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Impact of Weather Index-Based Crop Insurance on Risk Aversion: Do Formal Risk Transfer Institutions Change Farmers' Risk Preferences?

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Abstract

This study examines the effect of smallholder farmers' access to a formal climate risk transfer mechanism on their risk preferences. Survey and experimental data were collected from smallholder farmers that have access to weather index-based crop insurance (WICI) in Ethiopia. We use an endogenous switching (ESP) model to address self-selection and simultaneity bias. Results from the ESP model show that farmers who purchased WICI are less likely to be risk-averse compared with non-purchaser farmers. Similarly, non-purchasers would have attained a significant reduction in their risk-aversion if they had taken up the insurance product. We also find that WICI has a positive and statistically significant positive effect on farmers' real-life risk-taking behaviour as exemplified by mineral fertilizer use. The implication of our findings is that formal climate risk transfer mechanisms can positively influence households' economic decisions and outcomes, through reducing risk aversion. Therefore, they can possibly contribute to poverty alleviation and development within agrarian economies that are exposed to recurrent and severe climate shocks.

Keywords: Weather index-based crop insurance, endogenous preferences, experimental risk elicitation, endogenous switching probit, Ethiopia

JEL Classification: C91, D03, I38, N27

1 Introduction

Agricultural households in sub-Saharan Africa (SSA) are facing frequent and severe climate risks than ever before (Masih et al., 2014; Shiferaw et al., 2014). The absence or inaccessibility of formal credit and insurance markets limits the ability of agricultural households to withstand the effects of climate shocks (Harvey et al., 2014), and has been a key determinant of longer-term poverty dynamics (Chantarat et al., 2007; Barnett et al., 2008). In the presence of uninsured weather shocks, any reduction in farming households' agricultural production can have detrimental impacts on food and income available for consumption (Hertel and Rosch, 2010). Hence, most households respond by altering their economic behaviour and decisions, which have repercussions on their production. In this respect, it is generally assumed that farmers in developing countries are risk-averse as an ex-ante response to minimize the climate shock-induced income variability that they frequently experience. Accordingly, the households will self-insure by engaging in low-risk low-return agricultural activities (Rosenzweig and Binswanger, 1993) which in the short-run may seem sub-optimal (Yesuf and Bluffstone, 2009). However, in the long-term, risk aversion ultimately traps agricultural households in persistent poverty (Carter and Barrett, 2006; Dercon and Christiaensen, 2011).

Risk-aversion is a significant determinant of households' decisions that lead to: low investments in higher-income farm enterprise combinations (Nyikal and Kosura, 2005), assigning a lower value to education attainment (Brown et al., 2012), and low adoption of agricultural technologies (Liu, 2013; Ward and Singh, 2015; Brick and Visser, 2015; Holden and Quiggin, 2017). At the aggregate level, households' low investments in physical and human capital may further aggravate the productivity lag and income inequality in rural areas of SSA (Odusola et al., 2017), where according to Fosu (2015) high inequality has constrained poverty reduction efforts. Hence, risk-aversion is linked to development prospects of a country by influencing households' production, consumption, and labor supply decisions which in turn determine the accumulation of human, physical, and financial capital.

In light of this, there has been a growing interest in developing weather index-based crop insurance (WICI) schemes that provide a transparent risk transferring mechanism for smallholder farmers to help them better manage climate risks and exhibit risk-taking behaviour in their agricultural practices (Barnett et al., 2008). Few studies analyse the impact of WICI on households' decision to invest in high-risk high-return activities (Hill and Viceisza, 2012; Mobarak and Rosenzweig, 2012; Karlan et al., 2014). These studies examine how improving access to formal insurance markets affects farmers' willingness to take risky investment decisions using field experiments in developing countries. However, such an approach simultaneously captures risk preferences, beliefs about the background risk (i.e. uninsurable idiosyncratic risks associated with the investment), and opportunities to engage in a given behavior (e.g. available investment options) (Schildberg-hörisch, 2018). Furthermore, these studies implicitly take risk preferences as stable over time and exogenous in the WICI impact pathways. Hence, the fixity of farmers' risk preferences is assumed rather than measured – an approach akin to the standard economic assumption. Although standard economic models assume exogenous and stable preferences (Friedman, 1962; Stigler and Becker, 1977) overlooking the fundamental endogeneity of preferences would limit the insights that could be gained from examining household decision-making (Becker and Mulligan, 1997; Krackhardt, 1998; Netzer, 2009). "If preferences are affected by the policies or institutional arrangements we study, we can neither accurately predict nor coherently evaluate the likely consequences of new policies or institutions without taking account of preference endogeneity" (Bowles, 1998). Therefore, ignoring the endogeneity of risk preferences restricts an empirical enquiry into an important mechanism through which risk management policy or programme interventions may influence households' economic decisions and outcomes.

Risk preferences of households and the availability of institutions that facilitate risk bearing are not independent (Roumasset, 1976; Eswaran and Kotwal, 1986; Mendola, 2007). Farmers' access to WICI – a climate risk transfer mechanism – could be a stimulus that may influence their risk preferences. If the exposure of farmers in developing countries to extreme and frequent weather anomalies can cause risk-aversion among them (Di Falco and Vieider, 2018), improving their access to formal climate risk transfer mechanisms that buffer the households' income from the effects of weather shocks may have a reverse effect (i.e. reduce farmers' risk-aversion). To date, empirical studies have not explored this possibility as they have focused on the effects that farmers' risk preferences have on the uptake of WICI as demonstrated in Giné et al. (2008); Cole et al. (2013); Hill et al. (2013); Karlan et al. (2014); Jin et al. (2016). However, the implicit assumption that farmers' risk preferences are exogenous and cannot be changed may be excessive (Melesse and Cecchi, 2017). Our study contributes to the literature by examining the impact of agricultural households' access to WICI on their risk-aversion, while taking into account the endogeneity of both risk preferences and WICI uptake. The sources of endogenous WICI uptake are: (i) the effect of risk preferences on WICI uptake (simultaneity bias), and (ii) the effect of unobserved heterogeneity among farmers that can simultaneously affect risk preferences and WICI uptake (self-selection bias).

Our study is set in Ethiopia, where devastating negative rainfall shocks are ubiquitous (Suryabhagavan, 2017). The study provides valuable insights into the structural relationship between a pilot programme intervention that facilitates access to WICI and farmers' risk preferences. We rely on an experimental incentive-compatible risk elicitation method which according to Charness et al. (2013) and Meyer (2014) enables researchers to obtain an isolated measure of farmers' utility curvature parameters - risk preferences. In so doing, we analyse the impact of WICI on farmers' risk-aversion and explore the possible causes of the change in risk preferences. Our study contributes to the small but growing literature on the effects of markets on risk preferences (see section 2.2 for a review). To the best of our knowledge, this is the first empirical study that attempts to establish a causal relationship between farmers' access to crop insurance markets and its effects on risk preferences.

We utilize data collected from 240 smallholder farmers with access to a WICI scheme in Northern Ethiopia. Household survey data were collected from insured and uninsured agricultural households. A simple unframed risk experiment was also carried out to elicit the risk preferences using incentive compatible lotteries involving a choice between a sure amount and a lottery with two varying pay-offs but equal probability as presented in Brick et al. (2012). We use a simultaneous equations model (SEM) and an endogenous switching probit (ESP) model to estimate the impact of WICI on the risk-aversion of smallholder farmers after adjusting for observed covariates. Our results from the preferred model (ESP) show that there is significant positive self-selection for non-purchaser farmers. Risk-aversion and the decision not to buy WICI are positively correlated. We observe a negative selection effect for the purchaser farmers, but it is not statistically significant. We also find that WICI significantly decreases the risk-aversion of farmers. On average, the risk-aversion of farmers who have purchased WICI is significantly lower than what it would have been had they not purchased the insurance product. Similarly, the risk-aversion of non-purchaser farmers would have also been reduced if they had taken up WICI. Moreover, if every farmer in the study area is insured, the proportion of risk-averse farmers would decline significantly. If WICI uptake changes risk aversion, we should also plausibly observe that in real-life behavior, which we do: WICI increases mineral fertilizer use. Therefore, WICI uptake can change farmers' interpretation of the operating environment for farming and ultimately reduces their risk-aversion − a major driver of agricultural technology adoption.

Our research on the endogeneity of risk preferences in relation to insurance markets is conceptually relevant to explain economic decisions of agricultural households in the presence of climate risks. The findings of our study have important implications for policy and programme interventions that intend to spur economic development in agrarian economies in the era of frequent and severe climate shocks. Since formal climate risk transfer mechanisms significantly reduce farmers' risk-aversion, investments on risk management policies and strategies can have long-term effects on agricultural households by bringing up desirable economic behaviour that may enable them to break out of poverty traps and enjoy virtuous cycle of increasing income.

