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Dynamic Optimization of Area Revenue Insurance and Consumption Smoothing

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Abstract

This study examines the interaction between insurance, credit and liquidity constraints using a stochastic dynamic model. A risk averse farmer whose objective is to manage both production and market risk is assumed to maximize the expected utility of life-time consumption by using both area revenue (AR) insurance and consumption smoothing subject to a credit constraint. Results support the hypothesis that liquidity constraints can have a large impact on optimal insurance decisions, and that different levels of premium load, risk aversion level, and time-preferences can also affect optimal insurance decisions under liquidity constraints.

1. Introduction

Agricultural risk is typically assumed to originate from uncertain variations in commodity prices, yields, and production cost. Market risk is in terms of price variation resulting from the market supply and demand shifts. Production risk includes variability of crop yield due to spatial and temporal weather, which includes extreme rainfall or temperature events as well as natural disasters. These risks will in turn affect farmers' ability to repay loans. Lending institutions are less willing to provide loans to farmers if their probability of default is high. Farmers' reliance on credit as a source of liquidity introduces risks in terms of lenders' responses to changing conditions in agriculture that inuence their lending decisions and resulting credit availability. These uncertain responses give credit the characteristics of a random variable and thus, farmers' credit risk is an added element of their risk that has not been accounted for most of the previous studies.

Farmers use a wide array of instruments to manage production and market risk. Supplemental irrigation is used extensively in humid areas to protect against production risk. Multiple-peril crop insurance, which triggers payoffs based on individual-farm yield shortfalls, also has long been a popular option to manage production risk. Futures and options contracts, forward contracts, and other derivative pricing instruments have been used vastly for managing price risk. More recently, area-yield insurance which triggers payoffs based on county yield shortfalls instead of individual farm yield shortfalls has been made available to many farmers, which reduces the moral hazard and adverse selection problem inherent in traditional issuance. Revenue insurance, which protect against price and production risk at the same time, is currently being offered under a variety of designs including individual farm revenue insurance and area revenue insurance.

There is a large literature on the optimal use of risk management instruments for farmers. However, the vast majority of these studies use static models (e.g. Coble *et al.*, 2000; Wang *et al.*, 1998; Hennessy *et al.*, 1997; Mahul and Wright, 2000). Few studies have examined the use of insurance instruments in a dynamic framework. Among these few studies, some authors have recognized the importance of dynamic hedging and made important contributions in developing dynamic models for hedging with pricing instruments (e.g. Anderson and Danthine, 1983; Karp, 1987; Martinez and Zering, 1992; Vukina and Anderson, 1993; Myers and Hanson, 1996). However, even in studies using dynamic models, most studies on optimal risk management assume perfect credit markets, that is, farmers can borrow and lend as much as they want at going risk free interest rates. However, evidence from the consumption smoothing literatures suggests that liquidity constraint exist and constrain consumption.

In a multi-period setting, there is empirical evidence that in general U.S. Households smooth consumption through borrowing and savings. Smooth consumption across time can be used to counteract the effects of income variability across time (Friedman, 1957; Sargent, 1987). That is, in periods of high income farmers can lend to store wealth for future consumption or repay the borrowed funds; while in periods of low income farmers may borrow to maintain a desired consumption level. More importantly, some studies have examined the effect of liquidity constraints on consumption smoothing in the U.S. (e.g. Deaton, 1991 and Chah et al., 1995). In reality, lenders usually place a limit on the amount farmers can borrow. Whenever such a borrowing constraint is binding, it imposes a liquidity constraint on farmers. This evidence points to a possible relationship between borrowing and insurance decisions. Since liquidity constraints affect consumption decisions, it is logical to expect that liquidity constraints affect crop insurance decisions. This interaction between liquidity constraints, consumption smoothing, and insurance has not been comprehensively addressed in the literature.

The purpose of this study, therefore, is to explore farmers' risk management behavior using a dynamic framework in which credit market is not perfect. Specifically, we will derive a dynamic optimal area-revenue insurance choice and consumption level for a farmer who can also borrow and save subject to a liquidity constraint. Then we will conduct sensitivity analysis on risk aversion level, discount rate, and premium loading, to look at how the optimal insurance choices change for different kinds of farmers and different kinds of insurance products. These objectives are accomplished using a dynamic, time separable expected utility model. Dynamic programming (DP) is used to study optimal decision rules for consumption and insurance coverage for an individual farmer. The dynamic programming is coded in MATLAB using DDPSOLVE algorithm (Appendix a). DSSAT crop simulation model is used to determine optimal irrigation strategy and to simulate farm level yield. The approach and results are illustrated via a numerical example using county level data from Mitchell County in Georgia.

2. Literature Review

There have been programs administered by the Risk Management Agency (RMA) that provided crop insurance to farmers since 1938, and insurance designs have evolved over time. The concept of policies that trigger on county level index was proposed in the late 1940s (Halcow, 1949), but was not put into practice until 1990s for counties in the United States (U.S.) with adequate acreage over a 30-year historical period. County trigger contracts are relatively new to U. S. farmers, lenders, and insurance agents.

A recent development in agricultural insurance market is county level revenue index insurance program. Rigorous and applied literature on county trigger insurance policies that is readily applicable to farmers, insurance agents, and lenders is scarce, and is limited both in number and in depth. Schnitkey (2005) is a representative publication that shows how the county-trigger policies work and their potential risk reduction. Edwards et al. (2000) described insurance policies and addressed year-to-year cash-flow issues that insurance can help to solve. However, in these papers, farm yield to county yield correction is not addressed. In addition, decision rules are not included for country trigger policies. Farmers are left wondering which policies would be the most beneficial for them. Farmers need more in-depth information because they want to know how their risk, if any, the insurance policies will transfer.

Chaffin, Black, and Cao (2004) presented an approach to evaluate the performance of GRP insurance policies. The evaluation focused on how farm yields track to county yields and used case studies to demonstrate actual examples of tracking. A Monte Carlo simulation model was used to simulate net yields. Empirical cumulative distribution functions (CDFs) were utilized to compare GRP, APH, and not insuring.

Chaffin, Black, and Cao (2004) included actual decision guidelines and built a spreadsheet to evaluate the ability of GRPs to reduce risk for a farm. In the spreadsheet, a common mean is used to compare county and farm yields. Chaffin, Black, and Cao used CDFs to show the probability of outcomes to farmers based on the work of Hilker, Baldwin, and Black (1997) using CDFs. Cao's predicted yield indexes are based on very simple linear regression model that empirically estimated relationships between county average yields and monthly CDD measures. More sophisticated models that accounts for other relevant explanatory variables might be more appropriate to construct predicted yield indexes.

In addition, most of the studies cited above used static methods. Static models implicitly assume that credit markets are complete and there is no liquidity constraint. However, evidence form the consumption smoothing literature suggests that liquidity constraints exists and constrain consumption.

Consumption smoothing in developing counties has been extensively discussed in the existing literature. These studies provide empirical evidence that households use several strategies to smooth consumption, including off-farm employment, use of risk-decreasing inputs, informal credit and insurance arrangements, and livestock holdings. For example, Paxson (1992) used weather variability to estimate the response of saving to transitory income in Thailand, based on the permanent income hypothesis (PIH). She found evidence that Thailand rice farmers use consumption smoothing, but rejected the PIH hypothesis.

Townsend (1994) also tested for consumption smoothing among households in India and argued that there was evidence of partial insurance and that households smooth consumption not to the extent implied by “full insurance”.

Rosenzweig and Wolpin (1993) examined the role of Bullock purchases and sales in smoothing consumption and showed that bullock stocks play an important role in consumption smoothing in India. Lamb (2003), Rosenzweig and Stark (1989) also shows that farmers use off-farm income to smooth consumption.

In developed countries where complete credit and insurance markets are usually assumed to exist, consumption smoothing and risk management have also been examined. There is empirical evidence that in general U.S. households smooth consumption through borrowing and savings(e.g. Flavin, 1981 and Zeldes, 1989). More importantly, some studies have examined the effect of liquidity constrants on consumption smoothing in the U. S. (e.g., Deaton, 1991 and Chah et al., 1995). Clearly, this constraint restricts the amount of borrowing that can be undertaken to finance current consumption, production costs, and insurance premium payments. Deaton (1991) has argued that such liquidity constraints are a pervasive feature of reality and is demonstrated by the observed correlations between income and consumption, which are much higher than would be predicted by models without liquidity constraints (Pissarides, 1978; Flavin, 1985; Zeldes, 1989; Jappelli, 1990; Chah *et al.*, 1995).

