

Catastrophic Risk, Weather Index Insurance and Joint-Collateral Group Credit: The Case of the Thailand National Village Fund Program

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Abstract

This paper is devoted to gaining a better understanding of how catastrophic weather risk undermines access to group credit among smallholder farmers in developing countries, and how weather index insurance might be used to manage this risk to promote access to credit, technical transformation, and poverty reduction among them. As our case study, we focus on the Thailand rice sector and the Thailand National Village and Urban Community Fund Program (VFP), which offers group credit with joint collateral liability provisions in which one group member's collateral may be seized to repay the loan of another nonperforming group member. In rural areas, where VFP participants are mostly farmers dependent on rain-fed agriculture, VFP loan portfolios are especially vulnerable to catastrophic droughts and floods, which can simultaneously subject most if not all of its borrowers to financial stresses and undermine the effectiveness of the joint collateral provisions of VFP loans. We formulate, solve, and analyze a dynamic stochastic game model to study how joint collateral group lending works, focusing on how it is affected by systemic shocks and how its performance might be enhanced using weather index insurance. We find that when the collateral is relatively low, uninsured group credit tends not to perform significantly better than individual credit. However, jointly collateralized group credit, if bundled with index insurance, can substantially reduce loan defaults, and more so as systemic risk increases.

1. Introduction

This paper is devoted to gaining a better understanding of how catastrophic weather risk undermines access to credit among smallholder farmers in developing countries, and how weather index insurance might be used to manage this risk to promote access to credit, technical transformation, and poverty reduction among them. As our case study, we focus on the Thailand rice sector and the Thailand National Village and Urban Community Fund Program (VFP), a microfinance initiative instituted by the Government of Thailand in 2001 to promote access to credit, particularly among the rural poor.

The majority of rural borrowers participating in the VFP are farmers whose agricultural production relies on adequate rainfall. Rural village VFP loan portfolios are especially vulnerable to catastrophic droughts and floods that simultaneously subject most if not all of its borrowers to losses of income, making it difficult for most borrowers in the group to repay their loans and to meet their obligations under the joint collateral liability provisions of the VFP. Catastrophic drought and floods can cause village VFPs to fail financially, or otherwise severely restrict their ability to extend credit in the future.

Index insurance offers a possible remedy for the catastrophic risk problems that undermine the performance of the VFP. Unlike conventional insurance, which indemnifies the insured based on verifiable losses, index insurance indemnifies the insured based on the realized value of an underlying “index” that is highly correlated with losses but that cannot be influenced by the insured. Index insurance for rural areas highly dependent on agriculture are most often designed to provide payouts based on rainfall measured at proximate metrological stations, and may include contracts that provide payouts if rainfall is deficient, to cover drought risk, or if rainfall is excessive, to cover flood or prevented planting risk. However, a variety of indices have been implemented in practice or otherwise proposed, including area yields, satellite-measured vegetation indices, El Nino-Southern Oscillation indices, and river levels.

In the remainder of this paper, we examine joint-collateral group credit, modeled after the provisions of Thailand National VFP. To this end, we formulate, solve, and analyze a dynamic stochastic game model in which borrowers act strategically in making decisions to repay or default on their debt obligations. Of special interest is how systemic shocks, such as drought and flood, which affect borrowers simultaneously, affect the rates of default on joint collateral group credit contracts. Also of special interest is whether bundling index insurance contracts with credit that provide payouts when in the event of a systemic shock can improve the performance of joint liability group credit contracts. We find that when the collateral is relatively low, uninsured collateralized group credit tends to increase loan defaults and reduce willingness to pay (WTP) for the credit, relative to individual credit. However, collateralized group credit, if bundled with index insurance, can substantially reduce loan defaults, and more so as systemic risk increases.

2. The Thailand Village and Urban Community Fund Program

The Thailand Village and Urban Community Fund Program (VFP), commonly known as the “One Million Baht Village Fund”, is a micro-credit program implemented by the Government

of Thailand in 2001. The program calls for allocating one million baht (\$30,303) to every village and community as initial working capital for a locally run credit association. The initial working capital transferred to villages and communities at the inception of the program was approximately 78 billion baht (\$2.36 billion), or about 1.5 percent of Thai annual Gross Domestic Product. The VFP has reached over 99% of villages and communities in Thailand (Boonperm et al., 2013). According to the Thai Parliamentary Budget Office (PBO) report written by Vichianplerd (2015), in 2013, the program consisted of approximately 75 thousand village VFPs with 12.8 million members, approximately 20% of the Thai population.

The VFP is a source of lending to poor people who otherwise have difficulty obtaining credit from formal financial institutions. After obtaining credit, borrowers may use the money as start-up capital for occupational development and income-generating activities. According to Boonperm et al. (2013), the program targets new activities such as processing and packing that are not traditionally financed by existing financial arrangements. However, the majority of the program's borrowers are farmers who practice rain-fed agriculture.

In order to secure a VFP loan, the borrower is required to maintain a small amount of savings account approximately 3-10% of loan size. These savings cannot be withdrawn unless the members fulfill their debt obligations and are subject to seizure by the VFP if the loan is not repaid. As such, the savings account serves as collateral for the loan. However, to secure a VFP loan, the applicant must also have at least two guarantors who are members of the same VFP who are obligated to repay the debt if the borrower fails to do so and his collateral fails to cover the debt obligations. If the borrower and his guarantors do not meet their obligations, all their savings accounts will be seized, and none of them will be eligible to take out a loan again until the debt is fully repaid.

VFP repayment rates have declined gradually since the inception of the program. The repayment rates decreased from 95% in 2004 to 88% in 2006 and 77% in 2010. The Auditor General of Thailand identified found that overdue debt in 2006 was approximately 112 million baht (\$3.39 million) or 19% of the capital. Some funds stopped operating and/or their committees failed to administer financial activities. However, the Thai PBO reports that the VFP has been successful at increasing poor people's access to formal credit, with the percentage of households borrowing money from the VFP increasing from 19% in 2009 to 24% in 2013. The average loan amount was 15,625 baht (\$473), and the number of members in each fund ranged between 50 and 150.

3. The Northeast Thailand Rice Value Chain

Agriculture is the most important sector of Northeast Thailand's economy and rice is the most important crop in terms of area, value of production, and employment. Based on the data collected by National Statistic Office Thailand (NSO) (2014) and the Office of Agricultural Economics (OAE) (2014), agriculture accounted for 20% of the total GDP of the region during 2011-2013. In that year, approximately 64 million rais¹ (10.24 million hectare) were devoted to agricultural production, of which 67% was planted with rice, 7%

¹ 1 rai = 0.16 hectare, or 0.4 acre

with cassava, 6% with sugar cane, 3% with maize, and the remainder with other crops and fruits. In 2013, the NSO (2014) reported that there were approximately 2.4 million rice-farming households in Northeast Thailand, accounting 88% of all farming households and 20% of the total population.

The majority of rice farmers in the Northeast plant in-season rice that is highly vulnerable to drought. In the northeast region, drought is more severe and lasts longer than other regions of the country. Farmers begin planting in-season rice between the middle of May and the middle of August, Thailand's rainy season. Water supply during the rainy season is critical in the land preparation, vegetative, and reproductive stages of rice production². Drought can severely damage paddy during the reproductive stages, especially flowering, but can also reduce yields during other stages of plant growth (Redfern, Azzu & Binamira, 2012). Petchkam et al. (2005) study the vulnerability of rural villages to climate hazards in the lower Songkhram River Basin in the Northeast, and find that approximately 10% of villages can lose their entire crop in a dry year.

In 2015, Thailand suffered a catastrophic drought. The 2015 drought adversely affected rice farmers throughout the country, especially those in the northern regions. The quantity of water stored in reservoirs was not enough to meet agricultural needs. Farmers in many areas had to postpone planting in-season rice, and some could were unable to plant rice altogether. Total in-season and off-season rice production in the Northeast was approximately 5 billion baht (\$151 million), or approximately 17%, below the historical average.

However, rice farmers in Northeast Thailand are also vulnerable to excessive floods. The worst flood in Thailand's modern history occurred during the rainy season in 2011, when rainfall was approximately 25% above average (Poaponsakorn & Meethom, 2013). The extensive flooding was caused by the extended heavy rain from five tropical storms (World Bank, 2012). Poaponsakorn and Meethom (2013) further reported that unregulated changes in land-use patterns and flood mismanagement exacerbated the damage. The massive flooding affected 26 provinces, eight of which are in the Northeast, and inundated 5.5 percent of the country's total land mass (see figure 11). Crops such as rice, sweet corn, vegetables, and fruits were most affected by the floods. It was reported by the Word Bank (2012) that the floods damaged approximately 6.18 million rais or 10% of total agricultural land. 55% of the damaged area and 47% of affected farmers were in the Northeast. The damage also included losses of farm machinery such as tractors, plows, threshers, and farm tools. Flooding can heavily damage paddy during the rainy season, which lasts from the middle of May to the middle of October. Since the Northeast is a flood-prone area, a heavy monsoon during rainy season results in flooding, particularly in the river valleys. Petchkam et al. (2005) report that farmers who experienced severe floods lost 50-100% of their normal yields.

