

Article

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

Alice Bonou ^{1,*} , Markus Olapade ², Alessandra Garbero ³ and Leonard Wantchekon ^{4,5}

¹ Ecole d'Agrobusiness et de Politiques Agricoles, Université Nationale d'Agriculture, Porto-Novo 01 BP 55, Benin

² Center for Evaluation and Development, D-68161 Mannheim, Germany

³ International Fund for Agricultural Development, 00142 Rome, Italy

⁴ University of Princeton, Princeton, NJ 08544, USA

⁵ African School of Economics, Abomey-Calavi, Cotonou 02 BP 372, Benin

* Correspondence: albonou@gouv.bj

Abstract: This study aims to assess the effects of risk management tools on the agricultural performance of rural producers benefiting from the joint support of the Senegalese state and the International Fund for Agricultural Development (IFAD) through the co-financed project PADAER. Data collection covers two regions in Senegal: Kolda and Tambacounda. The sample comprises 1167 farmers, including 379 beneficiaries of the index-based insurance facilitated by PADAER (Programme d'Appui au Développement Agricole et à l'Entreprenariat Rural). The quasi-experimental method known as the propensity score matching method was 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, farmers would have recorded a loss of about USD 115 (FCFA 57,600). Not only did the index-based insurance for the harvest facilitated by the PADAER allow the beneficiary to cover this loss and realize a gain estimated at USD 25 (FCFA 12,749), but the added value of this paper is that it measures the effects of agricultural index-based insurance in Africa using real-world statistical data.



Citation: Bonou, A.; Olapade, M.; Garbero, A.; Wantchekon, L. Evaluation of the Effects of Introducing Risk Management Tools in Agricultural Development: The Case of PADAER Senegal. *Agriculture* **2023**, *13*, 989. <https://doi.org/10.3390/agriculture13050989>

Academic Editor: Bin Gao

Received: 14 August 2022

Revised: 8 September 2022

Accepted: 10 September 2022

Published: 29 April 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Keywords: index-based insurance; risk management; agriculture; investment; propensity score matching; Senegal

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 30–40% of the gross domestic product (GDP), and more than 70% of exported products are agricultural [1]. In Senegal specifically, agriculture represents 16.6% of the 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 [2]. 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 the environment: climate change, natural disasters, pollution, etc. [3]. Faced with these multiple risks, public policies propose a toolbox of instruments to limit their effects to guarantee food security and improve the standard of living of agricultural entrepreneurs.

There are four specific risks in an agricultural enterprise: price, agricultural yield (i.e., quantity produced), quality, and production cost [4,5]. Risk management tools are essential to enabling farmers to anticipate, avoid and respond to shocks [6,7]. 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 [8].

However, while much work has highlighted the positive impacts of insurance on agricultural development [9–12], few analyses have focused on index-based insurance in emerging and developing countries [6]. The work in [13] shows how index-based livestock insurance (IBLI) provides considerable risk coverage, as opposed to offering households access to a lottery. The authors of [14] assessed the impact of insurance on land productivity. As there are three economic performance indicators of cropping farms—profit, labor productivity, and land productivity [15]—it is important to assess the impact of crop insurance on profit and income to enhance the literature. Indeed, measuring the effects of agricultural index-based insurance in Africa has thus far been made difficult by the lack of real-world statistical data. This research aims to fill this gap by conducting an evaluation of the effectiveness of an agricultural development and rural entrepreneurship support program in Senegal and assessing its impact on the living standards of beneficiary farmers in Senegal.

The project evaluated is PADAER (Programme d’Appui au Développement Agricole et à l’Entreprenariat Rural) which was meant to support the introduction of financial risk mitigation in Senegal. To this end, the International Fund of Agricultural Development (IFAD), through PADAER, integrated weather index-based crop insurance into a support package for producer organizations (POs) in 2015. The project was implemented by the Ministry of Agriculture. In Senegal, at that time, the government subsidized 50% of the index insurance premium. In addition, PADAER offered a degressive subsidy on the remaining amount of the premium. If the POs belonged to the first generation, PADAER offered 90%. For second- and third-generation POs, PADAER offered 70% and 50%, respectively. When a PO reached the fourth generation, members were required to pay half of the premium themselves. In reality, this insurance provided a double subsidy, namely a 50% subsidy from the Senegalese state, and most of the second part is taken into account through PADAER.

