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The Dynamics of Insurance Demand under Liquidity Constraints and Insurer Default Risk

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ABSTRACT

Low demand for micro-insurance has been a prominent problem in developing countries. We study the dynamics of insurance demand by risk-averse farmers who can borrow and lend subject to a credit constraint and who also perceive a risk of insurer default. Credit constraints and the possibility of insurer default both reduce the demand for insurance. We then propose an alternative insurance design that allows farmers to enter an insurance contract while delaying payment of the premium until the end of the insured period. We show how this alternative design can increase insurance take-up by relaxing the liquidity constraint and assuaging farmers' concerns about insurer default. We also investigate the effects of the associated problem of farmers reneging on their delayed premium payment if the insured event does not occur.

Keywords: agricultural insurance, delayed premium payment, insurance demand, liquidity constraint, insurer default

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1. INTRODUCTION

A frequent explanation for weak demand for agricultural insurance, especially in developing countries, is that purchasers face liquidity constraints and lack trust in insurance providers. When premium payments are required up front farmers need savings or credit to buy insurance, so low savings and lack of access to credit markets can limit insurance demand. Furthermore, when premiums are paid up front farmers face the risk that the insurer will default on indemnities when the insured event occurs. This default risk can also limit insurance demand. Giné, Townsend, and Vickery (2008) find that liquidity constraints are an important factor reducing insurance participation in rural India. Similarly, Cole et al. (2011) use a field experiment in India to show that providing farmers with a cash transfer at the same time insurance is offered greatly increases take-up, suggesting the importance of liquidity constraints in limiting insurance demand. Cole et al. also find that insurance policy endorsement from a trusted third party significantly increases participation. A recent field experiment (Cai et al. 2009) confirms the importance of trust in the insurer in the context of livestock insurance in China.

Liquidity constraints and insurer default risk introduce considerations that are explicitly dynamic into insurance demand decisions, but there have been few attempts to model such phenomena formally in the context of dynamic optimization models. Gollier (1994, 2003) and Braun and Koeniger (2007) develop dynamic models of insurance demand that include liquidity constraints but do not address insurer default risk. To our knowledge, there are no insurance models in the literature that allow for both liquidity constraints and default risk.

One purpose of this paper is to develop a dynamic model of demand for agricultural insurance by risk-averse farmers who can borrow and lend subject to a liquidity constraint and who face risk of insurer default. Three initial results are derived. First, when liquidity constraints and the risk of insurer default are absent, the usual result from static insurance theory that a risk-averse farmer will always choose full coverage under an actuarially fair insurance offer continues to hold. This result is well known in the literature, but for completeness we illustrate that it still holds in our dynamic agricultural insurance model. Second, even when insurance is actuarially fair, a binding liquidity constraint causes farmers to reduce their demand for insurance. This is because once dynamics are explicitly introduced, an up-front premium payment can be extremely costly in the presence of a binding liquidity constraint. Third, a positive probability of insurer default reduces insurance demand even if insurance is actuarially fair and the liquidity constraint is not binding. This is because any up-front premium payments are lost in the case of insurer default.

Another goal of the paper is to analyze an alternative insurance design that may increase insurance demand by offsetting liquidity constraints and lessening farmer concerns about insurer default. The alternative design allows farmers to enter an insurance contract while delaying premium payment until the end of the insured period. This design will help counteract a liquidity constraint and also assuage farmers' fear of the worst-case scenario: a situation in which they do not receive an indemnity even when they have paid the premium and experienced the insured loss. The alternative design is found to ameliorate the problems caused by liquidity constraints and insurer default risk.

One of the problems with delayed premium payment is potential reneging by farmers if the insured event does not occur. For example, a livestock producer insuring an animal lot against death with delayed premium payment who subsequently experiences no deaths may be reluctant to make the delayed premium payment. In the paper we study the role of various incentive mechanisms that could be incorporated into the insurance design to minimize farmer reneging. For example, the farmer would be excluded from any future participation in the insurance program once she has reneged once. Other sanctions against reneging could also reduce or eliminate this problem. For example, delayed premium payment is already featured in some operational US crop insurance programs, but reneging has never been a serious issue because farmers who renege could be precluded from participating in any future government farm programs, leading to a severe penalty for nonpayment of premiums.