The remainder of the paper is organized as follows. Section 2 reviews prior works that provide a link between (insurance) markets and households' preferences and behaviour. Section 3 describes the insurance product, and presents the source of data and methods of data analysis. Section 4 presents the descriptive and econometric results of the study, and the discussion based on the results. Section 5 concludes.

2 Literature

2.1 Agricultural households, insurance markets, and risk-taking behaviour

At the heart of agricultural households economic model is the issue of whether production, consumption, and labor supply decisions are simultaneously determined or if they are separable. In true subsistence farming, a household consumes what it produces and must rely exclusively on its own resources (Singh et al., 1986). Hence, production, consumption and labour supply decisions are non-separable. However, the majority of agricultural households in developing countries are semi-commercial farms in which some inputs are purchased and some outputs are sold. If competitive markets exist for factors of production, outputs, and credit and insurance, prices are exogenous and (natural and market) risks can be completely diversified resulting a separable or non-recursive decision-making process (Roe and Graham-Tomasi, 1985). As such, production decisions (input use, adoption of farm technologies, and output choice) affect consumption via food production and income levels, and those production decisions are entirely independent of consumption.

However, in most developing countries, markets related to land, inputs, credit, insurance, and some basic commodities are incomplete, function poorly or may have high transaction costs for agricultural households (de Janvry et al., 1991). Hence, the decision process becomes non-separable (circular) (Singh et al., 1986; Taylor and Adelman, 2003; Mendola, 2007); a farming household as a consumer affects its behavior as a producer, and vice versa. In the presence of climate risks, as an adaptive response, farmers usually modify their production practices to safer but low-return activities as a means of providing self-insurance (Rosenzweig and Binswanger, 1993). In these circumstances, liquidity constraints generated by market imperfections shape agricultural households' decisions and behavioural responses that determine their immediate and long-term welfare.

Recently, field experiments have been carried out in developing countries to estimate the causal effect of relaxing insurance market constraints on the households' tendencies to invest in agricultural activities that are risky but highly profitable. Hill and Viceisza (2012) conduct a framed field experiment in rural Ethiopia to examine farmers' decision whether to invest in mineral fertilizers or not in the presence of an insurance market. They found that farmers' uptake of the insurance product has a positive effect on fertilizer purchases. In a randomized experimental setting in rural India, Mobarak and Rosenzweig (2012) find that rice farmers that were offered the index insurance product plant less drought resistant (high-risk) but high-yield rice varieties, which may bear desirable welfare effects on these households by improving both food availability and income. Similarly, Karlan et al. (2014) randomly assigned farmers in Ghana in three treatment arms to receive cash grants, premiums to purchase rainfall index insurance, or a combination of the two. They find that farmers that purchased insurance made larger agricultural investments and risky production choices with higher expected returns. All the studies mentioned above show the impact of WICI on risk-taking in agricultural investment decisions of farmers but not on their risk preferences *per se*. Our study examines the presence of a causal relationship between farmers' access to insurance markets and their risk preferences.

2.2 Endogenous risk preferences

The standard economic assumption of fixed and exogenously determined preferences has submerged the economic thought that natural, social, economic, financial, and political environment may shape preferences of individuals. The assumption of exogenous and stable risk preferences implies that one should obtain the same estimate of a curvature parameter of the utility function when measuring an individual's risk preferences repeatedly. However, this has not been the case in most recent empirical studies which show systematic variations in the parameter that characterizes an individual's risk preferences (Schildberg-hörisch, 2018). The endogeneity of preferences implies that policies and institutional arrangements affect the evolution of tastes and values regarding consumption, investment, and other socio-economic activities (Bowles, 1998). The changes in policies, institutions or the environment signal different stimuli to people and influence them to perceive a different world, which leads to changes in values and preferences (Gerber and Jackson, 1993).

In this regard, Palacios-Huerta and Santos (2004) developed a general equilibrium framework to examine the endogenous formation of preferences associated with the extent of credit market completeness in Bangladesh. The primary empirical prediction of the model is that risk-aversion attitudes will be endogenously related to credit market arrangements. They used the worst floods that the country experienced in 1988 as an exogenous variation that segmented the existing micro-credit institutions. Then, they compare individuals' attitudes toward risk during this situation and the more normal circumstances of 1992. They provide estimates of risk-aversion coefficients that are significantly lower and not statistically different across households where credit markets appear to be well-functioning.

Advances in behavioural economics include artefactual field experiments that offer insights into changes in individuals' risk preferences as a result of their exposure to output markets. The empirical analyses by Melesse and Cecchi (2017) in Ethiopia reveal that farm households with greater market experience are more risk tolerant. They indicate that risk-aversion is a trait that can be endogenously changed through increasing the households' exposure to markets, and thus the claim that farm households are inherently risk-averse may be excessive. However, they do not infer a specific mechanism to explain their findings. Outside the context of markets, there are also few but growing number of empirical studies that show changes in risk preferences due to individual's exposure to conflict and violence (Voors et al., 2012; Callen et al., 2014; Moya, 2018), climate shocks and natural disasters (Eckel et al., 2009; Cameron and Shah, 2015; Hanaoka et al., 2015; Cassar et al., 2017; Di Falco and Vieider, 2018), and financial shocks (Cohn et al., 2015).

3 Methodology

3.1 *Description of the WICI scheme*

This study evaluates the WICI scheme in Ethiopia. The existing scheme is the continuation of the Horn of Africa Risk Transfer for Adaptation (HARITA) pilot programme which was initiated in 2009 insuring 200 households in one district in Tigray regional state of Ethiopia (Madajewicz et al., 2013). Building on the success of HARITA, the R4 rural resilience initiative emerged in 2011 bringing together a network of partners including the World Food Programme (WFP), Oxfam America (OA), Relief Society of Tigray (REST), Nyala Insurance Share Company, Africa Insurance Company, Dedebit Credit and Savings Institution (DECSI), Mekelle University, and the International Research Institute for Climate and Society (IRI) (Madajewicz et al., 2017).

The main objective of R4 is to enable poor farmers to utilize an integrated risk management approach to strengthen their resilience to weather shocks and attain food and income security. In 2017, R4 reached a total of more than 31, 942 farming households in 11 districts in Tigray and 1 district in Amhara national regional states of Ethiopia (WFP/OA, 2017).[1] The crop insurance product under the R4 initiative covers

[1] The R4 pilot WICI scheme in Ethiopia is implemented in districts that suffer severe and frequent drought shocks. However,

major cereals (i.e. *teff*, wheat, barley, maize, and sorghum) that are widely produced in the study area. Insurance enrollment usually takes place between March and June. Farmers paid a premium of 160 ETB for a single insurance coupon during that time. The WICI scheme also has an insurance-for-work component which allows farmers to pay their premium by providing their labor to the public works of the national safety net programme (PSNP) (Madajewicz et al., 2017). An insurance coupon paid out on average 800 ETB during the production year.

A unique aspect of the WICI scheme under the R4 initiative is the comprehensive strategy that is implemented to handle the issue of weather-related basis risk. Basis risk is an inherent problem to index insurance such that there is a mismatch between the index-triggered payouts and the actual losses suffered by farmers. The WICI scheme has a separate R4 basis risk fund to ensure that losses are compensated for farmers in areas where the index has not adequately captured negative rainfall shocks (WFP/OA, 2017). These payments are made at the same time as the insurance payouts (ibid). Therefore, the WICI under the R4 initiative is more risk-free than the common index-based insurance products in other developing countries. Currently, the R4 initiative expanded to reach farmers in Senegal, Malawi, Zambia, Kenya and Zimbabwe (WFP/OA, 2018).

3.2 *Source and type of data*

This study is based on data collected from farmers that reside in *tabias* with access to WICI in Tigray regional state of Ethiopia. We collected primary data from insured and uninsured farming households using a household survey and an incentivized risk experiment. A multistage random sampling method was employed to generate a total sample of 240 agricultural households. Tigray regional state has a total of 34 districts. R4 is operating in 11 districts where each district comprises of 15 to 20 *tabias*, and not all the *tabias* in the R4 districts have access to the WICI. Therefore, we take this into account in our multistage random sampling procedure. First, we randomly selected 2 districts (namely Alamata and Raya Azebo) from the list of 11 districts with some of their *tabias* having access to WICI. Then, from a total of 16 *tabias* that have access to WICI in the two districts, five (two from Alamata and three from Raya Azebo) were randomly picked. Finally, we randomly selected a total of 120 purchaser and 120 non-purchaser households from the five *tabias*. A structured questionnaire was prepared to collect socioeconomic data that focus on the demographic, agronomic and institutional variables in the 2017 farming season.