The main research question can be stated as follows: what is the effect of the PADAER insurance program on farmer performance, as measured by production, investment, and income?

The specific research questions are as follows:

- Do the insured farmers modify their behavior, such as increasing agricultural investment?
- What is the insurance uptake rate?
- What are the main determinants of the decision to take up insurance?
- What is the effect of index insurance on production and income?

In this paper, we first explain PADAER (Programme d’Appui au Développement Agricole et à l’Entreprenariat Rural) and the theory of change, and then we present the methodology adopted. We end with the results, followed by a discussion and conclusions.

2. Materials and Methods

2.1. Impact Assessment of Public Policies

Development policies and programs 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 expected changes have occurred to replicate good practices and correct shortcomings [16].

Thus, policy and program evaluation serve as an important vector in the development process, identifying changes in the well-being of individuals that can be attributed to a particular project, program, or policy. The concept of attribution is at the heart of impact assessments. Impact evaluations generally aim to estimate the average impact of a program on the well-being of beneficiaries. They answer the following question: what is the impact (or causal effect) of a program on a given outcome [16]?

There are several ways to answer 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 are perfect, experimental methods or randomized controlled trials present the best results given their statistical properties [16].

In this study, we use a quasi-experimental method because first of all, no baseline study provides information on beneficiaries and comparison groups before the implementation of the program, and secondly, the selection into the insurance program PADAER is not random. The decision of whether or not to take out agricultural insurance is left to the agricultural entrepreneurs and is therefore strictly voluntary.

The impact of a program is conceptually the difference in the outcome for the same person when he or she benefits from a program and does not benefit from it. However, it is impossible to observe the same person at the same time in two different scenarios. In our case, the effect of the insurance facilitated by the PADAER is defined as the difference between what happens to an agricultural entrepreneur after the program and what would have happened to him or her in the absence of the program. 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 the 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 or she 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, the choice not to participate in the program would result in unobserved characteristics such as motivation and belief, for example, or the selection rules have been modified because the applicant’s proximity to the producer organization (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 can be used: the selection model on the observable and the selection model on the unobservable. In this study, the first method is used: The selection model on observable, with the matching method on the propensity score.

Initially introduced by the authors of [17] 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 modeling in the selection, which is less costly and easy to carry out [18]. This is based on two assumptions:

- The conditional independence hypothesis or assumption (CIA), means that selection bias can be controlled if there is a set of observable variables for which independence of assignment to treatment can be verified [18].
- There is a 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 [18].

2.2. Programme d’Appui au Développement Agricole et à l’Entreprenariat Rural (PADAER)

In the framework of the R4 Senegal project, the World Food Program (WFP), 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 to secure farmers’ income and assets. To support the introduction of financial risk mitigation, IFAD supported the government’s

aims through the co-financing of programs and projects such as PADAER, implemented by the Ministry of Agriculture. In conjunction with the World Food Program (WFP), PADAER integrated index-based crop insurance into its support package for producer organizations (POs) in 2015.

In 2015–2016, the PADAER pilot tested the inclusion of insurance products in seven agricultural producer organizations (POs) in the communes of Sinthiou, Maleme, and Koussanar in the department of Tambacounda. As a side note, PADAER only proposed the product to producer organizations (POs) and not to individual farmers. The project aimed at supporting agricultural development and rural entrepreneurship through interventions capable of improving farmers' ability to produce, store, and sell agricultural products. An index-based insurance was developed and proposed to POs. Consequently, farmers were granted access to inputs and PADAER's traditional services including seeds, fertilizer, pesticides, farming equipment, agricultural extension services, and a financial weather risk management tool.

By 2016–2017, this risk transfer component of PADAER's services had been extended to 36 POs: 15 POs in Tambacounda and 21 POs in Kolda. In total, 10 communes were covered. In the cropping season of 2017–2018, the insurance covered 54 POs in the Kolda and Tambacounda regions. The index insurance product is based on a weather index, which uses climate data from satellites and rain gauges from a period of 21 years to produce rainfall estimates. These data are 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 periods covered by insurance are divided into two phases. Phase 1 provides coverage of 80% of the insured sum during the planting and growth period, which takes place from 21 June to 31 July. Phase 2 provides coverage of 80% of the insured sum during the flowering phase, which takes place from 11 September to 20 October. The premium rates are defined by the village (cluster), and each cluster is defined as having a radius of 3 km.