Therefore, it is logical to expect that liquidity constraints affect insurance decisions. If such liquidity constraints exist, then a risky activity such as agriculture is likely to face even higher liquidity constraints than the rest of the economy. Hence, this study will contribute to existing literature by examining the use of revenue insurance within a dynamic framework while allowing crop farmers to smooth their consumption through savings and borrowing subject to borrowing constraints. Farm yield is generated by DSSAT simulation model, which is a parameterized deterministic plant growth model that simulates yield under specific weather conditions conditioned on a number of choice variables such as soil type, crop phenotype, planting date, irrigation level, etc., and thus is more accurate than simple linear regression model. For this study, these choice variables were selected based on recommendations from crop scientists.

3. Dynamic Model of Agricultural Insurance and Creidit

Consider a farmer who lives for an infinite number of periods and maximizes expected utility of lifetime consumption assuming a standard, discounted, time additive utility specification. The farmer's problem is to choose a set of contingency plans for consumption and an insurance plan that satisfy Bellman's functional equation:

$$\begin{aligned} &\mathrm{V_t(s)} = \max_{\mathrm{x_t}} \{\mathrm{f_t}(s_t, x_t) + \beta E_t V_{t+1}(\mathrm{s_{t+1}})\} \\ &s.t. s_{t+1} = g_t(s_t, x_t, \varepsilon_{t+1}) \end{aligned} \tag{3.1}$$

where E is expectation operator; β is a discount factor representing the farmer's rate of time preference in consumption; $\mathrm{V_t}(t = 0,..., T+1)$ is a sequence of value functions representing the optimal values of the state at time t; $\mathrm{s_t}$ is a vector of state variables that define the decision environment at time t but are not under the direct control of the decision maker at the at time; x_t is a vector of decision variables chosen at time t under the direct control of the decision maker; $s_{t+1} = g_t(s_t, x_t, \varepsilon_{t+1})$ is a vector of transition equations that link the state and control vectors, and describes the evolution of the state vector through time; f_t is a vector of return function and represents the immediate reward in time t, given the state vector s_t and the control vector x_t ; and ε_{t+1} is a vector of random shocks which introduce uncertainty into the future path of state variables because future realizations of the process are uncertain at time t when the current control variables must be chosen. The additive form of the functional equation implies that $V_t(t = 0,..., T+1)$ is a linear function of a sequence of return function over the time horizon of the optimization problem.

The Bellman equation captures the essential problem faced by a dynamic, future-regarding optimizing agent: the need to optimally balance an immediate reward f_t against expected future rewards $\beta E_t V_{t+1}(s_{t+1})$.

In our study, the immediate reward function is farmer's utility derived from consumption:

$$f_t = U_t = \frac{C_t^{1-\gamma}}{1-\gamma} \tag{3.2}$$

where C_t isconsumption at *t;* γ is relative risk aversion coefficient.

The state variable is net cumulative wealth (w); control variables are consumption and coverage. Thus, the farmer's problem is to choose a set of contingency plans for consumption and insurance coverage that satisfy Bellman's functional equation:

$$\mathrm{V(w_t,)} = \max_{x_t}\{\frac{C_t^{1-\gamma}}{1-\gamma} + \beta E_t V(w_{t+1})\} \tag{3.3}$$

Assume an imperfect credit market, a liquidity constraint is imposed:

$$\mathrm{w_t - c_t - pc_t - (P_{insurance})_t >= minnet} \tag{3.4}$$

where pc_t is production cost at time t; $(P_{insurance})_t$ is insurance price at time t; minnet is the minimum net wealth position that is allowed at any period, *t*.

The farmer's optimal choice of insurance will depend on the nature of the premium schedule, strike, coverage, load, and scale. The premium schedule is assumed to be given by:

$$P_{insurance} = \frac{1}{1+r}\theta\,(1+\alpha)\mathrm{E}\max(0, \mathrm{strike}_t * \mathrm{cov}\,erage_t - y_t^c) \tag{3.5}$$

Where ∂ is a loading parameter, (∂ >0 means a loaded premium insurance, while ∂ <0 means a subsidized insurance), y_t^c is the realized county level revenue for a given year; θ is a scale factor. Under the area-revenue (AR) design the number of insured acres can be higher than the number of planted acres. That is, the number of insured acres is computed as a product of the number of planted acres and a scaling factor, θ. In practice is θ lies between 0.9 and 1.5 of planted acres (Gerald, 2005).

Also subject to transversality condition,

$$\lim_{t\to\infty} \beta^t w_t = 0 \tag{3.6}$$

which rules out those that involve accumulation, in this case, the perpetual debt. That is, people cannot just borrow the funding today to repay yesterday's debt for infinitive period; they must eventually pay back all that is borrowed, so that current consumption cannot be financed indefinitely by borrowing money all of the life. In finite horizon models, in the last period the farmer cannot borrow and must pay back all of the previous loans; in infinite horizon models, this constraint is imposed as transversality condition which requires that the limit of the expected discounted wealth be zero. We future assume that farmer's debt cannot exceed two times of minimum possible revenue from next period production. That is, in the next period people must pay at least half of the previous debt. This will in effect rule out perpetual borrowing.

The transition function, is:

$$\mathrm{w}_{t+1} = (1+\mathrm{r})[\mathrm{w}_t - \mathrm{pc}_t - \mathrm{c}_t - \mathrm{P}_{\mathrm{insurance}}] + y_t^{\mathrm{farm}} + \theta \max(0, \mathrm{strike}_t * \mathrm{cov}\,erage_t - y_t^c) \tag{3.7}$$

Where r is the risk free interest rate; y_t^{farm} is realized individual farm revenue; y_t^c is realized county-level revenue.

4. Data

County-level revenue ($/acre) is obtained from multiplying county-level yield with market price. Farm-level revune ($/acre) is obtained from DSSAT simulation model based on Lin et. al's paper; farmer trigger irrigation when soil-water content is below 40%. Mitchell County in GA is chosen for our analysis. Both yield and price data are obtained from USDA Statistics Services. The minimum revenue in these years is 64.0458$/acre, while the maximum revenue is 391.986$/acre. Figure 1 shows the county-level revenue ($/acre) for cotton farmers in Mitchell County over years.

Wealth in the model represents the farmer’s aggregate net worth. We assume there is only one store of wealth and farmer can borrow or lend at the same rate. Also assume all revenue is insurable and there are no other government programs. Consequently, the discrete state space for wealth should reflect reasonable figures of

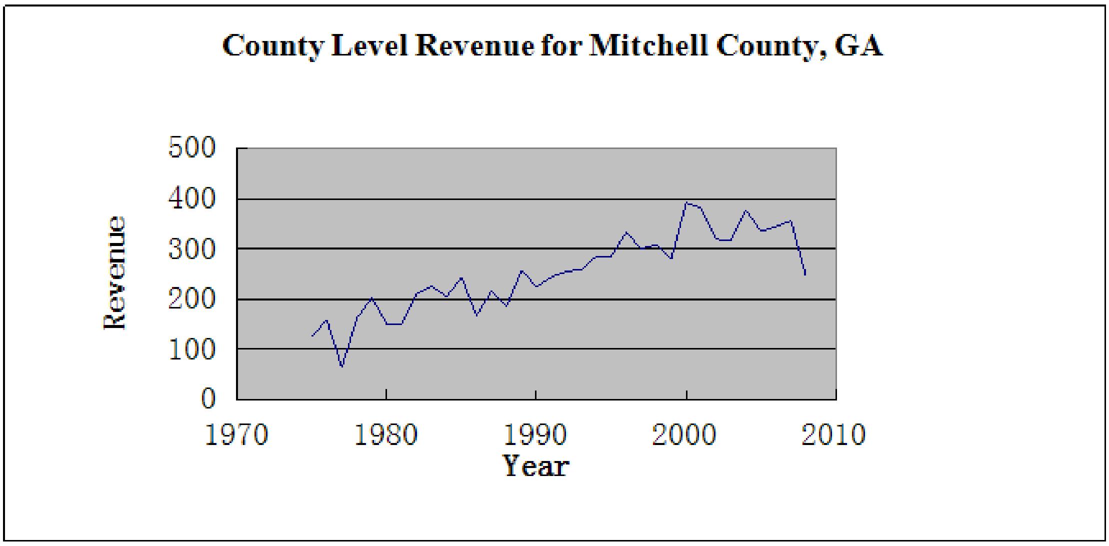

Figure 1. Graphs of county level revenue ($/acre) for corn farmers in Mitchell County, Georgia.