As part of the larger survey, an unframed incentivized risk experiment was also carried out individually to elicit the risk preferences of the sample farmers. Incentivized experiments are regarded as appropriate because they minimize self-serving biases, inattention, and strategic motives that distort self-reported risk attitudes (Camerer and Hogarth, 1999). This paper utilized the experimental game protocol outlined by Brick et al.

some of the *tabias* in the R4 districts do not have access to WICI. These *tabias* are excluded because of a mismatch between the historical drought seasons that the households reported and the satellite rainfall data (upon which the index is computed). N.B. In Ethiopian federal government structure, *Tabia (kebele)*, which comprises villages, is the smallest administrative unit within a district.

(2012)[2], which allows classifying risk-aversion categories based on expected utility theory (EUT). A simpler game protocol, similar to the one we used in this study, is a reliable measurement tool of risk preferences in a mostly illiterate sample (Dave et al., 2010) and adequately captures differences in individual risk preferences (Charness et al., 2013). The risk preferences elicitation experiment was administered individually after the completion of the survey. The maximum possible earning from the experiment was 20 ETB and on average the subjects received 11.30 ETB. This amount is higher than the opportunity cost of their time spent participating in the experiment and hence ensures a salient incentive for the farmers to make their decisions carefully.[3]

As depicted in Table 1, farmers were asked to make several choices involving real money. Each choice (task) is a decision between picking a sure amount of money in option A, and tossing a coin in option B to earn either 20 ETB if the head comes up or nothing, if tail did. Even though they made decisions on five tasks, only one was randomly picked at the end to determine their earnings. Since they could not know in advance which task will that be and each task has an equal chance of being used in the end, subjects are expected to think carefully about which option they prefer in each task. The first task is a rationality check and merely tests whether the participants understood the game. We also enforced monotonicity – if they switched they should switch from option A to option B only once. In our sample of farmers, only one subject shifted between option A and option B multiple times. Consequently, the subject was excluded from the analysis because the range of the risk preference parameter could not be computed. Hence, we are left with a sample of 239 heads of smallholder farming households for our analyses.

We followed the constant relative risk-aversion (CRRA)[4] utility function to compute the range of the risk preference parameter at each task where the switch could happen. Based on these ranges, we classified the risk preferences of farm households into four categories – risk-takers, risk-neutral, risk-averse, and highly risk-averse[5]. For instance, for a given farmer who shifted from option A to option B in the second task the range of the risk preference parameter ($-1.41 < r < 0$) is computed as compound inequalities given by;

$$\frac{20^{1-r}}{1-r} > \frac{0.5 \times 20^{1-r}}{1-r} \text{ and } \frac{15^{1-r}}{1-r} < \frac{0.5 \times 20^{1-r}}{1-r}$$

Based on Table 1, our ordinal risk preferences variable entails the four risk preference categories and ordered based on the level of risk-aversion as follows;

$$Risk\ preferences = \begin{cases} 1 & \text{if risk-taker} \\ 2 & \text{if risk-neutral} \\ 3 & \text{if risk-averse or highly risk-averse} \end{cases}$$

[2]It maintains the original design as outlined by Brick et al. (2012), but we used fewer decision tasks.

[3]Public works participation in the districts pays 14 ETB per day during the survey period.

[4]CRRA states that the degree of risk-aversion remains constant when both the monetary payoff of the lotteries and wealth increase proportionally. Under CRRA utility function, the range of the risk preference parameter is computed as; $u = \frac{x^{1-r}}{1-r}$.

[5]The highly risk-averse farmers are those who shifted at the 5th task or those who did not shift at all (pick option A throughout).

Table 1: Experimental game tasks and elicited risk preferences

Task	Option A	Option B		Risk-preference	Risk-preference
	Sure Amount	Outcome 1	Outcome 2	parameter range	Category
1	20	20; $\frac{1}{2}$	0; $\frac{1}{2}$	$r < -1.4$	Rationality-check
2	15	20; $\frac{1}{2}$	0; $\frac{1}{2}$	$-1.41 < r < 0$	Risk-takers
3	10	20; $\frac{1}{2}$	0; $\frac{1}{2}$	$0 < r < 0.42$	Risk-neutral
4	6	20; $\frac{1}{2}$	0; $\frac{1}{2}$	$0.42 < r < 0.7$	Risk-averse
5	2	20; $\frac{1}{2}$	0; $\frac{1}{2}$	$0.7 < r$	Highly risk-averse

The last two columns are not shown or told to the subjects

Moreover, to facilitate the estimation of treatment effects using a small sample and more flexible model specification, we converted our ordinal risk preference dependent variable into a binary variable indicating risk-aversion of farmers as follows;

$$Risk\ averse = \begin{cases} 1 & \text{if risk-averse or highly risk-averse} \\ 0 & \text{if risk-neutral or risk-takers} \end{cases}$$

3.3 *Empirical estimation strategy*

Using a naïve ordered probit model, the effect of WICI on the risk preferences of farmers can be estimated by regressing the latent variable representing the propensity of risk-aversion of farmer i (Y_i^*) on the WICI uptake of the farmer (T_i) and a vector of household characteristics (x_i) assuming exogenous WICI uptake – the correlation between the error term (ω_{1i}) and T_i is zero. α and β_1 are unknown parameters to be estimated.

$$Y_i^* = \alpha T_i + x_i \beta_1^{'} + \omega_{1i},\ \omega_1 \sim \mathcal{N}(0, \sigma^2) \tag{1}$$

where the subscripts indicate variation over farmers (i = 1, 2, ..., N). The latent risk-aversion variable (Y_i^*) and thresholds (η_1 and η_2) are not directly observed. But instead, we observe only

$$Y_i = \begin{cases} 1 & \text{if } Y_i^* \le \eta_1 \\ 2 & \text{if } \eta_1 < Y_i^* \le \eta_2 \\ 3 & \text{if } Y_i^* > \eta_2 \end{cases}$$

For this study, however, the assumption of exogenous WICI uptake decision of farmers is unrealistic due to self-selection and simultaneity biases. Hence, the ordered probit specification may result in biased estimates on the causal effect of purchasing WICI on the level of risk-aversion of farmers – causal inference cannot be derived from α. To address the problem of endogeneity in equation 1, we use a maximum likelihood estimator of an ordinal outcome with a binary endogenous regressor under the simultaneous equations model (SEM).

The maximum likelihood estimators have the properties of being consistent and asymptotically efficient (Greene, 2012). The SEM jointly determines equations 1 and 2 as a system of two equations that allows the errors terms to be correlated, and the binary dependent choice in equation 2 to be an endogenous regressor in the ordinal risk preferences outcome variable in equation 1. This enables us to estimate the coefficient on T_i (α) as the unbiased measure for the average treatment effect (ATE) – the average effect of changing the whole population from being non-purchasers to purchasers of WICI. The binary endogenous WICI uptake is modeled as;

$$T_i = x_i\beta_2^{'} + \gamma Z_i + \omega_{2i},\ \omega_2 \sim \mathcal{N}(0, \sigma^2) \tag{2}$$

where, the i^{th} farmer's propensity to purchase WICI (T_i^*) is a latent continuous variable for which only the binary variable T_i is observed such that;

$$T_i = \begin{cases} 0 & \text{if } T_i^* \leq 0 \\ 1 & \text{if } T_i^* > 0 \end{cases}$$

where x_i is a vector of variables identical to the one in equation 1 and Z_i is the instrumental variable (IV). α, γ, β_1 and β_2 are unknown parameters to be estimated. $(\omega_{1i}, \omega_{2i})^{'}$ is a vector of error terms that follows a bivariate standard normal distribution with correlation coefficient ρ described as;

$$\begin{pmatrix} \omega_{1i} & \omega_{2i} \end{pmatrix}^{'} \sim \mathcal{N}\left(\begin{pmatrix} 0 & 0 \end{pmatrix}^{'}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix}\right)$$

The SEM model described by Equations 1 and 2 is generally identified even in the absence of the excluded variable (Z_i). However, to improve identification we used a binary variable that indicates whether farmers live in the same village with the insurance foreman as the excluded variable from equation 1. Nigus et al. (2018) used a similar IV in their analysis on the effect of WICI on social capital. The rationale behind choosing this IV is that the insurance foremen are tasked for promoting and creating awareness among farmers about WICI. We, therefore, hypothesized farmers are likely to have better knowledge and attitudes about WICI if the foreman lives in the village they belong to, and ultimately influence their decision to opt for the insurance uptake. Moreover, the assignment of the foremen are an administrative level decision which is independent of the households' risk behaviour.

