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Evaluation of the Effects of Introducing Risk Management Tools in Agricultural Development: PADAER Senegal †

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Abstract: This study aims at analyzing the effects of risk management on the agricultural performance of rural producers benefiting from the joint support of the Senegalese State and FIDA. We use data from a study commissioned by PADAER in 2017. Collection covers two regions of Senegal: Kolda and Tambacounda. After auditing; our sample comprises 1196 producers including 198 beneficiaries of the indexed harvest insurance facilitated by the PADAER. The quasi-experimental method known as the Propensity Score Matching Method is used to determine the impact of subscribing to index-based insurance on the farmer's production, agricultural investments and annual income. Although the results of the estimates show that the project has not yet had any effect on production, without the intervention of this project producers would have recorded a loss of about 57,600 FCFA. Not only did the index insurance based on the harvest facilitated by the PADAER allowed the beneficiary to cover this loss and realize a gain estimated at 12,749 FCFA.

Keywords: index insurance; producers; investment; results; PADAER

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1. Introduction

Agriculture is the engine of development for African countries, as it plays an important role in their economies. In sub-Saharan Africa, agriculture accounts for 30 to 40% of Gross Domestic Product (GDP) and more than 70% of exported products are agricultural (FAO, 2014). In Senegal more specifically, agriculture represents 16.6% of GDP and employs 49.5% of the active population. In addition, 70% of the rural population works on farms and 95% of these farms are family farms (ANSD, 2019). Unfortunately, this flagship sector of the African economy is largely influenced by climatic hazards. Farms are often exposed to various risks because of their vulnerability, which is amplified by the evolution of our environment: climate change, natural disasters, pollution, etc. There are four specific risks in agricultural enterprise: price, agricultural yield (i.e., quantity produced), quality and production cost.

Faced with these multiple risks, public policies propose a toolbox of instruments to limit their effects in order to guarantee food security and improve the standard of living of agricultural entrepreneurs. Risk management tools are essential to enable farmers to anticipate, avoid and respond to shocks. If effective, agricultural risk management systems can safeguard the standard of living of those who depend on agriculture, strengthen

the viability of agricultural enterprises and create conditions that facilitate investment in the sector.

However, while much work has highlighted the positive impacts of insurance on agricultural development in developed countries, few analyses have focused on emerging and developing countries (Faltermeier, 2011). Measuring the effects of agricultural insurance in Africa has so far been made difficult by the lack of synthetic statistical data. This research aims to fill this gap by conducting an evaluation of the effectiveness of the agricultural development and rural entrepreneurship support programme in Senegal by assessing the investment and improvement of living standards of beneficiary farmers in Senegal. The main research questions are:

- Do the insured farmers modify their behavior like increase agricultural investment?
- Does the availability of financial risk management tools affect the use of non-financial (agricultural) risk management practices such as income diversification?
- What is the insurance Uptake Rate?
- What are the main determinants of the decision to take up the insurance?
- What is the effect of index insurance on production and income ?

In this work, we first explain PADEAR program and the theory of change, and then we present the methodology adopted. After the sampling design and the data collection is explained as well the model used. It ends with the results and discussion-conclusion.

2. PADAER Program

In the framework of the R4 Senegal project, the World Food Program (FAO) in partnership with the "*Compagnie Nationale d'Assurance Agricole du Sénégal"* (CNAAS) and other stakeholders, developed several insurance products in Senegal. These products allow the transfer of agricultural risk away from smallholder farmers. The products aim to mitigate the consequences of natural disasters in order to secure farmers' income and assets. FIDA aims to introduce financial risk mitigation as a large-scale agricultural development program in Senegal.

Through the co-financed programs and projects such as PADAER, FIDA also aims to introduce financial weather risk mitigation tools in order to mitigate the consequences of the natural disasters that jeopardize farmers' agricultural income and assets.

In conjunction with the WFP, PADAER integrated the index-based crop insurance into its support package to Producers Organizations in 2015. Information pertaining to the three agricultural seasons is presented in Table 1.

Table 1. Pilot Test index-based insurance years 2015–2018.

	Year 1	Year 2	Year 3
Communes	3	10	10
Producers Organizations	7	36	54
Members	233	636	354
Surface area	252 ha	622 ha	278 ha
Premium paid to the insurer	4,591,683 FCFA (7650 USD)	10,022,744 FCFA (16,700 USD)	6,943,955
Compensation received	12,311,937 FCFA (20,500 USD)	14,962,668 FCFA (24,931.13 USD)	-

Source: ASE, 2017.

In 2015–2016, IFAD pilot tested the inclusion of insurance products to PADAER in seven agricultural Producer Organizations (PO) in the communes of Sinthiou, Maleme, and Koussanar in the department of Tambacounda. As a side note, PADAER only proposed the product to PO's and not to individual farmers.

