Uptake and Impact of Interlinked Index-based Insurance with Credit and Agricultural Inputs: Experimental Evidence from Ethiopia *

Temesgen Belissa[2,3], Robert Lensink[2,4] and Ana Marr[1 *]

[1] University of Greenwich, United Kingdom.

[2] Wageningen University, the Netherlands.

[3] Haramaya University, Ethiopia.

[4] University of Groningen, the Netherlands.

* **Ana Marr** is corresponding author**.** University of Greenwich, United Kingdom.

Email: a.marr@gre.ac.uk

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Abstract

This paper examines the results of randomized experiments in Ethiopia that assess the relevance of bundling index-based insurance (IBI) with credit and inputs. We compare four IBI options and their impact on adoption of modern technologies, consumption and productivity: (1) standard IBI; (2) newly-developed IBI, i.e. promoted via farmer groups and featuring a delayed premium option; (3) new IBI bundled with credit; and (4) new IBI bundled with credit and inputs. We find that only when farmers adopt a package comprised of insurance, credit and inputs, do they significantly increase their investment in modern agricultural technologies and, consequently, productivity grows.

Keywords: Index-Based Insurance (IBI), Interlinked IBI-credit-input, Randomized Control Trial

JEL Classification Codes: O44, Q41, D92, G22

I. Introduction

As the majority of the poor reside in rural areas, an increase in productivity in the agricultural sector is of crucial importance for poverty reduction. Increments in productivity require that farmers adopt modern technologies, such as improved seeds and/or chemical fertilizers (Just & Zilberman 1983; Besley & Case 1993; Chirwa 2005; Simtowe 2006; Marr et al. 2016). However, adoption of modern inputs, especially in African countries, remains low. There is evidence that agricultural risk is one of the main reasons for low investment in modern agricultural technologies (Karlan et al. 2014), and consequently that a proper insurance system that reduces farmers vulnerability to risk would be extremely relevant.

Indemnity-based mutual insurance systems, however, suffer from the usual moral hazard and adverse selection problems. Furthermore, farmers are typically confronted with covariate risks due to weather shocks. It is therefore not surprising that possibilities to use standard indemnity insurance remain low in rural areas. Index-based insurance (IBI), which delinks the insurance pay-outs from individual farmer behaviour by triggering pay-outs when the index of a selective weather variable falls below a given threshold, may partly overcome the problems that exist with indemnity-based insurance. A reliable index, on the other hand, should closely correlate with the insured asset, and be objectively quantifiable and publicly verifiable in order not to be manipulated by either the insurer or the insured (Barnett et al. 2008; Skees 2008; Jensen, Mude and Barrett 2018). Thus, IBI may overcome classic incentive problems like information asymmetry and transaction costs associated with claim verification and contract enforcement in rural financial markets (Barnett et al. 2008). Yet, several recent experiments point at important challenges with index-based insurance, e.g. due to mismatch between the insurance pay-out and what happens to the farmer (i.e. so-called basis risk); low trust; high prices and liquidity constraints, which result in extremely low adoption rates: in general, the adoption of index-based insurance products turns out to be even below 10% (Cole et al. 2013). For a survey of experiences (and failures) with index-based insurance schemes in Sub-Saharan Africa refer to Miranda and Mulangu (2016).

Partly due to the disappointing experience with stand-alone (index) insurance products – but also because of the slow diffusion of modern technologies that is not only due to uninsured risk; see Foster and Rosenzweig (2010) for an overview – several organisations have started bundling agricultural insurance with other services, typically with credit or agricultural inputs. Recent examples are the credit-insurance bundling of the Weather Based Crop Insurance Scheme (WBCIS) in India and the insurance-agricultural inputs bundling scheme by Kilimo Salama in Kenya (Mukherjee et al. 2017). In most credit bundling systems, farmers are obliged to take up insurance to get the credit, while insurance can be taken up without credit as well. In the case of an input-bundling system, farmers, who bought insurance, in general, obtain guaranteed access to inputs, or even receive a discount on the price of the inputs.

In theory, the bundling of insurance may be beneficial for all parties involved, as the bundled product may insure risk and lead to, for example, easier access to credit and/or improved inputs for farmers; to improved adoption of the insurance product for the insurance company; and to a reduction in loan defaults and an increase in adoption of inputs for banks and input suppliers, respectively. Thus, while insurance provides a market mechanism to shield the welfare of smallholders from the adverse effects of weather and seasonality-based variations, agricultural loans (and access to inputs) serve farmers to acquire and adopt high-risk high-return agricultural inputs such as improved seed varieties, fertilizer, pesticide and herbicide. Interlinking insurance with credit and inputs may thus be important for the mutual benefit of smallholder borrowers, insurance providers and non-insurance providers (McIntosh, Sarris and Papadopoulos 2013; Farrin and Miranda 2015). The interlinked insurance-credit-input system may turn out to be a win-win strategy that encourages a financial environment where insurance and credit complementarily reinforce (crowd-in) each other, and where both the borrower and the lender remain better off.