We also used a full information maximum likelihood under the endogenous switching probit (ESP) model to take into account the interdependencies among WICI uptake and separate risk preference equations of purchasers and non-purchasers. ESP is a more flexible specification than SEM since it allows the effects of household characteristics on the risk-aversion of farmers to vary between the purchaser and non-purchaser farmers. Consequently, besides the ATE, we can also estimate the average treatment effect on the treated

(ATT) and average treatment effect on the untreated (ATU). The ATT is the average effect of WICI on those farmers who have purchased the insurance. The ATU is the average effect of WICI on the risk-aversion of non-purchasers had they decided to uptake the insurance.

The ESP model simultaneously considers a binary risk-aversion variable that describes the behaviour of farmers with two regimes (equations 3 and 4) and a switch (selection) function (equation 2) that determines which regime the farmer faces. Along with equation 2, the ESP can be specified as a system of equations for latent variables as;

$$Y^*_{1i} = x_{1i}\tau_1^{'} + \varepsilon_{1i} \tag{3}$$

$$Y^*_{0i} = x_{0i}\tau_0^{'} + \varepsilon_{0i} \tag{4}$$

where the observed farmer's WICI uptake decision is as defined under equations 2. $Y_1 i^*$ and $Y_0 i^*$ are the latent variables for farmers' risk-aversion of the purchasers and non-purchasers respectively. The observed Y_i is defined as:

$$Y_i = \begin{cases} Y_{1i} & \text{if } Y^*_{1i} > 0 \; and \; T_i = 1 \\ Y_{0i} & \text{if } Y^*_{0i} > 0 \; and \; T_i = 0 \end{cases}$$

Moreover: x_{1i} and x_{0i} are vectors of explanatory variables; γ, β_2, τ_1 and τ_0, are unknown parameters to be estimated; and ω_{2i}, ε_{1i}, and ε_{0i} are the error terms which are jointly normally distributed with a mean-zero vector and correlation matrix:

$$\Omega = \begin{pmatrix} 1 & \rho_0 & \rho_1 \\ & 1 & \rho_{10} \\ & & 1 \end{pmatrix}$$

where ρ_0, ρ_1 and ρ_{10} are the correlations between ε_0 and ω_2, ε_1 and ω_2, and ε_1 and ε_0 respectively. Except ρ_{10}, ρ_0 and ρ_1 are identified since the data provide information on the correlations (Miranda and Rabe-Hesketh, 2006). If $\rho_0 \neq \rho_1 \neq 0$, treating WICI as an exogenous variable delivers inconsistent estimator because WICI uptake decision is correlated with ε_0 and ε_1 (Huang et al., 1991).

The ESP analysis also does not require exclusion restrictions to identify treatment effects since the model can be identified by the non-linearities in the inverse mills-ratio (Heckman, 1978). As a consequence, Z_i can be unavailable and x_i, x_{1i} and x_{0i} may contain identical elements. However, Maddala (1983) noted specifying at least one exclusion restriction better identify the selection mechanism. To that end, we used the binary variable that captures whether the foreman lives in the same village with the household as the excluded variable from the vectors x_{1i} and x_{0i}. Following Aakvik et al. (2005) and Lokshin and Sajaia (2011), after estimating the parameters of the ESP model, we can compute endogeneity-bias corrected estimates of the variant treatment effect measures as:

$$
\begin{aligned}
ATT &= E\left[Pr(Y_1 = 1 \mid T = 1, X = x)\right] - E[Pr(Y_0 = 1 \mid T = 1, X = x)] \\
&= E\left[\frac{\Phi_2(x_1\tau_1, Z\gamma, \rho_1) - \Phi_2(x_0\tau_0, Z\gamma, \rho_0)}{F(Z\gamma)}\right]
\end{aligned} \tag{5}
$$

$$
\begin{aligned}
ATU &= E[Pr(Y_1 = 1 \mid T = 0, X = x)] - E[Pr(Y_0 = 1 \mid T = 0, X = x)] \\
&= E\left[\frac{\Phi_2(x_1\tau_1, -Z\gamma, -\rho_1) - \Phi_2(x_0\tau_0, -Z\gamma, -\rho_0)}{F(-Z\gamma)}\right]
\end{aligned} \tag{6}
$$

$$
\begin{aligned}
ATE &= E[Pr(Y_1 = 1 \mid T = 1, X = x)] - E[Pr(Y_0 = 1 \mid T = 0, X = x)] \\
&= E\left[F(x_1\tau_1) - F(x_0\tau_0)\right]
\end{aligned} \tag{7}
$$

where Φ_2 is the cumulative function of a bivariate normal distribution and F is the cumulative function of a bivariate normal distribution. The other variables and parameters are as described above.

4 Results and Discussion

4.1 *Descriptive statistics*

The experimental results show that 39 percent of farmers in the study area are risk-averse. Our estimate is comparable to the findings of a recent study by Jin et al. (2017) who used similar risk preference elicitation experimental games and found that 44 percent of the households in rural China are risk-averse. Table 2 depicts the mean values for the continuous variables and mean proportions for the binary variables under the two groups – purchasers and non-purchasers of WICI. We used the independent t-test to assess whether the mean values or proportions of a given variable vary across the two groups of households.

The averages show that non-purchasers are less risk-averse than purchaser farmers. A significantly larger proportion of purchasers live in the same village with the insurance foreman. On average, the purchaser households have a higher number of economically active members than their non-purchaser counterparts. The average land and livestock holdings of the non-purchasers are significantly higher than that of the purchasers. With regard to access to credit and ownership of television or radio, on average, the purchaser farmers are better off than the non-purchasers. In addition, a significantly higher proportion of the purchasers have personal ties with someone who works at the training and development office of the R4 WICI project.

4.2 *Results from the econometric models*

The selection equation (farmers' WICI purchase decision) and the outcome equation(s) (farmers' risk-aversion) of the SEM and ESP models are estimated simultaneously. To facilitate detailed discussion, the results from the selection and outcome models are presented separately in the following sub-sections.

Table 2: Mean and mean difference tests of the variables included in the analyses

Variables	Non-purchasers (N=119) Mean	Purchasers (N=120) Mean	t-test Mean Diff.
Variables of interest			
Risk preferences			
risk-taker	0.479	0.400	0.079
risk-neutral	0.193	0.150	0.043
risk-averse	0.328	0.450	-0.122*
Mineral fertilizers use	0.351	0.342	0.009
Same village with insurance foreman	0.361	0.733	-0.372***
Control variables			
age	39.66	41.53	-1.88
sex	0.824	0.742	0.082
education	0.378	0.408	-0.030
active people	2.403	3.042	-0.638***
asset holding[a]	15.06	15.76	-0.70
tropical livestock unit[b]	5.778	4.264	1.514***
land holding	1.330	1.102	0.228**
housing condition	0.807	0.792	0.015
access to credit	0.714	0.817	-0.102*
private transfer	0.445	0.342	0.104
cooperative member	0.723	0.675	0.048
iddir member[c]	0.950	0.975	-0.025
equb member[c]	0.471	0.442	0.029
ties with training office	0.101	0.642	-0.541***
own TV or radio	0.269	0.467	-0.198***
own phone	0.773	0.733	0.040

Notes: Appendix Table A1 presents the full description of each variable.
[a] Asset holding is an index (scaled between 0 and 100) constructed based on binary variables indicating the household's ownership of; stove, television, radio, telephone, fridge, and drip-irrigation equipment. [b] We measured livestock holding using Tropical Livestock Unit (TLU) based on Jahnke (1982) conversion factors as Camel 1.0; horse 0.8; cattle and mule 0.7 each; donkey 0.5; pig 0.2; sheep and goat 0.1 each; and chicken 0.01. [c] Self-help groups, which are widely prevailing informal institutions in Ethiopia.

4.2.1 *Selection model – Demand for WICI*

Our analyses are based on a sample of purchasers and non-purchasers that reside in *tabias* where the WICI scheme exists. Table 3 presents the estimation results on the selection (WICI uptake) equation after adjusting for the effects of observable and unobservable heterogeneity. We find a robust positive effect of living in the same village with the foreman (our instrumental variable) on the probability of farmers' WICI uptake. The ESP is our preferred model for the reasons described in section 4.2.2, and thus we discuss the results from column (2) in Table 3. The results show that farmers who live in the same village with the insurance foreman have a 17 percentage points higher probability to purchase WICI. A falsification test proposed by Di Falco et al. (2011) was executed to establish the admissibility of our instrument. As presented in Appendix Table A2, our IV does not enter as a statistically significant variable when included in a probit regression on the risk-aversion of non-purchaser farmers.

The average marginal effects (AME) for the remaining variables in the selection equation, i.e. the effects of changes in variables on the probability of WICI uptake, are also shown in Table 3 next to each coefficient estimate.[6] Households with a larger number of economically active family members have a higher probability of WICI uptake. Household income is an increasing function of economically active family members Manlagñit (2004) that may avail more financial resources for agricultural investments such as the purchase of WICI. Farmers' demand for WICI increases with their access to credit. Credit relaxes the households' liquidity constraints, and hence can significantly increase the probability that households purchase WICI. This result is similar to the findings of Giné et al. (2008) in rural India and Hill et al. (2013) in rural Ethiopia. The positive effect of *iddir* membership on the households' demand for WICI in Ethiopia is also documented in studies by Dercon et al. (2014) and Berg et al. (2017).