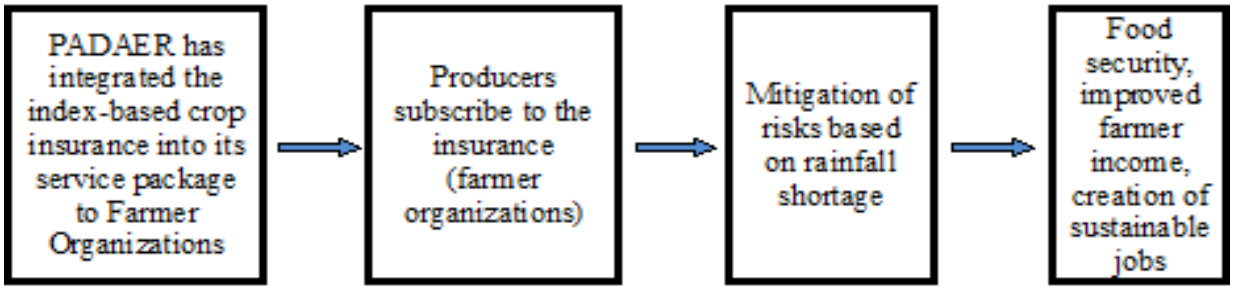
By 2016–2017, this risk transfer component of PADAER's services had been extended to 36 PO's: fifteen PO's in Tambacounda and 21 PO's in Kolda. In total, ten communes were covered. In the ongoing crop growth season of 2017–2018, the insurance covers 54 PO's in the Kolda and Tambacounda regions.

The index insurance product is based on a weather index, which utilizes climate data from satellites and rain gauges from a period of 21 years to produce rainfall estimates. This data is available for all regions in Senegal. The insurance covers risks related to droughts and excessive rainfall and as such is not focused on any particular crop. In detail, the time periods covered by insurance are divided in two phases: Phase 1 provides coverage of 80% of the insured sum during the planting and growth period which takes place from June 21 to July 31. Phase 2 provides coverage of 80% of the insured sum during the flowering phase which takes place from September 11 to October 20. The premium rates are defined by the village (cluster), and each cluster is defined as having a radius of 3 km.

The government in Senegal subsidises 50% of the premium. Furthermore, PADAER offers a tapering subsidy on the remaining amount of the premium. If the PO belongs to the first generation, PADAER offers 90%. For second and third generation PO's, PADAER offers 70% and 50% respectively. When a PO reaches the 4th generation, members are required to pay half of the premium themselves.

3. Intervention Description and Theory of Change

The theory of change (TOC) of index-based crop insurance for PADAER Producer Organizations is as follows:



Presented in this section are the key steps of the index-based insurance implementation process. There are several organizations involved in the index-based insurance implementation process in the areas of Kolda and Tambacounda include PADAER, WFP, CNAAS, SwissRe, ANACIM, PG, IRI, ANCAR, BAMTAARE and the Producer Organizations.

The following steps were identified during program implementation: installation of pluviometers and index design, meetings between PADAER and WFP, trainer training on index-based insurance, producer awareness raising, on training, ensuring census and registration of producers interested in insurance subscription, collection of insurance premiums, PADAER payment of additional premiums, CNAAS commission payment, a field visit to supervise producer activities, a field visit for damage assessment and rainfall-related data collection, field data analysis and validation by CNAAS and the reinsurer, and final compensation to the insured when necessary.

4. Research Methodology

4.1. Data

We obtained some data from the insurance partners or stakeholders like PADAER, CNAAS and WFP in addition to qualitative data in order to analyse the efficiency of the different implementation stages. We also conducted a survey in 2017 to collect quantitative and qualitative data at the member/farmer level with the aim of evaluating the process of implementing index insurance in the PADAER zone. This study was conducted in

the communes of the two regions of Senegal. These are the communes in the regions of KOLDA and TAMBACOUNDA. The data were collected from agricultural producers in the two regions who may or may not benefit from the support provided by the "*Programme d'Appui au Développement Agricole et à l'Entrepreneuriat Rural"* (PADAER), whose aim is to improve food security, sustainably improve the incomes of small producers (farmers and stockbreeders) and create sustainable jobs for rural people, particularly young people and women. This data covers the regions of Kédougou, Kolda, Matam and Tambacounda.

The sample consists of 1196 producers. Beneficiaries of the agricultural insurance facilitated by the PADAER through the POs form the treatment group called here "*insured"* and non-beneficiaries form the control group called here "*non-insured"*. It should be noted that the data was collected with CREA's assistance and covers two agricultural seasons, namely the 2015–2016 and 2016–2017 agricultural seasons. The variables of interest include: socio-economic characteristics, investment variables, income amount and sources, insurance take-up, and access to credit.

