Can Insurance Unlock Credit for Farmers in Developing Countries?

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Abstract

Smallholder farmers in developing countries are often credit-constrained due to inefficient and incomplete market mechanisms that make lending unattractive for both farmers and lenders as embedded risks are not completely mitigated. While bundling insurance with credit has long been considered a game-changer to solving this credit rationing problem, in the context of smallholders in developing countries, conventional indemnity-based insurance solutions has been fraught with the problems of enforcement of contracts and affordability. Index-based insurance products where payouts are linked to an objectively designed index which is triggered based on a measurable weather or other widespread events like drought, moisture levels, solves the moral hazard problem faced in conventional insurance solutions. However, other risks like basis risk that entails a standardized payout uncorrelated to the actual loss suffered by a smallholder necessitates further analysis of the conditions under which linking insurance with credit could be a gamechanger.

This study analyses the scenarios in which taking out insurance along with a loan is beneficial for the smallholders and supports repayment of the loan. The probability of default by farmers is estimated by identifying key levers which have been used to construct a model and build different scenarios to test the model through a cash flow analysis. Based on the empirical data taken for maize growing smallholder farmers in Ethiopia, the results obtained from scenario analysis have been used to build a decision tree that summarizes the conditions in which bundling of insurance with credit is beneficial for farmers. The study also delves into the determinants of lending decisions by the financial service providers (FSPs) and if bundling of insurance promotes or inhibits such decisions. The decision model for the FSPs, into which the probability of default by smallholders feeds in, is also built based on the empirical data for the maize-growing farmers in Ethiopia and the results have been validated with a survey that was sent out to different financial institutions that have been offering loans to smallholders in developing countries.

The cash flow analysis for the smallholders reveals that considering the probability of occurrence of a bad output year at 20%, crop insurance may not be desirable in most occasions. However, when cash flows considering bundling and unbundling of loan scenarios are compared with a no loan scenario, we found loan with insurance is preferred to not taking a loan altogether. Thus, we

conclude that insurance is the price that a not-creditworthy smallholder has to pay to avail loan. We also found that a smallholder relying only on farm income would not prefer to take a loan when insurance is bundled with it and the assumptions taken in the model makes purchasing insurance unviable. We propose that subsidies for purchasing insurance and subsequent premium payments may be offered to such a farmer.

The findings show that insurance will provide maximum utility to farmers in regions with significant weather uncertainty (e.g., regions facing climate risk). Moreover, insurance will benefit farmers working with crops that have high output variability (e.g., rice) compared to more resilient crops (e.g., sorghum). In the context of index insurance, we found a 27% probability of a basis risk. We propose that data collection methods should be improved so that basis risk may be further reduced.

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Acronyms and abbreviations

AIP	**Approved Insurance Provider**
CFA	**Chartered Financial Analyst**
CGIAR	**Consultative Group for International Agr Research**
CSA	**Climate-Smart Agriculture**
DBE	**Development Bank of Ethiopia**
DFA	**District Farmers Associations**
FAO	**Food and Agriculture Organization of the United Nations**
FSP	**Financial Service Provider**
GSL	**Group Savings and Loans**
IFC	**International Finance Corporation**
ILO	**International Labor Organization**
IRI	**International Research Institute for Climate and Society**
LDC	**Least Developed Countries**
NGO	**Non-Governmental Organization**
SACCOs	**Savings and Credit Cooperatives**
SC	**Share Company**

Executive Summary

In developing countries, many programs and policies have been introduced to increase general lending to the agricultural sector and to small farmers specifically. Despite these concerted efforts, smallholder farmers continue to be credit constrained and continue to lose opportunities to adopt productivity-enhancing projects that require greater cash outlays, while offering the prospect of higher yields and farm incomes. The intractability of the problem has generated considerable interest in harnessing agricultural insurance to reduce the risk that smallholders face upon adopting new technologies and production practices. The reduction in risk faced by farmers would lessen the risk of default faced by financial service providers (FSPs) encouraging them to provide credit to farmers and invest in developing sustainable methods to serve agriculture. We will refer to these as the two-problem market failure, the FSPs lending problem and farmer's repayment problem.

Conventional indemnity-based crop insurance products to underwrite farm loans issued by specialized agricultural development banks were besotted with the problem of asymmetric information *ex-ante* and the moral hazard of farmers not repaying their loans *post facto* and have thus been largely unsuccessful and financially expensive. However, index-based insurance products linked to either weather conditions or other indexes have significantly improved the performance of agricultural insurance by addressing these problems. Index based insurance has opened novel avenues for bundling of insurance with credit and serve as a win-win solution for farmers and FSPs that eliminate the desire for farmers to not pay their loans and incentivize FSPs to lend. In particular, it is expected that objectively designed index insurance products will be attractive for smallholders and FSPs alike.

On one hand, smallholders can expect a payout during bad years without undergoing onerous processes that entails verification and site visits by the insurer. On the other hand, insurers too obviate the problem of moral hazard as instead of indemnification of individual loss, they cover the loss under index-insurance that is correlated with the measurement of parameters like shortfall in rain and level of moisture which can be measured with improved remote sensing satellite technology.

The study reviews the conditions under which credit linked insurance could unlock agricultural lending for farmers by underwriting some of the systemic risks that plague agriculture. A two-tiered framework has been designed to identify key levers that influence the decision of FSPs to lend to the smallholders and the farmers' ability to repay the loan.

Key lessons

Although crop insurance can unlock credit for smallholders, bundling the two is far from being a silver bullet for the credit constraint problem. Nevertheless, FSPs are encouraged to offer crop insurance to reduce the risk of default by borrowers, attracting more clients, reaching poorer smallholders, and generating fee income. On the aspect of whether loans and insurance benefit farmers, the study develops key insights using scenario-based cash flow analysis and developing data-driven estimates for different

levers that determine the probability of default on loan repayment by maize growing farmers in Ethiopia as well the probability of lending by FSPs.

The evidence from the model strengthens the argument that loans benefit farmers and they can improve their cash balance even in the absence of non-farm income when loan is availed. Moreover, if index insurance is used, FSPs should take efforts to make borrowers understand the complexity of basis risk and the modalities of payouts and handle grievances when smallholders experience losses but do not receive payouts, or experience insured losses and receive some payouts, but still owe balances on their loans.

In this realm, the study has estimated basis risk at 27% indicating a very high level of matching between bad years as perceived by the smallholders and the instances of payouts. The study has found that purchasing insurance assisted in consumption smoothing of smallholders and the volatility of income also reduced. The results from the study indicated that insurance enabled farmers with lower levels of non-farm income/collateral to better utilize agriculture credit.

1. Introduction

The smallholder farmers in developing countries face both systemic and idiosyncratic risks while undertaking farming. The primary impediment to the adoption and usage of improved agricultural inputs like high quality seeds, renunciation of primitive agricultural technology has been identified as the reluctance of smallholders to take risk (Carter, et.al, 2014). As a fallout, the income levels of smallholders remain stagnant which perpetuates inter-generational poverty (Feder et al., 1985). Risk aversion prevents them from technology adoption by making them hesitant to invest their personal savings or offer it as a collateral, which hitherto could dampen the exogenous shocks of periodic income shortfalls which are a hallmark of subsistence farming practiced by the smallholders. In the words of Boucher et al. (2008), smallholders are wary of 'risk rationing'[1].

This risk aversion also extends to the lenders in agriculture finance. The lack of access to agricultural credit has long been identified as the primary constraint faced by farmers in developing countries, especially smallholders. As a result, governments and donors have, over several decades, tried a variety of programs and policies designed to increase lending to the agricultural sector generally, and to small farmers in particular. In spite of these efforts, the sector and smallholders continue to be credit constrained (World Bank, 2017). While agricultural credit can offer potential solutions, systemic risk is correlated across farmers, such as that posed by erratic weather, and this exacerbates the portfolio problem for microfinance and other potential lenders raising the cost of credit to the small farm sector.

Use of Insurance

Ordinarily, through insurance backed agricultural loans, the challenge of risk-inhibited technology adoption could be surmounted but the problem of asymmetric

[1] Risk or credit rationing refers to a situation when no lending institution is willing to extend credit to smallholder farmers following the usual terms of contract.

information and presence of inefficient markets make conventional individual indemnity-based agricultural loan markets unviable (Barnett et al., 2008; Hazell, 1992). Notably, technological advances in the field of remote sensing through satellites generated the field of 'index insurance' in which payouts are based on an easy-to-measure quantifiable and objective index, which cannot be influenced by the individual, but which is correlated with (but not identical to) individual outcomes. Conventional insurance relies on loss verification to control moral hazard. Unfortunately, for a small, remote farmer, a single loss verification will consume multiple years of premium payments, rendering this kind of insurance economically infeasible. Similarly, individual-specific loss rating is non-economic for small-scale, exposing conventional insurance schemes to adverse selection.

On the contrary, index insurance indemnifies insured farmers based on an external index such as directly measured average yields in a region or average yields as predicted by rainfall, remotely sensed measures of plant growth such as evapo-transpiration. Since an individual producer cannot influence any of these area measures, index insurance addresses the problems of moral hazard and adverse selection problems that rendered conventional insurance unattractive for small-holder farmers. Nonetheless, index insurance can only protect individuals against covariant risk, meaning shocks, like droughts, that are correlated across individuals since it is possible that a particular farmer had indeed lost her crops to a bad drought yet the payouts are not triggered in her case or are insufficient to cover the losses.

The empirical research on the efficacy of index insurance has shown mixed results. Elabed and Carter (2014); Karlan et al. (2014); Mobarak and Rosenzweig (2013) have shown strongly positive impacts of index insurance on small farm investment and technology adoption with index insurance significantly boosting investment in high returning technologies in the range of 25% to 35%. Meanwhile, Giné and Yang (2009) conclude that investment in new agricultural technology declines after entering into an index insurance contract.