what the farmer can save, per acre, given his crop revenue and expenses, insurance premium payment, and any insurance payoff. Under these assumptions, the wealth space was specified as a vector of possible wealth states ranging from $ -1,000 to $ 2,000 per acre, in $100 increments. These figures provide a very wide range of initial wealth levels that span reasonable per acre wealth levels that farmers can have. For example, a farmer with 100 acres and an initial wealth of $100 per acre would have a total of $10,000 of initial wealth; while a farmer with 100 acres and an initial wealth of -$100 per acre would have a total of $10,000 of initial debt.

There are two control variables: consumption and coverage. The consumption space is specified as a vector of possible consumption choice levels ranging from $0 to $10000 per acre, in $100 increments. Similarly, each consumption level is taken as the mid-point of the continuous consumption interval.

The discrete coverage space for individual farm insurance was specified as a vector of possible insurance coverage levels ranging from 0 to 0.85 in 0.01 increments.

A coverage level of 0 means that the farmer does not insure while a level of 0.85 means that the farmer insures 85% of expected revenue. Thus, a coverage level of 0.85 is the upper limit imposed by the revenue insurance design and, therefore it represents the maximum allowable insurance coverage. The rationale for placing an upper limit on the insurance design is that the deductible implied by the upper limit will act as an instrument to mitigate problems of moral hazard. And this is also how the programs actually work in practice (Gerald, 2005)

This study assumes that the farmer's measure of time preference is constant and is given by $\beta = 1/(1+\delta)$ where δ is the discount rate. The discount rate reflects the risk free rate of return, r, plus a risk premium required by the farmer based on the risk from the stream of cash flows from his/her farm. This study uses a discount rate of 11.25% based on an annual risk free rate of return of 5.43% on a 30-year T-bill (Federal Reserve Board, 2004) and, a risk premium of 5.82% based on historical estimate of risk premium for U.S. farmland.

The revenue trigger index, *strike*, is computed as the expected revenue to be consistent with the way it is computed in practice. A Bayesian Model is used to estimate next period revenue based on 31 year's historical data.

5. Results

5.1 Optimal Consumption and Insurance

In a benchmark scenario, relative risk aversion level is set to be 2, discount rate is set to be 0.8989, and premium-loading factor is set to be 0 (fair premium). The model is simulated for 100 years, starting at an initial state.

Figure 5.1 to 5.3 illustrates the time path of optimal decision (consumption and insurance coverage) and state variable (wealth) over time, when initial wealth is equal to 1800$/acre. Consumption decreases from initial 2900$/acre to 2410$/acre after 10 years, and then is relatively constant over time. Coverage at first decreases from 0.81 to 0.71, and then increases to around 0.76. Wealth decreases from initial 1800$/acre to around 300$/acre and then stays constant.

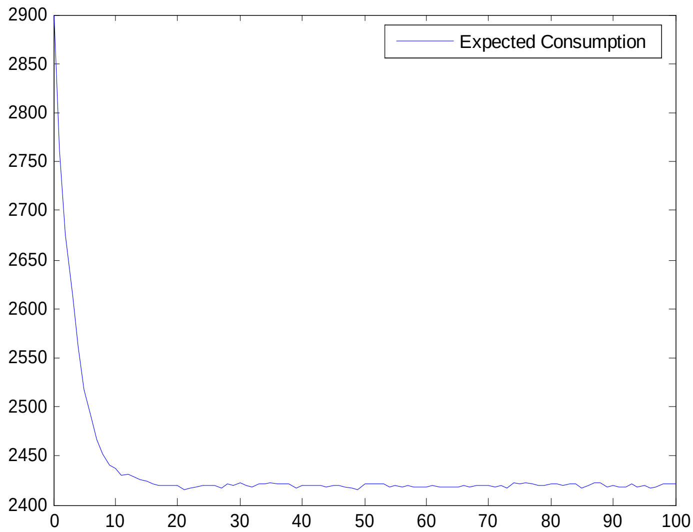

Figure 5.1 Time Series Plot of Consumption for a Farmer Facing Liquidity Constraint (Initial Wealth=1800$/acre, Constraint=-3000, Risk Aversion Level=2, Fair Premium)

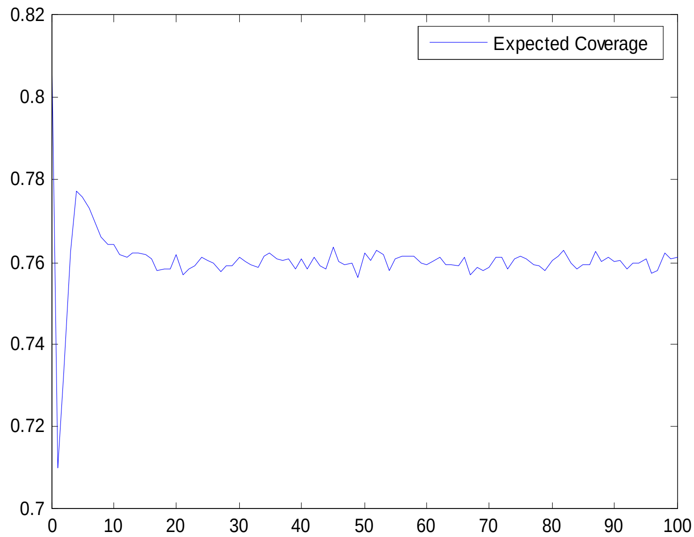

Figure 5.2 Time Series Plot of Optimal Coverage of Area Revenue Insurance for a Farmer Facing a Liquidity Constraint (Initial Wealth=1800$/acre, Constraint=-3000, Risk Aversion Level=2, Fair Premium)

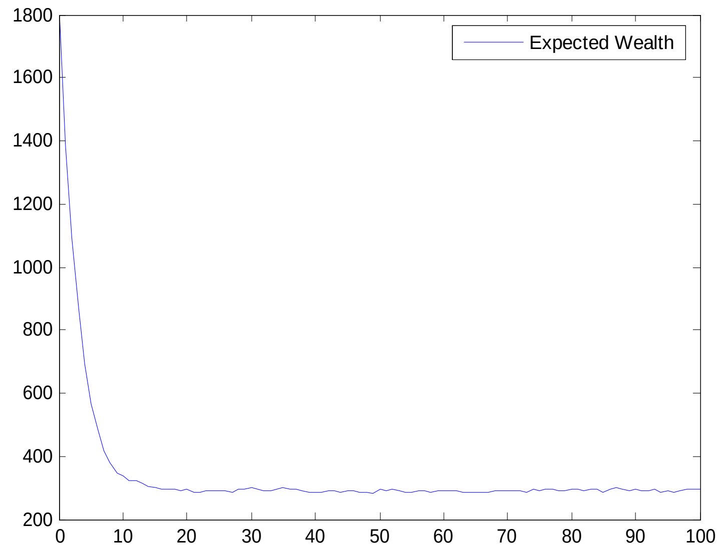

Figure 5.3 Time Series Plot of State Variable (Wealth) for a Farmer Facing a Liquidity Constraint (Initial Wealth=1800$/acre, Constraint=-3000, Risk Aversion Level=2, Fair Premium)

To get a better idea of the dynamic optimization process of the problem, we plot graphs for initial wealth equal to -500$/acre. For optimal consumption shown in Figure 5.4, consumption increases from 1950$/acre to 2410$/acre and then keeps constant, which is same as the equilibrium consumption level for initial wealth equal to 1800$/acre, implying that no matter what initial wealth is, consumption converges to 2410$/acre over time. For optimal coverage shown in Figure 5.5, coverage increases from 0.455 to 0.76 and stays constant, same as the equilibrium coverage level for initial wealth equal to 1800$/acre, implying that 0.76 is the optimal coverage over time. For state variable shown in Figure 5.6, wealth increases from -500$/acre to -300$/acre and stays there, consistent with the equilibrium wealth level for initial wealth equal to 1800$/acre, implying that future net cumulative wealth will be bounded around 300$/acre, which is consistent with the transversality condition(as long as wealth is bounded, limit of discounted wealth is equal to zero).

