption and (climate) riskier but more productive activities. While insured farmers generally increase their precautionary savings stocks, they only have a related recovery benefit after a mild drought or two seasons post severe drought. Logically, insurance coverage harms net income in good seasons but allows policyholder to recover faster when encountering a shock. Further, index insurance has a negative impact on credit decisions. *Ex-post* it diminishes the amount to borrow, and this financial independency seems amplified after severe drought. However, the strong preference for index insurance participation induces farmers to take a loan to finance insurance after the devastating drought event, whereas previous received payment is insufficient for that.

Implications from this study indicate that crop index insurance increases on-farm welfare and climate resilience during insurance coverage without damaging events, after receiving payouts and even two seasons post drought. Revealed behavior of sampled farmers as the real target group gives reasons to regard index insurance as an efficient climate adaptation strategy in Uzbekistan. A positive relationship between insurance and risky but profitable fertilizer may be expanded to irrigation and drought-resilient seeds. Hence, index insurance may increase climate resilience directly and indirectly through climate resilience enhancing investments. Embedding this narrative into promotion activities may further boost (the often low) index insurance adoption and its synergies in developing countries.

Yet, there are three caveats to consider. First, our suggestive evidence is conditional on an ideal index insurance setting with short payout times and no basis risk. Second, due to invalid instruments in the post-drought evaluation, we apply OLS estimation. Under these conditions, it reduces but still contains bias resulting from the endogenous insurance variable – estimates cannot be interpreted causally. Future research should shed more light on this. Lastly, we are aware of the limitations of experimental data conclusions but believe framed field experiments to be a powerful tool to learn about farmers' behavior and its consequences before market/policy implementation.

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