In this context, the objective of the research is to analyze the conditions under which credit linked insurance could unlock agricultural lending for farmers by underwriting some of the systemic risks that plague agriculture. As opined, index-based insurance products can effectively address systemic risks in agriculture in an affordable way in certain scenarios. Furthermore, financing from FSPs[2] can be vital for several reasons. Households may find formal finance as an additional tool for consumption smoothing over time which is one of the main drivers for borrowing small loans. But, additional financing holds key for investment in more productive activities too. Besides, fostering adoption of high yielding varieties of seeds, for instance, financing may also be needed for moving up the value chain and in transforming into a contract farmer for new high-quality commodities supplied to upscale international markets. There may also be a need for financing investments to make farming more resilient and adaptive to climate change.

Linking insurance to access to credit

In contrast to the conventional indemnity based agricultural insurance, index insurance is relatively cheap, easy to implement and administer, and offers good contractual incentives (Skees 2008). While index insurance products were initially introduced as a risk-reduction tool, they have now increasingly found utility in improving access to agricultural credit that facilitates smallholder farmers' ability to undertake productive investments (McCarney & Osgood, 2016). When a loan is bundled with index insurance, it reduces the risk of farmers default on loan payments by poor farmers owing to mitigating conditions like drought. It also thus increases the demand for agricultural loans, or alternatively makes it possible for the FSPs to lend to otherwise unbanked farmers.

[2] FSPs are defined here to include any kind of formal financial service provider that makes loans and may take savings and deposits. In rural areas, they include banks, microfinance institutions, financial NGOs, and various kinds of credit and savings groups including savings and credit cooperatives (SACCOs) that are weakly regulated. They do not include informal sources of loans and savings services such as small savings groups, traders, aggregators and other mechanisms that operate in value chains and provide finance linked to specific commodities.

The bulk of the literature that analyzed the interlinkage between index insurance and agricultural credit carried the implied assumption that smallholder farmers already have access to credit, and the focus of the analysis has been to understand how insurance impacts the demand for loans among farmers (Carter et al., 2016). However, since credit rationing is prevalent for smallholders in developing countries, it is vital to study how bundling index insurance with credit will alter the structure of the asymmetric information problem (McCarney & Osgood, 2016). In this regard, it is also important to study the basic mechanism design link between loans and index insurance; so that the role played by different local institutional, environmental, and social conditions in altering the outcomes of bundling these contracts may be analyzed.

Two level decision framework

The goal of the research has been accomplished by designing a two-tiered framework that attempts to answer the question as to what are the factors that influence the decision of FSPs to lend to the smallholders. Concurrently, farmers' ability to repay the loan has been analyzed through the lens of yield output and prices. Using this model, the research strives to understand if bundling of loans with insurance would make any significant difference in decision making by farmers and FSPs – the two principal agents of the study, or not.

2. Background

The agricultural sector and particularly smallholder farmers in developing countries usually miss opportunities for increasing productivity to some large extent attributed to their credit constraints and financial insecurity. Different programs and policies have been created to address this impediment, and one of the most studied is the credit-linked insurance, which could benefit farmers, FSPs and insurers (ILO & IFC, 2017).

This paper will focus on data based on Ethiopia to understand under which conditions insurance can unlock credit for farmers. Ethiopia was chosen because it has an established insurance market, there is an extensive field of work, and thorough available information. It is important to mention there is a large literature on the risk from the FSPs perspective and there is less research about the farmer's possibility of default. For simplification matters, this report will mainly focus on the FSPs' risks and the challenges of loan repayment. The background addresses situations related to how insurance has presented different outcomes in Africa and it is divided in four parts. The first one will present an overview of the FSPs risks and decisions when lending to smallholder farmers. The second section will suggest conditions in which linking insurance and credit could be effective. The third one will show the effects of this linkage in two countries in Africa. Finally, the fourth one will introduce some of the conditions in which index insurance promotes climate-smart agriculture in Ethiopia and Senegal. At the end, we will explain the market failures problems and our approach considering this background.

Key elements of the credit decision making process by FSPs

Farmers face limited access to agricultural credit, which restricts their capacity to invest in technology and better inputs, to be more productive and to increase their income (International Finance Corporation, 2014). Similarly, FSPs and micro finance institutions experience significant risks when deciding to lend to smallholder

farmers, which include irregular cash flow, seasonality and higher transaction costs (International Finance Corporation, 2014). In addition, FSPs generally consider the traditional credit analysis regarding the "four Cs": capacity (ability to pay on time), collateral, covenants (provisions in a bond indenture) and character (credit history) (CFA Institute, 2021).

In order to address risks and understand best possible practices for agricultural lending, in 2014 the International Finance Corporation (IFC) conducted a study in Latin America and the Caribbean and presented the following lessons learned, which can be scalable and applicable to similar situations if they are customized to the context.

First, the report suggests agricultural lending is mission and market driven and it mentions the importance of knowing the client and having specialized staff, training and incentives for loan officers. Second, their case studies showed a trend of adopting a "single, flexible agricultural credit product, and flexible payment terms, matched to agricultural production cycles" (International Finance Corporation, 2014, p. 16), along with collateral requirements such as movable or fixed assets or personal guarantor, depending on the size of the loan. Additionally, the flexible payment term was linked to their cash flow and harvest cycles. Third, there was a focus on the household production unit for the credit analysis, which went beyond the agricultural activity. Last, regarding risk mitigation practices, the authors' findings include:

> "(1) intensive, field-based client monitoring; (2) limitations on the number of loans per credit officer; (3) portfolio diversification (by clientele, geographical location, sector, and/or crop); (4) leveraging of credit bureaus and credit scoring; (5) use of "real" collateral (i.e., secured with legal title on fixed assets and certain movable assets); and (6) use of insurance products" (International Finance Corporation, 2014, p. 24).

Hence, even though FSPs face some risks providing credit opportunities to smallholder farmers, these findings show it is possible for them to be profitable while benefiting their targeted customers.

The role of crop insurance in the credit decision making process by FSPs

In 2017, the International Labor Organization (ILO) and the IFC published the paper "Unlocking Smallholder Credit: Does Credit-Linked Agricultural Insurance Work?" regarding credit-linked crop insurance, which compared credit market scenarios with and without insurance linkages to understand the impact in credit. Even though it mentions that there is not sufficient evidence and details to offer good practice recommendations, it does suggest insurance can unlock credit in some situations, but it will depend on the context and particular circumstances.

The key findings of this paper regarding the conditions in which insurance could unlock credit consider the interests of smallholders, FSPs and insurers. On the one hand, FSPs would benefit from crop insurance because it can reduce default risks, as well as interest rates and raise profits, among others (ILO & IFC, 2017). However, it can also imply additional efforts such as training and monitoring loan officers to explain this product to smallholders, particularly if it involves index insurance, since it comprises the complex concept of basis risk. Likewise, insurers would have to train FSPs to market it, pay them an incentive for promoting it and monitor smallholder performance. Another alternative discussed for FSPs purchasing meso insurance for portfolio coverage to protect against systemic risk, but this has not been implemented enough to determine its efficacy and there remains a chance the borrower will still default.

On the other hand, if correlated risks are significant where the FSPs operate, collateral would mitigate risks and insurance could be its substitute (ILO & IFC, 2017). Therefore, FSPs would be interested in credit-linked insurance if there is government pressure to lend or to be negligent about loan recovery, but they could

not choose it if borrowers can use collaterals. In case of mandatory insurance coverage, although this might be attractive for FSPs, the downside is it could discourage farmers from taking the loan, since they could have other ways of managing the risk or they disagree with the basis risk.

The paper concludes there is not enough research about insurance's effectiveness in reducing credit constraints for smallholder farmers. The authors suggest further studies could show how insurance affects FSPs' lending practices and how this impacts farmers' access and use of credit, as well as their productivity and income (ILO & IFC, 2017).

Case study of crop insurance unlocking credit for farmers: Zambia and Burkina Faso

In 2013, Van Asseldonk et al. analyzed the impact of linking crop insurance and credit in Africa, particularly in Zambia and Burkina Faso, where there is a high risk of weather events and underdeveloped insurance markets.

First, in Zambia, they linked the insurance policy with the Lima credit scheme, which provides credit services to smallholder farmers without collateral, based on Group Savings and Loans (GSL) approach (Van Asseldonk, et al., 2013). This model targets farmers who will potentially have farming as a business and it consists of depositing 50% of input requirements in a collateral account, supported by an insurance policy and guaranteed by the District Farmers Associations (DFA). The scheme was successful because interest rates decreased from 26% to 11% and it was attractive to banks since 50% of collaterals were ultimately offered by farmers participating in this credit strategy.

Second, in Burkina Faso, the project was developing a pilot with index-based insurance that covered drought risks in maize for 194 producers, along with a system that combined crop insurance and rural credit facilities (Van Asseldonk, et al., 2013). They used satellite information for payouts and even though insurance was optional,

credit agencies usually requested it. The pilot was useful and successful, insured farmers were almost all accompanied with credit and it was planned to be expanded to 10,000 producers in the next seasons.

In both cases, the authors show how linking crop insurance with credit could potentially offer advantages for farmers, since it can increase available resources, and smooth and enhance their income (Van Asseldonk, et al., 2013).

The role of insurance in supporting climate smart agriculture tools

Last, in 2020 a group of graduate students at Columbia University, together with the Finance, Competitiveness and Innovation Unit of the World Bank Group studied the conditions in which index insurance promotes climate-smart agriculture (CSA) by de-risking investment. Their case of study was based on Senegal and Ethiopia, where weather variability has increased and therefore, CSA provides potential adaptive capacity to farmers (Badani, et al., 2020).