² http://www.agriman.doae.go.th/home/t.n/t.n1/1Ricecrop_Requirement/01_Rice.pdf

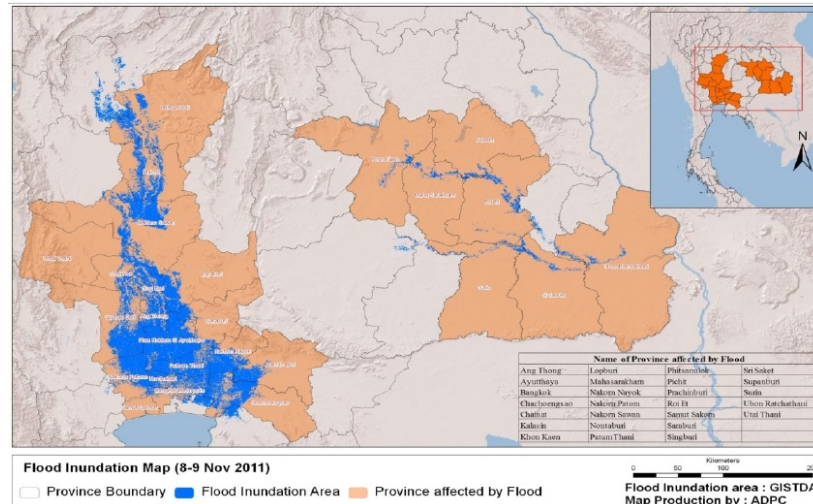


Figure 1. Map of flooded areas, November 8-9, 2011

4. Agricultural Insurance in Thailand

The Thailand multi-peril crop insurance (MPCI) program for rice farmers is government-subsidized program and operated as a public-private partnership. The Office of Insurance Commission (OIC), under the Fiscal Policy Office (FPO), Ministry of Finance, National Catastrophe Insurance Fund (NCIF) and Thai General Insurance Association (GIA) initially launched the program in 2011 on a voluntary basis, and assigned BAAC to serve as an intermediary between farmers and insurers. BAAC is also responsible for administering the insurance program, including reviewing applications, disbursing premium subsidies to insurance companies, and guaranteeing indemnities payments by insurance companies to insured farmers. The insurance program indemnifies farmers' losses arising from seven distinct natural perils: floods, droughts, typhoons, other windstorms, cold weather, hail, and pestilence. During production years 2011 and 2012, the government subsidized farmers by paying half of the premium (BAAC, 2013).

Since production year 2013, the MPCI program has offered five different premium rates based on region-specific risk. All provinces are assigned to one of five risk categories, with premium rates varying between 124 baht/rai (\$23.48 per hectare) to 465 baht/rai (\$88.07 per hectare), with the government covering between 52%-80% of the total premium. In the lowest risk area, farmers pay 60 baht/rai (\$11.36 per hectare) in insurance premium, and the government pays the remaining 64 baht/rai (\$12.12 per hectare). In the highest risk area, farmers pay 100 baht/rai (\$18.94 per hectare) in insurance premium, and the government pays the remaining 384 baht/rai (\$72.73 per hectare). Moreover, farmers who borrow from banks receive an additional 10 baht/rai (\$1.89 per hectare) subsidy if they purchase insurance. Insured farmers receive a maximum payout of 1,111 baht/rai (\$210 per hectare) for farm losses caused by floods, rainfall deficits, storms, cold weather, hail and fire, and a maximum payout of 555 baht/rai (\$105 per hectare) for the farm loss caused by pestilence. To be eligible for compensation, the insured farmer must reside in a province declared a disaster area by the government, and farm-level losses need to be verified by local authorities (Chantararat et al., 2012).

Between 2011 and 2014, the MPCCI program insured less than 2% of total planted area, indicating that although government subsidized a major portion of the premium, rice farmers were still uninterested in purchasing insurance. The cumulative average loss ratio for the program through 2014 was 263% with peak loss ratios of 554% in 2011 and 532% in 2012. Notably, in 2011, 2012 and 2013, the areas damaged and insured seem to be positively related. The percentages of the damaged and insured areas were quite high in 2011 and 2012, while those in 2013 were quite low. This suggest that the program suffers from intertemporal adverse selection, as farmers were able to predict bad weather before the close of sales in 2011 and 2012. Specifically, in 2011 massive flood caused by a tropical storm began in provinces in the north and the northeast Thailand in July, while the close of sales were in the mid of August. This prompted rice farmers to purchase more insurance than normal, or to extend the insured areas before the close of the sales in this year (Secretariat of the House of Representatives, 2015). The effects of the massive flood lasted until January 2012.

Weather index insurance programs are offered to Thai farmers only in certain provinces. Available weather index insurance indemnifies corn and rice producers for losses from drought, and utilize a rainfall index as a proxy for drought, which is highly correlated with crop failure in the insured areas (Fiscal Policy Office, 2010).

Index insurance products for corn and rice farmers are designed differently. The insurance product for corn farmers may be purchased without having to take out a loan. A flat premium rate is applied across all insured areas, and the indemnity varies and is proportional to the degree of the drought in each particular area. For rice, index insurance is bundled with loans in a form of micro insurance, and available only to borrowers (Sompo Japan, 2010; Win, 2016; Maki, 2016).

In 2007, the World Bank, in collaboration with the Department of Insurance (DOI, now OIC), GIA and BAAC, implemented a corn weather index insurance pilot project in Nakhon Ratchasima Province (Manuamorn, 2009). The project was expanded to cover four more provinces in 2008 and two more provinces in 2010. By 2013, corn weather index insurance was available in nine provinces. Only BAAC borrowers growing corn within 25 kilometers of specified weather stations were eligible to purchase the insurance (Fiscal Policy Office, 2010).

The weather index insurance contract for corn utilizes accumulated rainfall to identify a drought and compensate insured farmers. The contract premium is flat rate that may vary annually; for instance, in 2013 the premium was 110 baht per rai (\$20.33 per hectare) in all insured areas. The insurance covers losses incurred during three of the four corn growing stages: sowing (30 days), growing (20 days), and yielding (30 days). The harvesting stage is not covered under the contract. In each of the three insured stages, two thresholds, drought and severe drought, have been set for indemnity payouts. Insured farmers receive a partial indemnity if the accumulated rainfall recorded during the insured stage is between the two thresholds and a full indemnity if the accumulated rainfall falls below the severe drought threshold. BAAC is responsible for collecting and transferring insurance premiums to insurance companies and distributing indemnity payouts to insured farmers (Manuamorn, 2009; Secretariat of the House of Representatives, 2015).

Weather index insurance indemnity payouts for corn did not exceed premiums collected between 2007 and 2011 (Chantararat, 2016). In 2009, the loss ratio was 61%, an increase of approximately 300% over the preceding year. After the addition of two provinces in 2010, the program insured almost 3,200 farmers with the loss ratio of 71% (Win, 2016). In 2012, the program was suspended for unreported reasons, but was reinstated with additional coverage areas in 2013.

A rainfall index insurance program for rice farmers was piloted in Thailand in 2008 (Jeerachaipaisarn, 2012). The program was initiated by the Japan Bank for International Cooperation (JBIC) to protect insured farmers against drought in the Northeast. Khon Kean province was selected for the pilot project since it had 34 relatively reliable weather stations covering an area of approximately 10,000 km². In 2010, Sompo Japan Insurance Inc. cooperated with JBIC to launch the rainfall index insurance product in Khon Kean. They expanded the product to four additional provinces in the same region in 2011, after confirming the availability of reliable historical data for insurance (Sompo Japan, 2011; UNFCCC, 2012; Hirooka, 2013; Sirimanne & Srivastava, 2014). Since 2013, weather index insurance has been sold in nine provinces to more than 2,800 farmers (Sirimanne & Srivastava, 2014).

Unlike the index insurance for corn, the index insurance product for rice is bundled with a loan from BAAC. Premiums collected and the indemnity payouts are proportional to the loan principle. For instance, in 2012 the premium rate is 4.64 percent of the insured loan principal. The insurance covers loss from drought between July 1 and September 30. If the accumulated rainfall recorded during this period falls below the predetermined drought threshold, insured farmers receive indemnities equal to 15% of the loan principal. If it falls below the severe drought threshold, they receive 40% of the loan principal. The indemnities are paid to insured farmers through the BAAC (Hirooka 2013; Win, 2016; Maki, 2016).