2.3. Intervention Description and Theory of Change

The theory of change (TOC) of index-based crop insurance for PADAER producer organizations is as follows (Figure 1).

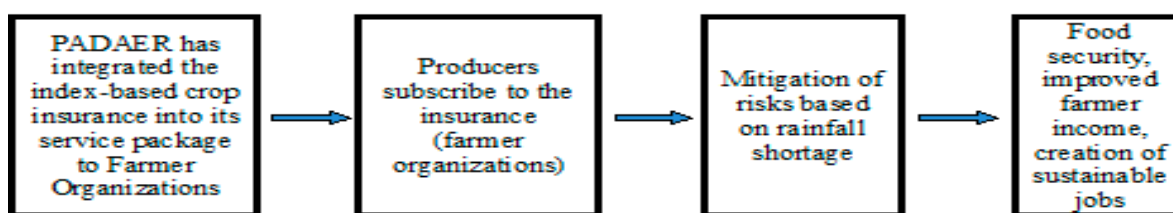


Figure 1. Theory of change (TOC).

This section presents 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, which include PADAER, WFP, CNAAS, SwissRe (Compagnie de Réassurance de le CNAAS), Agence Nationale de l'Aviation Civile et de la Météorologie (ANACIM), Planet Guarantee (PG), the International Research Institute for Climate and Society (IRI), Agence Nationale du Conseil Agricole et Rural (ANCAR), Base d'Appui aux Méthodes et Techniques pour l'Agriculture, Les Autres Activités Rurales et l'Environnement (BAMTAARE), and the producer organizations (POs).

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, raising producer awareness of training, conducting census and registration of producers interested in insurance subscription, the 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.

2.4. Data

Quantitative data were obtained from the insurance partners and stakeholders, such as PADAER, CNAAS, and WFP, in addition to qualitative data to analyze the efficiency of the different implementation stages. A survey was conducted in 2017 to collect quantitative and qualitative data at the farmer level with the aim to evaluate the process of implementing index insurance in the PADAER zone. This study was conducted in the communes of two regions in Senegal. These are the communes in the regions of Kolda and Tambacounda. Data were collected from farmers in the two regions who may or may not benefit from the support provided by PADAER, whose aim is to improve food security, sustainably improve the income of small farmers and create sustainable jobs for rural people, particularly young people and, women.

The sample consisted of 1167 producers. Beneficiaries of the agricultural insurance facilitated by PADAER through the POs comprised the treatment group, called the “insured” here, and non-beneficiaries formed the control group, called the “non-insured”. It should be noted that the data were collected with the assistance of the Centre de Recherches Économiques Appliquées (CREA) and covered two agricultural seasons, namely the 2015–2016 and 2016–2017 agricultural seasons. The variables of interest included socio-economic characteristics, investment variables, production variables, income amount and sources, insurance take-up, and access to credit.

2.5. Sampling Design

Primarily, producer organizations (POs) benefit from the technical and financial support that PADAER offers in addition the index insurance. The POs 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 requested a list of the 36 POs supported by PADAER for index insurance during either the 2015–2016 or 2016–2017 seasons. Those POs systematically belong to the treatment group. In our context, we considered a treatment PO, one of which 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 POs in 2017–2018. We then selected 35 POs to form a potential treatment group, as those POs might or might not receive the treatment. We also randomly selected 60 PADAER POs (30 from each region) to form a control group. Those POs did not receive support from PADAER index insurance and were not on the list of the potential PADAER POs that might benefit from PADAER’s insurance support for the 2017–18 season. However, those POs are located in the communes of index insurance. The sample was comprised of all 36 POs with index insurance support (treatment group), 35 POs who might receive index insurance support in 2017–18 (potential treatment group), and 60 POs without index insurance support from PADAER (control group). This amount totaled 131 POs in total, and in each PO, we randomly interviewed 11 farmers, resulting in a sample size of 1441 farmers. Due to missing data, the analysis was finally based on 1167 farmers.

2.6. Survey in Tambacounda and Kolda

Two (2) questionnaires were used during the data collection: (1) a household questionnaire and (2) a questionnaire administered to the PO leader (facilitator). All the questionnaires were administered with the participants’ consent. Questions were asked about the knowledge of index-based insurance and the payout modalities per season, the total area cultivated (ha), and total area insured (ha).

2.7. Model: Method for the Propensity Score

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 distinguished between the two groups concerning subscription or no subscription to the agricultural insurance facilitated by PADAER. Insured producers made up the *treated group*, and the uninsured formed the *control group*.