In this paper we describe the results of a randomized experiment we conducted in Ethiopia to examine the relevance of bundling index-based insurance with credit and access to inputs. We compare four index-based insurance options in terms of their impact on adoption of modern technologies, consumption and productivity: (1) a standard index-based insurance product; (2) a newly developed index-based insurance product that is promoted via farmer groups and has a delayed premium option; (3) the newly developed index-based insurance product bundled with a credit option and (5) the newly developed index-based insurance product bundled with credit and an input purchasing option. With the experiment, we aim to test three important questions. First, does a more favorable stand-alone index-based insurance product, with higher uptake, induce a significant increase in investment in new technologies, consumption and productivity? Second, does the bundling of a more favorable insurance product with credit and/or inputs purchasing option further increase the uptake of insurance? Third, does the bundling of insurance with credit and/or inputs significantly affect investment in new technologies, productivity and consumption? The study is undertaken in the Rift Valley zone of Ethiopia where rainfall shocks and drought adversely affect household welfare and where the prevalence of credit and insurance rationing was evidenced (Ali and Deininger 2014; Belissa et al. 2018). In the study area, given the need for an effective risk transfer mechanism, high and sustained rural technology uptake by farmers, and the need for increased investment in high-risk high-return agricultural inputs to increase productivity, it is important to assess whether the innovative interlinked insurance-credit-input intervention mechanism increases uptake of new technologies.

II. Relevance of the study

We are not the first testing bundled insurance products. However, rigorous empirical evidence on the relevance of bundling insurance with other services is scarce, and shows conflicting results. Furthermore, the few studies available differ fundamentally from ours. For instance, Bulte et al. (2018) examine the relevance of bundling insurance with inputs. Using a randomized experiment in Kenya, they show, as expected, that the adoption of certified seeds will increase if farmers obtain free insurance conditional on them buying certified seeds. However, and more importantly, the authors also found that the bundled product induced farmers to adopt other additional modern technologies (such as fertilizers), which were not directly linked to the free provision of crop insurance. Therefore, Bulte et al. (2018) tested the importance of free insurance (conditional on buying improved seeds) in terms of inducing voluntary investment in complementary agricultural inputs such as fertilizer. However, they did not consider bundling insurance with credit.

Three other studies are less positive about the relevance of bundled insurance products. These studies question in particular the significance of bundling index-based insurance with credit. In a field experiment conducted in Malawi, Giné & Yang (2009) tested the hypothesis that bundling credit with insurance would lead to more investment in new crops and consequently to an increase in demand for credit. Unexpectedly, they found that the bundling had adverse effects in terms of reduced demand for credit. The authors explain the reduction in demand for credit by arguing that loans already contain an implicit insurance component as farmers could simply default on the loan in times of bad weather. Therefore, bundling loans with insurance that is priced at an actuarially fair rate would actually lead to over-insurance, and thus a rise in costs of credit, suggesting that bundling credit with insurance may not be the optimal solution. Similar result is found by Karlan et al. (2011). Their randomized experiment in Ghana to examine the impact of providing insured loans to farmers shows that the loan uptake of treatment and control groups is equal. Karlan et al. (2014) compare impacts of capital grants, insurance, and a combination of the two, and find that risk is the binding constraint of farmers, and not credit. They show that providing insurance, without capital, increases investment. Based on a variety of experiments, they conclude: "Thus, the lesson should not be to simply bundle rainfall insurance with loans but to use the delivery infrastructure and perhaps the trust that microfinance institutions or banks may have in the community to market and distribute rainfall insurance." (Karlan et al. 2014, p. 648). However, it should be noted that in the above-mentioned experiments farmers were receiving the full insurance payouts. Farrin and Miranda (2015) suggest that the success of combining insurance with credit would increase substantially if the lender receives the indemnity, and the farmer the residual. This is precisely what we do in our experiment: the insurance premium payment, the lending costs as well as the costs for the inputs are all bundled. In case of an insurance payout, the farmer only receives the residual (insurance payouts minus all costs). Another main difference between our study and the three studies mentioned above is that we not only consider bundling with credit, but also with inputs.

Cassaburi and Willis (2016) study an interesting, completely different possibility to bundle insurance. They consider the relevance of interlinking insurance with a contract-farming scheme. The advantage of this system is that farmers receive the possibility to postpone the premium payment: the premium is simply deducted from revenues at harvest time, which avoids problems of defaults.[1] Interlinking insurance premium payments with contract farming encourages the uptake of insurance as it addresses a potential liquidity problem. The setting of our study differs fundamentally from that of Cassaburi and Willis (2016). As the smallholders we are working with are not engaged in contract farming, we do not interlink insurance with outputs. Moreover, we are primarily interested in the relevance of index-based insurance (and bundling) in terms of their impact on improving adoption of modern inputs and productivity. In the setting of Cassaburi and Willis (2016), this question seems irrelevant as contract farming usually includes the purchase of inputs, and thus the role of insurance in this sense will be limited. However, by using a similar approach as Belissa et al. (2018), we do give farmers the option to postpone premium payments to encourage uptake, in line with Cassaburi and Willis (2016). The index-based insurance product with delayed premium payments is promoted and offered via farmer groups (called Garees in Ethiopia). The promotion via the farmer groups aims to improve knowledge about, as well as trust in, the product. It also ensures that serious default problems remain limited, as has been suggested by Belissa et al. (2018).[2] Thus, we (partly) address the recommendation by Karlan et al. (2014) by not simply bundling rainfall insurance with loans, but also by changing delivery channels and by trying to improve trust in the product.

