Establishing a Complementary Risk Fund for Index Insurance

Client Organization: World Bank Group – Finance, Competitiveness and Innovation Team

World Bank Lead: Panos Varangis

Faculty Advisor: Daniel Osgood

Authors: Muath Waza Alqahtani, Paloma Chumacero Delgado, Tamara Hoffman, Kiran Kaul, Jiwei Zhan, and Yiqing Zhang

COLUMBIA | SIPA
School of International and Public Affairs

IFC International Finance Corporation
WORLD BANK GROUP

Table of Contents

Disclaimer: The views reflected in the study do not necessarily represent those of Columbia University or the World Bank. The views expressed herein should be attributed to the authors and not to the World Bank, Columbia University, or Professor Daniel Osgood. Contact details for the authors are provided as follows:

Muath Waza Alqahtani (mwa2127@columbia.edu)
Paloma Chumacero Delgado (pc2974@columbia.edu)
Tamara Hoffman (tdh2131@columbia.edu)
Kiran Kaul (kk3448@columbia.edu)
Jiwei Zhan (jz3265@columbia.edu)
Yiqing Zhang (yz4058@columbia.edu)

Abstract

Index insurance is a powerful financial tool that provides climate risk protection to low-income farmers in developing countries.[1] However, under traditional index insurance offerings, farmers continue to face basis risk; where payouts triggered by the index fall short of covering their losses. The capstone team was tasked with developing a methodology for determining the optimal size of a complementary risk fund that would help farmers expand their existing coverage under index insurance. The capstone builds on the work of last year's SIPA capstone project that focused on quantifying the historical mismatch between weather-based index insurance payouts and farmer needs to inform the design of a complementary fund. We similarly focus on analyzing data from the World Food Programme's R4 Rural Resilience Initiative[2] in the Amhara region of Ethiopia, and build onto last year's efforts by developing a methodology that quantifies the size of the complementary fund. The team also identifies opportunities for the fund to become efficient in terms of allocating payouts to farmers in years when losses are greater than expected. The team partnered closely with Columbia University's International Research Institute for Climate and Society to develop our methodology.

[1] Daniel Osgood and Kenneth E. Shirley, "Chapter 1: The Value of Information in Index Insurance for Farmers in Africa."
[2] The R4 Rural Resilience Initiative

Introduction

Background
Smallholder farmers are highly susceptible to climate risks that impact their agricultural productivity, causing declining yields and adverse effects on their households, businesses and livelihoods. Index-based insurance products have been developed as alternatives to traditional insurance products to mitigate these risks. However, such products are affected by basis risk, understood as the risk of losing productivity that is not captured by the index, which poses limitations for their adoption and effectiveness. To address these challenges, a complementary risk fund may be helpful to increase financial resilience and minimize loss. While index insurance products are becoming increasingly important as a mitigation strategy, they cannot cover all climate shocks and unforeseen disasters, highlighting the need for risk mitigation tools to increase farmer resilience and encourage productivity.

Main Objectives of the Project
The overarching aim of this capstone project is to alleviate the adverse effects of financial uncertainty on farmers in order to enhance their overall productive capacity. To achieve this goal, we have identified two key sub-objectives: enhancing farmers' resilience to volatile climatic conditions and minimizing their exposure to risk. By providing a robust solution to mitigate the impact of basis risk, this project aims to empower farmers to effectively manage unforeseen events, while minimizing their potential losses.

Main Types of Agricultural Insurance: Traditional loss-based insurance (indemnity) vs. index-based insurance

Agricultural insurance serves the purpose of enabling smallholder farmers to obtain necessary financial resources during difficult periods. Due to certain financial constraints, farmers may not have access to funds during unfavorable years and are unable to transfer money from more prosperous years to such challenging seasons. By providing financial assistance and paying financing fees, insurance allows farmers to overcome this challenge.

In the case of traditional, loss-based insurance, the losses of insured farmers are covered after being evaluated by the insurance provider. Although some farmers may not receive full coverage due to discrepancies in loss assessment, traditional insurance typically offers farmers with complete coverage. However, traditional insurance poses efficiency challenges due to high transaction and administrative costs incurred in verifying relatively minor covered losses. Further, as traditional insurance compensates farmers for individual claims, it creates a high probability of moral hazard and adverse selection. Index-based insurance, on the other hand, is designed to mitigate these problems by linking insurance payouts to an objective measure of loss. Index-based insurance involves triggering a payout based on predetermined points (a threshold) on the index that are correlated with the probability of crop loss. There are three different types of "crop" index insurance:[3]

1. Weather-based index insurance that utilizes climatic variables and weather parameters to determine the likelihood of crop loss.
2. Area-yield index insurance that calculates the payout based on the average yield harvested. In the event that the average yield of the area falls short of the insured yield, a payout is triggered.
3. A hybrid model that combines both approaches.

Index insurance offers several advantages due to its streamlined process. Specifically, it has the potential to minimize transaction costs and expedite the process by eliminating the need for individual claims to be verified by the insurance provider. As a result, index insurance can be more widely accessible to farmers. Further, as opposed to traditional loss-based insurance which covers idiosyncratic losses, index-based insurance covers covariate risks, affecting an entire community. Therefore, since it is not based on individual claims, index insurance eliminates the problems associated with moral hazard and adverse selection. However, despite its advantages, index insurance has a significant drawback in terms of its reliability in providing adequate financial protection to farmers. As index insurance payouts are solely based on rainfall measurements rather than actual losses, they often do not provide coverage for losses caused by other factors. This can lead to misunderstandings among policyholders who were expecting compensation. Further, the measured rainfall amount may differ from what the farmers experience in the field, which can result in a coverage gap and therefore may not entirely protect the farmer from loss. This limitation is commonly referred to as basis risk, which can leave farmers exposed to uncovered losses and thereby reduce farmers' productivity. To confront the challenges posed by basis risk, setting up a complementary fund for managing risks could prove beneficial in enhancing financial robustness and mitigating losses. As such, we have developed the ensuing problem statement to direct our project:

Problem Statement: What is the optimal size of a complementary risk fund for index insurance that would cover the 95th percentile of the basis risk?