The remainder of the paper is organized as follows. The next section outlines a dynamic model of conventional agricultural insurance where premiums are required to be paid up front. Liquidity constraints and insurer default risk are included, and their effects on the demand for insurance are outlined. Next we study the alternative insurance design and show how delayed premium payment can ameliorate some of the negative effects of liquidity constraints and insurer default risk. We also investigate the value farmers would place on the delayed premium payment feature. The paper then turns to discussion and analysis of the reneging problem and ways to counteract it. Finally, we conclude by discussing the importance of these dynamic insurance issues in a developing-country context.

2. A DYNAMIC AGRICULTURAL INSURANCE MODEL

Consider a risk-averse livestock farmer who uses insurance to manage the risk of livestock losses. Each period the farmer raises an animal lot that yields fixed revenue M in the next period if the animals survive and zero if they don't. There is a known probability q that the farmer loses her entire lot and receives no revenue.[1] The insurance policy is defined by a pair of variables (p, M), where p is the premium and M is the indemnity if the animals die before the end of the insured period. For simplicity we assume no moral hazard or adverse selection, so there is no need for a deductible. We also assume the insurance policy is actuarially fair (zero loading factor). Assuming the premium is paid at the beginning of the period the actuarially fair premium p is then determined by $p = qM/(1+r)$, where r is the risk-free per-period interest rate. The farmer can choose what proportion of the lot to insure, which is denoted by k ranging from 0 to 1. In a conventional insurance policy the farmer pays the premium at the start of the insured period and receives an indemnity at the end of the insured period if lot loss occurs during the insured period. We further assume the farmer perceives some probability of insurer default ξ. More formally, when insurance is taken out and the loss occurs, the farmer perceives she will get the indemnity with probability $(1-\xi)$.

The farmer is assumed to live forever (or care about her heirs) and maximizes discounted lifetime utility subject to a budget constraint:

$$\max_{\{c_t\}} E_0 \sum_{t=0}^{\infty} \beta^t U(c_t) \quad \text{s.t.} \tag{1}$$

$$S_t = w_t - c_t - pk_t, \tag{2}$$

$$w_{t+1} = (1+r)S_t + k_t(1 - y_{t+1}\Delta_{t+1})M + (1-k_t)(1-y_{t+1})M, \tag{3}$$

$$S_t \geq s, \tag{4}$$

where $U(.)$ is an increasing and concave utility function; c_t and w_t are consumption and wealth at period t; β is the discount factor; S_t is savings (borrowing if negative) at period t; Δ_{t+1} is a binary random variable with 1 indicating the event of insurer default, which follows a Bernoulli distribution with mean ξ and variance $\xi(1-\xi)$; y_{t+1} is a binary random variable with 1 indicating the event of livestock loss, which follows a Bernoulli distribution with mean q and variance $q(1-q)$; and s is the minimum net wealth position allowed by the credit market (a liquidity constraint). If $s = 0$, borrowing is not possible, whereas if $s = -\infty$, there is no liquidity constraint and any amount can be borrowed.

The farmer's problem is to choose consumption and insurance coverage levels that satisfy the Bellman equation

$$V(w_t) = \max_{c_t, k_t} \{U(c_t) + \beta E_t V(w_{t+1})\}, \tag{5}$$

subject to the constraints (2)–(4), and the transversality condition

$$\lim_{t \to \infty} \beta^t w_t = 0, \tag{6}$$

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[1] The assumption that the farmer loses either all animals or none is to simplify the presentation and does not influence major results.

which rules out perpetual borrowing. Necessary conditions for a solution can be written thus:[2]

$$U'(c_t) - \beta(1+r)E_t V'(w_{t+1}) - \lambda_t = 0 \quad , \tag{7}$$

$$\lambda_t \geq 0, \quad S_t - s \geq 0, \quad \lambda_t(S_t - s) = 0 \quad , \tag{8}$$

$$G(c_t, k_t) = E_t\left[V'(w_{t+1})(-(1+r)p + (1-\Delta_{t+1})y_{t+1}M)\right] - \lambda_t p = 0 \quad , \tag{9}$$

where λ_t is the Lagrange multiplier for the liquidity constraint.