4.1.1. Sampling Design

Primarily, we wish that Producer Organizations (PO) benefit from the technical and financial support PADAER offers in addition to of the index insurance. The PO's are located in the two regions of Tambacounda and Kolda and belong to one of the 10 communes covered by index insurance. In the sampling framework, we first selected a PO and then randomly selected 11 respondents from that PO. We created a list of 36 PO's supported by PADAER for index insurance either during the 2015–2017 or 2016–2017 seasons. Those PO's belong systematically to the treatment group. In our context, we considered a treatment PO, one who received support from PADAER at least once for index insurance. During the period of data collection, PADAER had yet to decide whether its support for index insurance would be extended to PADAER PO's in 2017–2018. We then selected 35 PO's to form a potential treatment group, as those POs might receive the treatment or not. We also randomly selected 60 PADAER PO's (30 from each region) to form a control group. Those PO's did not receive support from PADAER index insurance and are not in the list of the potential PADAER PO's that might benefit from PADAER's insurance support for the 2017–2018 season. However, those PO's are located in the communes of index insurance. The sample was comprised of all 36 PO's with index insurance support (treatment group), 35 PO's who might receive index insurance support in 2017–2018 (potential treatment group) and 60 PO's without index insurance support from PADAER (control group). This amount totaled 131 PO's in total and in each PO we randomly interviewed 11 farmers, resulting in a sample size of 1196.

4.1.2. Survey in Tambacounda and Kolda

We administered two (2) questionnaires: (1) a household questionnaire and (2) a questionnaire administered to the PO leader (facilitator). All the questionnaires were administered with participant's consent. We asked questions related to the knowledge of index-based insurance and the payout modalities per season, total area cultivated (ha), total area insured (ha), and in the case that there was a difference between the two areas to provide us with those. Other questions included: Why did you buy the insurance premium? What is the crop produced, crop insured, per speculation total production (kg), investment (FCFA), sales (FCFA), did you receive an indemnity? What was the total amount of the pay-out (FCFA)? Are you planing to susbcribe to the index insurance for the coming season? We also asked questions related to the process and farmer perceptions regarding it: What do you think about the subscription period? Is it the best period for you to pay the premium? Do you have any suggestions about the period? What do you

think about the pay-out period? What do think about the price of the premium? Is it affordable? Without the PADAER subsidies, would you be able to pay the insurance premium?

4.2. Impact Assessment of Public Policies

Development policies and programmes are generally designed to improve the well-being of the population. In recent decades, governments and technical and financial partners have been working to find out whether the changes hoped for have actually occurred, in order to replicate good practices and correct shortcomings (Gertler et al., 2011).

Thus, policy and programme evaluation is an important vector in the development process, identifying changes in the well-being of individuals that can be *attributed to* a particular project, programme or policy. The concept of attribution is at the heart of impact assessments. Impact evaluations generally aim to estimate the *average* impact of a programme on the well-being of beneficiaries. They answer the question: *what is the impact (or causal effect) of a programme on a given outcome?* (Gertler et al., 2011).

In Senegal, the government subsidises 50% of the premium. In addition, PADAER offers a degressive subsidy on the remaining amount of the premium. If the PO belongs to the first generation, PADAER offers 90%. For second and third generation POs, PADAER offers 70% and 50% respectively. When a PO reaches the fourth generation, members are required to pay half of the premium themselves.

There are several ways of answering this question. These methods can be grouped into two main categories: experimental methods, the *gold* standard of impact assessment methods, and quasi-experimental methods (*non-experimental according to other authors*). The choice of a method depends on the context of the study and the means available. Even if researchers agree that none of the methods is perfect, experimental methods or Randomised Controlled Trials present the best results given their statistical properties (Gertler et al., 2011).

In this study we use a quasi-experimental method, because firstly, we use secondary data, secondly, there is no baseline study that provides information on beneficiaries and comparison groups before the implementation of the programme and thirdly, the selection is not random. The decision whether or not to take out agricultural insurance is left to the agricultural entrepreneurs, and is therefore strictly voluntary.

The impact of a programme is conceptually the difference in the outcome for the same person when he or she benefits from a programme and does not benefit from it. However, it is obviously impossible to observe the same person at the same time in two different scenarios. In our case, the benefit effect of the insurance facilitated by the PADAER is defined as the difference *between what happens to an agricultural entrepreneur after the programme and what would have happened to him or her in the absence of the programme*. An immediate consequence of this definition is that the treatment effect is never directly observable, since the second term of the gap "*what would have happened in the absence of the program" did not* occur. The same person cannot, at a given date, have benefited from support and not have benefited from it. This is the fundamental problem of counterfactual impact assessment: to estimate the effect of a treatment, it is not enough to follow the entrepreneur after the treatment, it is also necessary to reconstruct what the trajectory of the same entrepreneur would have been on the same dates in a hypothetical situation, the *counterfactual situation* where he would not have benefited from the treatment. To solve this problem, it is necessary to find individuals who, although comparable in all respects to the individuals treated, were not treated. If there is an entrepreneur who is exactly similar to the one receiving support from the PADAER programme, the choice not to participate in the programme would result in the *unobserved characteristics such as* motivation, belief, for example, or that the selection rules have been modified because of the applicant's proximity to the PO or because bribes were offered. This is referred to as *selection bias*.