The operating results of the weather index insurance program for rice between 2010 and 2012 were mixed. The loss ratios were lower than 50% in 2010 and 2011. In 2012, although the program covered four more provinces than in 2011, the number of participating farmers decreased 86%. The indemnity payout exceeded the premium collected, yielding a loss ratio of 365% (Sinha & Tripathi, 2014).

5. A Dynamic Model of Index-Insured Collateralized Individual Credit

In this section, we formulate, solve, and analyze a dynamic stochastic optimization model of collateralized individual lending in order to set the stage for the dynamic stochastic optimization model of jointly collateralized group credit introduced in the following section.

Consider an infinitely-lived farmer who employs a subsistence production technology and has no means to borrow or save. Each period, the farmer receives an income that depends on whether a drought has occurred and an exogenous idiosyncratic random shock $\tilde{\epsilon}$ that is independent of drought conditions. Specifically, the farmer receives income $\bar{y}_1\tilde{\epsilon}$ if drought occurs and income $\bar{y}_2\tilde{\epsilon}$ otherwise, where $\bar{y}_2 > \bar{y}_1 > 0$ and $\tilde{\epsilon}$ is a positive i.i.d. random variable with mean 1. Each period, drought occurs with probability q_1 and does not occur with probability $q_2 = 1 - q_1$, independently of past occurrences.

The farmer begins each period with a predetermined liquid wealth w . Since the farmer cannot borrow or save, he consumes his entire liquid wealth, yielding current utility $u(w)$. The farmer's present value of expected *future* utility of consumption is thus

$$A \equiv \sum_{\tau=1}^{\infty} \delta^{\tau} \sum_{j=1}^2 q_j E_{\tilde{\epsilon}} u(\bar{y}_j \tilde{\epsilon}) = \frac{1}{\rho} \sum_{j=1}^2 q_j E_{\tilde{\epsilon}} u(\bar{y}_j \tilde{\epsilon}) \quad (1)$$

where ρ is the farmer's per-period subjective discount rate and $\delta = 1/(1 + \rho)$ the farmer's per period discount factor.

Suppose now that the farmer is offered an in-kind loan in the form of "hi- tech" seed³ that raises his income by a multiplicative factor $\gamma > 1$ in all states of nature the following period. In its most general form, the terms of the credit contract between the lender and the farmer are as follows:

Lender: At planting, the lender provides the farmer with hi-tech seed bundled with an index insurance contract that will pay an indemnity $I \geq 0$ to the farmer in the event of a drought.

Borrower: At planting, the farmer must pledge collateral K to the lender and agree to pay him an amount $L = (1 + r)(\kappa + \pi I)$ the following period, where $r > 0$ is the stated interest rate on the loan, $\kappa > 0$ is the cost of the hi-tech seed and π is the premium rate charged on the index insurance contract. We assume $L > K \geq 0$.

The farmer may or may not repay his loan the following period. If the farmer defaults, his collateral is seized by the lender and he is permanently banned from future credit. Additionally, he suffers a nonpecuniary utility penalty $\phi \geq 0$ due to moral regret, loss of reputation, and/or decline in social standing from defaulting. We refer to ϕ simply as the farmer's *creditworthiness*, noting that, other things being equal, the greater the farmer's creditworthiness, the less inclined he is to default on his loan. If the farmer repays his loan, then he has an option to take out a new loan or reclaim his collateral and not take out a new loan. However, if does not take out a new one, *he is again permanently banned from future credit, but does not suffer the additional nonpecuniary utility penalty*.

Let $V(w)$ denote the maximum attainable present value of current and expected future utility of consumption for an indebted farmer, given his current liquid wealth is w . Then the farmer's value function V must satisfy the Bellman functional fixed-point equation

$$V(w) = \max\{u(w) + A - \phi, u(w + K - L) + A, u(w - L) + C\} \quad (2)$$

where

$$C = \delta \sum_{j=1}^2 q_j E_{\tilde{\epsilon}} V(\gamma \bar{y}_j \tilde{\epsilon} + I_j) \quad (3)$$

is the present values of expected future utility for a creditworthy farmer who takes out a new loan. Here, I_j denotes the indemnity received by the farmer in drought state j ; more specifically, $I_1 = I$ and $I_2 = 0$.

³ Noted that, in reality, the VFP provide monetary loans. However, in this dissertation we assume that a farmer borrower is offered an in order to ensure that he will invest the loan in an activity that generates income.

Bellman equation (2) reveals that a farmer with a current debt obligation chooses between: 1) defaulting on his loan obligation and accepting a value equal to the current utility derived from consuming his liquid wealth $u(w)$, plus the future utility expected by a farmer permanently excluded from credit A , less the non-pecuniary utility penalty incurred from defaulting ϕ ; 2) repaying his loan but not taking out a new one, reclaiming his collateral K and accepting a value equal to the current utility of consumption $u(w + K - L)$ plus the future utility A expected by a farmer permanently excluded from credit; or, 3) repaying his loan and taking out a new one, accepting a value equal to the current utility of consumption $u(w - L)$ plus the future utility expected by a farmer with a loan C .

The terms of the drought insurance contract bundled with the loan are as follows. The indemnity paid by the insurance contract in the event of a drought is expressed as a proportion $\xi \in [0,1]$ of the expected shortfall in income, relative to its mean, due to the drought; specifically, $I = \xi\gamma(\bar{y} - \bar{y}_1)$ where $\bar{y} = \sum_{i=1,2} q_i \bar{y}_i$. The drought insurance contract carries a premium rate $\pi = q_1(1 + \theta)/(1 + r_f)$ per unit of indemnity, where θ is the premium load and r_f is the insurer's cost of funds. Here, $\theta = -1$ coincides with free insurance and $\theta = 0$ coincides with "actuarially fair" insurance.

The Bellman value function lacks known closed form expression. However, from equation 3, the value function can be completely recovered from knowledge of C , which may be characterized as the fixed-point of a univariate strong contraction map with modulus $\delta < 1$:

$$C \equiv \delta \sum_{j=1}^2 q_j E_{\tilde{\epsilon}} \max\{u(\gamma \bar{y}_j \tilde{\epsilon} + I_j) + A - \phi, u(\gamma \bar{y}_j \tilde{\epsilon} + I_j + K - L) + A, u(\gamma \bar{y}_j \tilde{\epsilon} + I_j - L) + C\} \quad (4)$$

Thus, by the Contraction Mapping Theorem, C , and therefore V , exist and are unique (Royden & Fitzpatrick, 2010). Furthermore, C can easily be computed numerically using either function iteration or Broyden's method (Miranda & Fackler, 2002).

It follows from equation 2 that, for $w > L - K$,

$$g(w) \equiv u(w) + A - \phi - \max\{u(w + K - L) + A, u(w - L) + C\} \quad (5)$$

is well-defined, continuous, and strictly decreasing and denotes an indebted farmer's net gain from defaulting, provided I interpret $u(c) = -\infty$ for $c \leq 0$. If $g(w) = 0$, the farmer is indifferent between defaulting and repaying. As such, if w^* is the unique root of g , it follows that an indebted farmer with liquid wealth w will default if, and only if, $w < w^*$. The critical liquid wealth w^* below which a farmer will default depends on his creditworthiness ϕ . We denote this dependency by $w^*(\phi)$ and note that, by the Implicit Function Theorem, $w^*(\phi)$ is strictly decreasing and continuous, provided the utility function is strictly increasing, strictly concave, and continuously differentiable (as previously assumed).

Assume now that the idiosyncratic income shock $\tilde{\epsilon}$ possesses a continuous cumulative distribution function F . Then the probability that a farmer of creditworthiness ϕ who takes

out a loan this period will default on his loan next period, conditional on a drought occurring ($j = 1$) or not occurring ($j = 2$), is given by

$$p_j(\phi) = \Pr\left(\gamma\bar{y}_j\tilde{\epsilon} + I_j < w^*(\phi)\right) = F(\hat{\epsilon}_j(\phi)) \quad (6)$$

where

$$\hat{\epsilon}_j(\phi) \equiv \frac{w^*(\phi) - I_j}{\gamma\bar{y}_j}. \quad (7)$$

Clearly, $p_j(\phi)$ is continuous and strictly decreasing at values of ϕ such that $\hat{\epsilon}_j(\phi)$ lies in the interior of the support of F . It follows that the unconditional probability that a farmer of creditworthiness ϕ will default on a loan next period is

$$p(\phi) = \sum_j q_j p_j(\phi). \quad (8)$$

6. A Dynamic Game Model of Joint Collateral Group Lending

Suppose now that two identical farmers, indexed by $p = 1, 2$, are offered a group loan for which they are held jointly liable for repaying⁴. That is, if one farmer is unwilling to repay his loan, the other farmer must repay both loans or both farmers are punished by being permanently banned from future credit and, in addition, each farmer suffers a nonpecuniary utility penalty $\phi \geq 0$ due moral regret, loss of reputation, and/or decline in social standing.