Before we dive into our proposed solution for addressing basis risk in agricultural index-based insurance, it is important to define what we mean by basis risk. Basis risk can be defined in various ways, but for the purpose of our project, we will use the following specific definition:

Definition of Basis Risk

Generally, basis risk refers to the disparity between the amount of payout received and the actual losses incurred. This implies that there may be discrepancy between the losses perceived by farmers and the actual insurance payouts they receive (or do not receive), highlighting a potential mismatch between farmers' expectations and actual coverage.

[3] World Bank Group, Index Insurance Forum

Basis risk can be classified into two distinct categories: upside basis risk and downside basis risk. Downside basis risk occurs when farmers face significant losses but receive little or no payout due to unreliable index calculations, resulting in a coverage gap. In contrast, upside basis risk occurs when farmers receive a payout despite not incurring any significant losses or when the index overestimates the loss incurred by the farmer, resulting in overpayment. For the purpose of this project, we aim to provide a practical solution to capture and address *downside basis risk.*

Proposed Solution

Index-based insurance is an effective solution but does not perfectly cover farmer risks. This capstone project aims at establishing a methodology for determining the optimal size of a complementary risk fund that would add to the existing coverage provided by index insurance, offering compensation when index insurance payouts are expected due to loss, but not triggered (downside basis risk).

The proposed fund is established with an initial capitalization, which will serve as the foundation for providing compensation to farmers when index insurance payouts are expected, but not initiated. In order to ensure the sustainability of the fund, it will be replenished by additional premiums paid by farmers seeking to hedge against the risk of future losses that are not captured by the index insurance.

Key Questions & Assumptions

In approaching this solution, we developed a set of questions and assumptions to guide our project:

1. Risk diversification effects are significant in Ethiopia, resulting in lower premiums and decreasing basis risks for farmers. Therefore, what would be the size of a fund required to address the problem of downside basis risk in index insurance?
2. How much should farmers pay into the fund, and what methodology can be used to determine payout amounts from the fund?
3. How would changes in the region's natural climatic variability, and other factors such as greater adaptation methods, improvements in methodologies and measurements, changes in farmer's recollection, etc. impact the proposed fund size, as well as the methodology for determining payout amounts and addressing downside basis risk?
4. How does basis risk change with climate change and specifically, what are the ways to capture the impact of climate change on the downside basis risk? How would climate change impact our methodology for determining payout amounts?

Summary of Key Findings

1. Farmers will pay 21.5% of the index insurance's maximum liability as a total premium for full coverage (i.e., hedge against 100% of risks). Within the farmers' payment, 59.9% of total premiums collected from villages are allocated to the index insurance, while the remaining 40.1% are allocated to a complementary risk fund.
2. Pricing of premiums for index insurance and basis risk are sensitive to the opportunity cost. As the opportunity cost increases, the price of premiums and basis risk increases.
3. The optimal complementary fund size consists of an initial capitalization of 19.68% of maximum liability, with expected re-capitalizations 13.67% of maximum liability in 1983 and 1984, and combined with a premium of 8.64% of maximum liability paid by farmers each year.
4. The fund could be self-sustaining without collecting farmers' premiums since 2009 with the fund size ceiling of 55.14% of maximum liability and farmers face lower financial burdens.
5. We test the robustness of our results by removing a major anomalous event and removing years in the distant past from the historical data. After removing the effect of bad years, both investors' and farmers' contributions have experienced varying degrees of reduction.

Case Study: Ethiopia

The capstone team had access to two historical datasets focused specifically in the Amhara region of Ethiopia. This area is located in the northwestern part of Ethiopia and its climate is affected significantly by variation in altitude, its latitudinal position, prevailing winds, air pressure and circulation and its proximity to the sea[4].

The two data sets utilized in this study were collected through the World Food Programme's R4 Rural Resilience Initiative in Ethiopia. The project conducted focus group discussions with smallholder farmers in the Amhara region to understand their perceptions of bad years. In the discussions, farmers were asked to recollect and rank their 8 worst years since 1983 based on the losses they experienced. These discussions act as a data source for calculating the difference between the index payouts and uncovered losses in farmer perceived bad years.[5] The project first kicked off in 2009 and by 2011 World Food Programme and Oxfam America launched the initiative[6]. The index used in Amhara under R4 relies on satellite measurements in determining how much farmer agreement of losses incurred corresponds to those covered by the insurance product.

[4] Outlook of future climate in northwestern Ethiopia
[5] Note: The data prior to 2000 is not complete
[6] The R4 Rural Resilience Initiative

Methodology

Our approach focuses on a basic framework that is made up of three key components. First our team calculated the pricing of the index insurance and basis risk. We then analyzed the impacts from pooling risk (diversification effects). Lastly, we assessed the impacts of payouts triggered on the fund's net cash flow.

Our project utilizes the data compiled through the R4 project in Ethiopia. We utilized two data sets from this project, the first data set named "Actual Payout" is constructed by satellite indexes that calculate what payouts since 1983 would have been. The satellite data specifically tracks rainfall and vegetation estimates. The second dataset named "Farmer Recollection Reordered" consists of farmer recollections of prior "bad" years, where the farmers ranked the 8 worst years since 1983 on losses. Both data sets contain the same sample size of 166 villages spanning from 1983 to 2020.

The following simplifying assumptions were made to conduct our analysis:

- Using Historical Data to Price Index Insurance
  We use both data sets - that contain historical payouts - to price current index insurance premiums.
- Applying Uniform Contributions
  The premiums our team calculated are the same across all farmers and villages. Farmers also pay the same premium every year.
- Reordering Payouts
  - Our datasets included a series of basis risk events arranged by year and by village. Both data sets were reordered from the largest to smallest in terms of size of payout recorded by the satellite and farmer rankings of bad years to good years (assuming farmer recollection is the "truth"). Both data sets matched their rankings one-to-one. We recognize that this might create a limitation, being that it assumes that the severity of the farmer's worst year is the same as the severity of the worst year in terms of payouts.
  - Index payouts have been filtered to the 1 in 5 size events; payouts smaller than that have been removed from the data set, thus price has been calculated assuming they have been removed.
  - We assume that 1 is the maximum payout per village, and for the whole project, it is 166, and the index insurance premium calculation is based on the 80% smaller payouts removed from the last capstone team.
- Excluding traditional insurance challenges
  Traditional insurance programs face a variety of asymmetric information challenges. For the purposes of our project, our team decided to exclude challenges, such as moral hazard, being that it is not clear how the complementary fund would solve these traditional insurance challenges. In order to address instances where farmers are not covered by the index insurance when a loss is incurred, we rely solely on the complementary fund.

