Dynamic Risk Management Under Credit Constraints

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*Paper presented at the NCR-134 Conference on Applied Commodity Price
Analysis, Forecasting, and Market Risk Management
St. Louis, Missouri, April 22-23, 2002*

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Practitioner's Abstract

The vast majority of previous studies on farmers' optimal risk management behavior have used static models and on the most part ignored use of borrowing and lending as an alternative method of managing risk. In this paper we develop a stylized multi-period risk management model for a risk averse farmer who can use revenue insurance to manage risk and also borrow and lend subject to a credit constraint. The model is applied to an example farm from Adair County in Iowa and the results provide three important messages. First, contrary to the full coverage of actuarially fair insurance result expected from using purely static analysis, at low revenues, insurance coverage may not be taken in the absence of debt. Second, if debt is available, full coverage will be taken at all revenue states and, third, premium wedges at reasonable levels have larger impact on coverage if debt is available because they eliminate the incentive to use insurance. Results also show that use of borrowing and lending for consumption smoothing reduces extant risk by approximately 77% while use of insurance only reduces risk by approximately 30%.

Introduction

The 1996 Federal Agricultural Improvement and Reform Act of 1996 (FAIR) reduced price supports provided to U.S. agriculture, shifting the responsibility for managing income risk directly to individual farmers. This has increased farmer, lender, and congressional interest in developing improved methods for allowing farmers to manage income risk.

Farmers now have a wide array of instruments for managing income risk. Futures, forward contracts, and other derivative pricing instruments have been available for many years. Multiple-peril (MP) yield insurance, which triggers payoffs based on individual-farm yield shortfalls, has long been an option to manage risk. More recently, area-yield insurance which triggers payoffs based on county yield shortfalls has been made available to many farmers. The latest innovation in risk management is direct protection against revenue shortfalls through revenue insurance. Revenue insurance is currently being offered under a variety of designs including indemnification based on an individual-farm or area revenue index, and alternative methods for valuing yield shortfalls.

There is a large literature on the optimal use of risk management instruments. The bulk of this literature focuses on pricing instruments such as futures or forward contracts and uses static models (e.g. Ederington, Anderson and Danthine 1981, Kahl, Myers and Thompson). Several 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, Martinez and Zering, Vukina and Anderson, and Myers and Hanson). A limited number of studies have focused on including various types of insurance instruments in a farmer's

risk management portfolio. The vast majority of these studies also use static models (e.g. Coble *et al.*, Wang *et. al.*, Mahul and Wright, Hennessy *et al.*). Atwood *et al.* is one of the few studies to examine the use of insurance instruments in a dynamic framework.

In a multi-period setting a potentially important alternative method to manage risk is available which has for the most part been ignored in risk management studies. It is well known that borrowing and lending can be used to smooth consumption across time (Friedman, Sargent). That is, in periods of low income a farmer may borrow to maintain a desired consumption level and in periods of high income the farmer can repay the borrowed funds or lend to store wealth for future consumption. Hence, borrowing and lending can be used to reduce risk across time. However, farmers must also manage their level of borrowing because of the cost involved (interest) and the constraints that are typically placed on the amount that can be borrowed.

The objective of this paper is to explore optimal risk management in a dynamic framework when the farmer can use a revenue insurance instrument to mange risk and also borrow and lend subject to a credit constraint. The impacts of the borrowing/lending, credit constraints, and insurance instrument designs are examined.

The objective is accomplished using a dynamic consumption model in a time separable expected utility framework. Dynamic programming (DP) is used to determine optimal paths for consumption, insurance, and borrowing/lending for an individual farmer. The approach is applied to an example farm using data from Adair County in Southwest Iowa.

The results will be of interest to farmers, lenders, and policy makers concerned with the design and use of risk management instruments. The results will also lend insights into the changes in risk management behavior that occur when farmers can also borrow and save.

Theoretical model

Consider a risk-averse crop farmer who faces a stochastic revenue stream due to random yields and prices. We assume the farmer has fixed assets (land, buildings, equipment, etc.) and chooses consumption to maximize utility over a given planning horizon. The fixed assets are financed using the farmer's own equity and debt. We also assume the farmer makes optimal production decisions of how much to plant and what technology to use separate from consumption decisions. Thus, the farmer's yield and crop revenue, which is given by price times yield, are considered to be exogenous to the model.

The farmer raises revenue through crop sales and through borrowing. However, borrowing is subject to a credit limit that is set by the lender. It is assumed that the farmer sells the crop immediately after harvest and that borrowing and lending decisions are also made at that time. We assume that the farmer's consumption decision for the entire crop year is made immediately after harvest.