In their paper, the authors identified three key exogenous variables, called switch factors: "1) weather and basis risk, 2) technology's cost, profitability, and embedded protection against climate risk, and 3) risk exposure and loss" (Badani, et al., 2020, p. 6). Considering these factors, they develop a risk analysis framework for the farmer's decision-making process which confirms the ability to de-risk investment using insurance depends on the interaction of the switch factors (Badani, et al., 2020).

Particularly, the model used in their study confirms that at low and moderate levels of climate risk, insurance is limited since farmers could use climate-smart technology. However, at high levels, CSA would not mitigate the risk completely and insurance could be more effective. Finally, as suggested by the previous studies, they argue it will all depend on the context, the magnitude of the climate impacts and the characteristics of the available technologies.

The two-problem market failure: FSP lending problem and farmer repayment problem

From the background, it is clear that FSPs face risks when providing credit opportunities for farmers, but these can be reduced by farmers' capacity to diversify their income. Additionally, in the case of Zambia and Burkina Faso, linking crop insurance with credit could provide advantages, but cases show success will depend on specific contexts, weather conditions, output volatility and financial market regulations.

Additionally, it is ultimately gathered that there are two market failures that exist in the agriculture space that will not be resolved by the private sector. For FSPs, their decision to lend to the agriculture sector is inhibited by the lack of stable cash flow to maintain frequent debt repayments. Hence, FSPs usually offset seasonality risks of repayment accepting it at the end of the crop season. However, there is always uncertainty about farmers' cash flows and their ability to repay, either at the end or periodically and thus, insurance could contribute to this risk. We will subsequently refer to this as the "lending problem".

For farmers, their ability to repay is largely affected by two main exogenous related factors that impact their yield output (droughts, efficacy of inputs) or prices. The following section will outline our approach to how we will look to address these two key problems.

3. Approach

In the study, the problem of credit availability to smallholders in developing countries in an imperfect market has been analyzed from the perspective of FSPs as well as that of the farmers. Essentially, FSPs are reluctant to lend to smallholders because of their wariness of the repayment capacity of such farmers. On the flip side, farmers also do not take out loans and rely on alternative sources of finance since they are uncertain of the future cash flows which determine the ability to repay. Primarily, uncertainty arises due to weather related events like droughts that can lead to exogenous output shocks and fluctuations in commodity market prices that engender price shocks.

In view of this, the approach for this study is based on reviewing both the FSPs lending decision problem and the farmers' repayment problem. The lending process adopted by the FSPs, and alongside, key determinants that affect the probability of default by smallholder farmers have been analyzed. Pertinently, the chances of default by a farmer on crop loans is a vital input for the lending decision made by the FSPs as the former 'feeds' into the latter from a modelling standpoint. Moreover, the relevance of bundling insurance with the crop loans for decision making by smallholder farmers and how its further impacts the decision making of the FSPs have also been analyzed by generating different scenarios for these two problems.

The research methods for this report include a desk research and a brief self-administered online survey targeting FSPs (Number of responses: 7, Number of FSPs represented: 5).

The FSPs' lending problem and farmers' repayment problem

In the context of smallholder farmers, the *ex-ante* capacity to repay the loan is a prime driver for FSPs to resolve the policy dilemma of lending or not. From the perspective of a farmer, who is the other economic agent, the *post-facto* willingness to

repay the loan as well the ability to do so are principal criteria to discursively analyze the probability of default. The willingness to pay is difficult to estimate as it depends on the ethical moorings and behavioral aspects manifested by the farmers. The problem could be resolved by maintaining a clearinghouse that stores credit history of borrowers, and on which FSPs can rely upon to ascertain the willingness to pay. However, in developing countries, such instruments are not viable since farmers usually take loans from informal sources like moneylenders with interlinkages and hence an intimate relationship is maintained. The moneylender, leveraging her proximity to the borrower, can observe her actions closely and hence the need of maintaining a credit history is obviated. More so, farmers are also associated with a particular moneylender and do not switch over as that would raise suspicion on her repayment capacity.

In essence, a formal credit bureau or exchange that exists in the credit markets in advanced economies does not exist in developing countries. FSPs therefore have no recourse but to presume *ex ante* that smallholder would default at the slightest pretext as willingness to pay could not be measured. Since default on repayment leads to harmful consequences for farmers such as the inability to borrow in future, liquidation of collateral, etc., we will assume that the farmer has the willingness to pay and, thus, we will focus solely on the ability to repay.

The capacity to repay has been calculated using cash flow simulation for a typical farmer growing maize in Ethiopia and who has taken out a crop loan. In order to simplify the problem, only one period has been considered implying that the farmer avails the crop loan at the beginning of the agriculture cycle in a given year and utilizes the loan to procure inputs like seeds, fertilizer essentially as a working capital loan and after harvesting and selling, s/he will repay the loan at the end of crop year while not carrying it forward. A positive cash flow at the end of the period signifies the capacity to repay the loan, else not. The exogenous variables like price of crop, shocks induced by lockdowns imposed in view of pandemics have also been

considered. Following previous studies (Badani, et al., 2020), it has been assumed that the probability of having a complete loss leading to a bad output year is one in five years, which means 20%.

The levers considered to determine the probability of lending by the FSP are (i) borrower's net income in previous years, (ii) volatility of farm income, (iii) availability of non-farm income, and (iv) uptake of crop insurance bundled with the crop loan. The probability of default by the farmer, which is an endogenous variable determined by other levers, also affects the probability of lending by FSPs. Specifically, probability of default is determined by (i) the extent to which s/he is engaged in crop diversification, (ii) the volatility of crop output, (iii) the volatility of crop price, (iv) the interest rate on the crop loan, (v) the proportion of input costs (related to the value of the crop), (vi) available non-farm income, (vii) insurance coverage, (viii) insurance loading, and (ix) basis risk[3]. These variables will be explained in the following sections.

Once the levers are identified, a range of values for each of them have been estimated relying on the available data and contemporary research studies undertaken to understand the problem of what determines the credit uptake by smallholder farmers. After different parameters have been estimated, the cash flow in one period has been analyzed under 16 different scenarios to ascertain the set of conditions in which insurance could be beneficial for farmers by generating a higher cash flow balance on one hand, and mitigating risks faced by FSPs through reduction in probability of default on the other.

The enabling scenarios have been structured around the probability of occurrence of a bad output year and a bad price year assuming that the two scenarios

[3] Basis risk is the risk arising out of no insurance payout or lesser payout than the actual loss suffered by the insured farmer when an adverse weather event like deficit in rainfall reduces crop output.

are independent[4], if crop insurance is bundled with the loan, and whether other income has been offered by the farmer. The capacity to repay has been analyzed through the lens of a cash flow analysis which involves the farmer's revenues and expenses, while considering different levers. Operational, non-farm and financing cash flows have been evaluated for the one-period of agricultural cycle to ascertain if the farmer would be solvent at the end so as to repay the loan.

Consequent upon building the scenarios, sensitivity analysis has been performed to fathom the effect of different parameters like enhanced availability of collateral on the outcome of the farmer's problem. After solving the lending problem for FSPs and repayment problems for the farmers, market clearing conditions for both agents will be laid down.

a. Levers Description - The farmers' repayment problem

Regarding the variables affecting the probability of default, these are crop diversification, volatility of output, volatility of crop price, interest rate on loan, share of input costs, non-farm income, insurance coverage, insurance loading, and basis risk. Table 1 presents these variables, their description and their average estimates.

Table 1. Probability of Default

No.	Exogenous variables (Xi)	Description	Average Estimates
1	Crop diversification	Crop diversification makes farmers more resilient to shocks on outputs or prices	12.1% increase to income per add'l crop
2	Volatility of output	Average expected loss for a 1-in-5 year for output	-20.5% drop for a bad output year
3	Volatility of crop price	Average expected loss for a 1-in-5 year for producer price	-36.1% drop for a bad price year

[4] Price and output are drawn from two independent distributions and hence it has been assumed that there is no correlation between output and price in this one period model. The assumption holds for a small country case like Ethiopia considered in this study.

4	Interest rate on loan (%)	High interest rate lowers ability to repay	14.25%
5	Share of input cost (% with relation to crop income)	High share of input costs hurts profits and creditworthiness, unless accompanied with an increase in yield (better technology)	52%
6	Non-farm income (% share of agricultural income)	Higher non-farm income or collateral value improves repayment ability	42.86% of farm income
7	Insurance coverage (% of the loan)	High coverage helps repayment in bad output years, but could be offset by basis risk	45.69%
8	Insurance loading	High insurance costs hurt farmer profits and repayment	25% of the premium
9	Basis risk	Basis risk occurs in a bad output year, when the farmer sees losses but insurance doesn't payout. Basis risk also occurs in normal years, but it is not common, thus we will not include it in this case.	14%-40%

i. Crop Diversification

Crop diversification is the practice of cultivating more than one variety of crops in the form of mixed cropping at the same time in order to reduce income risks by creating more than one source of income (Sarwosri and Musshoff, 2020). Moreover, the positive effects of diversification were investigated in several empirical studies (e.g., Bezabih & Sarr, 2012; Chavas & Di Falco, 2012). These studies provided evidence that crop diversification has the purpose of smoothing farmers' income during the 'bad season' for one particular crop. Because not all farm outputs would be affected in the same way by changing circumstances, diversification can spread risk and is an effective risk management technique. It reduces aggregate yield losses while also reducing price shocks caused by climate change (Auffhammer and Carleton, 2018). This aims to protect farmers from both output and price shocks, thus we can assume that crop diversification income would be unaffected by output and price shocks in our model.