Formalization of the model

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

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

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

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

These two variables correspond to the potential outcomes of the program. 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_i^0 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 following relation:

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

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 expectation of the difference:

$$\Delta^{ATE} = E(Y_1 - Y_0) \quad (2)$$

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 examined:

The average effect of the insurance on the entire population

$$\Delta^{ATE} = E(Y_1 - Y_0) \quad (3)$$

The average effect of treatment in the population of individuals treated

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

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 $(Y_0, Y_1) \perp T$), 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, then Equations (3) and (4) become

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

Once the previous independence property is no longer satisfied, using the mean score of the 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 groups 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:

$$\begin{aligned} E(Y|T=1) - E(Y|T=0) &= E(Y_1|T=1) - E(Y_0|T=0) \\ &= E(Y_1|T=1) - E(Y_0|T=1) + E(Y_0|T=1) - E(Y_0|T=0) \\ &= \Delta^{ATE} + B^{ATE} \end{aligned}$$

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 to estimate the mean effect of the treatment on the treated individuals. To accomplish this, two hypotheses were made: the conditional independence hypothesis or assumption (CIA) and the common support hypothesis.

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.

The logistic regression model is used for the estimation of the propensity score of a binary variable T :

$$\begin{aligned} \Omega(T) &= \{0, 1\} \\ T &= \begin{cases} 1 & \text{if the event occurred} \\ 0 & \text{otherwise} \end{cases} \end{aligned}$$

We try to model the probability that T is equal to one, knowing the values of the explanatory variables X_1, X_2, X_3, \dots , and X_n . The coefficients $\alpha, \beta_1, \beta_2, \beta_3, \dots, \beta_n$ must then be determined as follows:

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

Assumption of conditional independence

When one wishes to evaluate a program 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 program participation. The (unconditional) independence between the latent outcome variables (Y_0, Y_1) and the all observable characteristics location 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 unrealized results and the treatment allocation is verified. This is the assumption of independence conditional on the observable characteristics:

$$(Y_0, Y_1) \perp T | X$$

The condition of conditional independence for the identification of Δ^{ATT} is not as strong, since it only requires independence between the potential outcome in the absence of treatment and the treatment; in other words, we have

$$Y_0 \perp T | X$$

Common support hypothesis

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

$$0 < P(T = 1|X) < 1$$

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

$$P(T = 1|X) < 1$$

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 the 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 us consider the average effect of the treatment on the treated:

$$\begin{aligned}\Delta^{ATT} &= E(Y_1 - Y_0|T = 1) = E(Y - Y_0|T = 1) \\ &= E[Y - E(Y|T = 0)|T = 1] \\ &= E_{X|T=1}[E(Y_1|T = 1, X = x) - E(Y_0|T = 0, X = x)]\end{aligned}$$

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

$$\left\{ \begin{array}{l} \hat{\Delta}^{ATT} = \frac{1}{N_1} \sum_{i=I_1} \{y_i - \hat{g}(x_i)\} \\ I_1 \text{ is the subset of treated individuals} \\ N_1 \text{ is the number of treated individuals} \end{array} \right.$$

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 accomplish this, it is sufficient to match each individual treated with the control units that have the same characteristics x_i (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 $g(x_i)$.

3. Results

3.1. Insurance Take-Up Rate

The participation of farmers in PADAER's index-based insurance started timidly. The take-up rate for the 2015–2016 crop year was 17% (Table 1). This rate rapidly improved from 17% to 32% in one cropping year.

Table 1. 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.

For the rest of the analyses, the data from the 2016–2017 crop year was used.

Table 2 presents the crops covered by insurance in 2016–2017. The crops most cultivated in Senegal are corn, rice, peanut, millet, sorghum, beans, and watermelon. Analysis of the results of Table 2 revealed that 59% of farmers covered their corn crops with agricultural

insurance, 66% covered their rice crops, 14% covered their peanut crops, and 8%, 3%, 1%, 0.53% and 0.26% of farmers insured their mil, beans, sorghum, watermelon, and cotton crops, respectively.

Table 2. Crops are covered by agricultural insurance.

Crops	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
Watermelon	2	0.53

Source: ASE, 2017.

One can see that corn and rice were the most insured products. In this paper, we will restrict our analysis to these products.

Table 3 presents the type of subscription to index-based insurance in 2016–2017.