As a result of these biases, the impact cannot be measured by directly comparing the situation of individuals receiving support from PADAER with that of non-beneficiaries. To limit the consequences of these biases in the measurement in the present study, two methods were used: the selection model on observable and the selection model on unobservable.

4.3. The Selection Model on Observable: Matching Method on the Propensity Score

Initially introduced by Rosenbaum and Rubin in 1983 in their article entitled '*The central role of the propensity score in observational studies for causal effects*', the propensity matching score (PSM) makes it possible to measure impact by comparing the situation of individuals with the same observable characteristics. Its interest lies in the fact that it does not rely on overly burdensome assumptions of modelling in selection, which is less costly and easy to carry out (Khandker, 2009).

It is based on two assumptions, namely:

- The conditional independence hypothesis or *CIA*, which means that selection bias can be controlled if there is a set of observable variables for which an independence of assignment to treatment can be verified (Khandker, 2009).
- The common support hypothesis, relating to the support of the propensity score distribution. This hypothesis ensures that individuals with the same set of covariates can be both treated and untreated, or, in other words, that the individuals in each analysis group are similar enough to make the comparison meaningful (Khandker, 2009).

4.4. Estimate Propensity Score

4.4.1. Assignment to Treatment

Different classical methods can be used to describe the assignment to treatment, such as tests of comparison of means (*student test or ANOVA*), tests of comparison of distribution (chi-square) or a series of univariate and multivariate logistic regressions.

The objective of this preliminary step is to identify the variables that could potentially be included in the construction of the propensity score.

In the framework of this study, we already distinguish between the two groups concerned by the subscription or not to the agricultural insurance facilitated by the PADAER. Insured producers make up the *treated group* and the uninsured form the *control group*.

4.4.2. Formalization of the Model

Access to the programme (agricultural insurance) is represented by a random variable T for each individual i,

$$\begin{cases} T_i = 1 \ if \ the \ individual \ insured \\ T_i = 0 \ otherwise \end{cases}$$

The effectiveness of agricultural insurance intervention would be measured by two latent outcome variables

$$\begin{cases} Y_i^1 \ if \ the \ individual \ is \ insured \ T = 1 \\ Y_i^0 \ otherwise \ T = 0 \end{cases}$$

These two variables correspond to the potential outcomes of the programme. They are never simultaneously observed for the same individual. For an individual being treated, Y_i^1 is observed while Y_i^0, is unknown. In this case, the variable $Y^0{}_i$ corresponds to the result that would have been obtained if the individual had not been treated (counterfactual). For an untreated individual, on the contrary, we observe Y_i^0, while Y_i^1 is unknown.

The observed outcome variable, for each individual, can therefore be deduced from the potential variables and the treatment variable by the relation

$$Y_i = T_i Y_i^1 \quad + \quad (1 - T_i) Y_i^0 \tag{1}$$

Only the couple (Y_i, T_i) is observed for each individual.

The causal effect of the treatment is defined for each individual by the standard deviation

$$\Delta^{ATT} = \quad \mathrm{E} \ (Y_1 - Y_0) \tag{2}$$

This gap represents the difference between what the individual's situation would be if they were treated and what it would be if they were not.

Thanks to hypotheses on the joint law of (Y_0, Y_1, T), it is possible to identify certain parameters of the distribution of the causal effect from the density of the observable variables (Y, T). Therefore, estimating the insurance effect for each individual is not possible and one must focus on average treatment effects. Two parameters are usually specifically examined:

The average effect of the intervention in the population

$$\Delta^{ATT} = \quad \mathrm{E} \ (Y_1 - Y_0) \tag{3}$$

The average effect of treatment in the population of individuals treated

$$\Delta^{ATT} = \quad \mathrm{E} \ (Y_1 - Y_0 | T = 1) \tag{4}$$

These two parameters are equal only under certain very restrictive assumptions. In particular, if the outcome variables are independent of the treatment access variable, i.e., if $(Y0, Y1) \perp T$, it is possible to identify the two parameters of interest Δ^{ATE} and Δ^{ATT} defined in advance. Indeed, if this (sufficient) condition is met, (3) and (4) become:

$$\Delta^{ATE} = \Delta^{ATT} = \quad \mathrm{E} \ (\ Y_1 | T = 1) - \quad \mathrm{E} \ (Y_0 | T = 1) \tag{5}$$

Once the previous independence property is no longer satisfied, using the mean score of untreated individuals $E\,(Y_0 | T = 0)$ is not a good idea in non-experimental studies because it is more likely that the elements that determine the treatment decision also determine the outcome variable of interest. Thus, the outcomes of individuals in the treatment and control group will differ even in the absence of a treatment that gives rise to selection bias. Indeed, in this case, the natural estimator formed by the difference in the means of the outcome variables is affected by selection bias.