In particular, it has been estimated that 78.9% of Ethiopian farmers practice intercropping (Mesfin, Fufa, & Haji, 2011), thus it can be said that the average farmer in this country is diversified. In the case of maize, it typically grows together with beans. Under normal conditions, Ethiopian farmers grow on average three crops at the same time (Dessie et al., 2019). Even though we do not have an estimate on how diversification affects the farmer's revenue, an empirical study in Niger found that each additional crop increases the farmer's crop income by 12.1% for the 20% income quintile (Asfaw, Pallante, & Palma, 2018). Moreover, the same study concluded that diversification has a larger effect on the most vulnerable households in comparison to the greatest income quantiles. For the effects of the study, we will use this estimate of Niger for the case of Ethiopia.

ii. Volatility of Output

The output volatility depends heavily on the climate condition that might affect the farmer's probability of default. Climate change can lead to more frequent extreme events such as droughts, heat waves and floods which can cause bad years for farmers that have a big contribution to the agricultural production (FAO, 2011). The worse the climate condition within the year, the bigger chance of the crop failing would be.

Using the available historical data from FAO on yield per hectare of maize in Ethiopia from 1993 to 2019, we estimated the expected loss given the frequency of bad output years. Assuming a normal distribution, we calculated the percentile amount for 5%-45%, which was associated with a probability of a bad year. The first half of the distribution is used for bad years because these values are lower than the median. As a result, we obtained the expected loss in percentage terms for different levels of probability of a bad year.

iii. Volatility of Crop Price

Most agricultural commodity markets are characterized by a high degree of volatility. Low prices and high price volatility for agricultural commodities can be cyclical, thus reducing household income for farmers during periods of glut or harvest time (FAO, 2011). This is especially relevant for crops for which farmers either have no/limited storage capacity or lack the possibility to process raw crops into downstream products. In such situations, rural farmers often need to sell their farm produce at harvest time, resulting in the underpricing of farm products and exacerbating farmer poverty (David T, et al. 2016). Crop price volatility is also related to seasonal conditions.

Similar to the volatility of output, using the available historical data from FAO on the producer price of maize in Ethiopia from 1994 to 2018, we estimated the expected loss given the frequency of bad output years. While maize prices do exhibit high autocorrelation per Deaton and Laroque (1992) — which challenges the assumption of normality — empirical data (OECD 1993, page 30) shows that the kurtosis and skewness of maize prices are closer to Gaussian than other core crops like wheat, soya, and sugar. As a result, we assumed a normal distribution and calculated the percentile amount for 5%-45%, which was associated with a probability of a bad year. The first half of the distribution is used for bad years because these values are lower than the median. As a result, we obtained the expected loss in percentage terms for different levels of probability of a bad year.

iv. Interest Rate of Loan

It could be argued that smallholder farmers would not be able to pay higher interest rates (World Bank, 2014). The cost of default equals the increase of future loan interest rate plus opportunity costs that may result from impaired personal reputation. In joint lending, the credit default will be subject to multiple restrictions by rural financial institutions, joint lending group members and the insurance companies after the farmers purchase index insurance (Tang, Yi-Mei, et al, 2020).

Particularly, for Ethiopia, the simple average nominal lending interest rate is reported as 14.25% in the Annual Report 2019-20. However, with a 21.6 percent headline inflation rate, the real rate of interest remained negative 7.3 percent (National Bank of Ethiopia, 2020). For our model, we will use an interest rate of 14.25% as it is consistent with the results of our survey to FSPSs, which note that most of the surveyed FSPs with presence in Ethiopia charge an interest rate range of 10% to 20%.

v. Share of Input Cost

Input cost is one of the major costs in agriculture as it is the basis of the crop production, seeds or planting materials, fertilizers, pesticides, water, soil amendments, and farming equipment are considered as agricultural inputs. High input costs will hurt profits and farmer creditworthiness, portending higher probability of default. The average cost of maize production in Ethiopia was estimated in 2015 to be 41% of the final sale cost for farmers (Rashid, Getnet, and Lemma 2010). The level of investment into the farm (as expected) has a material impact on both costs and crop yields. A 2014 study by CGIAR found that improved varieties of maize yield 48–63% more than traditional varieties, but required higher input expenditure of 22.8–29.4%. Therefore, we add the high-investment maize cost to the original input cost, to reach a 52% share of input cost.

vi. Non-Farm Income

Farmers with a variety of income sources from farm and non-farm related activities are normally preferred clients for term loans. Diversified income sources allow for steadier loan repayment, reducing the need for a grace period and providing an alternative source for loan repayment in case of lower than anticipated profitability of the investment activity (Hollinger, 2004). When wage labor is not available, insurance is more valuable and the fraction of farm income insured is higher in this case for most probabilities of rainfall shock (Mukherjee, Cole, & Tobacman, 2020).

Participation in non-farm labor markets can affect access to credit markets. Given the frequent inadequacy of land to serve as collateral for agricultural loans in informal and formal credit markets, steady pay in the non-farm labour market is used by creditors as substitute collateral for loans (Reardon, 1999). Hence, non-farm earnings allow preferential access to local credit sources, and these non-farm and farm strategies converge to concentrate capital.

In Ethiopia, farmers have a non-farm income of 30% of total income (Porter, 2012). Assuming that the farmer only engages in two activities (agriculture and other non-agricultural activity), the estimate is equivalent to approximately 42.86% of the agricultural income.

vii. Insurance Coverage

The coverage level is the number of insurance contracts an individual can purchase to lower their yield risk. For example, an individual may want to take out two area yield insurance contracts per hectare to hedge against risk, in which case his coverage level is 200% per hectare. Assuming that coverage level is set at 100%, or that individuals are restricted to buying one contract per hectare. In low-income countries, this is a reasonable assumption as most contracts provide minimal or no choice to farmers beyond a coverage level of 100% (Ruee B.A, CJ, 2003). In most cases, the insurance covers loss of yield or revenue exceeding a deductible amount. Farmers, ranchers or growers can experience a loss of revenue due to low production and/or changes in the market price. The types of coverage available vary by crop and county due to the differences in each crop.

For the present study, we will refer to the coverage as the share of the loan that could be repaid with the insurance payout, this is the "insured share of the loan". Average insurance payouts in Ethiopia are around $80 (Ahmed, McIntosh, & Sarris, 2017). Taking into account the loan size (we will assume is $175.08, equivalent to the input costs), the average insurance coverage as a share of the loan is 45.69%.

viii. Insurance Loading

Insurance loading is the additional premium to risk based rate (not the standard rate) due to various considerations such as administrative costs, financial costs, and more importantly the uncertainty of the probability of bad years when claims will occur. It is also defined as (Premium Charged)/(Expected Claim Income) which loadings of 20% and 60% are low compared to reported commercial loadings, ranging from 70% to 430% for weather indexed insurance (Cole et al. 2009,) and 140% to 470% for indemnity insurance (Hazell 1992).

In practice, loading costs are on average 30% of the premium (Gollier, 2003), but can vary depending on administrative or marketing costs associated with implementing insurance. Loading is a particularly important concern when markets are relatively new or inexistent. This is the case for index insurance in Least Developed Countries (LDCs). The assumption used on this lever is that high insurance costs will hurt farmer profits and repayment. In Ethiopia, the commercial margin of Nyala, a company that offers crop-insurance loans in this country, is around 25% (Ahmed, McIntosh, & Sarris, 2017), which is the estimate we will use for our calculations.

ix. Basis Risk

In the context of index insurance, basis risk is the risk arising out of no insurance payout or lesser payout than actual loss when an adverse weather event like deficit in rainfall reduces crop output. It is a manifestation of significant deviation between what is quantified at the point of measurement and true losses faced by a smallholder farmer (Madajewicz, M. & Tsegay, A.H., 2013).

Thus, in case basis risk embedded in the agricultural product is high, it influences farmers' perception on the utility of bundling insurance with credit due to low insurance compensation vis-à-vis crop losses actually experienced. There is

thus a clear need to monitor crops and have a system in place to address basis risk (WFP, 2019).

High accuracy of the weather indexes is illustrated in a simple benchmark– how well the index would have covered historical droughts if it were sold in the past? Data shows that the index would have triggered payouts in 7 out of 9 years which were identified by the farmers themselves during interviews as the worst in the last three decades (Osgood., D 2016).

In the context of Ethiopia, the basis risk has been estimated following the R4 Ethiopia Drought Index Insurance jointly drawn by International Research Institute for Climate and Society (IRI), Columbia University and the World Food Program for around 200 villages in the Amhara region in the country. The index window consolidation application has been used to ascertain the upper and lower threshold of the proportion of the bad year matching in each of the villages based on the interviews conducted with the villagers.

For instance, 80% matching for a particular village implies that an index-based payout would have been triggered in as many proportions of the bad years that had happened in the past as reported by the villagers. Upon analysis of this application, the lower level of matching was found to be 60% and the upper level at 86% (IRI, 2021). The basis risk has thus been estimated to be in the range 14%-40%.

b. The FSPs' lending problem

In practice, the determinants affecting the probability of lending for FSPs include the farmer's probability of default, net income in the previous year, volatility of income, the loan collateral posted and the farmer's crop insurance. However, it is noted that in our one-period model, the assumption is that farmers only operate in a one-year period. Therefore, net income in the previous year and loan collateral posted are not included in the model as they are income or assets across multiple

time periods. In the model of our analysis, we consider farmer's probability of default, volatility of income, and farmer's crop insurance as the determinants affecting FSPs' lending.

i. Farmer's Probability of Default

A farmer's probability of default is determined by different levers, such as their crop diversification, volatility of output (depends on normal or bad output years), volatility of crop price (depends on normal or bad price years), interest rate on loan, share of input cost, non-farm income, insurance coverage, insurance loading and basis risk. These levers are presented in the farmers' repayment problem, detailing the variables' construction and providing estimates.