Both farmers suffer a decline in income if drought occurs. However, the farmers' incomes are further subject to mutually independent idiosyncratic shocks $\tilde{\epsilon}_p$ and $\tilde{\epsilon}_{-p}$ that are independent of drought conditions. In particular, if the farmers take out a group loan, farmer p 's income the following period will be $\gamma\bar{y}_1\tilde{\epsilon}_p$ if drought occurs and $\gamma\bar{y}_2\tilde{\epsilon}_p$ otherwise; similarly, farmer $-p$'s income the following period will be $\gamma\bar{y}_1\tilde{\epsilon}_{-p}$ if drought occurs and $\gamma\bar{y}_2\tilde{\epsilon}_{-p}$ otherwise.

Let G denote the present value of expected future utility for a farmer who has accepted a group loan with another identical farmer and let

$$v(w) = \max\{u(w + K) + A, u(w) + G\} \quad (9)$$

denote the maximum attainable present value of current and expected future utility of consumption for a creditworthy farmer with disposable wealth w , pledged collateral K , and no unfulfilled debt obligation. Equation 9 reveals that the farmer may choose between: 1) not taking out a group loan, in which case he reclaims his collateral and accepts a value equal to current utility derived from consuming his disposable wealth w and reclaimed collateral K , plus the expected future value for a farmer who has exited the group program A ; or 2) taking out a group loan and maintaining his current collateral, in which case he accepts a

⁴ Collateralized group lending used by the VFP may create positive assortative matching which allows risky and safe borrowers to sort themselves into relatively homogeneous groups (Guttman, 2008). This could be a gap for a next research regarding the VFP.

value equal to current utility derived from consuming his disposable wealth w , plus the expected future value for a creditworthy farmer with a group loan G .

Consider now an indebted farmer p who possesses liquid wealth w_p . Then: 1) the farmer has an incentive to repay both loans if $v(w_p + K - 2L) \geq u(w_p) + A - \phi$; 2) has an incentive to repay his loan if his partner repays his own loan, but no incentive to repay both loans, if $v(w_p - L) \geq u(w_p) + A - \phi \geq v(w_p + K - 2L)$; and 3) has no incentive to repay his loan, regardless of his partner's actions, if $u(w_p) + A - \phi \geq v(w_p - L)$. For these three cases, respectively, let $n_p = 2$, $n_p = 1$, and $n_p = 0$ denote the number of loans farmer p is willing to repay.

Now, let $V(w_p, w_{-p})$ denote the maximum attainable present value of current and expected future utility of consumption for an indebted farmer, given his current liquid wealth w_p and his partner's liquid wealth w_{-p} , given a drought has occurred ($i = 1$) or has not occurred ($i = 2$). Then the farmer's value function V must satisfy the Bellman equation

$$V(w_p, w_{-p}) = \begin{cases} u(w_p) + A - \phi & \text{if } n_p + n_{-p} < 2 \\ v(w_p - L) & \text{if } n_p \geq 1 \text{ and } n_{-p} \geq 1 \\ v(w_p - 2L + K) & \text{if } n_p = 2 \text{ and } n_{-p} = 0 \\ v(w_p - K) & \text{if } n_p = 0 \text{ and } n_{-p} = 2 \end{cases} \quad (10)$$

The four cases, respectively, correspond to: 1) one farmer is unwilling to repay his loan and the other is unwilling to repay both loans, causing the group to default, so that neither farmer repays his loan; 2) both farmers are willing to repay their own loans and do so; 3) farmer $-p$ is unwilling to repay his loan, but farmer p is willing to repay both loans and does so; and 4) farmer p is unwilling to repay his loan, but farmer $-p$ is willing to repay both loans and does so.

The Bellman value function lacks known closed form expression. However, the value function can be completely recovered from knowledge of G , which may be characterized as the fixed-point of a univariate strong contraction map with modulus $\delta < 1$:

$$G = \delta \sum_{j=1}^2 q_j E_{\tilde{\epsilon}_1, \tilde{\epsilon}_2} V(\gamma \bar{y}_j \tilde{\epsilon}_1 + I_j, \gamma \bar{y}_j \tilde{\epsilon}_2 + I_j). \quad (11)$$

Thus, by the Contraction Mapping Theorem, G , and therefore V exist and are unique. Furthermore, G can easily be computed numerically using either function iteration or Broyden's method.

Let w_1^* and w_2^* be defined by

$$u(w_1^*) + A - \phi = v(w_1^* - L) \quad (12)$$

$$u(w_2^*) + A - \phi = v(w_2^* + K - 2L) \quad (13)$$

and $w_1^* \leq w_2^*$. Then the farmer has no incentive to repay his loan if $w_p < w_1^*$; has an incentive to repay his loan, but not his partner's loan, if $w_1^* < w_p < w_2^*$; and has incentive to repay both loans if $w_2^* < w_p$.

The critical wealth depends on the group's creditworthiness ϕ . We denote this dependency by $w_k^*(\phi)$ and note that, by the Implicit Function Theorem, $w_k^*(\phi)$ is strictly decreasing and

continuous, provided the utility function is strictly increasing, strictly concave, and continuously differentiable (as previously assumed).

It follows from Equation (9) that an indebted group will default if, and only if,

$$w_p < w_1^* \text{ and } w_{-p} < w_2^* \quad (14)$$

or

$$w_{-p} < w_1^* \text{ and } w_p < w_2^* \quad (15)$$

That is, the group will default if, and only if, one farmer is unwilling to repay his loan and the other farmer is unwilling to repay both loans.

Now, let F denote the common cumulative distribution function of $\tilde{\epsilon}_p$ and $\tilde{\epsilon}_{-p}$. Then the probability that a group of creditworthiness ϕ will default on a loan next period, conditional on a drought occurring ($\phi = 1$) or not occurring ($\phi = 2$), is given by

$$p_j(\phi) = 2F(\hat{\epsilon}_{1j}(\phi))F(\hat{\epsilon}_{2j}(\phi)) - F(\hat{\epsilon}_{1j}(\phi))^2 \quad (16)$$

where

$$\hat{\epsilon}_{kj}(\phi) \equiv \frac{w_k^*(\phi) - I_j}{r\bar{y}_j}. \quad (17)$$

If F is continuous with connected support, then $p_j(\phi)$ is continuous and strictly increasing at values of ϕ such that either $\hat{\epsilon}_{1j}(\phi)$ or $\hat{\epsilon}_{2j}(\phi)$ lie in the support of F . If both $\hat{\epsilon}_{1j}(\phi)$ and $\hat{\epsilon}_{2j}(\phi)$ lie to the left of the support of F , then $p_j(\phi) = 0$; if both $\hat{\epsilon}_{1j}(\phi)$ and $\hat{\epsilon}_{2j}(\phi)$ lie to right of the support of F , then $p_j(\phi) = 1$.

The unconditional probability of default the following period is thus

$$p_j(\phi) = \sum_j q_j p_j(\phi). \quad (18)$$

7. Model Parameterization

To develop a model that may be solved and simulated numerically, we assume: The farmer's expected income with the subsistence technology equals 1; that is, $q_1\bar{y}_1 + q_2\bar{y}_2 = 1$. The farmer possesses a constant relative risk aversion utility function

$$u(w) \equiv \frac{w^{1-\alpha} - 1}{1-\alpha} \quad (19)$$

where $\alpha \geq 0$ is the coefficient of relative risk aversion. The farmer's idiosyncratic income shock $\tilde{\epsilon}$ is lognormally distributed with mean 1 and log standard deviation $\sigma_{\tilde{\epsilon}} \geq 0$.

Table 3 lists the model's exogenous parameters and provides the base-case values used in simulation. We chose base-case parameter values that are reasonably representative of Thai rice sector and the VFP. For example, collateral is set to 10% of the farmer's debt obligation; the loan interest rate, r , is set to 10% which is close to 7% of the VFP loan interest rate; and insurance premium load, θ , is set to 20%, to reflect a market-viable premium, given that index insurance in Thailand is not subsidized and offered by private insurance companies.