$$\mathrm{E}(Y|T = 1) - \mathrm{E}(Y|T = 0) = \mathrm{E}(Y_1|T = 1) - \mathrm{E}(Y_0|T = 0)$$
$$= \mathrm{E}(Y_1|T = 1) - \mathrm{E}(Y_0|T = 1) + \mathrm{E}(Y_0|T = 1) - \mathrm{E}(Y_0|T = 0)$$
$$= \mathrm{E}(\mathrm{Y}_1|\mathrm{T} = 1) - \mathrm{E}\,(\mathrm{Y}_0|\mathrm{T} = 1) + \mathrm{E}\,(\mathrm{Y}_0|\mathrm{T} = 1) - \mathrm{E}\,(\mathrm{Y}_0|\mathrm{T} = 0)$$
$$= \Delta^{ATE} + B^{ATE}$$

where B^{ATE} is the selection bias. This bias is caused by the fact that the average situation of individuals who received treatment would not have been the same in the absence of treatment as that of individuals who did not receive treatment. This is because these two populations are not identical except in the particular case of a controlled experiment. Thus, as the counterfactual mean of treated individuals

$E\,(Y_0 | T = 1)$ is not observed, a surrogate must be chosen in order to estimate the mean effect of the treatment on the treated individuals. To do this, two hypotheses are made: the conditional independence hypothesis, CIA, and the common support hypothesis.

4.4.3. Estimating the Propensity Score

When estimating the propensity score, there are two choices to be made: the estimation model to be used and the variables to be included in this model. In principle, any discrete model can be used. However, in comparison with linear probabilistic models, there is a preference for logit or probit models. These models should include all observed variables that influence selection in the treatment as well as the outcome.

We propose to use the logistic regression model for the estimation of the propensity score of a binary variable T.

$$\boldsymbol{\Omega(T) = \{0,1\}}$$

$$\boldsymbol{T = \begin{cases} 1 & \text{if the event occured} \\ 0 & \text{otherwise} \end{cases}}$$

We try to model the probability that *T is* equal to 1 knowing the values of the explanatory variables *X1, X2, X3, Xn*. The coefficients must then be determined *α, β1, β2, β3, ..., βn* such as

$$\begin{cases} \boldsymbol{logit\big(\pi(X)\big) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n} \\ \textbf{Or } \boldsymbol{logit\ \big(\pi(X)\big) = log\left(\frac{\pi(X)}{1-\pi(X)}\right)} \end{cases} \rightarrow \boldsymbol{\pi(X) = \frac{e^{\lambda h(x_i)}}{1+e^{\lambda h(x_i)}}}$$

4.5. Assumptions of the Method

4.5.1. Assumption of Conditional Independence

When one wishes to evaluate a programme using observational (non-experimental) data, one is faced with two populations, beneficiaries and non-recipients, who differ in the distribution of observable individual characteristics that are likely to affect programme participation.

The (unconditional) independence between the latent outcome variables *(Y0, Y1)* and the allocation to treatment *T* is a very unlikely hypothesis. A less restrictive condition is to consider that there is a set of conditionally observable variables *X for* which the independence property between the unrealised results and the allocation to treatment is verified. This is the assumption of independence conditional on observable characteristics.

$$\boldsymbol{(Y0, Y1) \perp T|X}$$

The condition of conditional independence for the identification of Δ^{ATT} is less strong, since it only requires independence between the potential outcome in the absence of treatment and the treatment, i.e.,

$$\boldsymbol{Y0 \perp T|X}$$

4.5.2. Common Support Hypothesis

This assumption ensures that for each unit treated there are control units with the same observed variables.

$$\boldsymbol{0 < P\ (T = 1|X) < 1}$$

For the estimation of Δ^{ATT} this hypothesis is reduced to

$$\boldsymbol{P\ (T = 1|X) < 1}$$

4.5.3. Estimating the Effect of Insurance on Producers Welfare

Under the two hypotheses of conditional independence and common support, in each cell defined by X, attribution to treatment is random and the outcome of control subjects can be used to estimate the counterfactual outcome of treated individuals in the event

of non-treatment. The principle of estimation is to use the information available on untreated individuals to construct a counterfactual for each treated individual.

Let's consider the average effect of the treatment on the treaties:

$$\Delta^{ATT} = \mathbf{E}(\boldsymbol{Y_1} - \boldsymbol{Y_0}|\boldsymbol{T} = \mathbf{1}) = \mathbf{E}(\boldsymbol{Y} - \boldsymbol{Y_0}|\boldsymbol{T} = \mathbf{1})$$

$$= \mathbf{E}[\mathbf{Y} - \mathbf{E}(\boldsymbol{Y}|\boldsymbol{T} = \mathbf{0})|\boldsymbol{T} = \mathbf{1}]$$

$$= \boldsymbol{E_{x|T=1}}[\mathbf{E}(\boldsymbol{Y_1}|\boldsymbol{T} = \mathbf{1}, \boldsymbol{X} = \boldsymbol{x}) - \mathbf{E}(\boldsymbol{Y_0}|\boldsymbol{T} = \mathbf{0}, \boldsymbol{X} = \boldsymbol{x})]$$

The final estimator of Δ^{ATT} is then obtained as the average of the deviations of the situation of the treated individuals and the constructed counterfactual.

$$\begin{cases} \hat{\Delta}^{ATT} = \dfrac{1}{N_1} \displaystyle\sum_{i=I_1} \{y_i - \hat{g}(x_i)\} \\ I_1 \text{ is the sub set of treated individuals} \\ N_1 \text{ is the number of treated individuals} \end{cases}$$

The problem is therefore to estimate, for each individual treated with characteristics x_i, the quantity

$$E(Y_0|X = x_i, T = 0) = g(x_i)$$

To do this, it is sufficient to match each individual treated with the control units that have the same characteristics Xi (matching on variables) or to make the match based on the propensity scores $\pi(X) = P(T = 1 | X)$ *of* the individuals in the two groups (matching on propensity score) and then to estimate $g(x_i)$.