As a determinant of the probability of lending, the probability of default is negatively associated with the probability of lending by FSPs. The definition of default by farmers on a credit product can vary among different FSPs but a rising default rate is often a burden for any FSPs since increasing default among groups of smallholder farmers means that FSPs receive less funding as repayment from farmers which limits their credit supply to potential borrowers. An event of systemic default could also make it impossible for FSPs to continue providing credit products for smallholder farmers in order to support productivity growth or technology use in agriculture. The FSPs usually have modest acceptable levels of probability of default. As an example, the maximum probability of default accepted by the FSPs surveyed was 15%.

ii. Farmer's Volatility of Income

Smallholder farmers' income can be extremely volatile for reasons including the volatility of output due to systematic or idiosyncratic risks and the volatility of crop prices in the market. Due to climate change and the resulting extreme adverse events, agricultural output can become more volatile which then contributes to more volatile farmer's income. The volatility of crop prices in the market is also a factor

beyond farmers' control but contributes to farmers' volatile income of the year. In the one-period model, prices and output are assumed to be independent for the purpose of analysis. It is worth noting that in our model, the volatility of income is embedded in the probability of default as it affects the farmers' cash flow.

iii. Farmer's Crop Insurance

Farmer's crop insurance is defined as financial products that provide compensation to farmers in case of output losses. The insurance can take the form of the percentage of coverage of the loan principal by the insurance product. A higher insurance coverage makes lending more viable for FSPs since insurance coverage reduces the risk of default for FSPs. The link between crop insurance and credit could potentially benefit smallholder farmers by smoothing and growing their income so as to enable them to repay their loan more easily.

4. The model for the farmer's capacity to repay

By using empirical data for maize from Ethiopia, we set up the model for the farmer's capacity to repay.

The need for a loan

When trying to explore the benefits of insurance for unlocking credit, we first need to make sure a loan will improve the farmer's conditions. After running a simulation of a farmer's one year cash flow with and without a loan[5], taking into consideration the crop income, income from crop diversification, non-farm income, and crop inputs, we found the following results:

Table 2. Cash flow output for a farmer with and without a loan

With a loan[6]		Without a loan	
With non-farm income	Without non-farm income	With non-farm income	Without non-farm income
$407.90	$225.52	$301.66	$184.37

When a farmer has access to credit, s/he can implement technological improvements such as using improved seeds and fertilizers. This investment will increase the amount of input costs but will increase productivity as well. In balance, the farmer's improved net income surpasses the cost of the loan, resulting in a better cash flow outcome. Under these circumstances, without negative output or price shocks, the farmer would be better off with a loan despite his availability of non-farm income.

[5] For additional details regarding the calculation of the cash flow outputs, see Appendix 2 (scenarios without a loan) and Appendix 3 (scenarios 2 and 4).

[6] Assuming the farmer does not take insurance.

General assumptions for the model

To analyze how insurance can boost agricultural lending, we analyzed the cash flow of an average farmer under different scenarios. The goal was to assess under what set of conditions insurance could be beneficial for farmers (higher cash flow balance), and for FSPs (lower probability of default). The following assumptions helped us to define the boundaries for a simple model in terms of calculation. However, we expect that this model could be used as the foundation for additional research on this topic, adding other layers of complexity or adapting it to particular contexts.

1. One period model.
2. The farmer borrows at the beginning of the crop season and will repay the loan at the end of the crop season, after selling its produce.
3. The loan the farmer gets is used for the technological upgrade of the crop (e.g., improved seeds and other inputs).
4. The loan is strictly used to finance input costs, this is, the size of the loan is equal to the input costs.
5. Crop insurance is index-based and only mitigates certain climate variability effects (effects of an output shock).
6. Output shocks and price shocks are independent events.

Since the calculations consider average estimates for maize farmers in Ethiopia, this model could be applicable for similar crops and contexts.

Scenarios

To set up the scenarios to analyze, we first identified risk mitigations measures that are commonly required from farmers when applying to a loan and have an incidence on the farmer's cash flow: non-farm income and insurance. As previously established, the non-farm income in the model refers to labor compensation.

Collateral is also a typical requirement for agricultural loans but as its value is stock and not a flow, we did not include it in the model at this point. In practical terms, we can think of non-farm income as income from a productive asset that we can also call collateral. Second, we also wanted to explore how insurance could support farmers to face certain exogenous shocks such as output and price shocks.

As a result of the combination of these variables, we obtained a total of 16 scenarios. We have four scenarios when there is not an output shock nor a price shock by combining the availability or no availability of non-farm income and crop insurance. Likewise, there are four scenarios when there is an output shock, other four when there is a price shock, and we also explore the presence of both shocks happening together. The scenarios' characteristics are detailed below in Table 3.

Table 3. Scenario configuration

Scenarios	Risk mitigation measures		Exogenous shocks		
Scenario 1	Non-farm income	Insurance	No output shock	No price shock	No Shock
Scenario 2	Non-farm income	No insurance	No output shock	No price shock	
Scenario 3	No non-farm income	Insurance	No output shock	No price shock	
Scenario 4	No non-farm income	No insurance	No output shock	No price shock	
Scenario 5	Non-farm income	Insurance	Output shock	No price shock	Output Shock
Scenario 6	Non-farm income	No insurance	Output shock	No price shock	
Scenario 7	No non-farm income	Insurance	Output shock	No price shock	
Scenario 8	No non-farm income	No insurance	Output shock	No price shock	
Scenario 9	Non-farm income	Insurance	No output shock	Price shock	Price Shock
Scenario 10	Non-farm income	No insurance	No output shock	Price shock	
Scenario 11	No non-farm income	Insurance	No output shock	Price shock	
Scenario 12	No non-farm income	No insurance	No output shock	Price shock	
Scenario 13	Non-farm income	Insurance	Output shock	Price shock	Output and Price Shock
Scenario 14	Non-farm income	No insurance	Output shock	Price shock	
Scenario 15	No non-farm income	Insurance	Output shock	Price shock	
Scenario 16	No non-farm income	No insurance	Output shock	Price shock	

The cash flow structure

The cash flow analysis involves the farmer's revenues and expenses, assuming the levers aforementioned. We can distinguish between five components of the cash flow:

$$Cash\ flow = Net\ agri\ income + Non\_farm\ income - Cost\ of\ financing - Cost\ of\ insurance + Insurance\ payout$$

i. Net agricultural income

Comprises revenues and expenses from agriculture operations. The crop income includes the revenue from maize, assuming an average land size of 0.25 hectares, an average annual production per hectare of 6.59 tons (estimates from 2019 according to FAO), and an average producer price of $205.60 per ton (estimates of 2018 according to FAO). It is important to note that the production per hectare takes the average estimate for Ethiopia and includes a premium of 55.5% due to the higher yield resulting from the use of improved seeds (Independent Science and Partnership Council, 2014). Another revenue source is the additional income due to crop diversification, taking into account that the average farmer grows two additional crops together with maize.

Lastly, we deducted the input expenses estimated as 52% of maize revenue. This percentage includes an additional 26.1% of costs due to the use of improved seeds and high-quality inputs, in comparison to the use of common seeds and inputs.

ii. Non-farm income

This component includes the non-farm income from labor compensation, which is equivalent to 42.86% of the net agricultural income (net income from maize and from crop diversification) in a normal year. Thus,

this percentage is higher in a bad output/price year, when agricultural income gets negatively affected.

iii. Cost of financing

The loan size is equivalent to the input costs, and the corresponding interest rate is 14.25%. The cost of financing basically includes the cost of the interest as the loan amount would be canceled out when it is repaid by the end of the period.

iv. Cost of insurance

We include the insurance premium and the corresponding 25% of commercial loading currently used by insurers in Ethiopia. The premium is a function of the probability of a bad output year or the frequency of payment and the payout. Given a 20% probability of a bad output year, or a one in five years probability, the premium would be 20% of the payout ($16). After adding the loading, the final cost for a farmer who wants to purchase insurance would be $20.

v. Insurance payout

The base insurance payout is $80, but this payment is not disbursed when basis risk occurs in a bad output year. According to empirical data, the average proportion of observed matching between effects on the farm in a bad output year and index triggering insurance payout is on average of 73% in Ethiopia, based on the R4 Ethiopia Drought Index Insurance. This is, there is a probability of 73% that basis risk does not happen and, correspondingly, a 27% probability of basis risk.

The capacity to repay: Scenario analysis

To calculate the cash flow balance for the end of the period or the cash flow output, we performed the aforementioned calculation for all 16 scenarios taking into account the following guidelines:

i. Normal output year vs. Bad output year

What basically differentiates a normal output year and a bad output year is the resulting production of maize. For the normal output year, we use the average production estimate, while for the bad output year we adjust this number by the expected loss based on the volatility of output (20.5% less production for a 20% probability of a bad output year). The bad output year is a result of an exogenous output shock such as droughts or lack of rainfall. This results in a lower maize income but it does not affect the income from diversification. Moreover, the input costs remain the same for both normal and bad years as the farmer cannot anticipate the adverse climate.

ii. Normal price year vs. Bad price year

For the normal price year, we use the average producer price estimate, while for the bad price year we adjust this number by the observed expected loss based on the volatility of price (36.1% lower price for a 20% probability of a bad price year). The bad price year is a result of an exogenous price shock, such as the increase of imports of the same product, which is not correlated with an output shock (e.g., a bad crop year will not trigger higher prices). The result is a lower crop income which does not affect the income from diversification.

iii. Insurance vs. No Insurance

The scenarios with insurance take into account the payout and premium (plus loading) while the scenarios with no insurance do not include these concepts.

iv. Non-farm income vs. No non-farm income

The scenarios with non-farm income take into account an additional income source from other economic activities, while the scenarios without non-farm income do not include this concept.