We use the necessary conditions to obtain the following results on insurance demand under different assumptions regarding the farmer's liquidity position and perceived probability of insurer default.

Proposition 1*:* With no liquidity constraint ($s = -\infty$) and no insurer default ($\Delta_{t+1} = 0$ with probability 1), a farmer faced with actuarially fair insurance will choose full insurance coverage ($k = 1$).

Proof: With no liquidity constraints or insurer default then (9) becomes

$$E_t\left[V'(w_{t+1})(-(1+r)p + y_{t+1}M)\right] = 0. \tag{10}$$

Now note that if $k_t = 1$ then $w_{t+1} = (1+r)(w_t - c_t - p) + M$ with probability 1. Therefore, (10) can be written as $V'(w_{t+1})E_t[-(1+r)p + y_{t+1}M] = 0$. But since $E_t(y_{t+1}) = q$ and $p = qM/(1+r)$ (as implied by actuarial fairness), then this necessary condition is immediately satisfied. This shows that $k_t = 1$ is a solution to (10) under the stated conditions. We also note that concavity of $U(.)$ guarantees that $G(c_t, k_t)$ is decreasing in k_t for any c_t (that is, $\partial G(c_t, k_t)/\partial k_t = E_t\{V''(w_{t+1})[-(1+r)p + My_{t+1}]^2\} < 0$). This guarantees $k = 1$ is the only solution.

This proposition shows that the standard static result on the optimality of full coverage for actuarially fair insurance continues to hold in a dynamic model that requires up-front premium payment and delayed indemnities, as long as the farmer can borrow freely at the risk-free rate and faces no risk of insurer default.

Proposition 2*:* With a binding liquidity constraint and no risk of insurer default, a farmer faced with actuarially fair insurance will choose an insurance coverage lower than full insurance ($k < 1$).

Proof*:* A binding liquidity constraint implies $\lambda_t > 0$. Then assuming no risk of insurer default, (9) becomes

$$G(c_t, k_t) = E_t\left[V'(w_{t+1})(-(1+r)p + y_{t+1}M)\right] - \lambda_t p = 0 \quad . \tag{11}$$

From Proposition 1 we have that $G(c_t, 1) = 0 - \lambda_t p < 0$ and that $G(c_t, k_t)$ is decreasing in k_t. Since the derivative is both negative at $k_t = 1$ and decreasing in k_t then the optimal k_t satisfying (11) must be less than 1.

This proposition shows that a binding liquidity constraint will reduce the demand for actuarially fair insurance below full coverage. Clearly, if the liquidity constraint is severe enough the optimal choice will be to forego buying insurance altogether.

Proposition 3*:* With a positive probability of insurer default and no liquidity constraint a farmer faced with actuarially fair insurance will choose an insurance coverage lower than full insurance ($k_t < 1$).

Proof*:* With no liquidity constraint but positive probability of insurer default, (9) becomes

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[2] Second-order conditions for a maximum are satisfied by the concavity of the utility function.

$$G(c_t, k_t) = E_t\left[V'(w_{t+1})(-(1+r)p + (1-\Delta_{t+1})y_{t+1}M)\right] = 0. \tag{12}$$

From Proposition 1 we have that

$$G(c_t, 1) = V'(w_{1,t+1})(1-\xi)[-(1+r)p] + V'(w_{2,t+1})q\xi[-(1+r)p] < 0, \tag{13}$$

where $w_{2,t+1} = (1+r)(w_t - c_t - p_t)$ and $w_{1,t+1} = w_{2,t+1} + M$. Since the derivative is both negative at $k_t = 1$ and decreasing in k_t then the optimal k_t that satisfies (12) must be less than 1.

This proposition shows that a positive probability of insurer default will reduce the demand for insurance below full insurance. Clearly, if the probability of insurer default is large enough the optimal choice will be to forego buying insurance altogether. Furthermore, together Propositions 2 and 3 suggest that the combination of higher liquidity constraints and higher risk of insurer default will reduce demand for insurance, eventually leading to farmer withdrawal from the insurance market.