5. Results

5.1. Insurance Uptake Rate

5.1.1. PADAER Indexed Insurance Subscription Rate

The participation of agricultural producers in PADAER's index-linked insurance has started timidly. The take-up rate for the 2015–2016 crop year was 17% (Table 2). This rate rapidly improved from 17% to 32% in one crop year.

For the rest of the analyses, the data from 2016–2017 crop year (the data collection year) were used.

Table 2. Distribution of insurance members by agricultural season.

	Insurance Enrolment 2015–2016		**Insurance Enrolment 2016–2017**	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Not Insured	998	83.44	817	68.31
Insured	198	16.56	379	31.69
Total	**1196**	**100.00**	**1196**	**100.00**

Source: ASE, 2017.

5.1.2. Speculations Covered by Agricultural Insurance in 2016–2017

The products most cultivated in Senegal are: Corn, Rice, Peanut, Millet, Sorghum, beans, Water melon. Analysis of the results of Table 3 reveals that 59% of producers covered their corn crop by agricultural insurance, 66% covered rice crop, 14% covered peanuts crop. 8%, 3%, 1%, 0.53% and 0.26% of producers have respectively their mil, beans, sorghum, watermelon and cotton crops insured.

We see that Corn and rice are the most speculated products. In this paper we will restrict our analysis to these products.

Table 3. Speculations covered by agricultural insurance.

Speculations	Frequencies	Percentage
Corn	225	59.37
Rice	252	66.49
Peanuts	53	13.98
Mil	30	7.92
Sorghum	4	1.06
Beans	10	2.64
Cotton	1	0.26
Water melon	2	0.53

Source: ASE, 2017.

5.1.3. Type of Subscription to Harvest-Based Index Insurance in 2016–2017

Among the subscription modalities available to producers, we have noted that many (85%) have opted for the cash payment method, while only 15% of producers prefer insurance through work. Insurance by work (Assurance Par le Travail, APT) is an innovative approach set up to allow producers who are willing to subscribe, barred by the lack of financial means. APT consist of using part of the harvest to pay for insurance.

In view of this result, we note that, when the producer has the means, they prefer to pay the insurance premiums in cash rather than through the APT.

Table 4. Type of subscription to harvest-based index insurance.

Type of Subscription	Frequencies	Percentage
Insurance per Cash	321	84.92
Insurance by work	**57**	**15.08**
Total	**378**	**100.00**

Source: ASE, 2017.

5.1.4. Area Analysis in 2016–2017

The distribution according to total surface area is the same in the insured group as in the non-insured group and for both products. Both groups are dominated by small producers. Table 5 shows that 45% of farmers who insured their corn field cultivated less than half of hectare of corn while 47% of them who insured their rice field cultivated the same area of rice.

Table 5. Cultivated area.

Cultivated Area	Corn				Rice			
	Unassured		Assured		Unassured		Assured	
	Freq.	Percen	Freq.	Percent	Freq.	Percent	Freq.	Percent
Less than 0.5 ha	205	25.09	172	45.38	349	42.72	179	47.23
between 0.5 ha and 0.99 ha	127	15.54	54	14.25	182	22.28	79	20.84
between 1 ha and 1.49 ha	196	23.99	79	20.84	164	20.07	58	15.30
between 1.5 ha and 1.99 ha	48	5.88	14	3.69	35	4.28	22	5.80
between 2 ha and 3 ha	189	23.13	49	12.93	66	8.08	29	7.65
More 3 ha	52	6.36	11	2.90	21	2.57	12	3.17
Total	**817**	**100**	**379**	**100**	**817**	**100**	**379**	**100**

Source: ASE, 2017.

Cross-analysis of the total and insured area by producers shows that large producers insure less than half a hectare at 52% (Table 6). This acreage proves that producers are not aiming at commercial production but rather at subsistence production. This behaviour

reflects a lack of trust for some and a lack of money for others. But 40% of them insure their entire production, which excludes the lack of trust.

Table 6. Cross-analysis of the total and insured area.