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Because revenue is stochastic, the farmer can buy insurance to protect revenue loss below a given level. Although several instruments are available for protection against revenue loss, such as futures, forward contracts, other derivative pricing instruments, yield and revenue insurance, we focus only on revenue insurance in this paper. For convenience, we assume that the insurance decision for the coming year is made right after harvest to coincide with the time consumption decisions for the current year are made. Obviously, there is a time gap between harvest and planting times. However, ignoring the time gap should have no substantive consequence for the results of our model. Thus, the farmer makes simultaneous decisions of how much to consume, how much to borrow (or save) and how much insurance coverage to buy for the coming year.

At the end of the production period, harvesting occurs, the crop is sold, and hence crop revenue is realized. The farmer is again at decision time and we denote this as the current period t. Assuming insurance was purchased at $t-1$, then the farmer would receive an indemnity payment that is given by $max(0, b_{t-1}G_t - R_t)$ where b_{t-1} is the insurance coverage that the farmer purchased in $t-1$, G_t is the expected revenue based on information available at time $t-1$, and R_t is the farmer's revenue realization. If we denote current period debt as d_t, current period consumption as C_t, and the insurance premium as P_t, then the farmer's budget constraint in period t can be written as:

(1) $C_t = R_t + max(0, b_{t-1}G_t - R_t) - (1+r)d_{t-1} + d_t - P_t$

where r is the interest rate which is assumed to be constant. We impose the restrictions $d_t \leq \lambda$ where λ is a borrowing limit that is set by the lender, and $-\gamma \leq d_t$ where γ is a limit on savings . Thus in every period, the farmer's consumption is given by cash inflows which comprise of crop revenue *plus* indemnity payments *plus* debt *less* cash outflows which comprise of the principal and interest on previous period's debt *plus* the insurance premium. The premium is usually computed as the discounted expected value of the indemnity payment, $P_t = \beta E_t[max(0,b_tG_{t+1} - R_{t+1})]$ where E_t is the expectation operator conditional on information available at decision time, t, and $\beta = 1/(1+r)$ is the discount rate.

When making the current year's consumption decision, the farmer knows current crop revenue, R_t, the current indemnity payment, existing level of debt, and the interest due. The farmer then decides how much to borrow and how much insurance coverage to buy for the coming year. At that time, G_{t+1} is also known because it is exogenously given by the insurance agency. However, R_{t+1} is unknown.

The farmer is assumed to make a sequence of consumption choices $\{C_t\}_{t=1}^{T}$ to maximize the expected discounted sum of utility of consumption over the planning horizon:

(2) $$\underset{\{C_t\}_{t=1}^{T}}{Max} E_t \sum_{t=1}^{T} \beta^{t-1} U(C_t)$$

subject to equation (1) and

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(3) $$C_T = R_T + Max(0, b_{T-1}G_T - R_T) - (1+r)d_{T-1},$$

the constraint $d_t \leq \lambda$, and a Markov probability process for crop revenue $\tilde{R}_{t+1} \sim g(R_{t+1}/R_t, z_t)$ where g is the probability density function for the crop revenue conditional on the current crop revenue R_t, and a vector of current information variables, z_t. E_t is the expectations operator conditional on information available at time t, $\beta = 1/(1+r)$ is the time preference parameter, and $U(.)$ is an increasing, differentiable, and concave von Neumann-Morgenstern utility function. The farmer's risk preferences are characterized by the concavity of the utility function. The constraint in equation (3) is a terminal condition that requires the farmer to pay back all debt in the final period, T. It also requires that all wealth in the final period is consumed. However, this restriction can easily be relaxed to allow a bequest motive whereby the farmer does not consume all of the final period wealth.

The farmer's optimization problem can be solved using discrete time stochastic dynamic programming (Miranda and Fackler). Furthermore, Miranda and Fackler (MF) have developed a MATLAB algorithm that can be used to solve the model. We define the state vector $x_t = (R_t, d_{t-1}, b_{t-1}, z_t)$, the control vector $u_t = (d_t, b_t)$, and the value function as $v_t(x_t)$. Then Bellman's equation for this problem is given by:

(4) $$v_t(x_t) = \underset{u_t}{Max}\left\{U(C_t) + \beta E_t v_{t+1}(x_{t+1})\right\}$$

subject to equations (1) and (3) and the constraint $d_t \leq \lambda$. The first term in equation (4) represents the immediate reward and is the instantaneous utility of consumption in period t. The second term represents the discounted sum of expected future rewards and is the expected discounted utility from all future consumption from period $t+1$ to T.

Model assumptions and parameters

In order to solve the model a number of assumptions are required. We apply the model to the optimal consumption and risk management problem faced by a representative corn farmer in Adair county in Southwest Iowa (SWIA).