Calculation of The Insurance Premium

In order to calculate the premium, we first calculated the average probability of losses by taking the positive difference between the losses based on farmers' recollections and the actual payout. We then calculated the pricing of the index insurance by using the following premium formula:

Premium = Expected Payout + [Cost of Capital * (Value at Risk – Expected Payout)]

For our illustrative example, we assumed a cost of capital at 8%. The expected payout was the probability of incurring losses multiplied by the maximum historical payout. The value at risk was calculated based on the 95th percentile of events (i.e., the amount of losses that may happen with a 95 percent confidence interval and a 5 percent chance of being wrong).

Calculation of The Basis Risk

To calculate the basis risk, we similarly calculated the difference between the losses based on farmers' recollections and the actual payout. Upon calculating, we only kept the positive differences. We then used the formula below to calculate the basis risk:

Basis Risk = E[|Actual payout - Farmers' collection|] + [Cost of Capital (Value at Risk – E[|Actual payout - Farmers' collection|])]

We again assumed a cost of capital at 8%. The expected payout in this formula is the average difference in payment. The value at risk is again based on the 95th percentile of events (i.e., the difference in payment that may happen with a 95 percent confidence interval and a 5 percent chance of being wrong). To obtain the price per village, we divided the total amount of basis risk and divided it by the number of villages.

Data Analysis

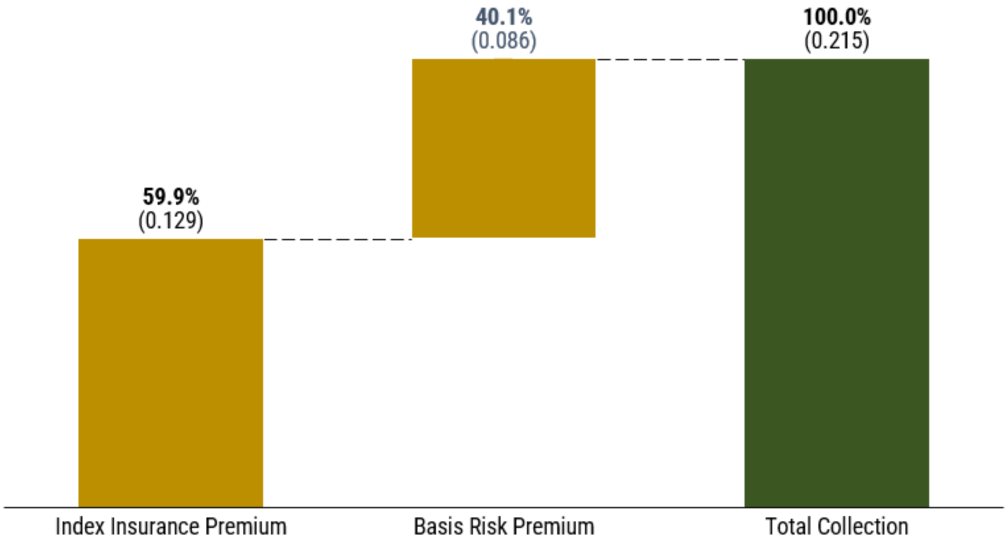
Premium Allocation

While index insurance is an innovative financial product for farmers, there are possibilities that the index used to calculate insurance payouts may not perfectly match the losses suffered by individual farmers. To deal with this problem, we consider farmers to bear two parts of the costs. Farmers pay a premium for the index insurance to cover the climate-related risks captured by the satellite and simultaneously pay an additional premium into the complementary risk fund to eliminate basis risk.

Both index insurance pricing and pricing of basis risk are based on the standard equation for premium (p) calculations, which is p = E[Payout] + r(VaR - E[Payout]), where r is the opportunity cost of money. E[Payout] is the size of the expected payout (including zero payout years) and VaR is the value at risk, the size of the 95th percentile event.

The premium is expressed as a percentage of the maximum liability averaged for an individual village. Based on calculations, the annual premium for the index insurance is 0.129 units per village and 0.086 units is the amount that each village has to pay to avoid any basis risk. The total cost borne by a village amounts to 0.215 units. In other words, 59.9% of total collections from villages goes to index insurance, while the remaining 40.1% goes into a complementary risk fund (see Figure 1). Farmers will therefore pay 21.5% of the index insurance's maximum liability as a total premium for full coverage (i.e., hedge against 100% of risks), which is consistent with the one in five frequency.

Figure 1: Premium Allocation Per Village



Calculation of the Premium and Value of Diversification

Index-based insurance is a homogeneous product, as the payout is determined by the value of a pre-specified index used to measure the loss. On the other hand, individual villages are idiosyncratic in nature, as specific risk profiles, practices and experiences can vary from village to village. Pooling insured villages together helps to spread risks across a diverse and more resilient group. As a result, the premium, factoring in risk diversification effects, can be lower than what each individual village would have to pay if farmers were to purchase it on their own under the same conditions.

To measure the benefits of risk diversification, we grouped the villages and recalculated the index insurance premium and basis risk pricing. The premium is determined by three factors: the expected payout, the opportunity cost (r), and the VaR at a 95th percentile level. In the two scenarios, before pooling and after pooling, the only variable that changed is the VaR at a 95th percentile level.

Specifically, in terms of index insurance, we calculated the VaR at a 95th percentile level individually for each village and computed averages to get the VaR at a 95th percentile level per village before pooling. To calculate the VaR at a 95th percentile level per village after pooling, we summed the index-based insurance payouts for 166 villages year by year and then divided that by the total number of villages (*see Table 1*).

Table 1: Index Insurance Premium

	Individual Villages	*Pooled Villages*
E[Payout]	0.107	0.107
r	8%	8%
VaR (at a 95th percentile level)	0.811	0.379
Premium	**0.163**	**0.129**

The same methodology applies to basis risk pricing. The only difference is that the dataset used to calculate VaR at a 95th percentile level and price index insurance is the actual payout of index-based insurance, while the dataset used to price basis risk is the positive gap between the desired amount of payout based on reordered famer recollection and actual payout of index-based insurance (*see Table 2*).