Table 3. 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.

Among the subscription modalities available to farmers, we noted that many (85%) preferred the cash payment method, while only 15% of farmers preferred insurance through work. Insurance through work (assurance par le travail (APT)) is an innovative approach set up to allow farmers who are willing to subscribe but are barred by the lack of financial means. APT consists of using a part of the harvest to pay for insurance (Table 3). In light 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 presents the details of insured areas in 2016–2017. The distribution of the total surface area was the same in the insured group as in the non-insured group and for both crops. Both groups were dominated by small farmers. Table 4 shows that 45% of farmers who insured their corn fields cultivated less than half of a hectare of corn, while 47% of those who insured their rice fields cultivated the same area of rice.

Table 4. Cultivated area.

Cultivated Area	Corn				Rice			
	Uninsured		Insured		Uninsured		Insured	
	Freq	Percent	Freq	Percent	Freq	Percent		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.

This analysis shows that most producers insured less than half a hectare. This highlights that farmers are engaged in primarily subsistence production rather than commercial production. This behavior reflects a lack of trust for some and a lack of money for others.

3.2. Determinants of the Decision Insurance Take-Up

Table 5 presents the determinants of the decision to take up insurance during the 2016–2017 cropping season. The results of the propensity score estimation show that education, gender, commune of residence, receiving information from television, and a lack of money were the factors determining participation in the index-based insurance program facilitated by PADAER.

Table 5. Determinants of participation in index insurance facilitated by PADAER.

Variables	Pscore	Standard Errors
Sexe	−0.185 *	0.0948
Education	−0.256 ***	0.0937
Age	0.00390	0.00333
Kolda	−0.0867	0.432
Communes (see below)	-	-
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
Watching Tv	0.288 ***	0.0924
Lack of money	−0.417 ***	0.102
Victime of bad rain	0.384	0.234
Well_being	−0.165	0.102
Food availability	−0.133	0.101
Dependence transfert	−0.104	0.136
Number of farms	0.0210	0.0370
Number of income Source	0.0567	0.0920
Constant	−1.200 ***	0.365

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

The main lessons that can be drawn from this model are that Wolof-speaking farmers residing in the communes of Bagadadji, Dioula Colon and Koussanar had a high level of participation in the index insurance facilitated by PADAER, whereas those residing in the commune of Maka Colibantang participated less in the program. The main variable preventing farmers from subscribing to insurance was a lack of money.

3.3. Estimating the Effect of Index Insurance on Investment

To estimate the effect of index insurance on investments in agricultural inputs, the total investment on the one hand and the investment in corn and rice, on the other hand, were taken into account. Investment is defined as the amount of money that a farmer did invest in inputs like fertilizers and pesticides for production. As one can see in Table 6, insurance did not affect these different investments. There was no specific difference between the investment of the index-insured and the non-insured.

Most of the producer organizations which participated in this program belonged to the first generation, and they had to pay only 10% of the insurance premiums. This explains the fact that the expenses of the insured and the uninsured did not differ significantly.

Table 6. Effect of index insurance on investment.

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

Standard errors are in parentheses. *** $p < 0.01$.

3.4. Estimating the Effect of Index Insurance on Production and Income

The estimate of the effect of index insurance on production was found to be insignificant. This result is not surprising in light of the small areas insured (Table 7).

Table 7. Effect of index insurance on production.

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

Standard errors are in parentheses. *** $p < 0.01$, * $p < 0.1$.

To estimate the effect of index insurance facilitated by PADAER on income, the annual household income, agricultural income, income from corn and rice, and income from corn and rice plus insurance benefits (payout) can be seen in Table 8.

Table 8. 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 (554,736)	−57,600 *** (21,920)	6178 (4838)	12,749 *** (4461)
Constant	401,744 (311,088)	103,906 *** (12,293)	4049 (2661)	3603 (2502)
Observations	1167	1167	1021	1167

Standard errors are in parentheses. *** $p < 0.01$.

The results show us that insurance had no effect on the total household income, and the effect on agricultural income was USD −115 (FCFA −57,600) (Table 8). This shows that the agricultural income of the beneficiaries decreased.

To better understand the source of this shortfall, the following estimation was performed: the effect of the insurance on income from corn and rice on the one hand and income from corn and rice plus the amount of compensation (payout) on these grains on the other. The results of this estimation show that the insurance did not affect the gross cereal income of the insured. However, it increases the net income (corn and rice cereal income plus insurance payout) by USD 25 (FCFA 12,749).