Our experiment shows, in line with Belissa et al. (2018), that the uptake of index-based insurance will increase substantially if the product is promoted via farmer groups and if premium payments are postponed. The uptake will even be further boosted if the new product is bundled with credit and input purchasing options.

[1] Note, however, that defaults are still possible due to side selling.

[2] Note that, unlike Dercon et al. (2014), we do not sell insurance to social groups. Dercon et al. (2014) examine the relevance of selling index insurance to social groups in Ethiopia (in their case to so-called Iddirs). In our study, farmers have to purchase index insurance individually at co-ops, but the product is marketed by Garee leaders.

Our most important result is that access to the new index-based insurance product alone does not significantly improve adoption of new technologies, as compared to the standard index-based insurance product, while the bundling of the new product with credit and/or inputs has a significant effect. While we cannot prove what drives this result, it strongly suggests that a wider adoption of improved technologies in rural areas in Africa will not be achieved by only providing access to index-based insurance, even if the conditions of purchasing index-based insurance are favorable. Access to credit, and access to input suppliers seem to be as important. Smallholders normally do not have easy access to credit, and often lack liquidity to buy inputs. Moreover, even if they have enough liquidity, smallholders are regularly unable to buy improved technologies, as input suppliers are often unavailable. A properly designed system of bundling insurance with credit and inputs that strengthens the agricultural value chain may therefore be the way forward to improve productivity in the agricultural sector.

The rest of the paper is organized as follows. Section III describes our intervention and randomization strategy. Section IV presents the balancing tests to check whether the randomization has worked. Section V explains our estimation strategy and presents the main results. Section VI discusses impact effects and section VII concludes the paper.

III. Intervention and randomization strategy

A. Sample and randomization

We conducted our experiment with a local insurance company, Oromia Insurance Company (OIC), in the Rift Valley zone of Ethiopia. In the Rift Valley zone we randomly selected two kebeles[3], Desta Abjata and Qamo Garbi. Then, from the two kebeles, we randomly selected 47 farmer groups, called Garees in Ethiopia. The baseline study was undertaken in May 2017; during the following two months, we implemented the training (June) and the experiment (July); while the end-line study was conducted in August 2018. To avoid ethical issues and to mitigate spillover effects, we used a cluster randomization to randomly assign the 47 Garees into four groups: T1, T2, T3 and T4 (to be explained below). All household heads from the 47 Garees (in total 1661) are part of our experiment; all of them are farmers. Nobody is member of more than one Garee. The sample composition is summarized in Table 1:

Table 1: Sample and Group composition

Group	Number of farmers	Number of Garees	Min/Max farmers in Garee	Mean/Median farmers in Garee
T1	420	11	15/56	38/35
T2	420	12	19/57	35/36
T3	401	12	27/40	33/34
T4	420	12	19/63	35/35
Total	1661	47	15/63	

Source: All data shown in tables was obtained from Authors' calculations.

The randomization resulted in three groups with 12 Garees (T2, T3 and T4) and one group with 11 Garees (T1). The number of farmers per Garee fluctuates between 15 and 63. The distribution of farmers over Garees differ a little bit per treatment group. However, the median of farmer numbers per Garee for the various treatment groups is similar: it varies between 34 for T3 and 36 for T2.

[3] A kebele is the lowest administrative unit in Ethiopia.

B. Explanation of the various groups

We randomly determined four groups, T1, T2, T3 and T4. T1 is the "control" group in the sense that this group did not get any specific treatment (or encouragement, or training). However, we were not allowed to impede T1 farmers from buying the standard index-based insurance from Oromia Insurance Company (OIC). In other words, T1 refers to the group who has access to the standard index-based insurance of OIC but nothing else.

T1: Control group, with access to the standard index-based insurance

Oromia Insurance Company offers a standard index-based insurance called Vegetation Index Insurance (VICI), which is accessible by smallholder farmers in the study area. The product is designed based on the intensity of vegetation cover or greenery on the earth's surface. The greenery level is measured by a satellite indicator: normalized difference vegetation index (NDVI)[4]. The NDVI is extracted at a geospatial resolution of 1 km × 1 km. The VICI is based on average NDVI over 16 years. Actual decal NDVI data for a given period is calculated for a set of households grouped in a one-crop production system (CPS) zone. The NDVI compiled for grids of 1 km × 1 km will then be arranged in percentile ranges from 1 to 20, 25 and 50, which will provide benchmark values for trigger and exit index points. It is assumed that uptake gradually increases and that therefore more risks can be pooled across areas with greater geo-spatial variations,

[4] NDVI is measured through images obtained from a geo-satellite weather infrastructure (the GeoNetCast System). The system enables to determine whether the observed area contains live green vegetation or not. The data from these images are converted into digital numbers (DN-values), i.e. Integers from 0 to 255 creating the NDVI.