Table 2: Pricing of Basis Risk		
	Individual Villages	*Pooled Villages*
E[Payout]	0.071	0.071
r	8%	8%
VaR (at a 95th percentile level)	0.461	0.268
Premium	**0.102**	**0.086**

After pooling all the villages together, the annual premium for index insurance decreased by 21% from 0.163 to 0.129, and basis risk pricing decreased by 15.2% from 0.102 to 0.086. We can see that in Ethiopia, the risk diversification effects are significant. And, from the comparison, a larger effect of risk diversification has been observed in the pricing of index insurance.

Sensitivity Analysis of the Opportunity Cost

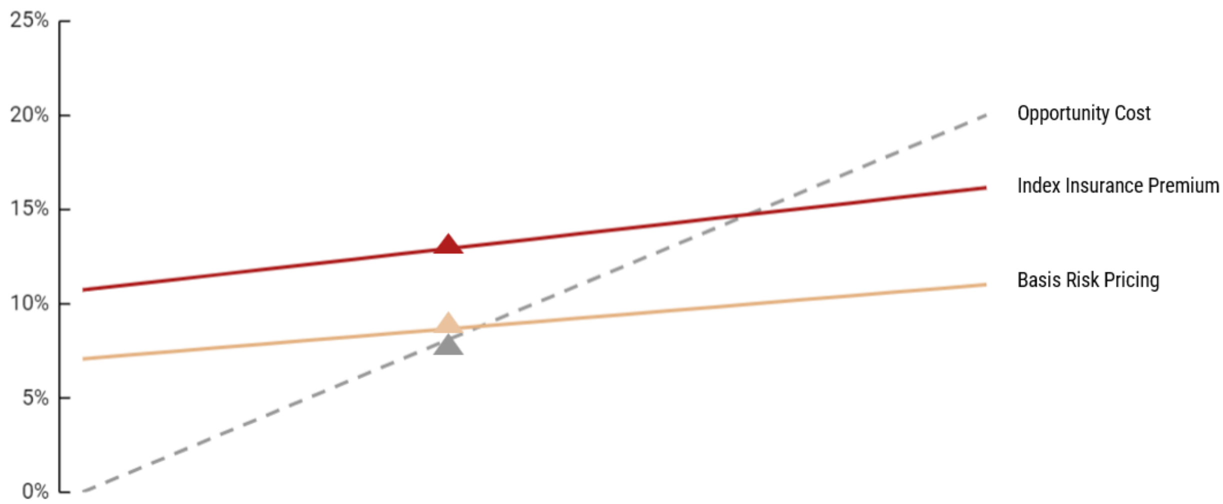
Opportunity cost is defined as the interest rate paid to the risk reserve fund. However, when investors become donors, opportunity cost is also interpreted as the cost of capital, or the potential returns that could have been achieved if the funds were invested elsewhere. Opportunity cost can vary based on a variety of factors, including the prevailing interest rate in the economy, perceived risks associated with the investments, etc.

In the case of Ethiopia, we consider 8% as the opportunity cost of money as an illustrative example. When the opportunity cost of money is 8%, each village pays an annual index insurance premium of 0.13 and 0.09 into the complementary risk fund, with a total cost of 0.22. The initial fund size is equal to VaR at a 95th percentile level minus E[Payout], and thus not a function of the opportunity cost. For a fund with an initial size of 32.67, annual basis risk premium collected from 166 villages is (0.09*166≈) 14.35.

Table 3: Premium Sensitivity Analysis of Opportunity Costs				
Opportunity Cost	**0%**	**8%**	**15%**	**20%**
Index Insurance Premium	0.11	0.13	0.15	0.16
Basis Risk Premium	0.07	0.09	0.10	0.11
Total Premium	**0.18**	**0.22**	**0.25**	**0.27**

As shown by the sensitivity analysis (*Table 3*), unsurprisingly, premiums for index insurance and basis risk increase gradually as opportunity cost increases. The results are fairly robust and suggest that providing index-based insurance can become more expensive and less accessible to farmers in regions with high opportunity costs. Additionally, compared to the basis risk premium, the index insurance premium is slightly more sensitive to changes in opportunity cost. This highlights that fluctuations in the opportunity cost may have a greater impact on the premium of index insurance.

Figure 2: The Variation of Premiums with Opportunity Cost



<u>Complementary Risk fund Cash Flow</u>

Index-based insurance is not able to cover all idiosyncratic risks faced by farmers. A complementary risk fund plays an essential role in making up for the deficiency. Villages could set up pools of funds to provide farmers additional compensation for the basis risk that occurs when index insurance payouts are not triggered or when payouts are lower than the desired amount. This would also enable individual villages to hold less resources on hand to manage the basis risk. Enrolling in the dual "program" of index insurance and the basis risk fund can empower farmers to hedge 100% of climate-related risks.

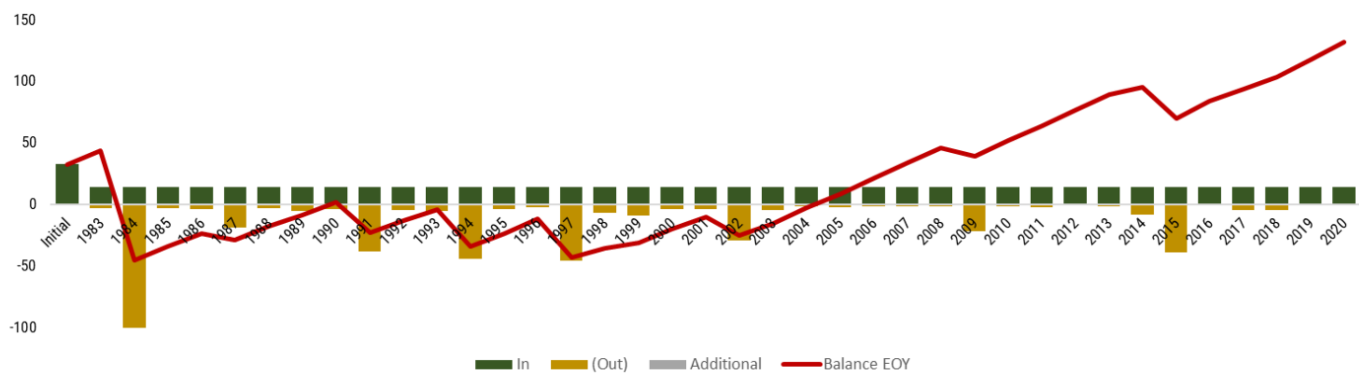
In designing the fund, we propose having hypothetical donors who donate money to the fund to serve as the initial fund size and without considering financing costs. The initial fund size (i.e., initial capitalization) is 32.67 units, calculated as the overall VaR at a 95th percentile level (44.41 units) minus the annual expected payout for 166 villages (11.73 units). Therefore, with a total maximum liability of 166 units, the initial investment is projected to be 32.67 units (or 19.68%) to establish a complementary risk fund. Of note, by using a 95th percentile level for the value at risk, we would expect the fund to become insolvent in one year out of twenty years.