Table 1. Model Parameters

Symbol	Value	Description
a_1	0.2	probability of drought
η	0.4	percent systemic risk
σ_y	0.3	income volatility
α	2	coefficient of relative risk aversion
ρ	0.05	per-period subjective discount rate
ϕ_i	0.5	default utility penalty, individual credit
ϕ_a	1	default utility penalty, group credit
r_h	0.25	expected return on hi-tech seed investment
κ	0.2	cost of hi-tech seed
r	0.1	loan interest rate
ξ	0.5	insurance coverage level
θ	0.2	insurance premium load
r_f	0.05	lender and insurer cost of funds
k	0.1	collateral as a percent of farmer's debt obligation

Table 4 lists parameters that are determined by and derived from the primitive base-case parameters. The per-period subjective discount factor, δ , is a function of the per-period discount rate ρ :

$$\delta = 1/(1 + \rho). \quad (20)$$

The probability of no drought q_2 , is a function of the probability of drought q_1 :

$$q_2 = 1 - q_1. \quad (21)$$

Without loss of generality, and to promote ease of interpretation, we normalize expected income to be 1. Thus, we can derive subsistence expected income, conditional on drought, \bar{y}_2 , subsistence expected income, conditional on no drought, \bar{y}_1 , and idiosyncratic income shock volatility, $\sigma_{\tilde{\epsilon}}$ from q_1 , q_2 , percent systemic risk η , and income volatility σ_y by solving:

$$\bar{y}_2 = \frac{1 - q_1 \bar{y}_1}{q_2} \quad (22)$$

$$\sigma_{\tilde{\epsilon}}^2 = (1 - \eta)\sigma_y^2 \quad (23)$$

$$\eta\sigma_{\tilde{\epsilon}}^2 = \sum_{i=1,2} q_i (\log(\bar{y}_i))^2 - \left(\sum_{i=1,2} q_i \log(\bar{y}_i) \right)^2. \quad (24)$$

Insurance premium rate, π , can be derived from q_1 , insurance premium load θ , and lender and insurer cost of funds r_f :

$$\pi = q_1(1 + \theta)/(1 + r_f) \quad (25)$$

and “hi-tech” seed productivity enhancement factor, γ , can be derived from expected return on hi-tech seed investment, r_h , and cost of hi-tech seed, κ :

$$\gamma = 1 + (1 + r_h)\kappa. \quad (26)$$

Knowing \bar{y}_1 from equation (22) and γ from equation (26), we can derive insurance indemnity, I , as following:

$$I = \xi\gamma(1 - \bar{y}_1). \quad (27)$$

Then I can derive farmer’s debt obligation which is a function of κ , π , I , and loan interest rate, r :

$$L = (1 + r)(\kappa + \pi I). \quad (28)$$

Lastly, we can derive collateral, K as a function of L and a percent of farmer’s debt obligation, k :

$$K = kL. \quad (29)$$

Table 2. Derived Model Parameters

Symbol	Description
a_2	probability of no drought
\bar{y}_1	subsistence expected income, conditional on drought
\bar{y}_2	subsistence expected income, conditional on no drought
γ	“hi-tech” seed productivity enhancement factor
σ_{ε}	idiosyncratic income shock volatility
δ	per-period subjective discount factor
L	farmer’s debt obligation
K	collateral
I	insurance indemnity, if drought
π	insurance premium rate

8. Model Solution

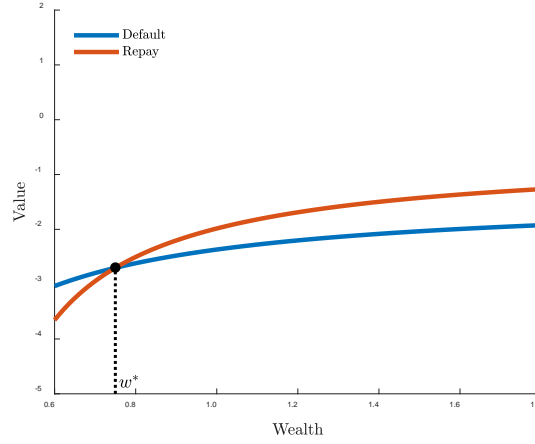


Figure 2. Conditional value functions with individual credit

Figure 21 shows that the farmer will default on loan if his initial wealth is less than w^* , and he will repay his loan if his initial wealth is greater than or equal to w^* .

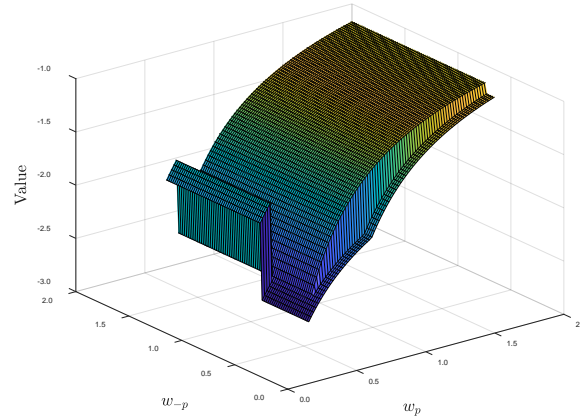


Figure 3. Representative agent p 's value function with group credit

Figure (22) shows that at a low level of w_{-p} and w_p , farmer $-p$ is unwilling to repay his loan, and farmer p is unwilling to repay both loans. Thus, the group defaults. At a low level of w_{-p} , and high level of w_p beyond the kink, farmer $-p$ is unwilling to repay his loan, but farmer p is willing to repay both loans and do so. At a high level of w_{-p} beyond the kink, and a low level of w_p , farmer w_p is unwilling to repay his loan, but farmer $-p$ is willing to repay both loans and do so. At a high level of w_{-p} , and w_p , both farmers are willing to repay their own loans and do so.

9. Collateralized Group Lending without Index Insurance

This section provides the analysis of the loan performance of the collateralized group credit compared to the collateralized individual credit by using various exogenous parameters. Measures of loan performance are the farmers' default rate and the farmer's wiliness to pay

(WTP) for credit. The exogenous parameters of interest are collateral as percent of loan, loan interest rate, probability of drought, income volatility, and percent of systemic risk.

- *Collateral as Percent of Loan*

Figure 23 and 24 illustrate the probability of default and farmer WTP for access to credit, respectively, as functions of the collateral as percent of loan, for collateralized individual and group credit. The farmer rarely defaults when the collateral required by the lender rises to approximately 40% of loan size. When the collateral is relatively low, specifically lower than 40% of the loan size, group credit will raise the probability of default, and the farmer will be willing to pay more for access the individual credit than for group credit.

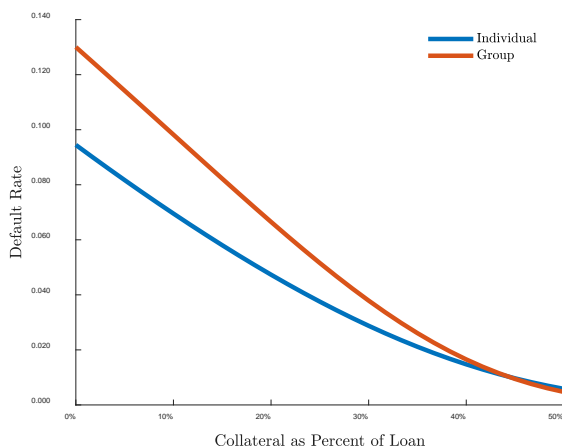


Figure 4. Default rate vs. collateral as percent of loan

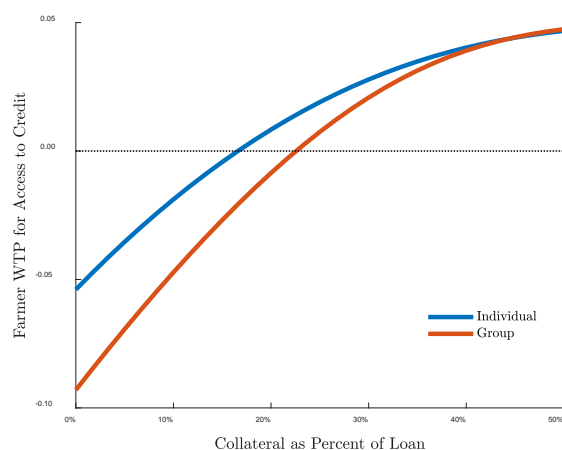


Figure 5. Farmer WTP for access to credit vs. collateral as percent of loan

- *Loan Interest Rate*

Figure 25 illustrates the impact of loan interest rate on the probability of default. When the interest rate charged on loan is relatively low, the farmer is less likely to default. However, when the lender increases the interest rate, the farmer's default rate steadily increases. In

particular, compared to the collateralized individual credit, the default rate of collateralized group credit deteriorates, and the farmer's demand for the group credit is lower when the interest rate is relatively high.