3. AN ALTERNATIVE INSURANCE DESIGN

We now turn to an alternative insurance design that allows farmers to buy insurance while delaying premium payment until the end of the insured period. In this design an insured farmer that loses her lot during the insured period receives the indemnity minus the premium at the end of the insured period. Otherwise, she pays the premium. We continue to assume the insurance remains actuarially fair to facilitate comparisons with the conventional insurance design. However, because the premium is paid at the same time as the indemnity in the alternative design, the actuarially fair premium is $p = qM$, which differs from the case of conventional insurance (because no discounting is necessary).

Under the alternative insurance design, the farmer's problem becomes as follows:

$$\max_{\{c_t\}} E_0 \sum_{t=0}^{\infty} \beta^t U(c_t) \quad \text{s.t.} \tag{14}$$

$$S_t = w_t - c_t \ , \tag{15}$$

$$w_{t+1} = (1+r)S_t + k_t(1 - y_{t+1}\Delta_{t+1})(M - p) + (1 - k_t)(1 - y_{t+1})M \ , \tag{16}$$

$$S_t \geq s \ . \tag{17}$$

And the corresponding necessary conditions are the following:

$$U'(c_t) - \beta(1+r)E_t V'(w_{t+1}) - \lambda_t = 0 \ , \tag{18}$$

$$\lambda_t \geq 0, \quad S_t - s \geq 0, \quad \lambda_t(S_t - s) = 0 \ , \tag{19}$$

$$G(c_t, k_t) = \beta E_t\left[V'(w_{t+1})((1 - y_{t+1}\Delta_{t+1})(M - p) - (1 - y_{t+1})M\right] = 0 \ . \tag{20}$$

We first consider the same scenario as in Proposition 1: no liquidity constraint and no risk of insurer default. It is straightforward to show that a farmer faced with actuarially fair insurance will choose full insurance coverage ($k_t = 1$) under delayed premium payment as well. Therefore delayed premium payment has no value under these conditions. To see this, note that (20) becomes

$$G\left(c_t, k_t\right) = E_t\left[V'(w_{t+1})(-p + y_{t+1}M)\right] = 0. \tag{21}$$

And, similar to the proof of Proposition 1, if $k_t = 1$ then $w_{t+1} = (1+r)(w_t - c_t) + M - p$ with probability 1. Therefore, (21) can be written as $V'(w_{t+1})E_t[-p + y_{t+1}M] = 0$. But since $E_t(y_{t+1}) = q$ and $p = qM$ (as implied by actuarial fairness), then this necessary condition is immediately satisfied, which shows that $k_t = 1$ is a solution to (21) under the stated conditions.

When there is a binding liquidity constraint, however, the result under delayed premium payment is different than in the conventional design. Under delayed premium payment we get the following result.

Proposition 4*:* With a binding liquidity constraint and no risk of insurer default, a farmer faced with actuarially fair insurance will choose full insurance coverage under delayed premium payment.

Proof: Equation (20) continues to hold at the optimum under a binding liquidity constraint ($\lambda_t > 0$). So when there is no risk of insurer default (20) reduces to (21) and, as just discussed, $k = 1$ is the solution to (21).

This result suggests that delayed premium payment can increase insurance demand when farmers face a binding liquidity constraint. The binding liquidity constraint will still affect the farmer's consumption decisions but not her decision to buy insurance.

Next we examine how insurance demand will change under delayed premium payment when the farmer perceives a positive probability of insurer default. In this case we get the following result.

Proposition 5: With a positive probability of insurer default and no liquidity constraint, a farmer facing actuarially fair insurance will choose an insurance coverage level lower than full insurance — that is, optimal $k_t < 1$ even under a delayed payment plan. However, the optimal insurance coverage is higher than that under the conventional insurance design with the same risk of insurer default.

Proof: With a positive probability of insurer default, (20) can be written as

$$G(c_t,k_t) = (1-q)V'(w_{1,t+1})(-p) + q(1-\xi)V'(w_{2,t+1})(M-p) , \tag{22}$$

where $w_{1,t+1} = (1+r)(w_t - c_t) + k_t(M-p)$ and $w_{2,t+1} = (1+r)(w_t - c_t) + M - k_t p$. Imposing $k_t = 1$, we have $w_{1,t+1} = w_{2,t+1} = (1+r)(w_t - c_t) + M - p$ and