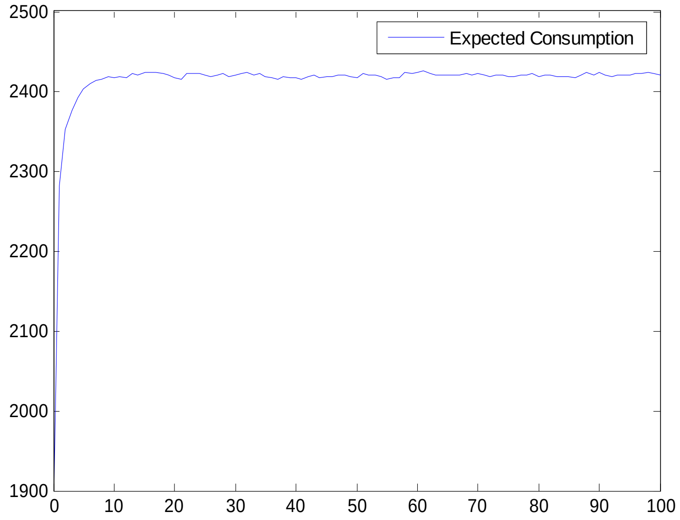

Figure 5.4 Time Series Plot of Optimal Consumption for a Farmer Facing a Liquidity Constraint (Initial Wealth=-500$/acre, Constraint=-3000, Risk Aversion Level=2, Fair Premium)

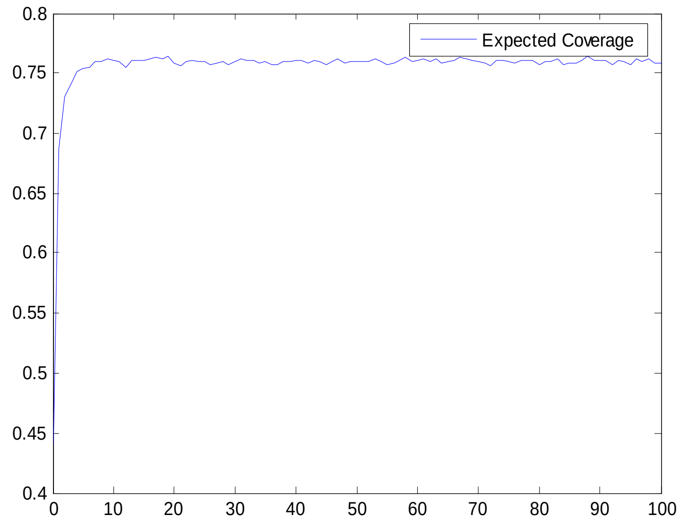

Figure 5.5 Time Series Plot of Optimal Coverage for a Farmer Facing a Liquidity Constraint (Initial Wealth=-500$/acre, Constraint=-3000, Risk Aversion Level=2, Fair Premium)

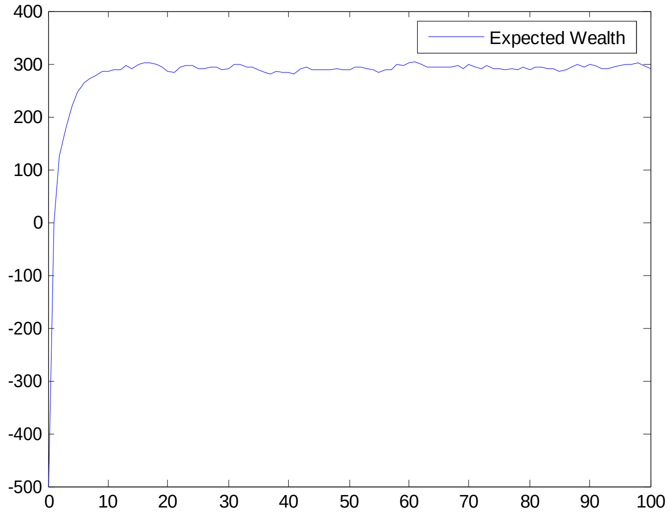

Figure 5.6 Time Series Plot of Wealth for a Farmer Facing a Liquidity Constraint (Initial Wealth=-500$/acre, Constraint=-3000, Risk Aversion Level=2, Fair Premium)

Figure 5.7-5.10 illustrate the relationship between wealth and consumption, wealth and coverage. Optimal consumption increases as initial wealth increases, while coverage increases as wealth increases when wealth if low and very high, and decreases with wealth when wealth is in the range of (700$/acre, 1400$/acre).

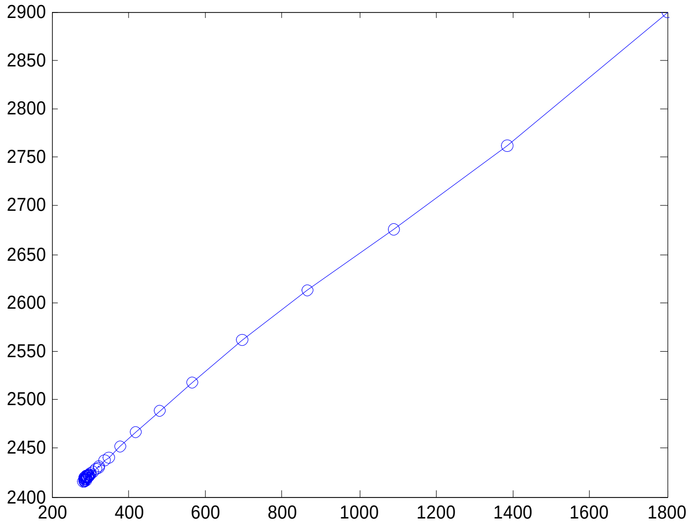

Figure 5.7 Relationship of Optimal Consumption and Wealth for a Farmer Facing Liquidity Constraint (Initial Wealth =1800, Constraint=-3000, Risk Aversion Level=2, Fair Premium)

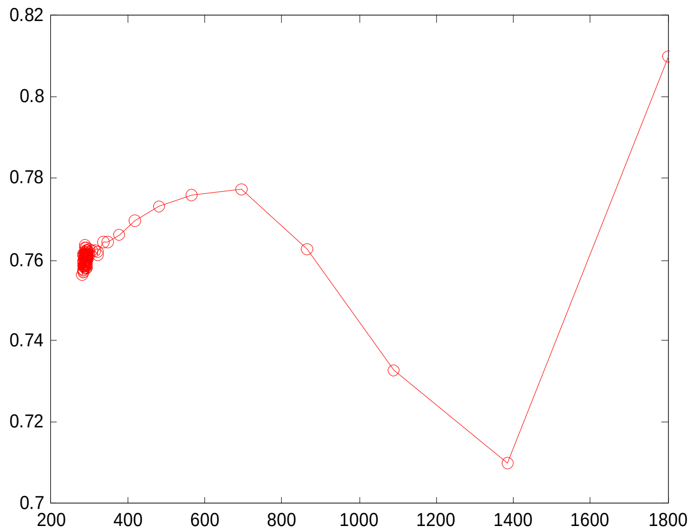

Figure 5.8 Relationship of Optimal Coverage and Wealth for a Farmer Facing Liquidity Constraint (Initial Wealth =1800, Constraint=-3000, Risk Aversion Level=2, Fair Premium)