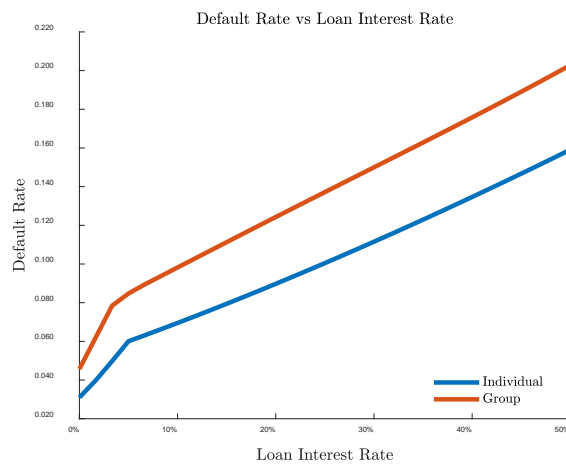


Figure 6. Default rate vs. loan interest rate

- *Probability of Drought*

Figure 26 and 27 illustrate the impact of probability of drought on the probability of default and the farmer WTP for credit. When the probability of drought increases, the default rate tends to decrease for both collateralized individual and group credit. However, the probability of default of the group credit deteriorates. This lowers the demand for the group credit compared to the group credit.

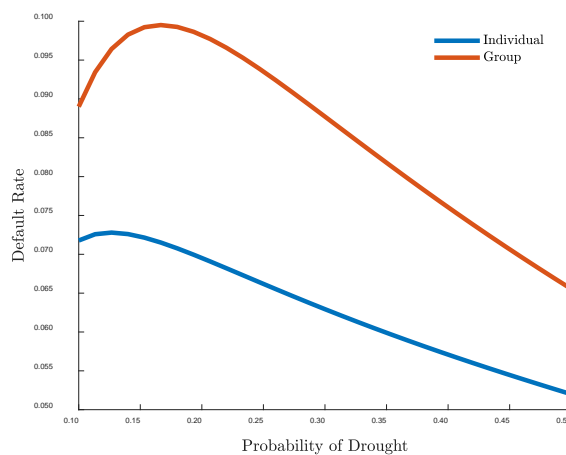


Figure 7. Default rate vs. probability of drought

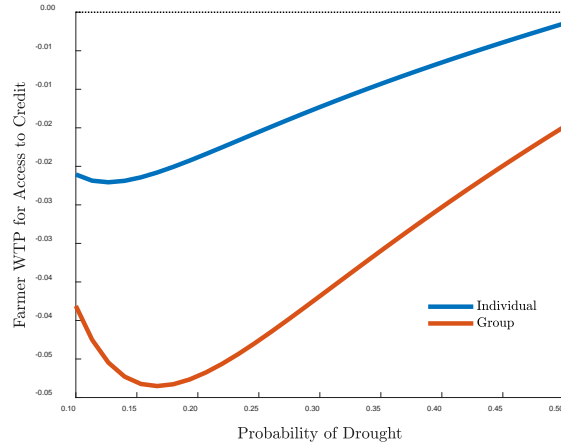


Figure 8. Farmer WTP for access to credit vs. probability of drought

- Income Volatility

Figure 28 and 29 show the impact of income volatility on the probability of drought and the farmer WTP for credit. When the farmer's income volatility is relative low, he rarely defaults. However, when the farmer income is more volatile, the loan performance of both collateralized individual and group credit deteriorates. The demand for the both individual and group credit decreases. However, the group credit tends to lower the probability of default when the farmer' income volatility is relatively high, specifically, greater than 0.50.

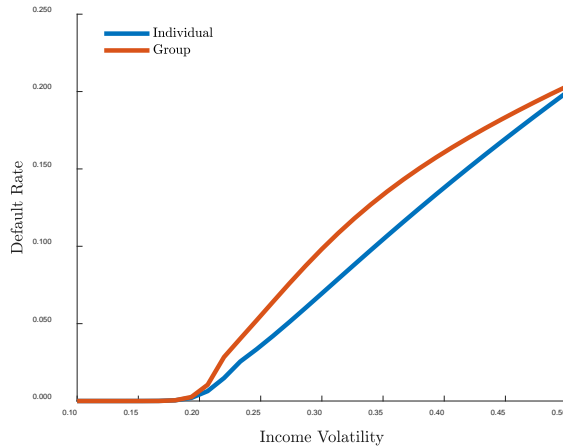


Figure 9. Default rate vs. Income volatility

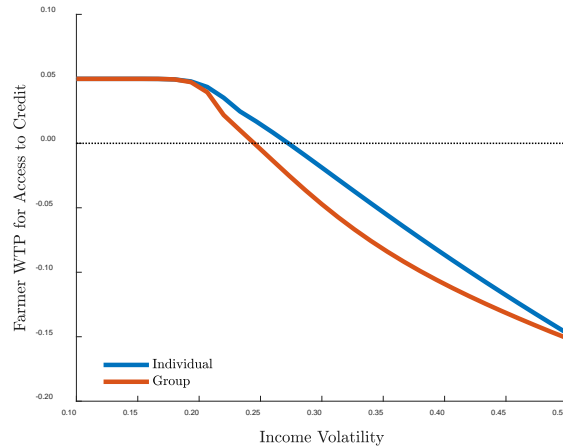


Figure 10. Farmer WTP for access to credit vs. income volatility

- *Systemic Risk*

Figure 30 and 31 illustrate the impact of systemic risk on the probability of default and the farmer WTP for credit. At relatively low percent systemic risk, the farmer in the collateralized group credit is less likely to default compared to the farmer in the collateralized individual credit. However, when the percent systemic risk rises, the default rate of the group credit become worse than the individual credit. This implies that the systemic shocks affect both the farmer and his partner's income in the group credit. The farmers' willingness to pay for both types of credit decreases, especially for the collateralized group credit, when the percent of the systemic risk increases.

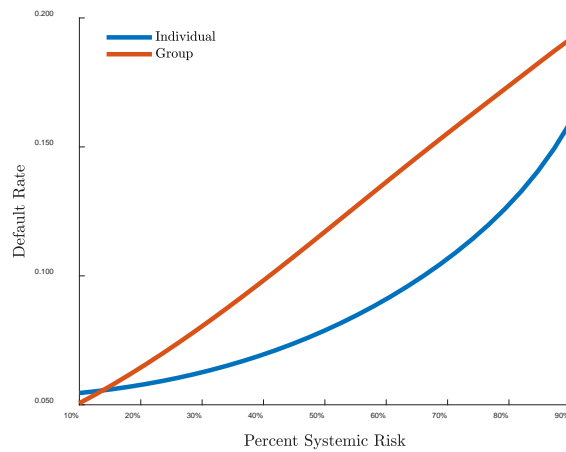


Figure 11. Default rate vs. percent systemic risk

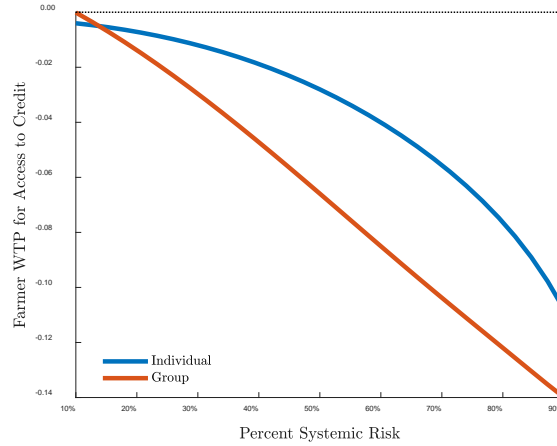


Figure 12. Farmer WTP for access to credit vs. percent system risk

10. Collateralized Group Lending with Index Insurance

In this section, we compare the loan performance and farmer WTP for collateralized group credit, with and without index insurance.

- *Collateral as Percent of Loan*

Figure 32 and 33 illustrate the probability of default, and the farmer WTP for access to group credit, respectively, as functions of the collateral as percent of loan, with and without index insurance. When the collateral is relatively low, the insured group credit lowers the default rates compared to the uninsured group credit. Particularly, if the lender increases the collateral above 40%, farmers in the insured group credit rarely default. The farmer's WTP for credit, with and without index insurance, increases when the lender raises the collateral, and he is willing to pay more for the collateralized group credit.