$G(c_t,1) = (1-q)V'(w_{1,t+1})(-p) + q(1-\xi)V'(w_{1,t+1})(M-p) = -\xi q(1-q)MV'(w_{1,t+1}) < 0.$

Since the derivative is both negative at $k_t = 1$ and decreasing in k_t then the optimal k_t satisfying (22) must be less than 1. To show that the optimal coverage level under delayed premium payment is higher than under the conventional design, let the optimal choice of consumption and insurance coverage under the conventional and alternative designs be denoted (c_t^0,k_t^0) and (c_t^1,k_t^1), respectively. Similarly, we denote the left-hand sides of (9) and (20) as $G^0(c_t,k_t)$ and $G^1(c_t,k_t)$, respectively, and the corresponding premiums as p^0 and p^1, noting that $(1+r)p^0 = p^1$. Then comparing (9) and (20) we get

$$G^1(c_t^0,k_t^0) = G^0(c_t^0,k_t^0) + q\xi p^1 V'[(w_t - c_t^0 - p^0 k_t^0)(1+r)] > 0 . \tag{23}$$

Because $L(c_t,k_t) = U(c_t) + \beta E_t V(w_{t+1})$ is concave in c_t and k_t (see the appendix for proof), and $G^1(c_t^0,k_t^0) = \partial^2 L/\partial k_t^2$, then the positivity of (23) implies $k_t^0 < k_t^1$.

Proposition 5 shows that the delayed premium payment design can increase insurance demand compared to the conventional design when farmers face a risk of insurer default. However, delayed payment does not increase demand to full coverage as was the case under a binding liquidity constraint (see Proposition 4). In the case of insurer default risk, delayed payment helps because insurer default does not mean a loss of premium if the insured event has occurred. However, delayed payment does not induce full coverage either because even if the farmer takes out full coverage she will still experience a loss if the livestock lot dies but the insurer defaults. So since even a full coverage decision cannot eliminate the risk of default the farmer undertakes less than full coverage (but a higher coverage level than would be undertaken under the conventional premium prepayment design).

4. THE VALUE OF DELAYED PREMIUM PAYMENTS

If there is no liquidity constraint and no risk of insurer default then delayed premium payment has no value to farmers. Without delayed premium payment farmers would pay $p = qM/(1+r)$ for full insurance at time *t,* and with it they would pay $p = qM$ for full insurance at time $t+1$. Because full insurance is chosen in both cases, farmers receive *M* with probability 1 at the end of every period under both designs. So if unconstrained borrowing and lending is allowed at the risk-free rate and there is no risk of insurer default, these two insurance designs would support exactly the same consumption path and would therefore be of equal value to farmers.

When there is a binding liquidity constraint or a risk of insurer default or both, however, the delayed premium payment design may have additional value to farmers, even when both designs feature actuarially fair premiums. The additional value arises because the delayed premium payment can increase insurance uptake, leading to a smoother consumption path than could have been achieved without the delayed payment. In effect, the delayed premium payment offsets the credit market imperfections underlying the liquidity constraint and the risk of insurer default. To investigate the magnitude of this value, let the consumption path under the conventional design with liquidity constraints and risk of insurer default be given by $\{c_t^0\}_{t=0}^{\infty}$ and the consumption path under delayed premium payment (under the same liquidity constraint conditions and risk of insurer default conditions) be given by $\{c_t^1\}_{t=0}^{\infty}$. Then a proportional measure of the value of the delayed premium payment feature to farmers is given by an *m* that satisfies

$$E_0 \sum_{t=0}^{\infty} U[(1+m)c_t^0] \equiv E_0 \sum_{t=0}^{\infty} U(c_t^1). \tag{24}$$

By definition, *m* is the proportional increase in consumption that must be achieved every period in order to make the farmer as well off in the absence of delayed premium payment as she would be with the delayed premium payment feature in place.