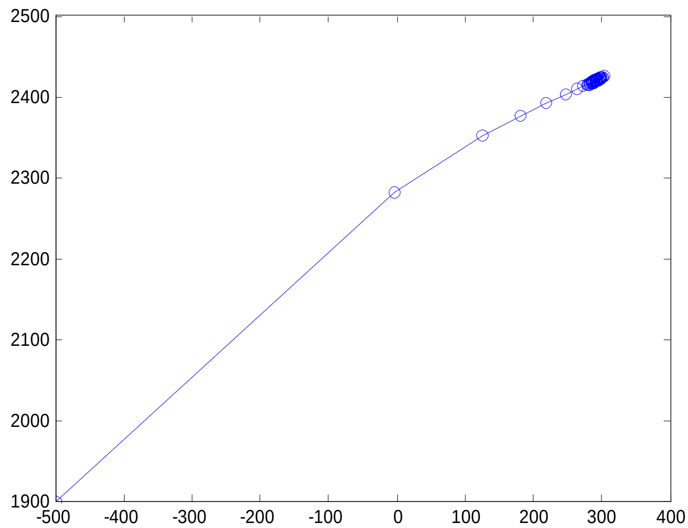

Figure 5.9 Relationship of Consumption and Wealth for a Farmer Facing Liquidity Constraint (Initial Wealth =-500, Constraint=-3000, Risk Aversion Level=2, Fair Premium)

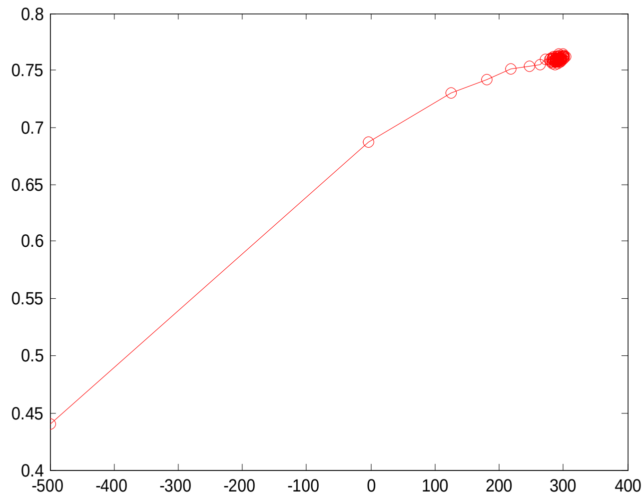

Figure 5.7 Relationship of Optimal Coverage and Wealth for a Farmer Facing Liquidity Constraint (Initial Wealth =-500, Constraint=-3000, Risk Aversion Level=2, Fair Premium)

We try to explain the results using economic theory. These results show that a farmer facing a liquidity constraint will take the maximum allowable coverage only at wealth levels in which the constraint is non-binding (1800$/acre shown in Figure 5.8). When wealth level is very low, liquidity constraint is binding, and thus the farmer cannot borrow desired amount of money to finance production costs, consumption and the purchase of insurance, therefore, he chooses to insure less than the maximum allowable coverage, which is different from the standard static solution, in which the farmer always take full coverage of actuarially fair premium. In other words, when initial wealth is very low, his marginal propensity to consume out of current wealth is equal to one. This is because the CRRA utility function makes consumption infinitely valuable as consumption approaches zero. Therefore, the farmer is willing to trade off anything (including insurance) in order to be able to consume more at low wealth levels. Therefore, when consumption is very low, it corresponds to low insurance coverage.

When initial wealth increases until 700$/acre, insurance coverage increases, then when wealth is in the range of (700$/acre, 1400$/acre), insurance coverage decreases as wealth increases, probably because of the nature of the utility function, which exhibits decreasing absolute risk aversion with respect to wealth. As risk aversion decreases to a point, demand for precautionary saving comes very low, and both consumption and insurance coverage increases.

Our results show that if farmers are faced with a liquidity constraint, they may choose reduced coverage, depending on the severity of the constraint, and the level of initial wealth level. A binding liquidity constraint farmers' ability to diversify downside risks over time. As shown by Gollier (2001) for the DARA utility function used in this study, a liquidity constraint induces more risk aversion, and is likely to be binding for poorer people, which makes them more risk-averse because of their inability to time diversify risk. In contrast, wealthier people are in a better position to smooth shocks to their income over time, because they are less likely to be liquidity constrained in the near future (Gollier 2001, 2003). More generally, within a continuous-time, infinite horizon framework, all value functions exhibit decreasing absolute risk aversion with respect to wealth. This result is consistent with his intuition that larger wealth better insulates the consumer from the liquidity constraint and, hence, reduces his aversion to risk.

5.2 Sensitivity Analysis

In order to learn how these results change with changes in the parameters of the model, sensitivity analysis is performed. The effect of changes in the premium loading, as well as changes in farmer's risk aversion and time preference, are examined.

Figure 5.11 and 5.12 shows the impact of increasing premium loading on optimal decisions. When insurance is heavily loaded (loading parameter is 0.6), consumption pattern doesn't change, while insurance coverage tends to decrease. In other words, the loading to some extent aggravate the severity of the liquidity constraints.

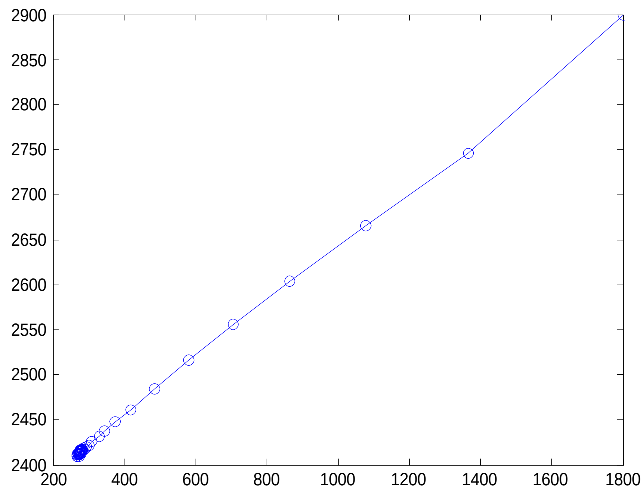

Figure 5.11. Optimal Consumption for a Farmer Facing a Liquidity Constraint when Premium is Heavily Loaded (load=0.6)

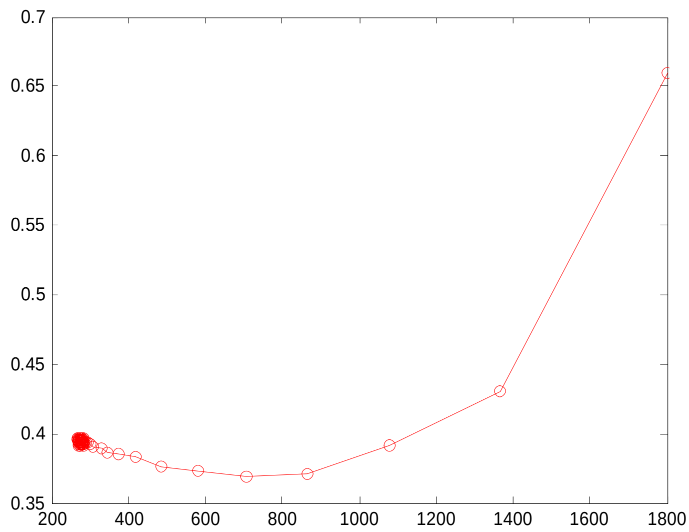

Figure 5.12 Optimal Coverage of Area Revenue Insurance for a Farmer Facing a Liquidity Constraint when Premium is Heavily Loaded (load=0.6)

Figure 5.13 and 5.14 shows the impact of premium subsidizing (loading parameter=-0.4) on optimal consumption and coverage. Similarly, consumption pattern doesn't change, while insurance coverage tends to increase. In other words, the loading somewhat relaxes the severity of the liquidity constraints, although at the constraint still less than maximum allowable insurance coverage will be taken.