Cash flow outputs per scenario

Considering all the aforementioned, we performed the calculations for each scenario and obtained the following results[7].

Table 4. Cash flow outputs per scenarios

Scenarios	Risk mitigation measures		Exogenous shocks	Capacity to repay
Scenario 1	Non-farm income	Insurance	No Shock	$387.90
Scenario 2	Non-farm income	No insurance		$407.90
Scenario 3	No non-farm income	Insurance		$205.52
Scenario 4	No non-farm income	No insurance		$225.52
Scenario 5	Non-farm income	Insurance	Output Shock	$398.48
Scenario 6	Non-farm income	No insurance		$338.48
Scenario 7	No non-farm income	Insurance		$216.09
Scenario 8	No non-farm income	No insurance		$156.10
Scenario 9	Non-farm income	Insurance	Price Shock	$265.66
Scenario 10	Non-farm income	No insurance		$285.66
Scenario 11	No non-farm income	Insurance		$83.27
Scenario 12	No non-farm income	No insurance		$103.27
Scenario 13	Non-farm income	Insurance	Output and Price Shock	$301.29
Scenario 14	Non-farm income	No insurance		$241.30
Scenario 15	No non-farm income	Insurance		$118.91
Scenario 16	No non-farm income	No insurance		$58.91

From the data we used, we can see that a price shock hits harder the farmer's finances, so s/he will always prefer an output shock than a price shock, even if s/he

[7] For additional details regarding the calculation of the cash flow outputs, see Appendix 3.

does not have insurance. Moreover, our model confirms that insurance protects the farmer from insolvency in the case of an output shock (or when it is accompanied by a price shock), this is, the cash flow output with insurance is higher than the one without insurance despite the availability of non-farm income. It is worth noting that these results disregard basis risk. However, when basis risk happens (probability of 27%) and the farmer does not receive the payout because of discrepancies between the effects on the farm and the index triggering the payout, the farmer would be better off without insurance because even though s/he experiences crop losses, the farmer does not receive the payout.

Furthermore, in our framing, the farmer is always better off with non-farm income as it does not depend on any output or price shock. In the absence of non-farm income, insurance cannot increase the cash flow balance in the same way. Insurance can even reduce the cash flow balance when there is not a payout, which could happen if there is not an output shock or if there is an output shock but basis risk happens.

Since the availability of the risk mitigation measures is defined *ex-ante* the approval of the loan and the shocks are *ex-post*, the following figure represents the decision tree that a farmer faces when deciding whether to purchase insurance or not when taking the loan, with the corresponding expected values.

Figure 1. Decision tree with expected values

We can see that, given a 20% probability of a bad output year (occurrence of output shock) and the same probability of a bad price year (occurrence of price shock)[8], a farmer, regardless of its availability of non-farm income, is expected to not purchase crop insurance (with non-farm income: $362 is lower than $371 / without non-farm income: $180 is lower than $188). The expected values, nevertheless, do not reflect the complete picture and thus should not lead the farmer's decision-making process as we will explain in the next section.

[8] We are assuming that an output shock and a price shock are independent events, so that the probability of an output and price shock happening at the same time would be the multiplication of both probabilities (20%*20% = 4%).

5. Implications of the model

The repayment of the loan and the subsistence level

Even though all scenarios show a positive cash flow balance, it is important to analyze if this amount after the loan repayment is enough for farmers to live above the subsistence level. A conservative estimation of living expenses would be the Food Poverty Line - 3772 Birr, equivalent to $91 per person per year (World Food Program, 2019a). When we compare the resulting cash flow outputs with the Food Poverty Line based on an average household of four people ($364), we find that the only cases in which the farmers can afford this minimum amount of food are when there are no shocks and the farmer has non-farm income (scenarios 1 and 2), and when there is an output shock and the farmer has both insurance and non-farm income (scenario 5).

Thus, in scenarios 3, 4, and 6 to 16, the farmers would be living below the subsistence level if they were to repay the loan. What is most probable is that the farmer would not repay the loan as s/he does not have the capacity to do so in practice. Maize farmers living below the subsistence level, however, is not uncommon since almost a quarter of the Ethiopian population cannot meet the minimum daily caloric requirement (World Food Program, 2019a) and maize farmers are probably among the most vulnerable population in the country.

It could be said that insurance improves the living conditions of the farmer's household in the case of an output shock, but according to our framing, the role of non-farm income is key to this end. As an example, when the farmer has insurance but only farm income (scenario 7), when facing an output shock, s/he cannot leave the subsistence level. After performing a sensitivity analysis, stressing key variables to assess the change in the cash flow output, we found that, in the presence of an output shock and in the absence of insurance, the farmer would need to increase the

non-farm income share to 54% to be able to meet the Food Poverty Line and repay the loan at the same time.

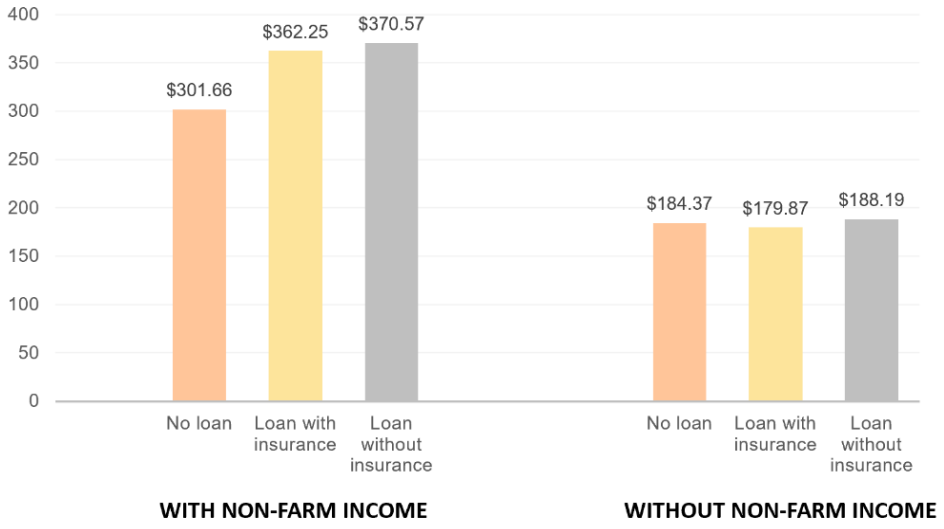
Additionally, in the presence of a price shock, the non-farm income share would need to increase between 62% (without insurance) and 66% (with insurance) for the farmer to meet her/his financial obligations while meeting the minimum caloric intake. Similarly, in the presence of both shocks, the non-farm income share would need to increase between 62% (with insurance) and 76% (without insurance). It is worth noting that later we will present a tool to easily perform this sensitivity analysis to the model presented, by customizing the values of different variables of the calculation.

Crop insurance and the FSP's lending problem

As we previously defined, the FSP's lending problem is related to their wariness of the repayment capacity of such farmers. The lending decision depends heavily on the farmer's probability of default and the holding of insurance. Under our model's assumptions, we found that insurance reduces the volatility of the farmer's cash flow[9], improves the capacity to repay when there is an output shock, and thus, increases the chances that an FSP approves the farmer's loan request. In fact, insurance could be seen as the necessary cost for a farmer to access credit.

[9] The standard deviation of the possible cash flow outputs considering output and price shocks is lower with insurance (64 vs 72) regardless of the availability of non-farm income.

Figure 2. Summary of the expected outputs for the farmer



If we analyze averages, since crop insurance only protects farmers when a bad output year takes place (e.g., 1 in 5 years), it will not be desirable in most occasions. This is, the expected cash flow output of a loan without insurance ($371) will be higher than the output of a loan with insurance ($362). However, if we see the broader picture and we additionally compare these outputs against the cash flow output without a loan ($302), we discover that a loan with insurance is preferred to not having credit at all. Hence, we understand insurance as the cost that makes the loan possible when the farmer's current conditions are not worthy of a loan approval.

This analysis holds for the situation when the farmer has non-farm income, however, when the farmer does not have non-farm income, s/he will prefer to remain without a loan if an insurance policy is necessary to access credit. This means that the assumptions we have taken in our model does not make the crop insurance business case viable. In this case, for farmers with non-diversified income sources, a subsidy for the insurance premium could be further analyzed to make the credit-insurance bundle economically feasible.

The results from the survey to FSPs also reaffirms the results from the model. In terms of the determinants of the FSP's lending decision, the surveyed financial institutions ranked crop insurance in second place when asked about the primary concerns in assessing a farmer's loan. In fact, nearly 70% of the FSPs surveyed in this study noted that having insurance provides an advantage to get credit approval. Furthermore, they ranked third and fourth some determinants of the farmer's probability of default such as the income volatility and the availability of non-farm income. It is worth noting that in terms of income volatility, the FSPs mentioned that production volatility and price volatility are the main factors that determine the farmer's income volatility.

The FSPs also provided determinants of the lending decisions outside our model. For instance, collateral continues being the most important lever that increases the probability of lending. As we said before, we can think of non-farm income as the revenue from an asset or a collateral. According to the results of the model, when the farmer does not have the non-farm income, the insurance cannot impact the cash flow enough to improve the farmer's capacity to repay as the cash flow output would be below the subsistence level. Thus, under the assumptions of the model, insurance has to be accompanied by non-farm income (or collateral) to effectively unlock credit. Other determinants of the lending decisions outside our model that the FSPs consider important, according to our survey, are the income in previous years, credit history, type of farming, among others.