As an extreme case, assume that the liquidity constraint and perceived risk of insurer default combine to reduce farmer demand for insurance to zero, so no insurance is undertaken. Then assuming no other source of wealth besides livestock production and that the liquidity constraint precludes all borrowing or lending, the farmer will simply consume $(1-y_t)M$ every period (that is, she will consume either *M* or nothing, depending on whether she suffers a loss). Furthermore, assume that delayed premium payment is sufficient to encourage farmers to take out full insurance at an actuarially fair premium and to increase farmers' trust in insurers to the extent that the perceived insurer default reduces to zero. In this case the farmer is guaranteed a certain consumption level of $M - p = (1-q)M$ every period. Substituting these results into (24) gives an upper bound for the value of delayed premium payment that is characterized by the following:[3]

$$E_0 \sum_{t=0}^{\infty} \beta^t U[(1+m)(1-y_t)M] \equiv \sum_{t=0}^{\infty} \beta^t U[(1-q)M] \quad , \tag{25}$$

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[3] This is an upper bound because it assumes the extreme case that liquidity constraints and the risk of insurer default send insurance demand to zero and preclude all borrowing and lending in the conventional insurance design, but that delayed premium payment encourages full insurance and completely discourages insurer default. If the conventional insurance design reduces insurance demand below full insurance but does not send it to zero or if the delayed premium payment increases insurance demand but does not encourage full insurance, or both, then the value of the delayed premium payment features would be less than this upper bound.

which, since M and q are constant, implies

$$EU[(1+m)(1-y_t)M] \equiv U[(1-q)M] \tag{26}$$

for all t. Now taking a second-order Taylor series approximation of the left-hand side of (26) at $y_t = q$ and $m = 0$ gives

$$\begin{aligned} &EU[(1+m)(1-y_t)M] \approx U[(1-q)M] - U'(.)ME(y_t - q) + U'(.)(1-q)Mm \\ &+ 0.5\{U''(.)M^2E(y_t - q)^2 + U''(.)(1-q)^2M^2m^2 - 2U''(.)(1-q)M^2mE(y_t - q) \end{aligned}, \tag{27}$$

where $U'(.)$ and $U''(.)$ denote first and second derivatives of the utility function with respect to consumption evaluated at $(1-q)M$. Using the facts that $E(y_t - q) = 0$ and $E(y_t - q)^2 = Var(y_t) = q(1-q)$ to eliminate and reduce terms, and noting that terms in m^2 can be ignored given the accuracy of the approximation (see Newbery and Stiglitz 1981), then substituting (27) into (26) and rearranging gives

$$m \approx 0.5Rq/(1-q), \tag{28}$$

where $R = -U''(.)(1-q)M/U'(.)$ is the farmer's coefficient of relative risk aversion evaluated at a consumption level of $(1-q)M$.

Equation (28) shows that the proportional welfare effect of the delayed premium payment feature may be large or small, depending on the level of farmer risk aversion and the probability of loss. As the probability of loss or the degree of relative risk aversion or both go to zero so does the value of the delayed premium payment (as expected). As the probability of loss approaches 1 the value of delayed premium payment becomes infinite unless farmers are risk neutral. Table 4.1 shows upper bound farmer valuations of delayed premium payment as a proportion of consumption over a range of relative risk aversion and loss probability values. The point is not to provide a definitive estimate of the value but to illustrate the potential range of values, and to show that farmers may place a very high value on delayed payment if they are highly risk averse, the probability of loss is high, and the liquidity constraint or the insurer default risk, or both, causes a severe reduction in insurance demand. For example, with relative risk aversion of 1 and loss probability of 0.1 the upper bound valuation estimate is 4.5 percent of consumption expenditures. But with relative risk aversion of 3 and loss probability of 0.3 the value increases to 31.5 percent of consumption expenditures.

Table 4.1—Upper bound estimates of the value of delayed premium payment to farmers as a proportion of per period consumption

***q* (loss probability)**	***R* (coefficient of relative risk aversion)**						
	0.0	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.02	0.000	0.005	0.010	0.015	0.020	0.025	0.029
0.04	0.000	0.010	0.019	0.029	0.038	0.048	0.058
0.06	0.000	0.014	0.028	0.042	0.056	0.071	0.085
0.08	0.000	0.018	0.037	0.055	0.074	0.092	0.110
0.1	0.000	0.023	0.045	0.068	0.090	0.113	0.135
0.12	0.000	0.026	0.053	0.079	0.106	0.132	0.158
0.14	0.000	0.030	0.060	0.090	0.120	0.151	0.181
0.16	0.000	0.034	0.067	0.101	0.134	0.168	0.202
0.18	0.000	0.037	0.074	0.111	0.148	0.185	0.221
0.2	0.000	0.040	0.080	0.120	0.160	0.200	0.240
0.22	0.000	0.043	0.086	0.129	0.172	0.215	0.257
0.24	0.000	0.046	0.091	0.137	0.182	0.228	0.274
0.26	0.000	0.048	0.096	0.144	0.192	0.241	0.289
0.28	0.000	0.050	0.101	0.151	0.202	0.252	0.302
0.3	0.000	0.053	0.105	0.158	0.210	0.263	0.315

Source: Authors' calculation.