so that transaction costs can be reduced. OIC expects that approximately one out of six households who purchased index-based insurance will face losses. Hence, the sum to be insured per policy is given as follows:

$$S_{vici} = \frac{P}{0.15} \quad (1)$$

Per policy, a premium of ETB[5] 100 needs to be paid to OIC. The insurance payout depends on the maximum sum insured and is determined according to the level of the NDVI. OIC uses the following system. Let T, E and A represent trigger, exit and actual parametric values of the NDVI index. Then, the amount of payout in each insurance period is calculated for individual VICI buyer smallholders as follows:

$$I_{vici} = \left(\frac{T-A}{T-E}\right)\left(\frac{P}{0.15}\right) \quad (2)$$

To determine insurance payouts, OIC uses a linearly proportional indemnification (LPI) approach. For instance, for a single insurance policy (most smallholders only buy one policy) with premium of ETB 100, the payout for a complete loss is 100/0.15, which is about ETB 667. In areas where the index indicates a 50% loss, a partial payout of ETB 333.5 is paid per policy.

T2: Newly developed index-based insurance, which offers a delayed premium option plus marketing via Garees

Farmers randomized in group T2 have access to a newly developed index-based insurance. This newly developed (maximum delay is 6 months) index-based insurance differs from the standard index-based insurance of OIC in this way:

[5] ETB (Ethiopian Birr), 1 USD = 27 ETB

farmers receive the option to postpone the premium payment after harvest. The idea is based on Belissa et al. (2018), in which a similar index-based insurance with delayed premium payments was experimented. Belissa et al. (2018) call this insurance an IOU. The premium on the IOU was set at 106 (6% higher than the standard index-based insurance) to control for time preference due to the delay in payment. In case of an insurance payout (bad weather), the premium is simple deducted from the insurance payment (so in case of a full loss, the farmer receives ETB 667 –ETB 106). If there is no insurance payout, a farmer may default on the premium payment. However, strategic default is minimized in several ways. Most importantly, in our current study, the IOU was marketed via farmer groups (Garees), leveraging on peer pressure within the group. In order to use group dynamics, we provided training to Garee leaders of garees randomized in T2 (same holds for garees randomized in T3 and T4, but not for garees randomized in T1). The aim of the training was to explain the details of the IOU and to generate trust in the product and the insurance company, and indirectly to encourage group dynamics to reduce strategic default. The Garee leaders were not financially incentivized to recruit smallholder farmers to buy the IOU, but were asked to explain the product during Garee meetings. Smallholder farmers buying an IOU had to sign a contract, a so-called legal 'promissory note' to guarantee payment of the delayed premium, and thus to minimize defaults.[6] Default possibilities were also minimized by not allowing smallholders to buy more than one IOU policy (but note, almost nobody bought more than one standard policy at the same time ever). Farmers assigned to group T2 (and T3 and T4) who prefer to buy the

[6] In theory defaults are still possible as contracts are sometimes difficult to enforce. However, from the experiment conducted by Belissa et al. (2018) we have learned that defaults will be very low if IOUs are promoted within a group setting (harnessing social capital) and by asking everybody to sign a formal contract.

standard index-based insurance product were able to do so. However, not one farmer decided to do so.[7]

T3 Bundling the newly developed index-based insurance with credit

Farmers randomized in group T3 received the option to buy a bundle, containing the newly developed index-based insurance or IOU (as explained under T2; with a premium of ETB 106) and ETB 200 for credit. The loan could be used for all purposes, and hence not restricted for buying inputs. Farmers have the option either to take-up the bundle or reject it. They were not allowed to separately take the newly developed index-based insurance alone (as in T2) without the credit part. Farmers, however, still had the option to buy the standard index-based insurance product of OIC (but nobody did so). If a smallholder farmer bought the bundle, they had to repay (after harvest) an amount of ETB 106+212 (credit plus interest). In line with the procedure explained above, the repayment is simply deducted from the insurance payout in case of bad weather (thus, in case of a full loss, the farmer receives after harvest ETB 667-ETB 318.

T4 Bundling the newly developed index-based insurance with credit, but also with an input voucher

Farmers randomly received the option to buy an extended bundle: it contains the same ingredients as for T3, but also a voucher worth ETB 300 that can only be used to buy inputs (thus it is like an in-kind credit), and which could be redeemed at the local input supplier offices. The availability of input suppliers was

[7] This reflects preference for the new product (T2) or the bundled product (T3, T4). However, it should be noted that we did not explicitly "market" the standard product. Thus farmers in T2, T3 and T4 may not have realized that they could buy the standard product as well.

guaranteed by the project members; by writing arrangements with the cooperative units. In line with T3, farmers had to accept the entire bundle (newly developed index-based insurance, plus normal credit, plus input voucher), or to buy the standard index-based insurance product. Again, in case of an insurance payout, the total premium (for new index-based insurance, normal credit as well as the input voucher) is deducted from the insurance payout. Thus, in case of a full payout, the farmer receives: ETB 667-ETB 212-ETB 424.

IV. Balancing tests

In order to test whether the randomization 'worked' we conducted balancing tests, by regressing baseline values of several control variables and outcome variables on a constant and treatment group T2, T3 and T4. A significant coefficient for T2, T3 and/or T4 indicates a significant difference from T1. We also present WALD tests to examine whether T2, T3 and T4 differ from each other. Table 3a and 3b present the results. Variable names are explained in Table 2.