4. Discussion

The demand for index-based insurance on the harvest index facilitated by PADAER was approximately 17% in the first season of its introduction and 32% in the second season [19]. One of the reasons for this low uptake is that individuals forget or underestimate bad events [20], or smallholders disqualify themselves and think that index insurance is a class issue. Also, this is consistent with the literature on index-based insurance.

The most cultivated products are corn and rice, two Senegalese staple foods. The main reason for this choice lies in the desire of farmers to guarantee food security while securing cash crops to increase agricultural income. Taking into account the acreage cultivated by the beneficiaries of this insurance, the program has affected more smallholder farmers who produce for survival. In reality, 80% of producers benefiting from index insurance cultivated an area of less than 1.5 ha for corn, and that number was 83% for rice producers. This trend would be confirmed even more if we considered the insured area, since few producers secure their entire production. These findings do not completely parallel the results of the authors of [21], who concluded that introducing insurance increases the production area of insured crops by around 20% and decreases production diversification.

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 should increase the investment. However, 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.

At the time of data collection for this study, almost all of the insured farmers belonged to the first generation, bearing about 5% of the index insurance premium. This result seems unique because, as stressed in [22], insurance is effectively less expensive if it underwrites an increase in investment and expected income. Recent studies also showed that the removal of risk through insurance can boost smallholder investment and income by 20–30%, indirectly identifying the huge year-after-year cost that farmers pay when they manage the risks they face on their own [19]. These authors also stressed increased investment induced by insurance regarding various crops in India [23], tobacco in China [21], corn in Ghana [24], and cotton in Mali [25].

The estimate of the effect of index insurance on production was statistically insignificant. The analysis of the cultivated and insured areas shows that the insured producers were “smallholders”. Cross-analysis of the total and insured acreage of corn producers showed that there was no significant difference between the insured and non-insured producers. The authors of [26] also reported that the impact of purchasing crop insurance on farm income, production expenses, and productive investments in agriculture was inconclusive in India. In China, insurance raised tobacco production by around 22% [21].

The effect of index insurance facilitated by PADAER showed us on the one hand that insurance did not affect the total household income. This result is in line with the one of [27], where it was shown that a crop insurance program did not lead to a significant increase in farmers’ incomes. On the other hand, the effect of index insurance facilitated by PADAER on farm income was USD −115 (FCFA −57,600). This result reflects the fact that the beneficiaries’ agricultural income was in a deficit. The results of an earlier study support our findings that the impact of insurance use on three economic performance indicators of cropping farms (profit, labor productivity, and land productivity) is significant but negative [15]. Hastily, we may conclude that insurance products can be replaced by another alternative for risk management. However, according to [28], index-based insurance is an innovation that circumvents many of the fundamental problems that hamper the development of insurance for weather risks in lower-income countries. Therefore, when asking about the source of this deficit, we estimated the effect of the insurance on the income from maize and rice on the one hand and the income from maize and rice increased by the amount of the indemnities on these cereals on the other hand. The results of this estimation showed that this deficit came from other sources. The insurance did not affect the gross cereal income of the insured, but it increased the net income (maize and rice cereal income) by USD 25 (FCFA 12,749). The authors of [29] also reported similar findings in the Philippines, where the amount of farmers’ income losses were significantly reduced as a result of the sample farmers’ participation in the rice insurance program. Therefore, without the compensation, insured producers would lose an average of USD 115 (FCFA 57,600) of their farm income. Not only does the index insurance facilitated by PADAER

compensate for this loss, but it also allows the insured to earn an average of USD 25 (FCFA 12,749) per insured hectare.

5. 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. Although the results of the estimates show that the project has not yet had any effect on production, without the intervention of this project, farmers would have recorded a loss of about USD 115 (FCFA 57,600). Not only did the index-based insurance for the harvest facilitated by PADAER allow the beneficiary to cover this loss and realize a gain estimated at USD 25 (FCFA 12,749), but this research is a process evaluation of the insurance tool 2 years after its launch. This short period could justify the results.

The success of index-based insurance 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 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. The added value of this paper is that it measures the effects of agricultural index-based insurance in Africa using real-world statistical data.

Interested governments and donors should begin by training and educating key actors on 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.