In addition to the benefit farmers derive from delayed premium payment, benefits may also accrue to insurers because of the resulting increased insurance demand. Hence, in the presence of liquidity constraints and risk of insurer default, delayed premium payment has the potential to increase social welfare by helping to overcome the effects of these problems and allowing farmers to smooth consumption and participate more in the insurance market, while at the same time increasing the size of the insurance pool for insurers.

5. THE RENEGING PROBLEM

One concern about the delayed premium payment design is the potential for reneging: farmers may default on premium payment when the insured event does not occur. The reneging problem could offset the advantages of delayed premium payment that we have shown above. Presumably, insurers would respond to losses from farmer reneging by increasing insurance premiums, which would lower participation and reduce the size of the insurance pool. If the reneging problem were serious enough the insurance market may even collapse. Therefore, an appropriate incentive mechanism for dealing with reneging is essential.

The effectiveness of alternative incentive mechanisms for dealing with reneging will depend on the characteristics of the market and institutional environment the insurance program is operating in. An effective mechanism in one context may not be feasible in another. In the United States, where crop insurance programs often allow deferred payment, the reneging problem has never been a major concern because farmers who default cannot participate in either the insurance or (perhaps more important) other government support programs in following years. This makes the costs of reneging far exceed its benefits. So in countries where the government is actively involved in providing agricultural insurance the reneging problem may be a minor issue because the government is in a better position to impose painful penalties for defaulting on premium payment. Governments may also be in a position to directly deduct insurance premium payments from government subsidies. For example, in China each farm household has a bank card (called Hui Nong Card) to which a variety of government subsidies are deposited. Therefore it would be feasible for government-operated insurance programs to charge the delayed insurance premium directly from the bank card to fully prevent reneging.[4]

However, it may be more difficult for private insurance companies to enforce delayed premium payment, especially in developing-country contexts where premiums are small and farmers are poor. Prohibiting farmers from purchasing insurance in the future is probably the most straightforward mechanism that should be feasible in most contexts. If the insurance contract adds value to the farmers this penalty may be sufficient to ensure delayed premium payment. In cases where future exclusion from the insurance market is not sufficient to guarantee a negligible rate of premium defaults, additional incentive mechanisms could be investigated. For example, a peer effect incentive may be helpful. This would require a farmer to find one or two partners to buy the insurance together. If someone in the group doesn't pay, no one in the group will be allowed to buy insurance in the future. Peer effect incentives have been successful in ensuring loan repayment in microfinance programs (Banerjee, Besley, and Guinnane 1994; Besley and Coate 1995; Armendariz de Aghion 1999; Ghatak 1999).

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[4] A field experiment in China conducted by a research team from the University of California, Berkeley directly deducted agricultural insurance premiums from the Hui Nong Card, so such an approach is feasible (personal communication with Jing Cai, PhD Candidate, University of California, Berkeley).

6. CONCLUSIONS

This study makes two major contributions to the agricultural insurance literature. First, we develop a dynamic model of demand for insurance by a risk-averse farmer who can borrow and lend subject to a credit constraint, and who also perceives some probability of insurer default. Using this model, we demonstrate how liquidity constraints and the possibility of insurer default reduce the demand for insurance, possibly leading to a breakdown of the insurance market. Second, we investigate an alternative insurance design that allows farmers to enter an insurance contract while delaying payment of the premium until the end of the insured period. We then show how this alternative design increases insurance take-up by relaxing the liquidity constraint and easing farmers' concerns about insurer default. We also show conditions under which the delayed premium payment feature will be valued highly by farmers.