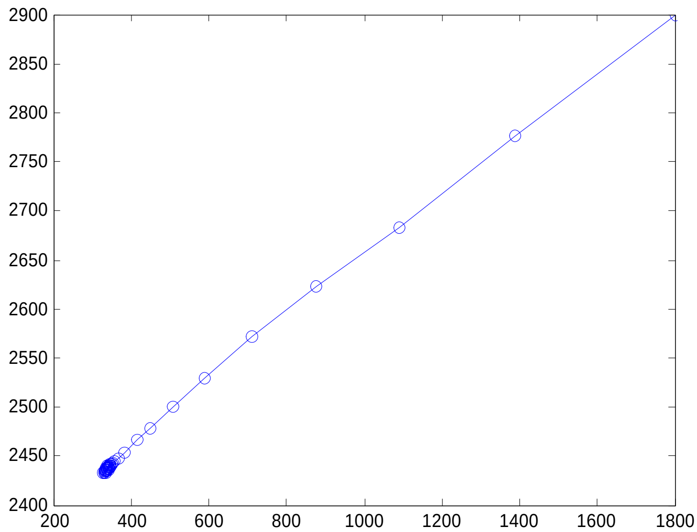

Figure 5.13 Optimal Consumption for a Farmer Facing a Liquidity Constraint when

premium is subsidized (load=-0.4)

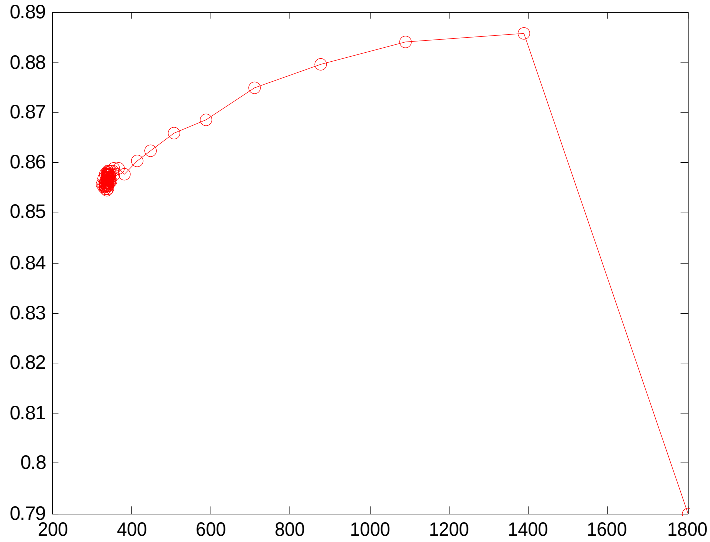

Figure 5.14 Optimal Coverage of Area Revenue Insurance for a Farmer Facing a Liquidity Constraint when premium is subsidized (load=-0.4)

The effect of an increase in risk aversion was investigated by re-estimating the model when γ= 3, and then the results were compared with the benchmark results when γ=2 (Figure 5.7 and 5.8). Current consumption drops from 2990$/acre for r=2 to 2780$/acre for r=3; while future equilibrium consumption increases from 2410$/acre to 2420$/acre. The result is reasonable because higher risk averse producers will have higher propensity for precautionary saving, thus current consumption is decreases and future consumption increases.

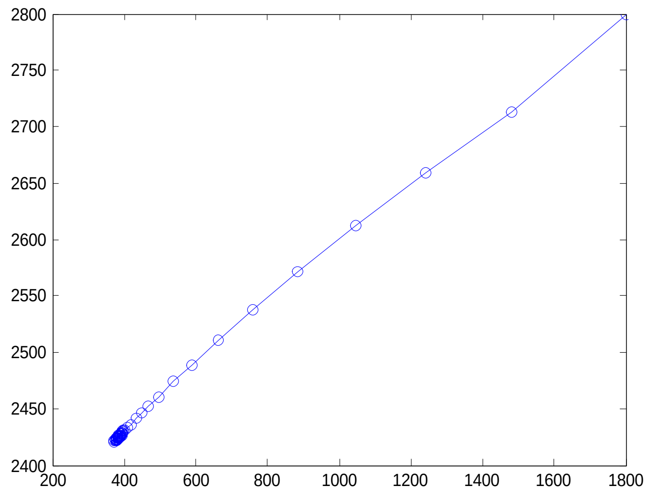

Figure 5.15 Optimal Consumption for a High Risk Averse Farmer Facing a Liquidity Constraint

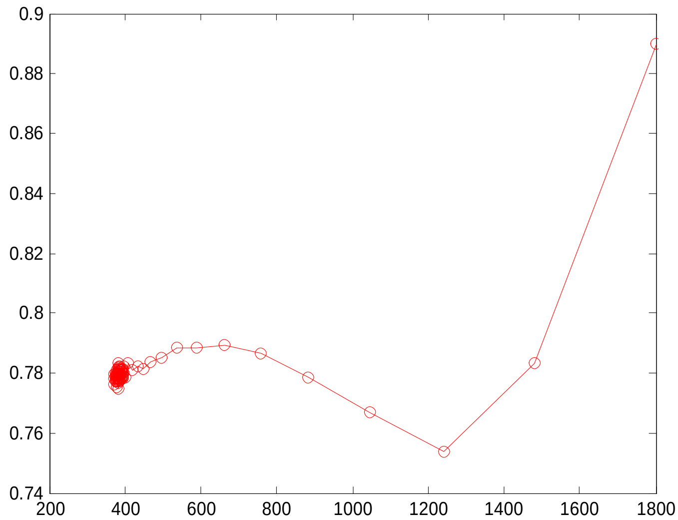

Figure 5.16 Optimal Coverage of Area Revenue Insurance for a High Risk Averse Farmer Facing a Liquidity Constraint

As for the optimal coverage line, initial coverage increases from 0.81 for r=2 to 0.878 for r=3; while future equilibrium coverage increases from 0.76 to 0.78. It in effect shifts the optimal coverage line in the benchmark case up. Within an insurance-consumption smoothing framework, an increase in risk aversion (the utility function becomes more concave) have two effects. First, by Jensen's inequality and, because risk aversion is a measure of the demand for insurance, the increase in risk aversion would mean an increase in the demand for insurance. Second, increase in risk aversion would have an effect of increasing precautionary demand for savings because of the CRRA utility function. However, the increase in precautionary demand for savings comes at the expense of insurance. Therefore, the net effect of the increase in risk aversion is ambiguous. Furthermore, for the type of utility function used here risk aversion and demand for precautionary savings are controlled by the same parameter, γ. In this case with particular parameters for the dynamic model, it seems that the effect of the demand for insurance dominates the precautionary motive for accumulating wealth.

Finally, the effect of changing the farmer's measure of time preference parameter from the benchmark value β=0.8989 to 0.99 was investigated. This is equivalent to changing the discount rate from 11.25% to 1%. In other words, the farmer is relatively more patient in the sensitivity analysis scenarios than in the base case. One would expect this increase in the farmer's rate of patience to generate an increase in desire to accumulate wealth (precautionary savings) and as a consequence, reduce current consumption and increase future consumption, and indirectly reduce current insurance demand. The results showed this to be true for the consumption line, but not true for coverage line, where coverage line is shifted up compared to the benchmark case, and optimal current coverage is shown to increase from 0.81 to 0.878 when discount rate decreases.

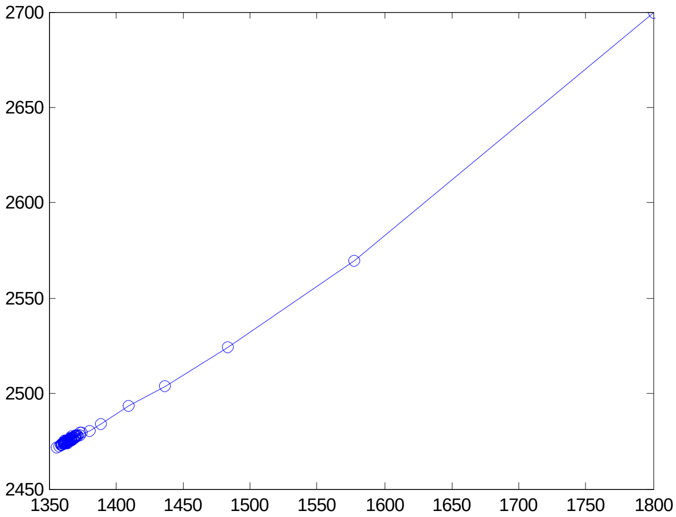

Figure 5.17 Optimal Consumptionof Area Revenue Insurance for a Risk Averse Farmer Facing a Liquidity Constraint (beta=0.99)