Farmers that have ties with a person who works in the training office of the R4 WICI pilot project are more likely to purchase WICI. This may work through the person's role in familiarizing a farmer about the existing agricultural risk management technology in the study area. In particular, farmers' contact with the training personnel of the project can facilitate the flow of information that could positively shape their knowledge and attitudes towards WICI, and ultimately can affect their decision to purchase WICI. However, we cannot rule out the possible effect of WICI uptake on the ability of farmers to meet and know people who work in the project.

On the contrary, the number of livestock owned and cooperative membership are negatively and significantly correlated with farmers' WICI uptake. Households with more livestock can rely on the sale of their livestock to buffer the effects of climate shocks Sango et al. (2007), and so they may prefer to opt against the uptake of WICI. The negative correlation between farmers' membership of a cooperative organization and WICI uptake may imply that farmers consider cooperatives as a substitute for purchasing the insurance product.

[6]The coefficient estimates on our control variables are merely correlational and could only serve as suggestive results for further enquiry. Hence, we are interested only in the direction of the associations.

Table 3: Selection model: Purchase of WICI

Variables	(1) SEM Probit (WICI uptake)		(2) ESP Probit (WICI uptake)	
	Coeff.	AME	Coeff.	AME
same village with foreman	0.8021***	0.1808***	0.7439***	0.1665***
	(0.2054)	(0.0433)	(0.2357)	(0.0497)
age	0.0265	0.0060	0.0175	0.0039
	(0.0163)	(0.0037)	(0.0168)	(0.0037)
sex	-0.2644	-0.0596	-0.2531	-0.0566
	(0.2679)	(0.0603)	(0.2872)	(0.0638)
education	0.2248	0.0507	0.1893	0.0424
	(0.2156)	(0.0493)	(0.3055)	(0.0684)
active people	0.1294*	0.0292*	0.1545*	0.0346*
	(0.0729)	(0.0161)	(0.0890)	(0.0201)
asset holding	-0.0041	-0.0009	0.0002	0.0001
	(0.0111)	(0.0025)	(0.0108)	(0.0024)
tropical livestock unit	-0.0829*	-0.0187**	-0.1120***	-0.0251***
	(0.0434)	(0.0095)	(0.0293)	(0.0063)
land holding	-0.2703*	-0.0609*	-0.2357	-0.0527
	(0.1583)	(0.0357)	(0.1528)	(0.0346)
housing condition	0.0772	0.0174	0.2024	0.0453
	(0.3019)	(0.0680)	(0.2663)	(0.0596)
access to credit	0.4014*	0.0905*	0.4649*	0.1040*
	(0.2311)	(0.0519)	(0.2429)	(0.0541)
private transfer	0.0080	0.0018	0.0917	0.0205
	(0.2726)	(0.0614)	(0.2507)	(0.0560)
cooperative member	-0.6758**	-0.1524***	-0.5734**	-0.1283**
	(0.2696)	(0.0578)	(0.2478)	(0.0537)
iddir member	1.0999	0.2480	1.6156**	0.3615**
	(0.9376)	(0.2078)	(0.6988)	(0.1507)
equb member	0.2085	0.0470	0.2442	0.0546
	(0.2523)	(0.0563)	(0.3050)	(0.0682)
ties with training office	1.9116***	0.4310***	2.0568***	0.4602***
	(0.2996)	(0.0447)	(0.3222)	(0.0555)
own TV or radio	0.2298	0.0518	0.0222	0.0050
	(0.3193)	(0.0720)	(0.2828)	(0.0633)
own mobile phone	-0.1732	-0.0390	-0.1613	-0.0361
	(0.2974)	(0.0667)	(0.3155)	(0.0702)
Constant	-2.6104***		-2.9502***	
	(0.9843)		(0.9083)	
Observations	239		239	

Notes: Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
SEM, ESP and AME stand for simultaneous equations model, endogenous switching probit and average marginal effect respectively.

4.2.2 ***Risk-aversion model***

Our outcome variable takes the form of either an ordinal risk preferences variable ordered in accordance with farmers' levels of risk-aversion or a binary variable coded as 1 to represent risk-aversion and 0 otherwise (see section 3.2). The SEM and ESP estimations were used to estimate the binary WICI uptake and the ordinal or binary risk-aversion equations simultaneously. The ESP is our preferred model for two main reasons. First, the likelihood ratio test of independence between the selection and outcome equations shows that SEM is not a relevant specification for our data. Second, the Wald test rejects the joint independence of the risk-aversion equations in the two regimes and the selection model. The test provides evidence that the naïve ordered probit or probit estimates (reported in Appendix Table A4) are biased and inconsistent due to the presence of unobserved factors affecting the selection process and farmers' risk-aversion simultaneously. Moreover, the test also reveals that ESP is an appropriate model specification than describing the behaviour of all farmers with a single risk-aversion equation – as it is the case under SEM. Therefore, to economize space, we only discuss the results from the ESP model.

In the risk-aversion (outcome) equations for the two regimes (purchasers and non-purchasers), there are few variables that significantly correlate with farmers' risk preferences (Table 4). As a formal and informal means of relaxing liquidity constraints, purchaser households' access to credit and *equb* are negatively correlated with their risk-aversion. The positive correlation between agricultural landholding and risk-aversion is observed under both regimes. In addition, risk-aversion of the non-purchasers and asset holdings are also positively correlated. Land and asset holdings are proxies for wealth and income-generating capacity of rural households. A positive correlation between income and risk-aversion of the households is also presented in Bosch-Domènech and Silvestre (2006). Households' personal ties with the training personnel of the WICI scheme and ownership of radio or television – proxies for the households' access to information – are negatively correlated with the risk-aversion of the non-purchasers group. The other covariates do not enter as significant predictors in the risk-aversion equations of the purchaser and non-purchaser farmers.

The error terms in the equations determining the uptake of WICI and farmers' risk-aversion of the non-purchasers are perfectly negatively correlated (ρ_0 = -1) and statistically significant. The correlation among the error terms in the selection equation and the risk-aversion model of the purchasers (ρ_1) is also negative but it is not statistically significant. These findings imply that self-selection exists only for the non-purchaser farmers. Non-purchaser farmers are significantly more risk-averse than a potentially random farmer from the same sample. Without addressing the endogeneity of risk preferences, risk-aversion may appear to have a positive effect on WICI uptake and may compel us to state that more risk-averse farmers are likely to purchase WICI (Appendix Table A3). Therefore, in non-experimental data, attempting to establish a relationship between WICI uptake and risk preferences without taking into account the notion of self-selection and endogenous preferences may risk ending up with biased findings.

Table 4: Effect estimates for the covariates under the risk-aversion equations

Variables	(1) SEM Ordered Probit (Risk preferences)				(2) ESP Probit (Risk-aversion)	
		Average Marginal Effect (AME)			Purchasers	Non-purchasers
	Coeff.	Risk-taking	Risk-neutral	Risk-aversion	Coeff.	Coeff.
purchase WICI	-0.1639	0.0597	-0.0017	-0.0580		
	(1.7387)	(0.6320)	(0.0175)	(0.6146)		
age	0.0104	-0.0038	0.0001	0.0037	-0.0018	-0.0167
	(0.0139)	(0.0050)	(0.0002)	(0.0049)	(0.0194)	(0.0154)
sex	-0.0099	0.0036	-0.0001	-0.0035	0.1757	-0.1108
	(0.2494)	(0.0908)	(0.0026)	(0.0882)	(0.4175)	(0.3429)
education	0.0803	-0.0293	0.0008	0.0284	0.1399	-0.1159
	(0.1860)	(0.0676)	(0.0022)	(0.0657)	(0.3391)	(0.2663)
active people	0.0876	-0.0319	0.0009	0.0310	0.1477	-0.0735
	(0.0600)	(0.0213)	(0.0011)	(0.0209)	(0.0899)	(0.0721)
asset holding	0.0049	-0.0018	0.0001	0.0017	-0.0042	0.0386***
	(0.0091)	(0.0033)	(0.0001)	(0.0032)	(0.0112)	(0.0145)
tropical livestock unit	-0.0302	0.0110	-0.0003	-0.0107	0.0084	0.0178
	(0.0400)	(0.0143)	(0.0005)	(0.0140)	(0.0640)	(0.0302)
land holding	0.1487	-0.0541	0.0016	0.0526	0.3484*	0.2678*
	(0.1569)	(0.0578)	(0.0028)	(0.0556)	(0.2093)	(0.1585)
housing condition	-0.1073	0.0391	-0.0011	-0.0380	-0.0560	-0.1067
	(0.2182)	(0.0794)	(0.0027)	(0.0771)	(0.3725)	(0.2782)
access to credit	-0.5262*	0.1916*	-0.0055	-0.1861*	-0.8426**	-0.1938
	(0.2713)	(0.1000)	(0.0078)	(0.0952)	(0.3640)	(0.2754)