Author Contributions: Conceptualization, M.O., L.W. and A.G.; methodology, A.B., M.O., L.W. and A.G.; software, A.B. and M.O.; validation, A.B., M.O., L.W. and A.G.; formal analysis, A.B. and M.O.; investigation, A.B. and M.O.; resources, M.O. and A.G.; data curation A.B. and M.O.; writing—original draft preparation, A.B. and M.O.; writing—review and editing, L.W. and A.G.; visualization, A.B., M.O., L.W. and A.G.; supervision, M.O.; project administration, A.B. and M.O.; funding acquisition, M.O. and A.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the International Initiative for Impact Evaluation (3IE), grant number: Thematic window 13_II/1024.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the authors. Data were collected by the authors.

Acknowledgments: We extend our thanks to Ndiack Fall for data collection management. We thank all the researchers (Guy-Vanie Miakonkana, Lucia Di Trioia, Aziz Dao, Mamadou Camara, Moussa Sawadogo, Lidia Dandedjrohoun, Kabirou Biaou, Lucie Gayelle Assonfack Kana, Simplicie Adjisse, Ngagne Mbaou, Semou Diouf and Richard Houessou) and the enumerators for their valuable contribution to this project. Finally, we are grateful to all farmers of Tambacounda and Kolda and workers of these institutions for their contributions to this work: ASE, IFAD (WRFM), 3ie, PADAER, UCAD (CREA), BAMTAARE, PAM, CNAAS, SwissRe, PlaNet Guarantee (PG), ISRA and ANACIM.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. FAO. *The State of Food Insecurity in the World, Italy*; FAO: Rome, Italy, 2014; 57p, Available online: <https://www.fao.org/3/i4030e/i4030e.pdf> (accessed on 12 August 2022).
2. ANSD. *Rapport de l'Agence Nationale de la Statistique et de la Démographie, Enquête Régionale Intégrée sur l'Emploi et le Secteur Informel, Sénégal*; 2019; 288p, Available online: http://www.ansd.sn/ressources/rapports/Senegal_ERI-ESI_RapportFinal.pdf (accessed on 12 August 2022).
3. Dankelman, I. Climate change, human security and gender. In *Gender and Climate Change: An Introduction*, 1st ed.; Dankelman, I., Ed.; Routledge: London, UK, 2012; pp. 83–105. [CrossRef]
4. Miller, A.; Dobbins, C.L.; Pritchett, J.G.; Boehlje, M.; Ehmke, C. Risk Management for Farmers; No. 1239-2016-101536, Staff Paper 04-11; 2004; 27p. Available online: <https://www.semanticscholar.org/paper/RISK-MANAGEMENT-FOR-FARMERS-Miller-Dobbins/3a1b60db7d0424792eb653d005551ac9b7c8cdb6> (accessed on 14 April 2022). [CrossRef]
5. Góral, J.; Wigier, M. *Risk in the Food Economy—Theory and Practice*; Instytut Ekonomiki Rolnictwa i Gospodarki Żywnościowej—Państwowy Instytut Badawczy ul. Świętokrzyska 20: Warszawa, Poland, 2017; 272p, ISBN 978-83-7658-681-6.
6. Atozou, B.; Lawin, K.G.; Niang, D. Impact of Weather Index Insurance on Groundnut Farmers' Technical Efficiency in Senegal: A Propensity Score Matching Approach. *J. Sustain. Dev.* **2017**, *10*, 131–142. [CrossRef]
7. Yanuarti, R.; Aji, J.M.M.; Rondhi, M. Risk aversion level influence on farmer's decision to participate in crop insurance: A review. *Agric. Econ.* **2019**, *65*, 481–489. [CrossRef]
8. Barnett, B.J.; Mahul, O. Weather index insurance for agriculture and rural areas in lower-income countries. *Am. J. Agric. Econ.* **2007**, *89*, 1241–1247. [CrossRef]
9. Jensen, N.; Barrett, C. Agricultural index insurance for development. *Appl. Econ. Perspect. Policy* **2017**, *39*, 199–219. [CrossRef]
10. Cole, S.A.; Xiong, W. Agricultural insurance and economic development. *Annu. Rev. Econ.* **2017**, *9*, 235–262. [CrossRef]
11. Pelka, N.; Musshoff, O.; Finger, R. Hedging effectiveness of weather index-based insurance in China. *China Agric. Econ. Rev.* **2014**, *6*, 212–228. [CrossRef]