Although delayed premium payment is already featured in some operational US crop insurance programs, it has received less attention in the developing-country context where liquidity constraints and lack of trust in insurers are likely to be much more important. This paper highlights the important role that delayed premium payment potentially could play in agricultural insurance markets and programs in developing countries.

Nevertheless, for delayed premium payment to be effective the related problem of farmer reneging on premium payments when the insured event does not occur needs to be addressed. We discuss the reneging problem and suggest alternative incentive mechanisms that may be applied to reduce or eliminate the incentive to renege. Results suggest that excluding farmers from future participation in the insurance market or program if they renege will often be a sufficient incentive to overcome the reneging problem.

APPENDIX

Proof of Concavity of $\boldsymbol{L(c_t, k_t)}$
Noting $L(c_t, k_t) = U(c_t) + \beta E_t V(w_{t+1})$ and
$w_{t+1} = (1+r)S_t + k_t(1 - y_{t+1}\Delta_{t+1})(M-p) + (1-k_t)(1-y_{t+1})M$. Therefore we have

$$\frac{\partial^2 L(c_t,k_t)}{\partial c_t^2} = U''(c_t) + \beta(1+r)^2 E_t[V''(w_{t+1})] < 0, \tag{A.1}$$

$$\frac{\partial^2 L(c_t,k_t)}{\partial k_t^2} = \beta E_t[V''(w_{t+1})Z_{t+1}^2] < 0, \tag{A.2}$$

$$\frac{\partial^2 L(c_t,k_t)}{\partial c_t \partial k_t} = \beta(1+r) E_t[V''(w_{t+1})Z_{t+1}] \ , \tag{A.3}$$

where $Z_{t+1} = (1 - y_{t+1}\Delta_{t+1})(M-p) - (1-y_{t+1})M$. We further compute

$$\begin{aligned}
&\frac{\partial^2 L(c_t,k_t)}{\partial c_t^2}\frac{\partial^2 L(c_t,k_t)}{\partial k_t^2} - \frac{\partial^2 L(c_t,k_t)}{\partial c_t \partial k_t}\frac{\partial^2 L(c_t,k_t)}{\partial c_t \partial k_t} \\
&= \beta U''(c_t) E_t[V''(w_{t+1})Z_{t+1}^2] + \beta^2(1+r)^2 E_t[V''(w_{t+1})] E_t[V''(w_{t+1})Z_{t+1}^2] \\
&-\beta^2(1+r)^2\{E_t[V''(w_{t+1})Z_{t+1}]\}^2 > 0
\end{aligned} \tag{A.4}$$

The inequality is implied by $\beta U''(c_t) E_t[V''(w_{t+1})Z_{t+1}^2] > 0$ and

$$E_t[V''(w_{t+1})] E_t[V''(w_{t+1})Z_{t+1}^2] - \{E_t[V''(w_{t+1})Z_{t+1}]\}^2 > 0. \tag{A.5}$$

To see why (A.5) holds, we let $w_{t+1,1} = (1+r)S_t + k_t(M-p) + (1-k_t)M$ be the wealth level when $y_{t+1} = 0$, $w_{t+1,2} = (1+r)S_t + k_t(M-p)$ be the wealth level when $y_{t+1} = 1$ and $\Delta_{t+1} = 0$, and $w_{t+1,3} = (1+r)S_t$ be the wealth level when $y_{t+1} = \Delta_{t+1} = 1$. Denoting the probabilities of these three wealth outcomes as δ_1, δ_2, and δ_3, the three associated values of $V''(w_{t+1})$ as X_1, X_2, and X_3, and the associated values of Z_{t+1} as Z_1, Z_2, and Z_3, we can write the left-hand side of (A.5) as

$$\begin{aligned}
&\left(\sum_{j=1}^{3} \delta_j X_j\right)\left(\sum_{j=1}^{3} \delta_j Z_j^2\right) - \left(\sum_{j=1}^{3} \delta_j X_j Z_j\right)^2 \\
&= \delta_1\delta_2(Z_1 - Z_2)^2 + \delta_1\delta_3(Z_1 - Z_3)^2 + \delta_3\delta_2(Z_3 - Z_2)^2 > 0
\end{aligned} \tag{A.6}$$

Concavity of $L(c_t, k_t)$ in c_t and k_t is implied by (A.1), (A.2), and (A.4).

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