Table 4: Continued

Variables	(1) SEM Ordered Probit (Risk preferences)				(2) ESP Probit (Risk-aversion)	
		Average Marginal Effect (AME)			Purchasers	Non-purchasers
	Coeff.	Risk-taking	Risk-neutral	Risk-aversion	Coeff.	Coeff.
private transfer	0.0429	-0.0156	0.0005	0.0152	0.3215	-0.1995
	(0.1688)	(0.0615)	(0.0018)	(0.0597)	(0.3058)	(0.2487)
cooperative member	0.1077	-0.0392	0.0011	0.0381	0.2579	0.2287
	(0.4147)	(0.1516)	(0.0050)	(0.1468)	(0.3442)	(0.2802)
iddir member	0.0603	-0.0220	0.0006	0.0213	-0.6984	-0.2619
	(0.5895)	(0.2144)	(0.0061)	(0.2084)	(1.0722)	(0.5744)
equb member	-0.2570	0.0936	-0.0027	-0.0909	-0.6361**	-0.3840
	(0.2566)	(0.0944)	(0.0046)	(0.0909)	(0.3220)	(0.2742)
ties with training office	0.5394	-0.1964	0.0057	0.1908	0.2331	-0.6350*
	(1.0368)	(0.3732)	(0.0101)	(0.3651)	(1.3863)	(0.3541)
own TV or radio	-0.2505	0.0912	-0.0026	-0.0886	-0.2023	-1.0390***
	(0.2272)	(0.0828)	(0.0040)	(0.0802)	(0.3253)	(0.3234)
own mobile phone	0.0061	-0.0022	0.0001	0.0021	-0.3848	0.0533
	(0.2321)	(0.0845)	(0.0024)	(0.0821)	(0.3685)	(0.3700)
Constant					0.7835	-0.0015
					(2.6599)	(0.7831)
rho (ρ_i)			0.0916		-0.4714	-1***
			(1.0999)		(1.3241)	2.43E-11
Observations			239		239	
Test of $\rho_i = 0$ (p value)			0.934		0.045	

Notes: Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

SEM, ESP and AME stand for simultaneous equations model, endogenous switching probit and average marginal effect respectively.

We used Stata commands developed by Roodman (2011) and Lokshin and Sajaia (2011) for the simultaneous equations model (SEM) and endogenous switching probit (ESP) analyses, respectively.

Tests of joint independence (p values) are based on the likelihood ratio and Wald tests under the SEM and ESP models respectively.

4.2.3 *The effect of WICI on risk-aversion*

Table 5 reports the ATT, ATU, and ATE estimates, derived from the ESP model as described in equations 5, 6 and 7, respectively. Purchaser farmers are 43 percentage points less likely to be risk-averse compared with the counterfactual scenario of non-purchaser farmers. This translates to a reduction in the risk-aversion of the purchasers by around 50 percent compared to what it would have been had they not purchased WICI. The non-purchaser farmers would have also attained, on average, 26 percentage points reduction in their risk-aversion if they had taken up WICI. This translates to a 79 percent decline in the probability of risk-aversion from the initial sub-population of risk-averse farmers in the non-purchasers group. Moreover, the average risk-aversion of farmers would have been lowered by 35 percentage points had all farmers in the study area decided to purchase the insurance product. Put differently, if every farmer in the study area is insured, the probability of risk-aversion would be 90 percent lower compared with the counterfactual scenario of none of the farmers had purchased WICI. If we do not take into account the simultaneity and self-selection biases in analysing the impact of WICI uptake on farmers' risk-aversion, we will have a perversely signed average treatment effect estimate (Appendix Table A4).

Table 5: Treatment effect estimates: Impact of WICI on risk-aversion

Treatment effect estimates	Observations	Estimate
Average Treatment Effect on the Treated (ATT)	120	-0.4267***
		(0.0221)
Average Treatment Effect on the Untreated (ATU)	119	-0.2620***
		(0.0235)
Average Treatment Effect (ATE)	239	-0.3506***
		(0.0160)

Notes: Standard errors in parentheses. *** $p<0.01$
We used the Stata command developed by Lokshin and Sajaia (2011) for estimating the treatment effects.

4.2.4 *Observed risk-taking behaviour: WICI and adoption of mineral fertilizers*

In this section, we examine to what extent the effect of WICI on farmers' risk-aversion is translated into their economic risk-taking behaviour in daily life. We use the decision to apply mineral fertilizers as an observed risk-taking behaviour of farmers. A binary outcome variable for fertilizer use takes the value of 1 if the farmer used mineral fertilizers during the production year in the survey period, and 0 otherwise. Since the early work by Rosenzweig and Binswanger (1993), it has been shown that farmers in developing countries employ a self-insurance mechanism by avoiding high-risk high-return agricultural technologies to minimize income variability. Mineral fertilizers perfectly match the definition of high-risk high-return agricultural technologies. According to Fosu-Mensah and Mensah (2016), a profound yield-enhancing effect of mineral fertilizers is realized in soils with sufficient moisture. In the context of rainfed agriculture, their result may mean that the desirable yield- and income-boosting effects of mineral fertilizers are associated with the presence of favourable weather conditions during the agricultural season. Otherwise, households may not recover what they spend to purchase mineral fertilizers in the absence of sufficient rain. Therefore, taking farmers' decision to adopt mineral fertilizers as our outcome variable enables us to examine whether WICI uptake has a positive effect on farmers' risky but profitable agricultural investment decisions in an environment characterised by erratic weather conditions.

The parameter estimates of the ESP model are depicted in Appendix Table A5. The positive and statistically significant impact of WICI on the adoption of mineral fertilizers matches our expectation. Table 6 shows that the likelihood of mineral fertilizers use by purchasers of WICI increased by 60 percentage points. Similarly, the adoption rate of non-purchasers would have increased by 33 percentage points if they had taken-up WICI. These findings imply that the magnitude of the impact of WICI on the application of mineral fertilizers is larger for purchaser farmers. Insuring all farmers in the study area would have increased the probability of mineral fertilizer application by 46 percentage points compared to the scenario where none of the households had purchased WICI. In this case, the adoption rate of mineral fertilizers in the study area would have been increased to 81 percent. If our analysis had not considered self-selection bias, the effect of WICI on mineral fertilizers use would have appeared to be negatively signed (Appendix Table A6).

Our results show that farmers who purchased WICI are more likely to benefit from favourable agricultural seasons above and beyond non-purchasers because of their investments in yield-boosting agricultural technologies. Based on our findings in subsection 4.2.3, change in risk-aversion may be a plausible mechanism through which WICI uptake causes an effect on farmers' risk-taking behaviour in their agricultural investment decisions − adoption of mineral fertilizers. WICI improves the households' circumstances since the insurance payouts during negative rainfall shocks can stabilise income and ensure smooth consumption (Janzen and Carter, 2018). Thus, WICI uptake reduces the income and consumption variability related with agricultural households' production decisions. Consequently, WICI uptake can change farmers' interpretation of the operating environment for farming and ultimately reduces their risk-aversion: a major driver of agricultural technology adoption.

Table 6: Treatment effect estimates: Impact of WICI on mineral fertilizers use

Treatment effect estimates	Observations	Estimate
Average Treatment Effect on the Treated (ATT)	120	0.5958***
		(0.0249)
Average Treatment Effect on the Untreated (ATU)	119	0.3295***
		(0.0226)
Average Treatment Effect (ATE)	239	0.4611***
		(0.0161)

Notes: Standard errors in parentheses. *** $p<0.01$
We used the Stata command developed by Lokshin and Sajaia (2011) for estimating the treatment effects.

5 Conclusion

In the presence of uninsured climate risks, farmers in developing countries are generally risk-averse as a self-insuring mechanism to avoid income variability (Rosenzweig and Binswanger, 1993). This economic behaviour permanently keeps them in low-income low-investment vicious cycle (Carter and Barrett, 2006; Dercon and Christiaensen, 2011). One focus area of active research has been analysing how preferences are formed and change in the presence of external stimuli. There has been a long-standing argument about the importance of policies and institutions in shaping the households' preferences (Roumasset, 1976; Eswaran and Kotwal, 1986; Bowles, 1998; Palacios-Huerta and Santos, 2004; Mendola, 2007). However, in the context of formal climate risk transfer mechanisms, previous studies that examined the relationship between the uptake of WICI and real-life risk-taking behaviour of farmers considered risk preferences as given, which restricts an empirical enquiry into change in risk preferences as a plausible mechanism. By taking the case of Ethiopia, this study adds to the existing literature on the causes of change in risk preferences by providing valuable insight into the structural relationship between a programme intervention that facilitates access to WICI and farmers' risk-aversion.