As would be expected, for some variables the tests suggest unbalance. This is, for instance, the case for Drought2016, for which T2 differs significantly from T1. However, for the majority of the cases, the regressions suggest balance. Considering that around 5% of the variables will turn out to be unbalanced due to chance, the randomization seems to have worked relatively well.

Table 2: Variable type and definition

Variables	Variable type and definition
Age	Continuous, age of the household head in years
Gender	Dummy, gender of the household head, 1= male headed 0 = female headed
Education (years)	Continuous, household head's level of education in years of schooling
Drought2016	Dummy, drought experience of the household in 2016; =1 if the household experienced drought in 2016
Land size	Continuous, household's land holding, measured in a local unit called qarxi, where 1 qarxi = 0.25 hectares
Loan	Dummy, whether the household bears outstanding loan; 1=if the household bears outstanding loan
Inputs	Continuous, value of household's total investment in high-risk high-return agricultural inputs in ETB
Fertilizer	Continuous, value of household's investment in fertilizer in ETB
Seed	Continuous, value of household's investment in improved seed varieties in ETB
Consumption	Continuous, value of household's weekly food consumption expenditure in ETB
Productivity	Continuous, measured as the ratio of maize yield per land size. Smallholders in the study area dominantly produce maize.

Table3a: Balancing tests

Variable	Age	Gender	Education	Familysize	Drought2016	Landsize
T2	-0.174	0.000	0.812	0.927	0.193**	0.271
T3	-0.086	0.018	0.307	-0.010	0.044	-0.088
T4	1.171	0.014	0.593	0.427	0.036	2.531**
_cons	35.764***	0.862***	3.850***	5.833***	0.040	7.767***
T2=T3	0.94	0.80	0.61	0.30	0.16	0.96
T2=T4	0.25	0.86	0.82	0.60	0.13	0.09*
T3=T4	0.24	0.96	0.71	0.30	0.91	0.02**
N	1661	1661	1661	1659	1661	1661
r2_a	0.002	-0.001	0.006	0.014	0.055	0.041

*p<0.10; **p<0.05; ***p<0.01. . p-values based on Cluster robust standard errors

Table 3b: Balancing tests

Variable	Saving	Loan	Teff	Sorghum	Maize	Wheat
T2	-0.074	-0.160	0.002	-0.148	0.305	0.426
T3	0.141	0.055	0.025	-0.148	1.900	-0.148
T4	0.100	0.007	0.055	-0.143	2.702	-0.307
_cons	0.607***	0.474***	0.000	0.148	16.210***	0.981
T2=T3	0.18	0.09*	0.17	1	0.42	0.49
T2=T4	0.29	0.04**	0.13	0.30	0.32	0.35
T3=T4	0.77	0.68	0.43	0.30	0.77	0.79
N	1661	1661	1661	1661	1661	1661
r2_a	0.029	0.025	0.007	0.006	0.012	0.003

*p<0.10; **p<0.05; ***p<0.01. p-values based on Cluster robust standard errors

Table 3c: Balancing tests

Variable	Inputs	Fertilizer	Seed	Consumption	Productivity
T2	-31.505	-147.924	116.419	33.730	0.220
T3	90.075	47.581	42.494	19.043	0.533
T4	205.836	52.845	152.990*	32.258	-0.236
_cons	1910.369***	1152.464***	757.905***	474.297***	2.555***
T2=T3	0.63	0.16	0.62	0.74	0.48
T2=T4	0.33	0.08*	0.82	0.98	0.24
T3=T4	0.47	0.97	0.12	0.72	0.10
N	1661	1661	1661	1659	1661
r2_a	0.001	0.009	0.001	0.000	0.024

*p<0.10; **p<0.05; ***p<0.01. p-values based on Cluster robust standard errors

V. Uptake of insurance

We estimate the effects of the newly designed stand-alone index-based insurance product (IBI) and the interlinked treatments on IBI adoption decision of the households as follows:

$$Z_{ij} = \tau_0 + \tau_1 T_2 + \tau_2 T_3 + \tau_3 T_4 + \tau_i X_{ij} + \varepsilon_{ij} \quad (3)$$

where Z_{ij} represents the uptake of IBI, τ_0 represents the constant indicating IBI uptake by farmers who only have access to the standard index-based insurance product of Oromia Insurance Company (OIC); the coefficients τ_1, τ_2 and τ_3 measure the increase in uptake due to giving farmers access to the newly developed index-based insurance product (i.e. with delayed premium payment option, and delivered via farmers groups); the newly developed index-based insurance product bundled with credit; and the new insurance product bundled with credit and the input voucher, respectively. X_i is a vector of baseline characteristics and ε_i is an error term.

Table 4 presents regression results for equation (3). The results are based on a linear probability model, with clustered standard errors (at Garee level) to account for the cluster randomization. Uptake of index-based insurance by farmers who only have access to the standard index insurance product equals 8.8%, which is in line with usual uptake of index insurance products offered by OIC. Providing access to a new index insurance product, which is promoted via farmer groups and has a delayed premium payment option, increases uptake enormously, almost by 19%. Bundling the new index insurance with credit or bundling it with both credit and inputs, increases uptake even more, by 25% and 32%, respectively (as compared to uptake of the standard index insurance product).