The agricultural lending business is risky. Four out of five FSPs surveyed consider that lending to farmers is riskier than lending to actors in other sectors, as the agricultural portfolio has more non-performing loans. This situation configures an opportunity for crop insurance to be an instrument to boost agricultural lending. Little by little, crop insurance becomes a more popular instrument for credit. Most of the surveyed FSPs are familiar with giving loans to farmers with crop insurance; actually, three out of five banks have more than 40% of their agricultural portfolio

tied with crop insurance. Even with available collateral, insurance provides an additional value. Three out of five FSPs mentioned that having insurance increases the loan amount for the farmer and reduces the collateral required.

Conditions for crop insurance

In short, from the analysis explained before, these would be the main conditions for insurance to unlock credit:

- **Contexts with climate variability or other output risks**
  We have seen that output shocks trigger insurance payouts. So, villages more exposed or crops more vulnerable to output risks, that usually do not qualify for credit due to high income variability, will be most benefited from the purchase of crop insurance. Even with average to high levels of basis risk, the farmer will prefer to take the credit-insurance bundle if the technological improvement provides enough profits to cover potential unrecognized losses.

- **Average level of non-farm income or collateral**
  The results from the model showed that at least an average level of non-farm income is key for the farmers' ability to repay their loans as these are stable sources of income. However, a farmer with a high or average level of non-farm income probably does not find it too difficult for the FSP to approve his/her loan request. On the other hand, FSPs have declared that farmers with an insurance policy may access other benefits such as the requirement of less collateral. Hence, it is possible that insurance unlocks credit for farmers with less than average levels of non-farm income or collateral.

- **High operational and financial costs**
  From the model, we have learned that it is key that the technological improvement is profitable enough for the loan to make sense. In this regard,

we have found that input costs at a level of 75% of maize income or higher disincentivize farmers to acquire a loan. Even more, an interest rate of 34% or higher causes the same effect. Thus, in a scenario where costs are high (input, credit, loading, etc.) and so the farmers need to evidence even higher financial capability, a loan can still be viable only when a farmer holds an insurance policy.

Customizing the model: A digital tool for future research

In order to provide certain flexibility to customize this model to different scenarios beyond the 16 analyzed in this report, we created the "Ethiopia Loan & Insurance Scenario Analysis Tool"[10] with invaluable assistance from the IRI. Based on a tool previously created by the IRI using the software R Shiny, we translated our model and its assumptions into this online platform. The user will be able to modify the values of the levers that affect the farmer's capacity to repay a loan, and a few additional variables like the level of production, producer price, and living expenses, which may vary depending on the context that one wants to analyze.

This digital tool provides three levels of analysis. First, the tool provides the cash flow outputs for a farmer with insurance, no insurance, and insurance with basis risk, under different shocks. This allows us to evaluate under what conditions insurance protects the farmer against insolvency, understood as living under the subsistence level. Second, the tool calculates the expected cash flow outputs when the farmer does not get a loan, gets a loan with insurance, and without insurance. At this second stage, the tool allows us to evaluate if the choice of loan plus insurance is profitable enough. Lastly, the tool provides a sensitivity analysis for the variables of

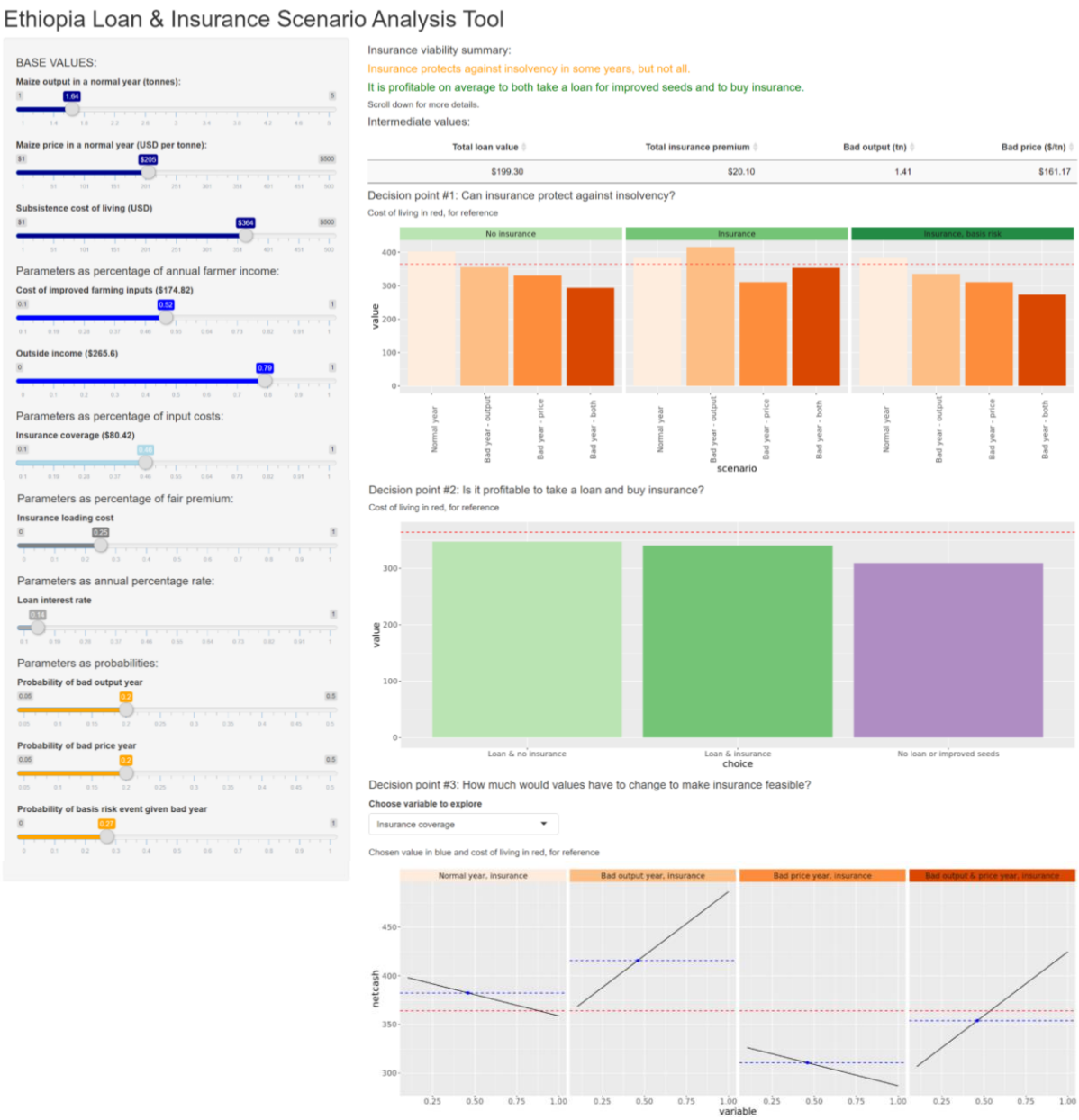
[10] The tool can be accessed here: https://fist-shiny.iri.columbia.edu/wb_capstone_scenario_tool/ (User name: capstone / Password: SIPA)

insurance coverage and outside income[11], to better understand what changes can be made to make a business case for the credit-insurance bundle.

The tool is aimed at FSPs who want to assess farmers' capacity to repay and the need for crop insurance to unlock credit, and researchers who want to undertake additional analysis on this topic.

[11] For simplification matters, the tool combines the non-farm income and crop diversification income under the category of outside income, as both of them are stable additional income for the farmer (they do not get affected by output or price shocks).

Figure 3. Customizable tool simulation



6. Conclusions and recommendations

Looking back at the broad question of whether loans and insurance benefit farmers, using a scenario-based cash flow analysis based on empirical estimates for different factors affecting farmers, we found a few key insights. As it is expected, insurance is shown to have a drag on farmer profits in the absence of an output shock. Across scenarios, insurance has a negative probability-weighted expected value on farmer cash flows. However, farmers are much better off with a loan + insurance than no loan at all.

Given that insurance is often mandated by FSP's for loan provision, a primary function of insurance for farmers is to facilitate credit access. 70% of financial service providers that we surveyed cited insurance as an important attribute for a creditworthy agricultural borrower. Insurance also demonstrated value in cash flow smoothing, as we found the volatility of income falls when using insurance. Having non-farm income, however, proved to be a more effective ballast for farmer cash flows than insurance. Non-farm income also improved the efficacy of insurance for farmers. Additionally, our survey results indicated that insurance enabled farmers with lower levels of non-farm income/collateral to utilize credit.

Based on our findings, insurance will provide maximum utility to farmers in regions with significant weather uncertainty (e.g., regions facing climate risk). Moreover, insurance will benefit farmers working with crops having high output variability (e.g., rice) better than those working with more resilient crops (e.g., sorghum). One potential risk for farmers considering index insurance is basis risk. We found a 27% probability of a basis risk event using insurance (financial losses without an insurance payout). As higher basis risk could weaken insurance's viability, we believe that a greater focus should be made on aligning the insurance contract's underlying index with the risks of farmers, which may require higher investment towards data collection.

Further research expanding on our analysis would be prudent. First, a scenario analysis of FSP's willingness to lend, similar to our analysis of farmers' capacity to borrow, would be useful. Second, analyzing the difference in insurance for domestically-consumed crops (e.g., teff) vs export-heavy crops (e.g., coffee) could add nuance to our framework. Lastly, given the relationship between weather and crop yields, adding dynamic output probabilities based on climate forecasts would be fitting given current environment challenges for emerging markets.

Acknowledgments

This research project involved numerous activities including empirical research, interviews, surveys as well as reviewing existing literature and would not have been possible without the direction of Panos Varangis (World Bank) and analytical rigor of Dr. Daniel Osgood who dedicated a considerable amount of time to focusing our analysis in the right areas.

Panos Varangis, Global Lead for Agricultural Finance and Agricultural Insurance in the Finance, Competitiveness & Innovation - Global Practice at the World Bank Group, provided expert contributions towards the progress made to date on this important assignment as well as developing the framework for how this model will be used in practice.