Initial Fund Size = Value at Risk (95%) - Expected Payout

Once the initial capital is in place, the complementary risk fund functions as follows: each year, the fund receives a cash inflow equal to the basis risk premium collected from 166 villages. This is approximately 14.35 units based on a premium of 0.086 unit per village (0.086*166 ≈ 14.35). The cash outflow for each year is the sum of positive differences between the desired amount of payouts and the actual payouts made through the index insurance for all 166 villages. At the end of each year, the fund's balance, named "Balance EOY" is calculated as the previous year's balance plus cash inflow minus cash outflow.

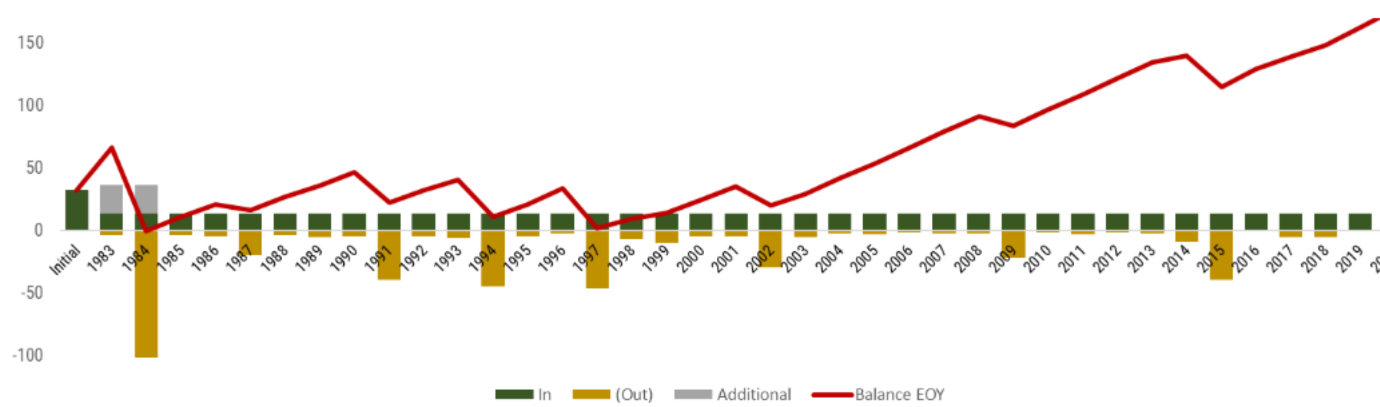
Fund Cash Inflow = Basis Risk Premium + Recapitalization
Fund Cash Outflow = Loss Differences
Balance EOY = Balance BOY + Fund Cash Inflow - Fund Cash Outflow

Figure 3: Full Era Fund Cashflow without Additional Injection



Based on the calculations above, the fund will experience a large cash outflow in 1984, and will thus frequently run out of money before 2005 (*see Figure 3*). For Ethiopia, 1984 is a uniquely salient year due to recurring drought and civil war, triggering the largest payout from the risk fund. Under these circumstances, recapitalizations are required to sustain the fund and maintain a positive cash balance. Solver, a tool embedded in Excel, was employed to determine the optimal amount that minimizes the required recapitalization for the fund while also ensuring its sustainability. Our findings indicate that injecting an additional capital of 22.70 units in both 1983 and 1984 represents the optimal choice (*see Figure 4*).

Figure 4: Full Era Fund Cashflow with Optimal Additional Injection



Ceiling of Risk Fund

As depicted in Figures 3 and 4, the fund’s balance steadily increased year by year after 2007, irrespective of whether recapitalization occurred or not. This increase is largely due to an accumulation of the premium collected from farmers. The main goal of the fund is to ensure sustainability, if the premium is not necessary to sustain the fund, collecting it anyway would result in a surplus that could be diverted towards other investment opportunities. One opportunity is to direct the premium earmarked for sustainability towards low-risk investments to maintain liquidity for sudden payouts. The remaining premiums, collected without sustainability considerations, can be invested in high-risk financial products to seek higher returns. Meanwhile, it should be noted that due to the unavailability of vegetation satellite data prior to the year 2000, reliance on current fund calculations for the entire time series dating back to the 1980s would result in an overestimation of the necessary resources and premiums. As a consequence, resources go into the fund, including farmer premiums that could be used more effectively for adaptation or investments. Therefore, we propose establishing a ceiling to determine the maximum sustainable fund size and to avoid having farmers pay a premium every year.

The optimal capital recapitalization solution entails an initial fund size of 32.67 units in the first year, with subsequent investments of 22.7 units in each of the following two years, and a collective annual premium payment of 14.35 units by farmers as a whole group. Once this is established, we gradually reduce the premium to zero, starting from the last year (2020).

We monitor the changes in the "The Balance EOY" metric and halt the process when it turns negative. We retained the results that led to a positive balance and calculated the maximum value of “The Balance EOY” as the ceiling (*see Figure 5*).