Total Area	Insured Area						
	Less than 0.5 ha	**between 0.5 ha and 0.99 ha**	**between 1 ha and 1.49 ha**	**between 1.5 ha and 1.99 ha**	**between 2 ha and 3 ha**	**More than 3 ha**	**Total**
Less than 0.5 ha	70	0	0	0	0	0	70
	100.00	0.00	0.00	0.00	0.00	0.00	100.00
between 0.5 ha and 0.99 ha	21	48	0	0	0	0	69
	30.43	69.57	0.00	0.00	0.00	0.00	100.00
between 1 ha and 1.49 ha	36	3	75	0	0	1	115
	31.30	2.61	65.22	0.00	0.00	0.87	100.00
between 1.5 ha and 1.99 ha	9	2	1	13	0	0	25
	36.00	8.00	4.00	52.00	0.00	0.00	100.00
between 2 ha and 3 ha	23	1	3	1	47	0	75
	30.67	1.33	4.00	1.33	62.67	0.00	100.00
More than 3 ha	13	0	0	0	2	10	25
	52.00	0.00	0.00	0.00	8.00	**40.00**	100.00
Total	172	54	79	14	49	11	379
	45.38	14.25	20.84	3.69	12.93	2.90	100.00

Source: ASE, 2017.

5.2. Propensity Score Estimation

Table 7 presents the determinants of the decision to take up the insurance during the 2016–2017 cropping season. The result of the Propensity Score estimation shows that education, gender, commune of residence, receiving information from television, lack of money are the factors determining participation in the Index Insurance program facilitated by PADAER.

Table 7. Determinants of participation in index insurance facilitated by the PADAER.

Variables	Pscore	Standard Errors
Sex	−0.185 *	0.0948
Education	−0.256 ***	0.0937
Age	0.00390	0.00333
Kolda	−0.0867	0.432
Wolof		0.202
Communes		
Bagadadji	0.839 *	0.442
Dioula Colon	1.216 ***	0.464
Sare Bidji	0.383	0.470
Sare Yoba Diega	0.146	0.495
Koussanar	1.250 ***	0.193
Maka Colibantang	−1.414 ***	0.344
Sinthiou Malema	0.152	0.238
Tankanto Stopover	0.253	0.474
Tv	0.288 ***	0.0924
Lack of money	−0.417 ***	0.102
Victim of bad rain	0.384	0.234
Well_being	−0.165	0.102

Food	−0.133	0.101
Depend_transf	−0.104	0.136
Nbre_Champ17	0.0210	0.0370
Nb_Source_inc	0.0567	0.0920
Constant	−1.200 ***	0.365

Observations: 1167 ; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; Source: ASE, 2017.

The main lessons that can be drawn from this assessment include the following: the program facilitates women's participation, participation is inclusive and does not hide any social strata. Wolof-speaking producers residing in the communes of Bagadadji, Dioula Colon and Koussanar have a high level of participation in the index insurance facilitated by PADAER, whereas those residing in the commune of Maka Colibantang and lacking money participate less in the program.

5.2.1. Estimating the Effect of Index Insurance on Investment

To estimate the effect of index insurance on investment, we have taken the total investment on the one hand and the investment in Corn and rice on the other. As we can see in Table 8, insurance has no effect on these different investments. There is no specific difference between the investment of the index insured and the non-insured. This is due to the different subsidies the participants have received.

Table 8. Effect of index insurance on investment.

Variables	Total Investment	Investing In Corn	Investment In Rice
ATT	10,210	3778	−299.7
	(6342)	(2962)	(2231)
Constant	77,915 ***	31,939 ***	13,985 ***
	(3556)	(1706)	(1176)
Observation	1167	970	561

Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; Source: ASE, 2017.

In fact, most of the producer organisations that took part in this programme are first-generation organisations, and they only had to pay 10% of the insurance premiums. This explains the fact that the expenses of the insured and the uninsured do not differ significantly.

5.2.2. Estimating the Effect of Index Insurance on Production

The estimate of the effect of index insurance on production is found to be insignificant. This result is not surprising in view of the areas sown by the insured (Table 9).

Table 9. Effect of index insurance on production.

Variables	Corn	Rice
ATT	−79.12	−196.8
	(49.60)	(375.5)
Constant	302.4 ***	407.1 *
	(27.81)	(210.6)
Observations	1167	1167

Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; Source: ASE, 2017.

5.2.3. Estimating the Effect of Index Insurance on Income

To estimate the effect of index insurance facilitated by PADAER, we used total household income, agricultural income, income from Corn and rice and finally income from Corn and rice plus insurance benefits.

The result shows us that insurance has no effect on total household income and the effect on agricultural income is −57,600 FCFA (Table 10). This result shows that the agricultural income of the beneficiaries is in deficit.

Table 10. Estimating the effect of index insurance on income.

Variables	Total Income	Farm Income	Income from Corn and Rice	Income from Corn, Rice and Compensation
ATT	729,970	−57,600 ***	6178	12,749 ***
	(554,736)	(21,920)	(4838)	(4461)
Constant	401,744	103,906 ***	4049	3603
	(311,088)	(12,293)	(2661)	(2502)
Observations	1167	1167	1021	1167

Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; Source: ASE, 2017.