Dr. Daniel Osgood, Research Scientist at the International Research Institute for Climate and Society, was an invaluable resource for presenting our ideas as well as providing the tools needed to complete this assignment. His guidance enabled the Capstone team to structure and analyze a complex problem with discrete moving parts. We would also like to acknowledge the Columbia Earth Institute's Financial Instruments Sector Team for their feedback and guidance, especially Max Mauerman. Max has been enormously helpful in getting us the technical resources needed to defend our thesis.

Lastly, we would like to thank Suzanne Hollmann, Saleha Awal, and the Columbia SIPA Capstone Program for their assistance with both the administrative and technical components of putting a Capstone project together.

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Appendix 1: Summary of results of the survey to FSPs

Our team also decided to collect a survey to obtain additional information on the FSPs process to provide loans to farmers. The survey had the intention to validate the inputs used in the financial models mentioned above. For the data collection process, the team implemented a Kobocollect online survey. The data collection period started on February 02, 2021, and finished on March 22, 2021. Twelve questions integrated the survey, and five different banks responded, for a total of seven different responses. The following table represents the number of answers per FSP.

All of the banks that responded have operations in Africa; only one had additionally, operations in Asia and Europe. Having responses from FSPs operating in Africa is advantageous for matching their answers with our model, especially since the information integrated into our assumptions came from that region. In fact, all the FSPs have a presence in Ethiopia.

Main Findings

Linking financial products with agriculture is a growing field, and the considerations behind the loan assessment process for farmers are still blurry. In that sense, our survey asked the FSPs the primary concerns in assessing a farmer's loan. According to our results, farmers' collateral is the primary consideration for FSPs; insurance is the second consideration; income in the previous year & income volatility occupied the third place, and farmers' other income is the least important consideration.

Previous credit history with other financial institutions, type of farming, bank account usage, landholding title, rain based or irrigated crops were other

considerations mentioned by the FSP as necessary inputs during a loan assessment process.

As mentioned above, FSPs consider insurance as the second primary input for loan assessment. Nearly 70% of the FSPs noted that having insurance provides an advantage to get approval. According to our results, most of the survey FSPs are familiar with giving loans to farmers with crop insurance; three out of five banks have more than 40% of crop-insurance in their agricultural loans. Three out of five FSPs mentioned that having insurance increases the loan amount and reduces the collateral.

According to the FSPs, production volatility (weather, pest, and diseases, farmer's ability, etc.) & price volatility are the main factors that determine the farmer's income volatility. Social unrest, infrastructure, and market for the product are other factors that the FSP identifies as factors that affect farmers' income.

All of the FSPs consider that lending to farmers is riskier than lending to producers in other sectors. Nearly 70% of the respondents mentioned that agricultural non-performing loans are higher than non-performing loans in other sectors. Only 42% of FSPs have a maximum accepted probability of default for approving loans to farmers, and in all of those cases, their response was 15%. In terms of farmers' interest rates, four out of five FSPs mentioned that they charge an interest rate range of 10% to 20%.

Appendix 2: Detailed calculation of cash flow outputs without a loan

Cash flow (US dollars)	No shocks	
	No insurance + Non-farm income	No insurance + No non-farm income
	S1 Normal Year (O+P)	S2 Normal Year (O+P)
Net agricultural income		
Crop income (maize)	$217.77	$217.77
Plus: Income from crop diversification	$55.89	$55.89
Less: Crop inputs	$89.29	$89.29
Cash from ag operations	**$184.37**	**$184.37**
Non-farm income		
Non-farm income	$117.29	$0.00
Cash from non-farm operations	**$117.29**	**$0.00**
Closing cash flow balance	**$301.66**	**$184.37**

Appendix 3: Detailed calculation of cash flow outputs per scenario

Scenario 1-4: No shock

Cash flow (US dollars)	No shocks			
	Insurance + Non-farm income	No insurance + Non-farm income	Insurance + No non-farm income	No insurance + No non-farm income
	S1 Normal Year (O+P)	S2 Normal Year (O+P)	S3 Normal Year (O+P)	S4 Normal Year (O+P)
Net agricultural income				
Adjusted Production	6.59	6.59	6.59	6.59
Adjusted Price	$205.60	$205.60	$205.60	$205.60
Crop income (maize)	$338.63	$338.63	$338.63	$338.63
Plus: Income from crop diversification	$86.91	$86.91	$86.91	$86.91
Less: Crop inputs	$175.08	$175.08	$175.08	$175.08
Cash from ag operations	**$250.46**	**$250.46**	**$250.46**	**$250.46**
Non-farm income				
Non-farm income	$182.39	$182.39	$0.00	$0.00
Cash from non-farm operations	**$182.39**	**$182.39**	**$0.00**	**$0.00**
Cost of financing				
Loan	$175.08	$175.08	$175.08	$175.08
Less: Loan repayment	$175.08	$175.08	$175.08	$175.08
Less: Interests on loan	$24.95	$24.95	$24.95	$24.95
Cost of insurance				
Less: Insurance premium	$20.00	$0.00	$20.00	$0.00
Insurance payout				
Plus: Insurance payout	$0.00	$0.00	$0.00	$0.00
Closing cash balance	**$387.90**	**$407.90**	**$205.52**	**$225.52**

Scenario 5-8: Output shock

Cash flow (US dollars)	Output shock			
	Insurance + Non-farm income	No insurance + Non-farm income	Insurance + No non-farm income	No insurance + No non-farm income
	S5 Bad Year (O)	S6 Bad Year (O)	S7 Bad Year (O)	S8 Bad Year (O)
Net agricultural income				
Adjusted Production	5.24	5.24	5.24	5.24
Adjusted Price	$205.60	$205.60	$205.60	$205.60
Crop income (maize)	$269.22	$269.22	$269.22	$269.22
Plus: Income from crop diversification	$86.91	$86.91	$86.91	$86.91
Less: Crop inputs	$175.08	$175.08	$175.08	$175.08
Cash from ag operations	**$181.05**	**$181.05**	**$181.05**	**$181.05**
Non-farm income				
Non-farm income	$182.39	$182.39	$0.00	$0.00
Cash from non-farm operations	**$182.39**	**$182.39**	**$0.00**	**$0.00**
Cost of financing				
Loan	$175.08	$175.08	$175.08	$175.08
Less: Loan repayment	$175.08	$175.08	$175.08	$175.08
Less: Interests on loan	$24.95	$24.95	$24.95	$24.95
Cost of insurance				
Less: Insurance premium	$20.00	$0.00	$20.00	$0.00
Insurance payout				
Plus: Insurance payout	$79.99	$0.00	$79.99	$0.00
Closing cash balance	**$398.48**	**$338.48**	**$216.09**	**$156.10**

Scenario 9-12: Price shock

Cash flow (US dollars)	Price shock			
	Insurance + Non-farm income	No insurance + Non-farm income	Insurance + No non-farm income	No insurance + No non-farm income
	S9 Bad Year (P)	S10 Bad Year (P)	S11 Bad Year (P)	S12 Bad Year (P)
Net agricultural income				
Adjusted Production	6.59	6.59	6.59	6.59
Adjusted Price	$131.38	$131.38	$131.38	$131.38
Crop income (maize)	$216.39	$216.39	$216.39	$216.39
Plus: Income from crop diversification	$86.91	$86.91	$86.91	$86.91
Less: Crop inputs	$175.08	$175.08	$175.08	$175.08
Cash from ag operations	**$128.22**	**$128.22**	**$128.22**	**$128.22**
Non-farm income				
Non-farm income	$182.39	$182.39	$0.00	$0.00
Cash from non-farm operations	**$182.39**	**$182.39**	**$0.00**	**$0.00**
Cost of financing				
Loan	$175.08	$175.08	$175.08	$175.08
Less: Loan repayment	$175.08	$175.08	$175.08	$175.08
Less: Interests on loan	$24.95	$24.95	$24.95	$24.95
Cost of insurance				
Less: Insurance premium	$20.00	$0.00	$20.00	$0.00
Insurance payout				
Plus: Insurance payout	$0.00	$0.00	$0.00	$0.00
Closing cash balance	**$265.66**	**$285.66**	**$83.27**	**$103.27**

Scenario 13-16: Output and price shock

Cash flow (US dollars)	Output shock + Price shock			
	Insurance + Non-farm income	No insurance + Non-farm income	Insurance + No non-farm income	No insurance + No non-farm income
	S13 Bad Year (O+P)	S14 Bad Year (O+P)	S15 Bad Year (O+P)	S16 Bad Year (O+P)
Net agricultural income				
Adjusted Production	5.24	5.24	5.24	5.24
Adjusted Price	$131.38	$131.38	$131.38	$131.38
Crop income (maize)	$172.03	$172.03	$172.03	$172.03
Plus: Income from crop diversification	$86.91	$86.91	$86.91	$86.91
Less: Crop inputs	$175.08	$175.08	$175.08	$175.08
Cash from ag operations	**$83.86**	**$83.86**	**$83.86**	**$83.86**
Non-farm income				
Non-farm income	$182.39	$182.39	$0.00	$0.00
Cash from non-farm operations	**$182.39**	**$182.39**	**$0.00**	**$0.00**
Cost of financing				
Loan	$175.08	$175.08	$175.08	$175.08
Less: Loan repayment	$175.08	$175.08	$175.08	$175.08
Less: Interests on loan	$24.95	$24.95	$24.95	$24.95
Cost of insurance				
Less: Insurance premium	$20.00	$0.00	$20.00	$0.00
Insurance payout				
Plus: Insurance payout	$79.99	$0.00	$79.99	$0.00
Closing cash balance	**$301.29**	**$241.30**	**$118.91**	**$58.91**