Empirically isolating the causal effect of farmers' WICI uptake on their risk-aversion is a challenging task. There may not only be a simultaneity bias – risk-aversion of farmers determine their WICI uptake decision – but also be self-selection-bias – the presence of unobserved farmer characteristics that affect both WICI uptake and risk-aversion. We used the ESP model to take into account both sources of biases. Our results from the selection model show that promotion and training officers of WICI can play a significant role in getting farmers to take-up the insurance product. The treatment effect estimates provide evidence for a significant reduction in the risk-aversion of farmers in response to the uptake of WICI. However, without taking into account the notion of endogenous preferences and WICI uptake, the selection and treatment effect estimates will be biased and perversely signed.

We find that farmers who purchased WICI are less likely to be risk-averse compared with non-purchaser farmers. Similarly, non-purchasers would have attained a significant reduction in their risk-aversion if they had taken up the insurance product. Overall, if every farmer in the study area is insured, the probability of risk-aversion would have been 90 percent lower compared with the counterfactual scenario of none of the farmers had purchased the WICI. We also find that WICI has a positive and statistically significant effect on farmers' real-life risk taking behaviour - mineral fertilizer use. Therefore, WICI uptake can change farmers' interpretation of the operating environment for farming, by reducing income and consumption variability, and ultimately reduces their risk-aversion. In turn, change in farmers' risk-aversion can be a major channel through which WICI uptake influences their investment decisions on high-risk high-return agricultural technologies.

Our study contributes to evidence-informed policymaking that intends to spur economic development in agrarian economies in the era of frequent and severe climate shocks. Investments on policies and strategies aiming to improve farmers' uptake of formal climate risk transfer mechanisms can have long-term effects on the households by bringing up desirable economic behaviour that may enable them to break out of poverty traps and enjoy virtuous cycle of increasing income. Thus, the role of climate risk management policies in general and WICI in particular in the poverty alleviation and economic development of agrarian economies can also be channeled through their effects on households' risk preferences, which influence their major economic decisions and outcomes.

Since our analyses are based on cross sectional data, we can assess only the between-farmers variation in risk-aversion associated with WICI uptake. There is a need for further investigation on the within-farmer effects of WICI uptake on risk-aversion using panel data. In so doing, one can robustly identify whether the observed change in farmers' risk-aversion in relation to purchase of WICI is attributed to change in the risk preferences within a given farmer. The special basis-risk fund of the WICI scheme under the R4 initiative, which we have evaluated in this study, makes it distinct from the common index-based insurance products that do not have such a feature. Future research on the impact of WICI without the basis-risk fund on farmers' risk-aversion would show the generalizability of our findings. Moreover, comparative assessments on the adoption and impact of WICI with and without the basis risk fund would also be insightful concerning the identification of effective and efficient design feature of the insurance product.

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Appendix A. Appendix Tables

Appendix Table A1: Description and statistics of variables

Variables	Description	Obs	Mean	Std.Dev.	Min	Max
Variables of interest						
risk-taker	binary; =1 if risk-taker, 0 otherwise.	239	0.439	0.497	0	1
risk-neutral	binary; =1 if risk-neutral, 0 otherwise.	239	0.172	0.378	0	1
risk-averse	binary; =1 if risk-averse, 0 otherwise.	239	0.389	0.489	0	1
mineral fertilizers use	binary; =1 if the household (HH) uses mineral fertilizers, 0 otherwise.	231	0.346	0.477	0	1
WICI purchase	binary; =1 if buy insurance, 0 otherwise.	239	0.5021	0.501	0	1
insurance foreman	binary; =1 if the HH lives in the same village with the insurance foreman, 0 otherwise.	239	0.548	0.499	0	1
Control variables						
age	continuous variable for the age of the HH head.	239	40.60	10.57	19	72
sex	binary; =1 if the HH head is male, 0 otherwise.	239	0.782	0.413	0	1
education	binary; =1 if the HH head attend formal education, 0 otherwise.	239	0.393	0.490	0	1
active people	continuous variable for the number of economically active HH members.	239	2.724	1.920	1	13
asset holding	continuous variable for asset holding.	239	15.41	12.24	3.898	83.94
tropical livestock unit	continuous variable for the total livestock holding.	239	5.017	4.376	0	19.90
land holding	continuous variable for total land holding.	239	1.216	0.826	0	4.625
housing condition	binary; =1 if the housing condition is average and above, 0 if leaking or falling apart.	239	0.799	0.401	0	1
access to credit	binary; =1 if the HH gets credit, 0 otherwise.	239	0.766	0.424	0	1
private transfer	binary; =1 if the HH received private transfers, 0 otherwise.	239	0.393	0.490	0	1
cooperative member	binary; =1 if the HH is member of a cooperative organization, 0 otherwise.	239	0.699	0.460	0	1
iddir member	binary; =1 if the HH is member of a burial savings group, 0 otherwise.	239	0.962	0.191	0	1
equb member	binary; =1 if the HH is member of informal rotating and saving association, 0 otherwise.	239	0.456	0.499	0	1
ties with training office	binary; =1 if the HH head has personal ties to training officer(s) of R4 project, 0 otherwise.	239	0.372	0.484	0	1
own TV or radio	binary; =1 if the HH owns television or radio, 0 otherwise.	239	0.368	0.483	0	1
own phone	binary; =1 if the HH owns phone, 0 otherwise.	239	0.753	0.432	0	1

Appendix Table A2: Falsification tests: Testing the correlation between the instrumental variable and risk-aversion of non-purchasers

Variables	(1) Probit (Risk-aversion)		(2) Probit (Risk-aversion)	
	Coeff.	AME	Coeff.	AME
same village with foreman	0.0910	0.0328	0.2806	0.0900
	(0.2482)	(0.0894)	(0.2762)	(0.0872)
age			-0.0009	-0.0003
			(0.0147)	(0.0047)
sex			-0.1873	-0.0601
			(0.3657)	(0.1171)
education			-0.1541	-0.0494
			(0.2848)	(0.0906)
active people			-0.0475	-0.0152
			(0.0819)	(0.0261)
asset holding			0.0410**	0.0131**
			(0.0181)	(0.0055)
tropical livestock unit			-0.0091	-0.0029
			(0.0347)	(0.0111)
land holding			0.2031	0.0651
			(0.1615)	(0.0510)
housing condition			-0.1133	-0.0363
			(0.3262)	(0.1045)
access to credit			-0.2107	-0.0675
			(0.2902)	(0.0921)
private transfer			-0.1537	-0.0493
			(0.2750)	(0.0882)
cooperative member			-0.0960	-0.0308
			(0.3345)	(0.1071)
iddir member			-0.1170	-0.0375
			(0.6723)	(0.2158)
equb member			-0.3120	-0.1000
			(0.2814)	(0.0896)
ties with training office			0.3124	0.1002
			(0.4813)	(0.1544)
own TV or radio			-1.0334***	-0.3314***
			(0.3631)	(0.1079)
own mobile phone			0.0246	0.0079
			(0.3874)	(0.1243)
Constant	-0.4795***		-0.2147	
	(0.1506)		(0.8292)	
Observations	119	119	119	119

Notes: Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
AME stands for average marginal effect.

Appendix Table A3: Selection effect after adjusting only for the observables

Variables	(1) Probit (WICI uptake)		(2) Probit (WICI uptake)	
	coeff.	AME	Coeff.	AME
risk-averse	0.3240*	0.1277**	0.1779	0.0434
	(0.1676)	(0.0644)	(0.2057)	(0.0498)
age			0.0259**	0.0063**
			(0.0112)	(0.0026)
sex			-0.1888	-0.0460
			(0.2558)	(0.0622)
education			0.1972	0.0481
			(0.2084)	(0.0513)
active people			0.1408**	0.0343**
			(0.0566)	(0.0138)
asset holding			-0.0090	-0.0022
			(0.0098)	(0.0024)
tropical livestock unit			-0.0797***	-0.0194***
			(0.0277)	(0.0064)
land holding			-0.2946**	-0.0718**
			(0.1498)	(0.0364)
housing condition			0.1226	0.0299
			(0.2659)	(0.0649)
access to credit			0.4025*	0.0981*
			(0.2320)	(0.0562)
private transfer			0.0025	0.0006
			(0.2179)	(0.0531)
cooperative member			-0.7394***	-0.1802***
			(0.2464)	(0.0560)
iddir member			0.8545	0.2082
			(0.7648)	(0.1843)
equb member			0.2909	0.0709
			(0.2516)	(0.0604)
ties with training office			1.9702***	0.4800***
			(0.2775)	(0.0381)
own TV or radio			0.3258	0.0794
			(0.2662)	(0.0648)
own mobile phone			-0.1338	-0.0326
			(0.2792)	(0.0679)
Constant	-0.1205		-2.0706**	
	(0.1042)		(0.9393)	
Observations	239	239	239	239

Notes: Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
AME stands for average marginal effect.