Table 4: Uptake of IBI

Variable	Uptake	Uptakecontrols
T2	0.186***	0.180***
T3	0.249***	0.253***
T4	0.321***	0.320***
_cons	0.088***	0.152**
Controls	No	Yes
T2=T3	0.00	0.00
T2=T4	0.00	0.00
T3=T4	0.03	0.03
N	1661	1661
r2_a	0.070	0.071

*p<0.10; **p<0.05; ***p<0.01. p-values based on cluster robust standard errors. Included controls in column Uptakecontrols: Baseline values for: Age; Gender; Education; Drought2016; Landsize; Loan; Fertilizer; Seeds and Productivity (we did not include Family size due to the existence of some missing values).

VI. Impact Effects on Investment, Consumption and Productivity

In order to test the impact of the various treatments, we start by presenting our Intention-to-Treat (ITT) estimates, using the following double-difference specification:

$$Y_{it} = \gamma_1 T_{2i} + \gamma_2 T_{3i} + \gamma_3 T_{4i} + \gamma_4 Post_t + \gamma_6 Post_t T_{2i} + \gamma_7 Post_t T_{3i} + \gamma_8 Post_t T_{4i} + \beta X_{it} + \varepsilon_{ijt} \quad (4)$$

where Y_{it} represents a vector of outcome variables (for farmer *i*, in period *t*), including *Inputs* (value of investment in high-risk high-return agricultural inputs: *Seed+Fertlizer*), *Seed* (value of investment in improved seed varieties), *Fertlizer* (chemical fertilizer and pesticide/herbicide), *Consumption* (value of weekly food consumption), and *Productivity.* T_2, T_3 and T_4 are randomization dummies as defined above. X_{it} represents a vector of controls (*Constant, Age, Gender, Education, Drought2016,* and *Landsize*: the variables that turn out to be unbalanced in the balancing tests, excluding the outcome variables). *Post* is a zero-one dummy with 'one' indicating post-treatment. The main coefficients of interest are γ_6, γ_7 and γ_8, indicating the additional (compared to having access to standard index insurance alone) of having access to the new index insurance product; the new product with credit or the new product with credit and an input voucher.

Note that for the ITT analysis, we regress the outcome variables on the randomized groups irrespective of their uptake status. That is, the ITT analysis compares impacts of having access to a particular treatment. Due to the RCT design, simple post-treatment regressions without controls would provide unbiased estimates of the coefficients. However, because of the randomization at the group level, and the implied decrease in power, we prefer double-difference estimates that control for possible remaining sample selection bias due to unobserved variables that do not change over time. We also add controls to reduce remaining endogeneity issues, but also to improve precision. In the appendix we present simple post-treatment regression, as well as double-difference regressions without controls. These estimates provide similar results, especially the double-difference regressions without controls.

Table 5: Post Treatment ITT DD estimates, with controls

Variable	Inputs	Fertilizer	Seed	Consumption	Productivity
Post	320.202***	308.162***	12.040	-0.481	-0.147***
T2	-124.777	-182.120*	57.343	11.020	0.349
T3	87.129	47.222	39.907	14.802	0.539
T4	-187.471	-170.624	-16.847	-2.221	0.163
PostxT2	-99.062*	-10.129	-88.933	40.160***	-0.142
PostxT3	218.717**	36.740	181.976*	54.193***	0.157
PostxT4	647.969***	386.171***	261.798**	96.041***	0.412***
Age	18.027**	10.938**	7.089*	3.081**	0.009
Gender	125.010	259.948**	-134.938	40.395	0.086
Education	9.946	2.653	7.293	0.819	-0.008
Drought	260.489	63.054	197.435	103.232**	-0.409*
Landsize	140.344***	80.253***	60.091**	10.378**	-0.155***
_cons	19.064	-98.851	117.914	241.218***	3.410***
(a)PostxT2=PostxT3	0.01	0.28	0.03	0.00	0.16
(b)PostxT2=PostxT4	0.00	0.00	0.00	0.00	0.00
(c)PostxT3=PostxT4	0.00	0.00	0.54	0.00	0.02
N	3322	3322	3322	3320	3322
r2_a	0.203	0.305	0.079	0.064	0.214

*p<0.10; **p<0.05; ***p<0.01. Double-difference estimates. P-values based on cluster-robust standard errors. Rows (a), (b) and (c) refer to p values of Wald equality tests.

Table 5 shows the results of the double-difference ITT regression. It shows that reported investments in productive inputs (*Inputs*) are significantly higher if farmers have access to insurance interlinked with credit and/or with credit and inputs, as compared to having access to index-based insurance (IBI) alone. Controlling for all covariates, interlinking IBI with credit as well as interlinking IBI with both credit and agricultural inputs, increase total investment in high-risk high-return inputs by ETB 328 and ETB 549, respectively (see Column 2, in Table 5).

It is interesting to consider impacts on inputs disaggregated into fertilizer and improved seeds. Providing farmers access to a new index-based insurance product bundled with either credit or with credit and inputs increases adoption of both seeds and fertilizer. However, it appears that, only if farmers are given access to index insurance bundled with both input voucher and unconditional credit, the increase in purchase of fertilizer is significant, while the increase in purchase of seeds is only significant if the index insurance is bundled with input voucher. The same holds for productivity.