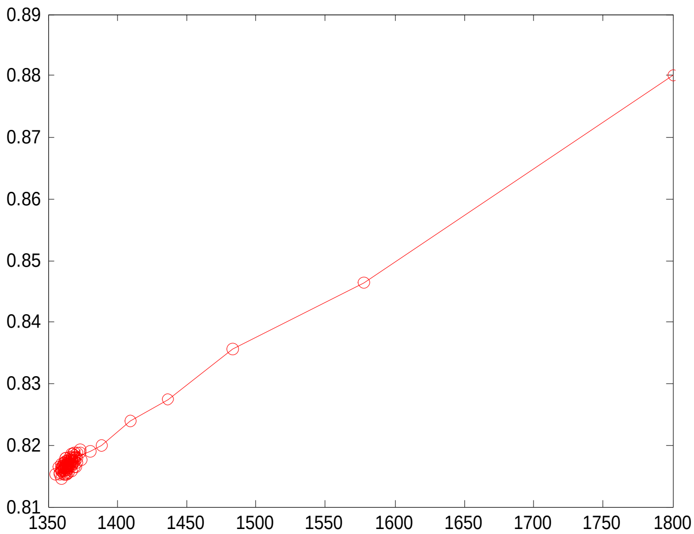

Figure 5.18 Optimal Consumptionof Area Revenue Insurance for a Risk Averse Farmer Facing a Liquidity Constraint (beta=0.99)

6. Summary and Conclusions

The main objective of this study is to derive dynamic optimal consumption and insurance coverage choices for a risk averse farmer who uses insurance to manage risk and also borrows and saves to smooth consumption. This study try to contribute to existing literature by examining the use of revenue insurance within a dynamic framework while examining the relationship between insurance, consumption, and credit risk. A dynamic stochastic model is developed and solved numerically to obtain the optimal dynamic choices for a representative corn farm in Mitchell County, Georgia. A crop simulation model - DSSAT is used to simulate farm-level yield to examine the basis risk of the area insurance contract. Further, the effects of premium load, risk aversion level, and time preferences are investigated under a variety of sensitivity analysis.

The findings were that if farmers are faced with a liquidity constraint, then they may choose coverage lower than the maximum allowable coverage, depending on the severity of the constraint and the initial wealth level. When the liquidity constraint is binding, the farmer may choose to insure less because current consumption is too valuable. The liquidity constraint induces induces more risk aversion, and is likely to be binding for poorer people, which makes them more risk-averse because of their inability to time diversify risk.

Sensitivity analysis found that future consumption doesn't change with change in premium loading or subsidy, while premium loading has an effect of decreasing coverage and current consumption, and premium subsidizing has an effect of increasing coverage and current consumption. Analysis also found that as risk aversion increases it generates an increase in the farmer's motive for holding precautionary savings at the expense of insurance demand. This finding is, in part, dependent on the nature of utility function used. In this study a CRRA utility function used in which risk aversion and the demand for precautionary savings are determined by the same parameter. For the values used in this study, the demand for insurance seems to dominate demand for precautionary savings. Finally, the sensitivity analysis showed that the results of this study are very sensitive to the farmer's rate of time preference.

References:

Anderson, R.W., and Danthine, J.P. "Cross Hedging". *Journal of Political Economy,* (December 1981):1182-96.

Anderson, R.W., and Danthine, J.P. "The Time-Pattern of Hedging and the Volatility of Futures Prices". *Review of Economic Studies,* 50(April 1983):249-66.

Arrow, K.J. "Uncertainty and the Welfare Economics of Medical Care." *American EconomicReview*, Vol. 53(1963) pp. 941-973.

Besley, T. "Nonmarket Institutions for Credit and Risk Sharing in Low-Income Countries." *Journal of Economic Perspectives*, Vol. 9, No. 3(1995), 115-127.

Chaffin, B. & Black, J. R. "*Risk Management Education*". (2004). GRP Evaluation Spreadsheet. Web site: http://www.aec.msu.edu/agecon/blackj/grp.htm.

Chah, E.Y., Ramey, V.A., and Starr, R.M. "Liquidity Constraints and Intertemporal Consumer Optimization: Theory and Evidence from Durable Goods." *Journal of Money, Credit and Banking*, Vol. 27, 1(Feb., 1995), 227-287.

Chambers, R.G. "Insurability and Moral Hazard in Agricultural Insurance Markets." *American Journal of Agricultural Economics,* 71(August 1989): 604-16.

Chavas, J. P., and M. T. Holt. "Acreage decisions under risk: the case of corn and soybeans." *American Journal of Agricultural Economics* 72, no. 3(1990): 529-538.

Coble, K.H., Heifner, R.G. and Zuniga, M. "Implications of crop yield and revenue insurance for producer hedging." *Journal of Agricultural and Resource Economics*. 25(2000):432-452.

Coble, K.H., Heifner, R.G. and Zuniga, M. "Implications of crop yield and revenue insurance for producer hedging." *Journal of Agricultural and Resource Economics*, 25(2000):432-452.

Coble, K.H., Knight, T.O., Pope, R.D., and Williams, J.R. "Modeling Farm-Level Crop Insurance Demand with Panel Data." *American Journal of Agricultural Economics,* 78(May, 1996): 439-447.

Coble, K.H., Knight, T.O., Pope, R.D., and Williams, J.R. "An Expected-Indemnity Approach to the Measurement of Moral Hazard in Crop Insurance."*American Journal of Agricultural Economics,* 79(February, 1997): 216-26.

Cook, P.J. and Graham, D.A. "The Demand for Insurance and Protection: The case of Irreplaceable Commodities." *Quarterly Journal of Economics,* Vol. 91, 1(1977):143- 156.

Deaton, A. "Saving and Liquidity Constraints." *Econometrica*, Vol. 59, 5(Sep., 1991): 1221- 1248.

Doherty, N.A. "Some Fundamental Theorems of Risk Management." *Journal of Risk and Insurance*, Vol. 42, 3(Sep., 1975): 447-460.

Duncan, J. and Myers, R.J. "Crop Insurance Under Catastrophic Risk." *American Journal of Agricultural Economics,* 82(4) (November 2000):842-55.

Ederington, L.H. "The Hedging Performance of the New Futures Markets." *Journal of Finance,* 34(March 1979):157-70.

Edwards, W., Barnaby, G. A., Drummond, H. E., Baquet, A. & John Harvey, J. (2000). "*Managing risk through crop insurance*". East Moline, IL: John Deere and Company, John Deere Publishing, East Moline, IL.

Epstein, L.G. "Decreasing Absolute Risk Aversion and Utility Indices Derived from Cake- Eating Problems. *Journal of Economic Theory*, 29(1983):245-64.

ERS/USDA."Commodity Costs and Returns." *Economic Research Service*, *United States Department of Agriculture (USDA).*

http://www.ers.usda.gov/data/costsandreturns/testpick.htm.

Flavin, M.A. "The Adjustment of Consumption to Changing Expectations About Future Income." *Journal of Political Economy*, Vol. 89, No. 5(Oct., 1981), 974-1009.

Flavin, M.A. "Excess Sensitivity of Consumption to Current Income: Liquidity Constraints or Myopia? *Canadian Journal of Economics*, Vol. 18, No. 1, Econometrics Special (Feb., 1985), 117-136.

Friedman, M. A Theory of the Consumption Function. Princeton, N.J.: Princeton University Press, 1957.

Gerald, G, "THE DYNAMICS OF AGRICULTURAL INSURANCE AND CONSUMPTION SMOOTHING" DISSERTATION Submitted to Michigan State, 2005

Gollier, C. "The Economics of Risk and Time." Massachusetts Institute of Technology, 2001.

Gollier, C. "To Insure or Not to Insure?: An Insurance Puzzle." *The Geneva Papers on Risk and Insurance Theory*, Vol. 28, No. 1 (June 2003):5-24.

Goodwin, B.K. "An Empirical Analysis of the Demand for Multiple Peril Crop Insurance." *American Journal of Agricultural Economics*, 75(May 1993): 425-434.

Gray, A.W., Richardson, J.W. and McClaskey, J. "Farm-Level Impacts of Revenue Assurance." Review of Agricultural Economics. 17:(1995): 171-183.