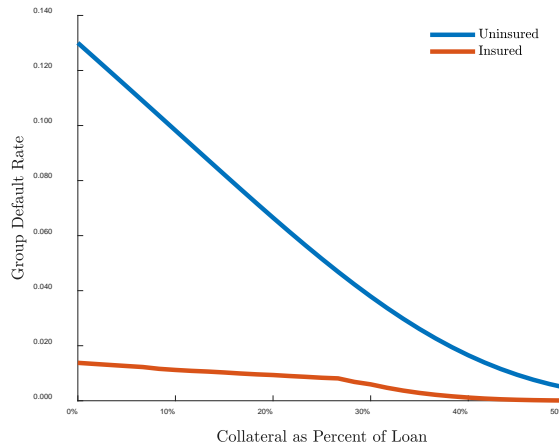


Figure 13. Default rate vs. collateral as percent of loan – group credit

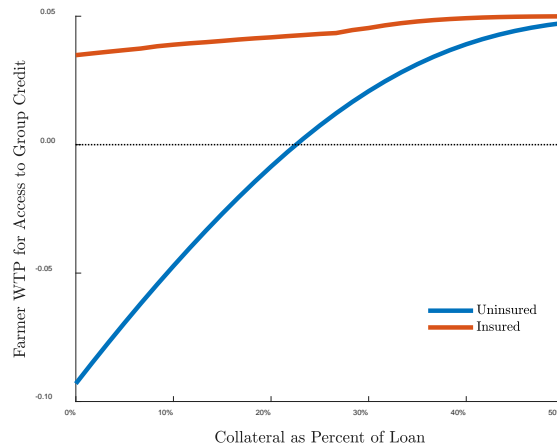


Figure 14. Farmer WTP for access to group credit vs. collateral as percent of loan

- *Loan Interest Rate*

Figure 34 illustrates the impact of loan interest rate on the probability of default and the farmer WTP, between collateralized group credit with and without with and without index insurance. When the loan interest rate is relatively low, the farmer is less likely to default. If the lender increases the interest rate, the probability of default for both types of credit increase. The default rate for group credit with index insurance will be lower than without index insurance when the interest rate is less than 30%. However, the demand for group credit, with and without index insurance, increases when the lender decreases the interest rate.

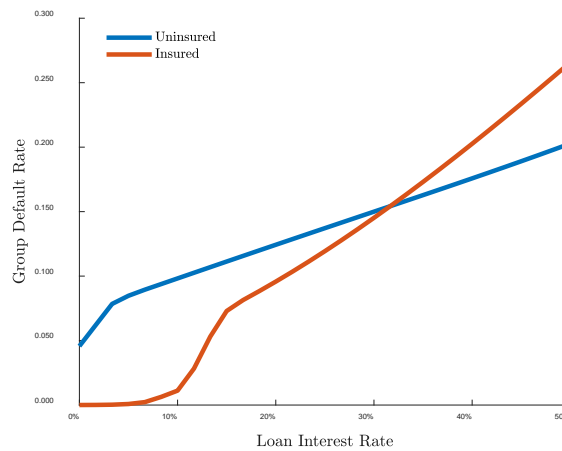


Figure 15. Default rate vs. loan interest rate – group

- *Insurance Premium Load*

Figure 35 and 36 illustrate the impact of insurance premium load on the probability of default and the farmer WTP, on collateralized group credit with and without index insurance. Index insurance can reduce the probability of default. When the lender provides free insurance, the farmer is less likely to default. If the insurer increases the insurance premium

load, the probability of default will increase, and the farmer' WTP for the group credit with index insurance will continually decrease.

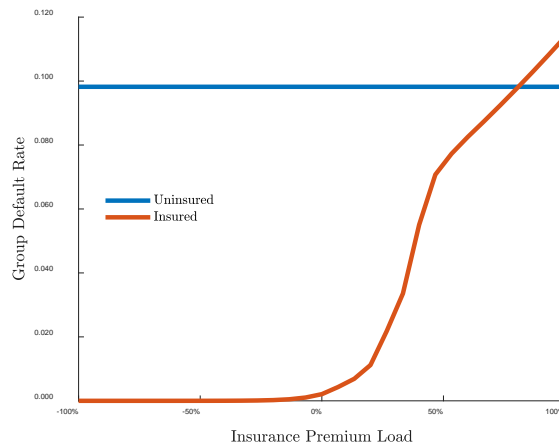


Figure 16. Default rate vs. insurance premium load – group

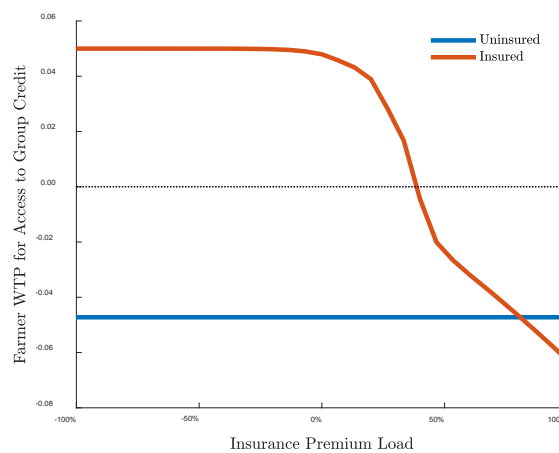


Figure 17. Farmer WTP for access to credit vs. insurance premium load – group

- *Insurance Coverage Level*

Figure 37 and 38 illustrate the impact of insurance coverage level on the probability of default and the farmer's WTP for collateralized group credit with and without index insurance. As the insurance coverage level rises, the probability of default with collateralized group loan with index insurance will fall. However, when the coverage level reaches approximately 80%, the default rate of the insured group begins to rise but still lower than the uninsured group. In addition, the increase in the insurance coverage level will raise the WTP for the insured group loan.

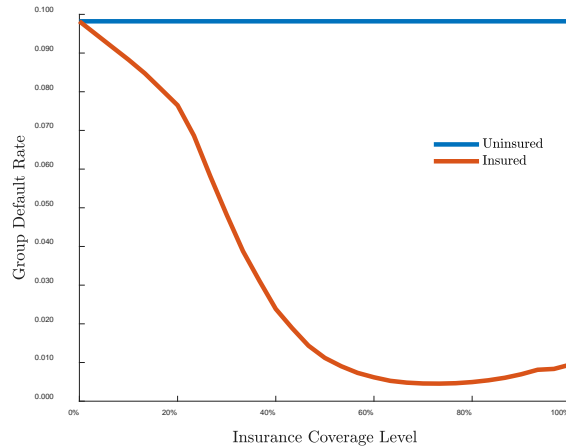


Figure 18. Default rate vs. insurance coverage level

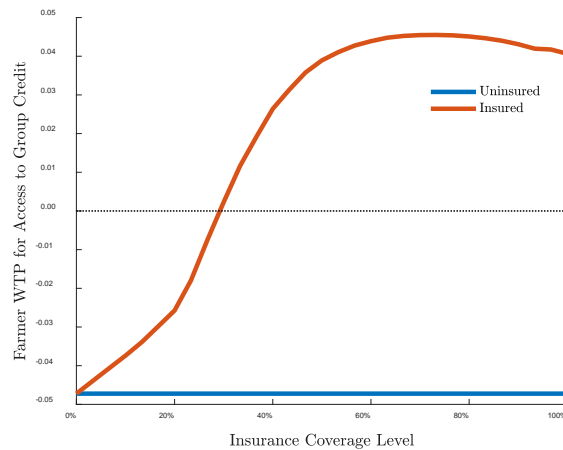


Figure 19. Farmer WTP for access to credit vs. insurance coverage level

- *Probability of Drought*

Figure 39 and 40 illustrate the impact of probability of drought on the probability of default and the farmer WTP for collateralized group credit with and without index insurance. Insured group credit performs better than uninsured group credit when the probability of drought is less than 40%. However, the default rate of the insured group credit tends to increase steadily when the probability of drought rises.

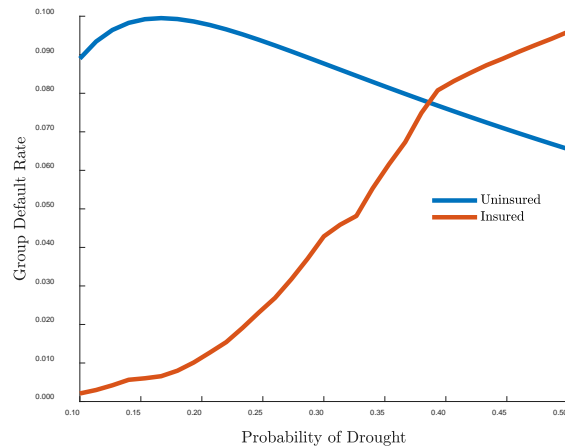


Figure 20. Default rate vs. probability of drought – group

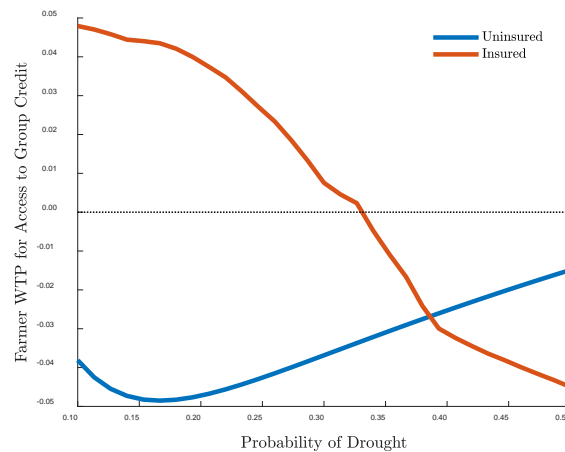


Figure 21. Farmer WTP for access to credit vs. probability of drought – group

- Income Volatility

Figure 41 and 42 illustrate the impact of farmer income volatility on the probability of default and the farmer's WTP for collateralized group credit with and without index insurance. The farmer is less likely to default when his income volatility is relative low. When his income volatility reaches 0.2, the default probability begins to rise. However, the insured group credit dramatically lowers the default rates compared to the uninsured group credit, when the income volatility rises. The demand for insured and uninsured collateralized group credit decreases as the farmer's income volatility rises.