Probably the most important result is that encouraging the uptake of index-based insurance by allowing delayed payments and improving trust does increase adoption of insurance enormously, but it does not significantly improve investment in new technologies, neither does it improve productivity. Access to the new index-based insurance product alone only significantly improves consumption. Probably the new index-based insurance product results in a decrease of precautionary savings without increasing the uptake of new technologies. These results suggest that for a long-term improvement of welfare in the agricultural sector a bundling of insurance with credit is needed, and that insurance alone is not enough.

Finally, we present local average treatment effects (LATE) estimates. The LATE estimates show the additional impact of actual uptake of the newly developed index-based insurance (uptake2), the bundle of new index insurance with credit (uptake3) and the bundle with both unconditional credit and input voucher (uptake4), for the compliers, in comparison to T1.[8] The results refer to 2sls estimates, using the randomization dummies (T2, T3 and T4) as external instruments. As the external instruments are perfectly correlated with the treatment dummies, a double difference specification could not be used. Therefore, we rely on a post-treatment IV regression, with baseline controls. In line with an Ancova specification, we also added the lagged dependent variable. The LATE specification reads as follows.

$$Y_{it} = \gamma_1 uptake_{2i}{}^{p} + \gamma_2 uptake_{3i}{}^{p} + \gamma_3 uptake_{4i}{}^{p} + \gamma_4 Y_{i,t-1} + \gamma_5 X_{it-1} + \varepsilon_{ijt} \qquad (5)$$

Where the superscript p refers to predicted value.

In the appendix we present post-treatment LATE estimates without lagged dependent variable.

Table 6 presents the results. The LATE results are, in terms of significance, very similar to the ITT results. The main difference is that the impacts of actual purchase of compliers are much bigger than the ITTs. Again the main result is that the bundled products significantly increase investment in new

[8] Note that the constant refers to T1; that is, the value of the outcome variable for farmers that have access to the standard index-based insurance product. This implies that coefficients of uptake2, uptake3 and uptake4 reflect the increase in the outcome variable of purchasing the newly developed index-based insurance (uptake 2), buying the bundle of new index insurance with unconditional credit (uptake3) or buying bundle with credit and additional in-kind credit in the form of an input voucher (upatke4) vis-à-vis having access to the standard index-based insurance (and not vis-à-vis purchasing the standard index insurance).

technologies (*Inputs, Fertilizer, Seed*), and *Productivity*, while encouraging stand-alone new index-based insurance, by allowing delayed premium payments and by improving information and trust, only significantly improves consumption. As an increase in productivity, e.g. by an increase in investment in modern technologies, is of utmost importance for long-run agricultural growth and welfare improvements in the agricultural sector, these outcomes strongly suggest that stand-alone insurance is not enough. Rather, our experiment provides strong evidence that bundling insurance with credit is needed. Impacts become even stronger if the bundle also includes an input voucher.

Table 6: Post Treatment LATE estimates, with controls and lagged dependent

Variable	Inputs	Fertilizer	Seed	Consumption	Productivity
uptake2	-479.171	27.384	-202.074	132.534***	0.140
uptake3	685.529**	55.018	606.027*	152.477***	0.659**
uptake4	1460.806***	880.248***	689.652**	221.390***	1.126***
LInputs	0.864***				
LAge	5.435	1.258	2.689	0.036	0.004
LGender	-44.964	159.822	-262.707	2.771	0.131
LEducation	-7.184	-10.102	2.315	-0.676*	-0.004
LDrought	139.855	146.049**	62.251	1.847	-0.829**
LLandsize	28.184*	3.559	17.554	0.729	-0.014*
L.Fertilizer		1.259***			
LSeed			0.555**		
LConsumption				1.059***	
LProductivity					0.943***
_cons	246.126	-157.010*	338.745	-30.379**	-0.076
(a)Uptake2=uptake3	0.00	0.73	0.10	0.01	0.22

(b)Uptake2=uptake4	0.01	0.00	0.00	0.00	0.01
(c)Uptake3=uptake4	0.05	0.00	0.86	0.00	0.07
N	1661	1661	1661	1659	1661
r2_a	0.594	0.834	0.283	0.981	0.875

*p<0.10; **p<0.05; ***p<0.01. 2sls regression. Endogenous variables: uptake2; uptake3; uptake4. External instruments: T2,T3 and T4. *L.* refers to lagged value. P-values based on cluster-robust standard errors. P-values Wald tests given in rows a,b and c.

VII. Conclusion

Adoption of modern technologies by smallholder farmers, particularly in Africa, is a necessary requirement for productivity growth to occur, leading to overall poverty reduction and wellbeing. In this paper, we investigate the role that insurance, credit and agricultural inputs play in encouraging farmers to invest in improved seeds and fertilizer, which can lead to greater farm productivity.

Our experiments in Ethiopia show that uptake of index-based insurance rises when we improve the design of the product by allowing farmers to pay insurance premium after harvest and by delivering the product via trusting farmer groups, which improves information about insurance and boosts trust in it. We also found that uptake is further increased when this type of insurance is bundled with credit and an input voucher.