Grimard, F. "Household Consumption Smoothing through Ethnic Ties: Evidence from Cote d'Ivoire." Journal of Development Economics, August 1997, 53(2) pp. 391-422.

Hall, R.E., and Mishkin, F.S. "The Sensitivity of Transitory Income: Estimates from Panel Data on Households." Econometrica, Vol. 50, No. 2(Mar., 1982), 461-482.

Halcrow, H.G. . "Actuarial structures for crop insurance". Journal of Farm Economics, (1949), 21, 418-43.

Hilker, J., Baldwin, D., & Black, R. (1997). "*Risk, probability, and managing income variability*". Module 5. In E. N. Blue (Ed.), Managing Risk and Profits. Iowa State University Extension Publication FM-1854, Iowa State University, Ames, IA.

Holmstrom, B. "Moral Hazard and Observability." *Bell Journal of Economics,* Vol. 10, 1(1979):74-91.

Hofflander, A.E., Renshaw, E. and Renshaw, V. "Optimal Insurance." *Journal of Risk andInsurance*, Vol. 38, 2(Jun., 1971): 207-214.

Jappelli, T. "Who is Credit Constrained in U.S. Economy?" *Quarterly Journal of Economics*, Vol. 105, 1(Feb., 1990): 219-234.

Karp, L.A. "Methods for Selecting the Optimal Dynamic Hedge When Production is Stochastic". *American Journal of Agricultural Economics,* 69(August 1987):647-57.

Lamb, R. "Fertilizer Use, Risk, and Off-Farm Labor Markets in the Semi-Arid Tropics of India." *American Journal of Agricultural Economics*, 85(2) (May, 2003):359- 371.

Leland, H.E. "Saving and Uncertainty: The Precautionary Demand for Saving." *QuarterlyJournal of Economics*, 82(1968): 465-473.

Love, H. A., and S. T. Buccola. "Joint risk preference-technology estimation with a primal system." *American Journal of Agricultural Economics* 73(3) (1991): 765-774.

Martinez, S.W., and K.D. Zering. "Optimal Dynamic Hedging Decisions for Grain Producers". *American Journal of Agricultural Economics,* 72(November 1992):879-88.

Meyer, J., and D. J. Meyer. "Risk Preferences in Multi-Period Consumption Models, The Equity Premium Puzzle, and Habit Formation Utility." *Journal of Monetary Economics* (forthcoming).

Miranda, J.M. "Area Yield Crop Insurance Reconsidered." *American Journal of Agricultural Economics*, 73(May 1991):233-42.

Miranda, M.J. and Glauber, J.W. "Systemic, Reinsurance, and the Failure of Crop Insurance Markets." *American Journal of Agricultural Economics*, 79(February 1997):206-215.

Miranda, J.M. and Vedenov, D.V. "Innovations in Agricultural and Natural Disaster Insurance." *American Journal of Agricultural Economics*, 83(3) (August 2001):650-55.

Myers, R.J. and Hanson, S.D. "Optimal Dynamic Hedging in Unbiased Futures Markets". *American Journal of Agricultural Economics,* 78(February 1996): 13-20.

Myers, R.J., and S.R. Thompson. "Generalized Optimal Hedge Ratio Estimation". *American Journal of Agricultural Economics*, 71(November 1989):858-68.

Parkin, J.M.and Wu, S.Y. "Choice Involving Unwarranted Risky Events and Optimal Insurance." *American Economic Review,* Vol. 62, 5(1972):982-987.

Paxson, C.H. "Using Weather Variability to Estimate the Response of Savings to Transitory Income in Thailand." *American Economic Review*, Vol. 82, No. 1(Mar., 1992), 15-33.

Pissarides, C.A. "Liquidity Considerations in the Theory of Consumption." *Quarterly Journal of Economics*, Vol. 92, 2(May, 1978): 279-296.

Rothschild, M. and Stiglitz, J. "Increasing risk: A definition" *Journal of Economic Theory*, 3(1971):66-84.

Rothschild, M. and Stiglitz, J. "Increasing risk II: Its Economic Consequences." *Journal of Economic Theory*, 2(1970):225-43.

Rosenzweig, M.R. and Stark, O. “Consumption Smoothing, Migration, and Marriage: Evidence from Rural India.” *Journal of Political Economy*, Vol. 97, No. 4(Apr., 1989), 905-26.

Rosenzweig, M.R. and Wolpin, K.I. “Credit Market Constraints, Consumption smoothing, and the Accumulation of Durable Production Assets in Low-Income Countries: Investments in Bullocks in India.” *Journal of Political Economy*, Vol. 101, No. 2(Apr., 1993), 223-244.

Saha, A., C. R. Shumway, and H. Talpaz. “Joint Estimation of Risk Preference Structure and Technology using Expo-power Utility.” *American Journal of Agricultural Economics* 76, 2(1994): 173-184.

Sandmo, A. “The effect of Uncertainty on Saving Decisions.” *Review of Economic Studies*, 37(1970):353-360.

Sargent, T. J. *Dynamic Macroeconomic Theory.* Cambridge, Massachusetts: Harvard University Press, 1987. Shavell, S. “Risk Sharing and Incentives in the Principal and Agent Relationship.” *Bell Journal of Economics.* Vol. 10, 1(1979):55-73.

Townsend, R.M. “Risk and Insurance in Village India.” *Econometrica*, Vol. 62, No. 3(May, 1994), 539-591.

Zeldes, S.P. “Consumption and Liquidity Constraints: An Empirical Investigation.” *Journal of Political Economy*, Vol. 97, No. 2(Apr., 1989), 305-346.

Appendix A

Table A. U.S. corn production costs and returns per planted acre (dollars per planted acre), excluding Government payments, 1996-2000

Item	1996	1997	1998	1999	2000
Gross value of production					
Primary product: Corn grain	366.46	327.60	259.76	228.15	244.26
Secondary product: Corn silage	3.47	3.77	3.12	2.55	2.41
Total, gross value of production	369.93	331.37	262.88	230.70	246.67
Operating costs:					
Seed	26.65	28.71	30.02	30.29	30.02
Fertilizer 2/	51.21	50.37	45.51	42.84	43.16
Chemicals	27.42	26.87	27.36	28.40	28.82
Custom operations 3/	11.30	11.30	11.29	11.37	11.48
Fuel, lube, and electricity	24.43	24.55	22.96	23.04	29.12
Repairs	15.78	16.17	16.65	17.17	17.55
Purchased irrigation water	0.30	0.32	0.31	0.31	0.31
Interest on operating capital	3.86	3.96	3.61	3.50	4.53
Total, operating costs	160.95	162.25	157.71	156.92	164.99
Allocated overhead:					
Hired labor	2.83	3.07	3.19	3.28	3.36
Opportunity cost of unpaid labor	28.99	29.89	30.63	31.43	32.21
Capital recovery of machinery and equipment	63.02	64.50	66.46	68.49	70.16
Opportunity cost of land (rental rate)	80.79	84.81	86.35	86.77	89.36
Taxes and insurance	6.98	7.00	7.05	6.96	7.13
General farm overhead	10.38	12.21	11.47	10.88	11.11
Total, allocated overhead	192.99	201.48	205.15	207.81	213.33
Total, costs listed	353.94	363.73	362.86	364.73	378.32
Value of production less total costs listed	15.99	-32.36	-99.98	-134.03	-131.65
Value of production less operating costs	208.98	169.12	105.17	73.78	81.68
Supporting information:					
Yield (bushels per planted acre)	130	130	136	135	138
Price (dollars per bushel at harvest)	2.82	2.52	1.91	1.69	1.77
Enterprise size (planted acres) 1/	189	189	189	189	189
Production practices: 1/					
Irrigated (percent)	15	15	15	15	15
Dryland (percent)	85	85	85	85	85

1/ Developed from survey base year, 1996.

2/ Cost of commercial fertilizers, soil conditioners, and manure.

3/ Cost of custom operations, technical

Source: http://www.ers.usda.gov/Data/CostsAndReturns/data/recent/Corn/R-USCorn.xls

Appendix B
Table B. Statistics of County Level Revenue for Corn Production in Mitchell County, GA, 1975-2008

Revenue

max	min	mean	stdev
391.986	64.0458	251.9307	80.029312092