12. Heimfarth, L.E.; Finger, R.; Musshoff, O. Hedging weather risk on aggregated and individual farm-level: Pitfalls of aggregation biases on the evaluation of weather index-based insurance. *Agric. Financ. Rev.* **2012**, *72*, 471–487. [CrossRef]
13. Jensen, N.D.; Barrett, C.B.; Mude, A.G. Index-Based Insurance: Lottery Ticket or Insurance? *ILRI Research Brief*. 2015. Available online: <https://cgspace.cgiar.org/bitstream/handle/10568/67727/ResearchBrief53.pdf?sequence=1> (accessed on 12 August 2022).
14. Kurdyś-Kujawska, A.; Sompolska-Rzechuła, A.; Pawłowska-Tyszko, J.; Soliwoda, M. Crop Insurance, Land Productivity and the Environment: A Way forward to a Better Understanding. *Agriculture* **2021**, *11*, 1108. [CrossRef]
15. Spörri, M.; Baráth, L.; Bokusheva, R.; Fertő, I. The Impact of Crop Insurance on the Economic Performance of Hungarian Cropping Farms. In Proceedings of the 123rd EAAE Seminar, No. 706-2016-48355. Dublin, Ireland, 23–24 February 2012.
16. Gertler, P.J.; Martinez, S.; Premand, P.; Rawlings, L.B.; Vermeersch, C.M.J. *Impact Evaluation in Practice*; The International Bank for Reconstruction and Development/The World Bank: Washington, DC, USA, 2011.
17. Rosenbaum, P.R.; Rubin, D.B. The central role of the propensity score in observational studies for causal effects. *Biometrika* **1983**, *70*, 41–55. [CrossRef]
18. Khandker, S.B.; Koolwal, G.; Samad, H. *Handbook on Impact Evaluation: Quantitative Methods and Practices*; The International Bank for Reconstruction and Development/The World Bank: Washington, DC, USA, 2009.
19. Carter, M.; de Janvry, A.; Sadoulet, E.; Sarris, A. Index insurance for developing country agriculture: A reassessment. *Annu. Rev. Resour. Econ.* **2017**, *9*, 421–438. [CrossRef]
20. Skees, J.R. Challenges for use of index-based weather insurance in lower income countries. *Agric. Financ. Rev.* **2008**, *68*, 197–221. [CrossRef]
21. Cai, J. The impact of insurance provision on households' production and financial decisions. *Am. Econ. J. Econ. Policy* **2016**, *8*, 44–88. [CrossRef]
22. Carter, M.; Cheng, L.; Sarris, A. Where and how index insurance can boost the adoption of improved agricultural technologies. *J. Dev. Econ.* **2016**, *118*, 59–71. [CrossRef]
23. Mobarak, M.; Rosenzweig, M. Risk, insurance, and wages in general equilibrium. *Natl. Bur. Econ. Res.* **2014**, *19811*, 1–45. Available online: <http://www.nber.org/papers/w19811> (accessed on 14 April 2022).
24. Karlan, D.; Osei, R.; Osei-Akoto, I.; Udry, C. Agricultural decisions after relaxing credit and risk constraints. *Q. J. Econ.* **2014**, *129*, 597–652. [CrossRef]
25. Elabed, G.; Carter, M. *Ex-Ante Impacts of Agricultural Insurance: Evidence from a Field Experiment in Mali*; Université de Californie à Davis: Davis, CA, USA, 2016.
26. Aditya, K.S.; Khan, M.T.; Kishore, A. Adoption of crop insurance and impact: Insights from India. *Agric. Econ. Res. Rev.* **2018**, *31*, 163–174. [CrossRef]
27. Zhao, Y.; Chai, Z.; Delgado, S.M.; Preckel, P.V. An empirical analysis of the effect of crop insurance on farmers' income. *China Agric. Econ. Rev.* **2016**, *8*, 299–313.

28. Skees, J.R. Innovations in index insurance for the poor in lower income countries. *Agric. Resour. Econ. Rev.* **2008**, *37*, 1–15. [[CrossRef](#)]
29. Rola, A.C.C.; Aragon, C.T. Crop Insurance Participation Decisions and Their Impact on Net Farm Income Loss of Rice Farmers in the Lakeshore Municipalities of Laguna, Philippines. In Proceedings of the Annual Meeting of the Philippine Economic Society, Intercontinental Hotel Manila, Metro Manila, Philippines, 15 November 2013.

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.