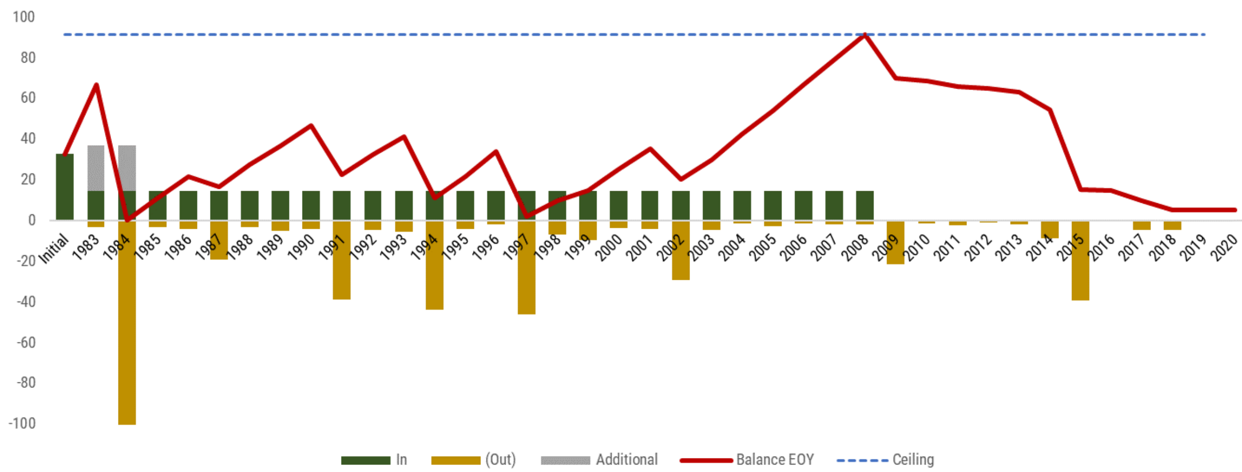
Table 4-1: Full Era Fund Cashflow Analysis (units)

Scenarios	**Investors Contribution**		**Farmers Contribution**
	Initial Fund Size	**Recapitalization**	
Full Era (1983-2020)	32.67	22.7/year for two years	14.35/year
Full Era with the Ceiling 91.53 units	32.67	22.7/year for two years	11.73/year from 1983 to 2008; 0/year after 2009

Table 4-2: Full Era Fund Cashflow Analysis (% of max liability)
Max Liability: 166 units

Scenarios	Investors Contribution		Farmers Contribution
	Initial Fund Size	Recapitalization	
Full Era (1983-2020)	19.68%	13.67%/year for two years	8.64%/year
Full Era with the Ceiling 55.14%	19.68%	13.67%/year for two years	7.07%/year from 1983 to 2008; 0%/year after 2009

Figure 5: Full Era Fund Cashflow with Optimal Additional Injection (Ceiling)



As seen in Figure 5 since 2009, the fund is self-sustaining and does not require farmers to pay a premium. The maximum ceiling in this case is 91.53 units. This means, with a maximum liability of 166 units covering 166 villages, and holding farmers and investors' contribution constant, the fund will have 14.35×12 = 172.20 units at its disposal.

Tail Risk Analysis

When calculating the fund size based on basis risks, it is important to consider the varying effects of climate change in different time periods. For instance, during the 1980s, Ethiopia experienced many periods of drought. The basis risk during this period was overvalued due to limitations in satellite technology, inaccuracies in farmer's collections, and deviations from today's climate. In order to improve the accuracy of the model and account for rare and extreme events, we have selected three scenarios for tail risk analysis: "Removal of 1984", "Removal of the 1980s" and "Keeping the 2000s". This analysis will provide insight into the degree of influence these scenarios may have on the contributions of investors and farmers.

We utilized the same methodology to recalculate each scenario's basis risk pricing and initial fund size. We then used the tool Solver to calculate the optimal recapitalization.

Table 5-1: Scenarios Analysis (units)

Scenarios	Investors Contribution		Farmers Contribution
	Initial Fund Size	Recapitalization	
Full Era (1983-2020)	32.67	22.7/year for two years	14.35/year
Removal of 1984	31.02	No need of recapitalization	11.73/year
Removal of the 1980s	41.71	3.72/year for five years	12.36/year
Keeping the 2000s	22.9	No need recapitalization	8.42/year

Table 5-2: Scenarios Analysis (% of max liability)
Max Liability: 166 units

Scenarios	Investors Contribution		Farmers Contribution
	Initial Fund Size	Recapitalization	
Full Era (1983-2020)	19.68%	13.67%/year for two years	8.64%/year
Removal of 1984	18.69%	No need of recapitalization	7.07%/year
Removal of the 1980s	25.13%	2.24%/year for five years	7.45%/year
Keeping the 2000s	13.80%	No need recapitalization	5.07%/year

Scenario 1: Removal of 1984

Scenario one explores the impact of removing the worst year, 1984, from the complementary risk fund. This year was distinguished by recurring drought and resulted in the largest payout from index insurance, making it a uniquely salient year. In addition to adverse climate conditions, 1984 was socially and politically a year where many farmers' land rights were threatened. This resulted in farmers becoming reluctant to risk producing surplus foods for the market.

As seen in Table 5, the removal of 1984 reduced both the total premium and initial fund size by 18.26% and 5.05%, respectively *(see Table3, Figure 6 and Figure 7)*. Despite these reductions, the risk fund becomes self-sustainable without the need for additional cash injections.

This is a significant outcome. It indicates that the fund can operate effectively and sustainably without relying on continuous external sources of funding. The removal of 1984 highlights the importance of historical data in assessing risk and ensuring the sustainability of the fund. By identifying and addressing historical outliers, the risk fund can better manage risk and maintain its long-term sustainability. The removal of 1984 has two implications. Firstly, it sheds light on the level of acuity that we possess in relation to the data that is currently accessible. Secondly, as the observation pertains to a bygone era of the 1980s, it serves to underscore the transformations that have transpired between that epoch and the present.

Scenario 2: Removal of the 1980s

Scenario two examines the impact of removing the entire decade of the 1980s from the risk fund. This decade was characterized by severe droughts in Ethiopia, particularly in the Sahel region, which had a significant impact on the risk fund.

By removing the 1980s, the fund experienced a decrease in its total premium by 13.87% and an increase in its initial fund size by 27.67%. The significant reduction in total premium can be perceived as an advantage for farmers because they will pay a lower premium while receiving the same level of risk coverage. The increase in the initial fund size may be viewed as a disadvantage because it implies that the fund has to borrow more money from the investors at the beginning. However, this increase provides the fund with more resources to draw upon, enabling it to better manage risk and respond to unexpected events. The total amount of recapitalization required to ensure the fund's sustainability becomes 3.72/year. This is not as significant of a reduction (83.61%) when compared to the full era scenario. Therefore, by removing the 1980s we improved the overall contributions needed for the fund *(see Table3, Figure 6 and Figure 8*)

The rationale behind the removal of the 1980s from the analysis, as a diagnostic, is the basis risk fund is not getting worse. Essentially, were this fund to exhibit a decline over the course of time, it would constitute compelling evidence of the intensification of the basis risk issue attributable to climate change. However, such a trend is not apparent in the available data, and as such, clear-cut evidence is lacking. Other than climate change, there are also several reasons that may result in this outcome. It is likely that farmer recollection is less accurate for events that occurred further back in time; farmer practices have likely changed since the 1980s due to various factors, such as technology and market conditions; satellite data has likely become more reliable since the 1980s, etc.