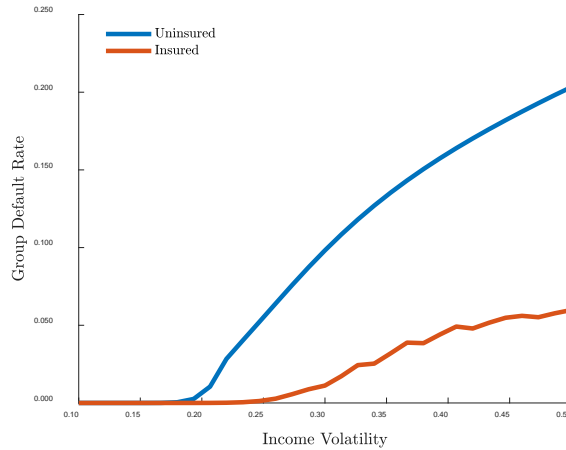


Figure 22. Default rate vs. income volatility – group

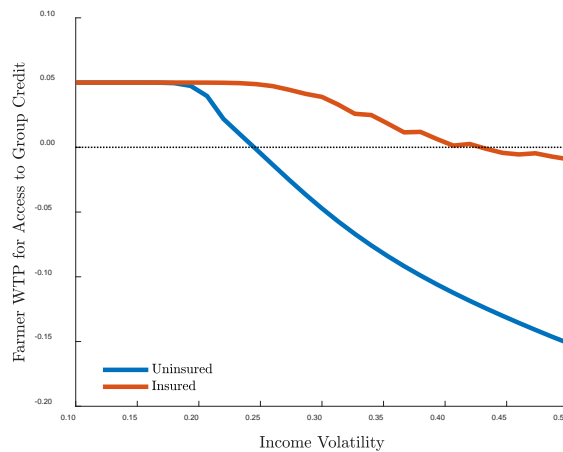


Figure 23. Farmer WTP for access to credit vs. income volatility – group

- *Systemic Risk*

Figure 43 and 44 illustrate the impact of systemic risk on the probability of default and the farmer's WTP for collateralized group credit with and without index insurance. When the percent of systemic risk increases, the probability of default with the insured group loan falls to zero. This contrasts to the uninsured group loan where the probability of default dramatically increases as systemic risk rises. Although the demand for the uninsured group loan dramatically decreases, the demand for the insured group loan steadily increases as systemic risk rises.

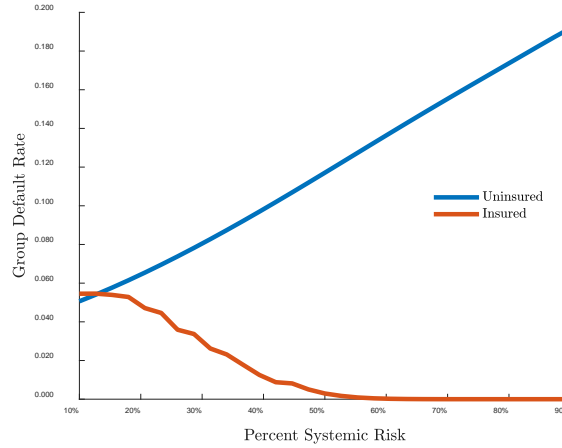


Figure 24. Default rate vs. percent systemic risk – group

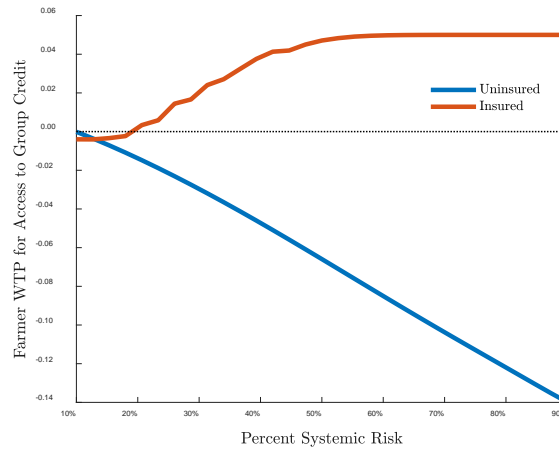


Figure 25. Farmer WTP for access to credit vs. percent systemic risk – group

11. Summary and Conclusions

In this section, we perform a theoretical analysis of joint collateral group lending and weather index insurance. Joint collateral group lending is a mechanism that the VFP currently applies in order to secure loans against the defaults. Group lending has advantages over individual lending on information that villagers have on each other's, and that is unavailable to the lender. This could alleviate adverse selection problem that would undermine the performance of the VFP. Joint collateral group mechanism refers to the obligation of members in group lending to repay a debt if a member in the group fails to do so. If the members do not meet their obligations, their pledged savings accounts, which serve as collateral, will be seized, and they will not be able to take out a loan until the debt they guaranteed is repaid. Specifically, we formulate, solve, and analyze a dynamic stochastic optimization model to study how joint collateral group lending works and how its performance might be enhanced using weather index insurance.

This chapter focuses on joint collateral group lending mechanism that the VFPs uses to protect their loan portfolio from default. We perform a theoretical analysis, and numerically solve and simulate a dynamic stochastic optimization model to examine the potential impact of collateralized group credit on loan performance and WTP for the loan. We compare the results with collateralized individual credit, which is used as a baseline. The loan performance is measured by the probability of default and the farmer's WTP for credit. I also examine how loan performance and WTP for the loans are affected using weather index insurance. We find that, first, when the collateral is relatively low, the collateralized group credit tends to reduce loan performance and WTP for credit, compared to collateralized individual credit. Second, index insurance can improve the performance of collateralized group loans, particularly when systemic risk is high. Third, index insurance is less effective when interest rate charged by the lender and insurance premium load are high

Thailand National Village and Urban Community Fund Program (VFP) is the most important formal financial institution providing credit to smallholder farmers in Thailand. Since smallholder farmers are generally too poor to provide adequate collateral to secure their loans, the VFP employs joint liability group lending and limited collateral requirement mechanisms to secure loans against defaults. However, a decline in VFP loan repayment rates since 2004 raise concerns regarding sustainability of the VFP.

Since the majority of VFP clients are farmers who rely on rainfed agriculture, catastrophic weather could have adverse impact on the sustainability of the VFP. We perform a risk analysis employing World Bank Rapid Risk Assessment protocols to investigate how catastrophic weather and other systemic shocks disrupt the northeast Thai rice value chain, with special interest in how they affect the performance of the VFP. We find that northeastern farmers face major risks from drought, flood, low input prices, and high input prices. Although floods are less like to occur than droughts, extreme floods cause greater damage than extreme droughts. Low output prices and high input prices are less problematic. Moreover, the rice buffer stock program used to control rice prices is ineffective because high minimum prices have led the accumulation of rice stocks.

One possible solution for protecting the VFP performance against defaults from the catastrophic weather is to back loans with index insurance. Unlike conventional insurance, index insurance indemnifies the insured based on a realized index that is correlated to the losses such as rainfall. Hence, index insurance is free from moral hazard, has low adverse selection and administrative costs. It is more affordable to poor farmers. To better understand how index insurance might affect VFP performance, we develop a stochastic dynamic game model of the joint collateral group lending mechanism used by the VFP. Model simulations confirm that index insurance can substantially improve the performance of collateralized group credit when systemic risk due to droughts and floods is significant. The simulation analysis also shows that index insurance is less effective at reducing loan defaults if the collateral requirement is very low, the interest rate charged by the lender is very high, or the insurance premium are very high.

I use the Townsend Thai dataset to perform econometric analysis to examine whether collateral requirements in the form of a small savings account affect VFP loan repayment rates. Estimate obtained by applying entropy balanced logistic regression and instrumental variable methods indicate that the requirement of a small savings accounts increases loan

repayment rates for the VFP. Moreover, greater loan amounts and interest rates tend to raise VFP loan repayment rate. However, the effect of interest on the loan repayment is an anomalous result. Lastly, although the result is insignificant, the extreme deviation of annual average rainfall reduces farmer VFP loan repayment rates.

Overall, the results from this paper indicate that index insurance can be a possible and effective solution for Thai government to improve loan performance of the VFP.

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