When asked about the source of this shortfall, we estimated the effect of the insurance on income from Corn and rice on the one hand, and on income from Corn and rice plus the amount of compensation on these grains on the other. The result of this estimation shows that this deficit comes from other sources. The insurance has no effect on the gross cereal income of the insured, the better it increases the net income (Corn and rice cereal income increased) by 12,749 FCFA.

6. Discussion

The demand for insurance based on the harvest index facilitated by the PADAER is approximately 17% in the first season of its introduction and 32% in the second season. One of the reasons for this failure is that individuals forget or underestimate bad events (Skees et al., 2008) or smallholders disqualify themselves and think that index insurance is a class issue.

The most speculated products are maize and rice, two Senegalese staple foods, to the detriment of annuity products. The main reason for this choice lies in the desire of producers to guarantee food security while securing cash crops could increase agricultural income. Taking into account the acreage cultivated by the beneficiaries of this insurance, the program has affected more small farmers who produce for survival. In reality, 80% of producers benefiting from index insurance cultivate an area of less than 1.5 ha for maize and 83% for rice producers. This trend is even more confirmed if we consider the insured area since few producers secure the entire production.

The estimated effect of index insurance on investment is statistically insignificant. At first glance, this result is inadmissible because in addition to traditional investments, insurance premiums are increasing. But when we look at the mechanism put in place to facilitate the access of low-income farmers to participate in index insurance, this result is quite conceivable. In reality, this insurance benefits from a double subsidy. A 50% subsidy from the Senegalese State and most of the second part is taken into account by FIDA through PADAER. This IFAD subsidy varies from 50% to 90% of the second half. If the PO belongs to the first generation, PADAER offers 90% of the second half of index insurance premiums. For second and third generation POs, the PADAER offers 70% and 50% of the balance respectively. It is from the fourth generation onward that PO members will pay half of the insurance premium. At the time of data collection of this study, almost all of the insured producers belonged to the first generation bearing about 5% of the index insurance premium.

The estimate of the effect of index insurance on production is statistically insignificant. The analysis of the cultivated and insured areas shows that the insured producers are "smallholders". Cross-analysis of total and insured acreage of corn producers shows that there is no significant difference between insured and non-insured producers. Aditya et al. (2018) had also reported similar findings that impact of crop insurance purchase on farm income, production expenses and productive investments in agriculture are inconclusive in India. So, the results on the impact of insurance are not conclusive to prove that insured farmer subsumes higher risks compared to the uninsured.

The effect of index insurance facilitated by the PADAER shows us on the one hand that insurance has no effect on total household income. This result is in line with the one of Zhao et al. (2012) who shown that crop insurance program did not lead to a significant increase in farmers' income. On the other hand, the effect of index insurance facilitated by the PADAER on farm income is −57,600 FCFA. This result reflects the fact that the beneficiaries' agricultural income is in deficit. Results of earlier study support our findings that the impact of insurance use on three economic performance indicators of cropping farms (profit, labour productivity and land productivity) is significant but negative (Spörri et al. 2012). Hastily, we can conclude that insurance products can be replaced by another alternative for risk management. But according to Skees, (2008), index insurance is an innovation that circumvents many of the fundamental problems that hamper the development of insurance for weather risks in lower income countries. Sowhen asked the source of this deficit, we estimated the effect of the insurance on the income from maize and rice on the one hand and on the income from maize and rice increased by the amount of the indemnities on these cereals on the other hand. The result of this estimation shows that this deficit comes from other sources. The insurance has no effect on the gross cereal income of the insured, the better it increases the net income (maize and rice cereal income increased) by 12,749 FCFA. Rola and Aragon (2013), had also reported similar findings that in Philippines, the amounts of farmers' income losses were significantly reduced as a result of the sample farmers' participation in the Rice Insurance Program. So, without the compensation, insured producers would lose an average of 57,600 FCFA on their farm income. Not only does the index insurance facilitated by PADAER compensate for this loss, it also allows the insured to earn an average of 12,749 FCFA per insured hectare.

7. Conclusions

Index insurance based on the harvest facilitated by PADAER is an extremely promising solution for improving the lives of populations for whom climatic events can decide their destiny. However, it is not yet a panacea for poverty reduction. Even its impact on agricultural income has yet to be determined. It ensures food security, thus enabling producers who are victims of climatic hazards to combine famine and lack of food in the past. Its success requires a lot of work, intense reflection and excellent management. With the help of governments and donors, the infrastructure can be developed to create stable data and a rational market for index insurance. Once the framework is in place, private insurers can step in to expand the market through existing distribution networks, and to stabilize risk through objective standards and reinsurance. Ultimately, index insurance cannot be reduced to a profitable industry; it can help governments to make better choices in poverty reduction and risk management.

Interested governments and donors should begin by training and educating key actors in the concept of index insurance. Private insurers should start by developing relationships with existing distribution networks. These steps will lay the foundation for a functioning market.

Institutional Review Board Statement:

Informed Consent Statement:

Data Availability Statement:

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