Scenario 3: Keeping the 2000s

Scenario three focuses on the impact of using only modern data, specifically data from the 2000s, for the risk fund. It is noteworthy to mention that a new satellite has become available in the year 2000. Explicitly, when discussing the timeframe from the 2000s to the present, this period includes the modernist satellite, while any period preceding the year 2000 does not.

By restricting the data to the 2000s, the risk fund encounters a reduction in its total premium by 41.32% and a reduction in its initial fund size by 29.91%. Despite the substantial reductions observed, the fund attains self-sustainability, negating the need for any supplementary cash injections. This observation indicates that, with less severe climate change effects, the fund can allow for more efficient use of resources *(see Table3, Figure 6 and Figure 9).*

The rationale behind keeping 2000s as a diagnostic is if, hypothetically speaking, the pre-2000 data represented what occurred in the future as a surprise, it is pertinent to consider what consequences would have resulted.

Figure 6: Full Era Fund Cashflow with Optimal Additional Injection

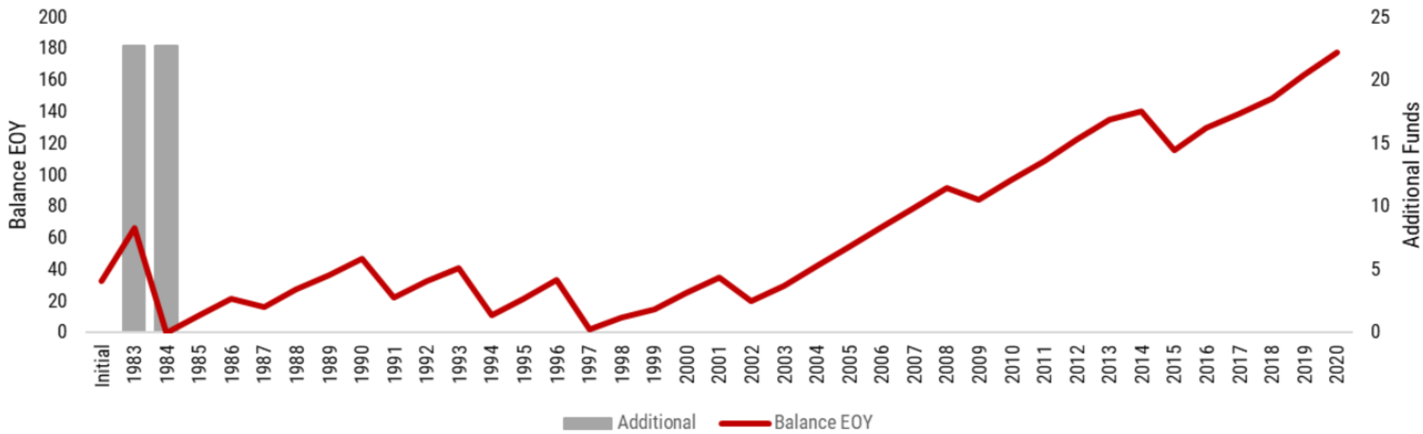


Figure 7: Fund Cashflow after Removing 1984 with Optimal Additional Injection

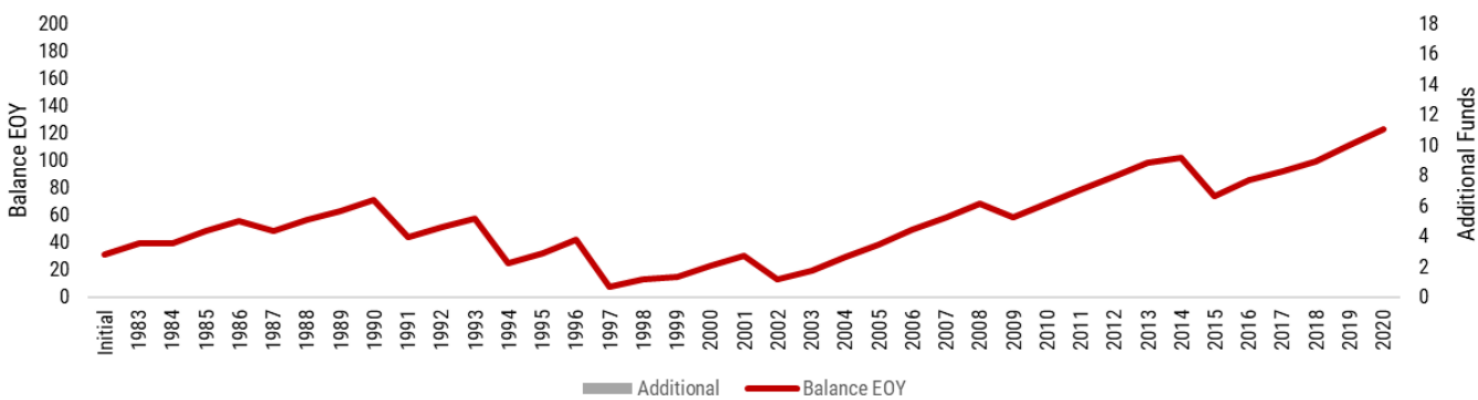


Figure 8: Fund Cashflow after Removing 1980s with Optimal Additional Injection

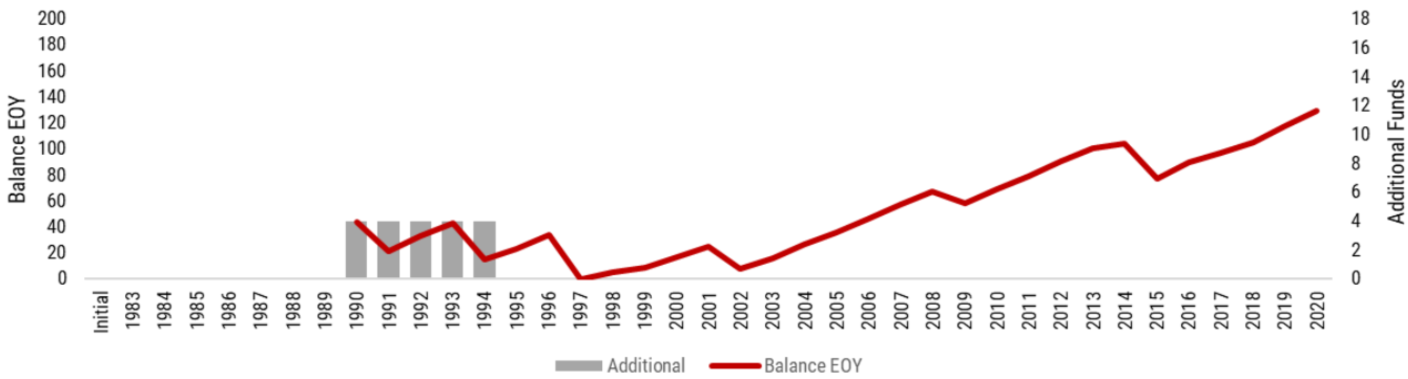
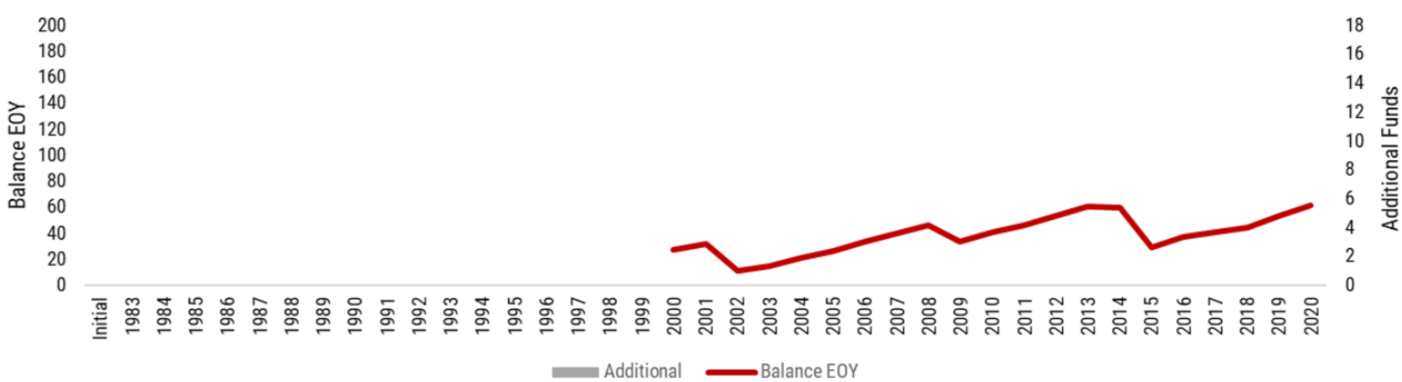


Figure 9: Fund Cashflow in the Modern Era without Additional Injection



Implementation Mechanisms

We've identified scenarios in which the fund can and will become self-sustaining. In addition to these scenarios, we want to propose potential strategies for distributing the funds to farmers. First farmers can take a sample of crop yields to show the losses incurred. Another method is picture-based insurance, where farmers can take photos of their crops to verify their claims. This method is currently being piloted in the Amhara region. Community feedback and consensus is another approach, which relies on community members to confirm losses. Once this is confirmed a yield audit is then triggered. Through this method, the community members manage the complementary risk fund often through the local farmers union and decide how funds will be allocated. Risk events that occur frequently on a local basis are best managed by the community as opposed to extreme weather-related events that impact larger regions.

Updates

The payouts recorded are based on a mix of satellite rainfall and satellite vegetation estimates. The satellite for vegetation estimates, however, were only in the sky since 2000. Historical payouts prior to 2000 were not officially recorded, but instead have been estimated through another satellite that had launched in the 1980s. This is a potential reason for why we see a higher basis risk in the data before 2000. Recently, the IRI team has incorporated those old satellites estimated to the pre-2000 payouts and updated the data set. In utilizing the updated data, we still find that the overall basis risk decreases as expected.