Appendix Table A4: The effect of WICI on risk-aversion after adjusting only for observable household characteristics

Variables	(1) Ordered Probit (Risk preferences)				(2) Probit (Risk-aversion)	
		AME				
	Coeff.	Risk-taking	Risk-neutral	Risk-aversion	Coefficient	AME
purchase WICI	0.1410	-0.0513	0.0015	0.0498	0.1674	0.0578
	(0.1996)	(0.0723)	(0.0027)	(0.0701)	(0.2237)	(0.0769)
age	0.0083	-0.0030	0.0001	0.0029	0.0015	0.0005
	(0.0081)	(0.0029)	(0.0001)	(0.0028)	(0.0092)	(0.0032)
sex	0.0092	-0.0034	0.0001	0.0033	-0.0819	-0.0283
	(0.2295)	(0.0835)	(0.0025)	(0.0810)	(0.2417)	(0.0835)
education	0.0678	-0.0247	0.0007	0.0239	-0.0834	-0.0288
	(0.1771)	(0.0645)	(0.0021)	(0.0625)	(0.1985)	(0.0685)
active people	0.0804	-0.0293*	0.0009	0.0284*	0.0777	0.0268
	(0.0492)	(0.0177)	(0.0011)	(0.0172)	(0.0526)	(0.0180)
asset holding	0.0054	-0.0020	0.0001	0.0019	0.0093	0.0032
	(0.0090)	(0.0033)	(0.0001)	(0.0032)	(0.0090)	(0.0031)
tropical livestock unit	-0.0247	0.0090	-0.0003	-0.0087	-0.0093	-0.0032
	(0.0247)	(0.0089)	(0.0004)	(0.0086)	(0.0262)	(0.0090)
land holding	0.1681	-0.0612	0.0018	0.0593	0.2124	0.0734
	(0.1047)	(0.0379)	(0.0022)	(0.0367)	(0.1312)	(0.0446)
housing condition	-0.1111	0.0404	-0.0012	-0.0392	-0.1079	-0.0373
	(0.2142)	(0.0778)	(0.0026)	(0.0755)	(0.2376)	(0.0820)
access to credit	-0.5547***	0.2019***	-0.0060	-0.1958***	-0.4882**	-0.1687**
	(0.1927)	(0.0674)	(0.0067)	(0.0651)	(0.2187)	(0.0733)
private transfer	0.0428	-0.0156	0.0005	0.0151	0.1308	0.0452
	(0.1686)	(0.0613)	(0.0019)	(0.0595)	(0.1864)	(0.0642)
cooperative member	0.1693	-0.0616	0.0018	0.0598	0.0902	0.0312
	(0.2055)	(0.0745)	(0.0030)	(0.0721)	(0.2230)	(0.0769)
iddir member	0.0090	-0.0033	0.0001	0.0032	-0.2542	-0.0878
	(0.5103)	(0.1857)	(0.0056)	(0.1801)	(0.4878)	(0.1685)
equb member	-0.2848	0.1036	-0.0031	-0.1006	-0.3995*	-0.1380**
	(0.1847)	(0.0666)	(0.0037)	(0.0648)	(0.2056)	(0.0697)
ties with training office	0.3620*	-0.1317*	0.0039	0.1278*	0.5560**	0.1921**
	(0.2179)	(0.0782)	(0.0045)	(0.0762)	(0.2364)	(0.0798)
own TV or radio	-0.2658	0.0967	-0.0029	-0.0938	-0.4667**	-0.1613**
	(0.2083)	(0.0750)	(0.0036)	(0.0731)	(0.2340)	(0.0794)
own mobile phone	0.0164	-0.0060	0.0002	0.0058	-0.0105	-0.0036
	(0.2293)	(0.0834)	(0.0025)	(0.0809)	(0.2428)	(0.0839)
Constant					-0.1791	
					(0.6485)	
Observations	239				239	

Notes: Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
AME stands for average marginal effect.
See section 3.2 for the explanations on the dependent variables in columns 1 and 2.

Appendix Table A5: Coefficient estimates of the ESP model for adoption of mineral fertilizers

	(1)	(2)	
Variables	Probit (WICI uptake) Selection model	Probit (Mineral Fertilizer Use) Purchasers	Non-purchasers
purchase WICI	0.7501***		
	(0.1734)		
age	0.0264**	0.0246*	0.0199
	(0.0123)	(0.0127)	(0.0140)
sex	-0.1250	0.5713	-0.2801
	(0.2655)	(0.3905)	(0.3234)
education	0.0437	0.2232	0.4925**
	(0.1880)	(0.2386)	(0.2339)
active people	0.1401**	0.0567	-0.0051
	(0.0566)	(0.0666)	(0.0782)
asset holding	-0.0046	0.0190	-0.0337**
	(0.0127)	(0.0129)	(0.0166)
tropical livestock unit	-0.0878***	-0.0477	0.0315
	(0.0256)	(0.0350)	(0.0320)
land holding	-0.3051*	-0.1350	-0.4658***
	(0.1561)	(0.2100)	(0.1710)
housing condition	0.1164	0.3357	-0.2610
	(0.2536)	(0.3905)	(0.2989)
access to credit	0.4263*	0.2748	0.1231
	(0.2398)	(0.3561)	(0.2756)
private transfer	0.1014	-0.7282**	0.3609
	(0.2147)	(0.2898)	(0.2537)
cooperative member	-0.7316***	-0.4266	-0.4866*
	(0.2337)	(0.2638)	(0.2586)
iddir member	1.0368	0.1512	1.5145**
	(0.7269)	(0.6144)	(0.7086)
equb member	0.1178	0.0220	-0.1046
	(0.2246)	(0.2932)	(0.2476)
ties with training office	1.9954***	1.0420***	1.4253***
	(0.2732)	(0.3007)	(0.4404)
own TV or radio	0.2022	-0.3141	1.0087***
	(0.2943)	(0.3292)	(0.3532)
own mobile phone	-0.0612	0.3666	0.1513
	(0.2864)	(0.3550)	(0.3480)
Constant	-2.6298***	-3.3458***	-1.3837
	(0.9115)	(0.9944)	(0.8937)
rho (ρ_i)		1***	1***
		(4.32e-13)	(1.09e-11)
Observations	231	231	231
Test of ρ_1=ρ_0=0 (p value)		0.0071	

Notes: Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
ESP stands for endogenous switching probit.
We used Stata commands developed by Lokshin and Sajaia (2011) for the ESP analysis.

Appendix Table A6: Adoption of mineral fertilizers conditioning on observable factors

Variables	(1) Probit (Mineral Fertilizer Use)		(2) Probit (Mineral Fertilizer Use)	
	Coeff.	AME	Coeff.	AME
purchase WICI	-0.0244	-0.0090	-0.3665	-0.1224
	(0.1701)	(0.0627)	(0.2358)	(0.0778)
age			0.0091	0.0030
			(0.0098)	(0.0033)
sex			0.3179	0.1062
			(0.2553)	(0.0844)
education			0.3151	0.1053
			(0.1988)	(0.0654)
active people			-0.0247	-0.0083
			(0.0518)	(0.0173)
asset holding			0.0027	0.0009
			(0.0085)	(0.0028)
tropical livestock unit			0.0145	0.0048
			(0.0250)	(0.0083)
land holding			-0.3298**	-0.1102**
			(0.1394)	(0.0456)
housing condition			-0.0799	-0.0267
			(0.2496)	(0.0833)
access to credit			0.3387	0.1132
			(0.2328)	(0.0773)
private transfer			-0.1191	-0.0398
			(0.1918)	(0.0639)
cooperative member			-0.0541	-0.0181
			(0.2181)	(0.0728)
iddir member			0.6029	0.2014
			(0.4964)	(0.1649)
equb member			-0.2113	-0.0706
			(0.2147)	(0.0715)
ties with training office			0.3413	0.1140
			(0.2431)	(0.0806)
own TV or radio			0.2160	0.0722
			(0.2336)	(0.0776)
own mobile phone			0.2664	0.0890
			(0.2609)	(0.0870)
Constant	-0.3830***		-1.6433**	
	(0.1208)		(0.6428)	
Observations	231	231	231	231

Notes: Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
AME stands for average marginal effect.