Most interestingly, our results show that although the newly designed index-based insurance surges uptake, this does not encourage investment in new technologies. While, when the newly designed insurance is bundled with credit (both, unconditional credit and credit in-kind, that is an input voucher), then farmers invest in acquiring better seeds and fertilizer, which results in greater productivity. This is the clearest finding that demonstrates the positive impact of bundling insurance together with credit and inputs, compared to offering farmers insurance alone.

This outcome appears to contradict Karlan et al. (2014), who find that credit is not the binding constraint to investment and who conclude that by delivering insurance through better channels that can raise trust, investment would rise. By contrast, our research shows that credit is clearly a constraint to higher investment in modern agricultural technologies and that insurance alone – even when delivery methods and trust have been improved such as when our newly designed insurance is introduced – does not lead to higher investment.

However, some caveats are important to be acknowledged. Our research does not allow us to determine the impact of credit alone on investment. In other words, our research shows the impact of the package, comprised of credit and insurance together, on investment. It could be that credit alone can lead to higher investment or it could be that insurance is a necessary additional ingredient. But, our research, as it stands at the moment, cannot distinguish between these potential effects.

Also, our experiments bundled credit with the newly designed insurance but it did not bundle credit with the standard insurance product; therefore, we are not able to analyse any potential differences in impact on investment and productivity depending on the type of insurance (although we do not expect a different result). In addition, data about loan repayment and premium payment are not yet available, which could allow us to measure the costs of our intervention. These are worthwhile areas for further research and analysis.

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Appendix A: Alternative ITT and LATE estimates

This appendix presents two sets of alternative ITT estimates, and one set of alternative LATE regressions. Table A1 presents simple post-treatment ITT (OLS) regressions, without controls (we also conducted post-treatment regressions with baseline controls, but they give similar results)

Table A1: Post Treatment ITT estimates

Variable	Inputs	Fertilizer	Seed	Consumption	Productivity
T2	-130.567	-158.052	27.486	74.036	0.078
T3	308.791	84.321	224.470	73.382**	0.690
T4	853.805***	439.017**	414.788**	128.445**	0.176
_cons	2248.598***	1471.564***	777.033***	476.750***	2.417***
N	1661	1661	1661	1661	1661
r2_a	0.033	0.039	0.015	0.017	0.021

*p<0.10; **p<0.05; ***p<0.01. Post treatment estimates. P-values based on cluster-robust standard errors.

The post-treatment results differ somewhat from the DD regressions presented in the main text. However, for both groups of regressions it turns out that T2 is never significant, while T4 is almost always significant.

Table A2 presents double-difference regressions without controls. The results, in terms of significance of the treatment indicators (Post*T2 et cetera), is very much the same as the outcomes presented in the main text.

Table A2: Post Treatment ITT DD estimates (without controls)

Variable	Inputs	Fertilizer	Seed	Consumption	Productivity
Post	338.229***	319.100***	19.129	2.453	-0.138***
T2	-31.505	-147.924	116.419	33.730	0.220
T3	90.075	47.581	42.494	19.043	0.533
T4	205.836	52.845	152.990*	32.258	-0.236
PostxT2	-99.062*	-10.129	-88.933	40.306***	-0.142
PostxT3	218.717**	36.740	181.976*	54.340***	0.157
PostxT4	647.969***	386.171***	261.798**	96.187***	0.412***
_cons	1910.369***	1152.464***	757.905***	474.297***	2.555***
N	3322	3322	3322	3320	3322
r2_a	0.039	0.075	0.011	0.016	0.022

*p<0.10; **p<0.05; ***p<0.01

Table A3: Post Treatment LATE estimates, with controls

Variable	Inputs	Fertilizer	Seed	Consumption	Productivity
uptake2	-846.368	-751.810	-94.559	186.196	1.063
uptake3	908.238	241.096	667.142	204.822**	2.118*
uptake4	1094.430*	451.049	643.381*	225.435**	1.458*
L.Age	19.672**	13.015**	6.658	3.095**	0.009
L. Gender	93.096	351.625**	-258.528	48.129*	0.199
L. Education	6.503	-0.277	6.781	0.372	-0.012
L. Drought	311.302	133.163	178.139	105.283**	-0.826**
L. landsize	144.713***	90.654***	54.059**	10.996**	-0.157***
_cons	303.217	-5.364	308.582	233.490***	3.216***
N	1661	1661	1661	1661	1661
r2_a	0.176	0.240	0.082	0.105	0.095

*p<0.10; **p<0.05; ***p<0.01. *p<0.10; **p<0.05; ***p<0.01. 2sls regression. Endogenous variables: uptake2; uptake3; uptake4. External instruments: T2,T3 and T4.L. refers to lagged value. P-values based on cluster-robust standard errors. P-values Wald tests given in rows a,b and c.

The regressions presented in the appendix provide additional evidence for our finding that, while allowing farmers to postpone premium payment does improve uptake, it does not improve investment in modern agricultural technologies. In order to improve uptake of new technologies and to improve welfare our analysis suggests that it is highly important to combine the insurance product with credit.