Conclusion

The analysis in this report indicates the high potential of using a complementary risk fund to bridge the gap between index-insurance payouts and losses incurred by farmers. The report provides a stylized exercise of a distinct case to illustrate the overarching approach and methodology. Using the data sets compiled by the R4 project in Ethiopia allowed us to demonstrate how the complementary fund may potentially minimize the impact of uncertainty on farmers to help increase their productive capacity.

The proposed approach allows farmers to benefit from the diversification effect, which results in a much lower premium when compared to their individual risk. The report also sheds light on the cashflow sustainability of the complementary risk fund. It indicates that the fund can be self-sustaining without any required recapitalization. External sources of funds may only be required in salient years, which rarely occur, such as 1984 in Ethiopia where recurring drought and civil war triggered larger losses.

Much future work remains. Future projects may need to focus on three major areas. The first area should center around incorporating upside risk in the pricing methodology. The inclusion of the upside risk will allow farmers to save at least part of their overpayments for future expenses, therefore, potentially lowering the premium and making it cheaper for farmers to insure their farms. The second area of research may focus on investigating the material implications of climate change and improvement of famers' practices on the pricing methodology. The third area should focus on identifying practical mechanisms of measuring basis risk. These methods need to be cost-efficient, effective, and most importantly minimize any moral hazards.

Acknowledgements

Our Columbia SIPA Capstone team would like to extend our sincerest gratitude to Max Mauerman and Dante Salazar Ballesteros and the Columbia Climate School's International Research Institute (IRI) for Climate and Society for supporting our project's efforts.

At SIPA, we are especially grateful to our Advisor, Professor Daniel Osgood, Research Scientist on the Financial Instruments Sector Team at IRI, for educating our team on the world of index insurance and guidance throughout our project. Additionally, we are thankful for the Columbia SIPA Capstone Program and to Suzanne Hollmann and Saleha Awal for their help.

Finally, we would like to extend our gratitude to our client, Panos Varangis at the World Bank. Panos provided invaluable expertise, enthusiasm and direction as we compiled our findings.