The control and state variables are continuous except for insurance coverage which is discrete because farmers can only purchase coverage in pre-determined proportions of insurable revenue. However, in order to simplify the solution, we use a discrete approximation of the continuous state and vector spaces. The insurance coverage space was specified as $b_{t-1} = \{0, 0.50, 0.55, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85\}$ comprising of 9 possible coverage levels. This is a state variable in period t because coverage had to be chosen in period $t-1$. The state space for incoming debt, d_{t-1}, was specified as a vector of possible debt states ranging from -$ 700 to $ 700 in $ 20 increments. Each debt state is taken to be a mid-point of the continuous debt interval. The state spaces for crop revenue were specified as 8, equally spaced, possible crop revenue states ranging from $ 70

to $ 350. Each revenue state is taken to be a mid-point of the continuous revenue intervals, respectively. The upper bound state of $ 350 per acre represents the revenue interval of $ 330 or above and the lower bound state of $ 70 represents the revenue interval of $ 90 or below. The choice of these range of values was based on empirical analysis discussed below. The information contained in the state vector of current information variables is fully characterized by the revenue transition probabilities also discussed below. We assume a constant interest rate, r, of 10% per annum. In addition we assume that the farmer's measure of time preference is constant and is given by $\beta = 1/(1+r)$.

A logarithmic utility function was specified. The logarithmic utility function exhibits decreasing absolute risk aversion (DARA) which is a desirable property because farmers have generally been found to have DARA preferences (Saha *et al.*, Chavas and Holt). There are other types of power utility functions that also exhibit DARA but these require explicit assumptions concerning the value of the farmer's coefficient of relative risk aversion. The logarithmic utility function is just a special case of this family of functions with a coefficient of relative risk aversion of one. However, some studies have found that this coefficient is typically above one (Love and Buccola, Szpiro). Hence, there is a trade-off of using the logarithmic function as opposed to using a more flexible functional form. Finally, we assumed that utility is additively separable. This implies that the farmers are temporally risk neutral where, temporal risk aversion is defined as the dislike of gambles with lengthy consequences (Ingersol).

Crop revenue distribution

The farmer's stochastic crop revenues depend on jointly distributed prices and yields. Two types of revenue insurance designs are offered to farmers, individual revenue (IR) and area revenue (AR) insurance. In the IR design, the insurable revenue is computed as a product of pre-planting futures price and the expected farm yield while, the indemnification index is computed as the harvest time futures price times the actual farm yield. In the AR contract design the area yield is used instead of farm yield to compute the insurable revenue and the indemnification index.

In this study we focus on IR insurance using the farmer's own revenue (own yield times realized price) as the indemnification index. Crop revenue is a product of yields and cash prices. County corn yields and cash prices were available for Adair county in SWIA from 1974 to 1993. The price data were obtained from Robert Wisner in the Department of Economics at Iowa State University and the yield data are based upon MP insurance records (farm) and National Agricultural Statistics Service (NASS) (county) records. Examination of the graph of yields showed that yields increase over time which is consistent with *a priori* expectations. In general corn yields would be expected to have an upward trend and to be highly volatile over time. Also, some studies have found that the random shocks that cause uncertainty in yields are non-normal. For example, Wang et al who used the same yield data from SWIA, found the shocks to be negatively skewed and to have more kurtosis than the normal distribution.

The cash price data used were Thursday prices for cash markets in the Southwestern Crop Reporting District of Iowa. These were averaged for the month of October to obtain a figure that we considered to be the annual cash price at harvest time. These annual prices were multiplied by the county yield to obtain an average county revenue that was adjusted to obtain an estimate for farm revenue.

Most commodity prices have been found to have stochastic trends and time-varying volatility (Myers). A number of studies have modeled prices as an Autoregressive Conditional Heteroskedasticity (ARCH) process or as a Generalized ARCH (GARCH) process (e.g. Baillie and Myers, Lai *et al.*, Wang *et al.*).

It is difficult to have reasonable *a priori* expectations of what the revenue distribution would look like. So we began our identification process by examining the revenue graph looking for possible trends or patterns. No systematic trends or patterns were found in the revenue series. This would suggest that the trend and patterns evident in price series and yields seem to offset each other.

We examined the sample autocorrelation functions (ACF) and partial autocorrelation functions (PACF) for the revenue series to see if they follow an AR process. Both the ACF and PACF cut off immediately and there was no evidence of geometric decay in either function as would be expected if revenue followed an AR or moving average (MA) process. The results from these graphs suggest that the revenue series is essentially a white noise process. We formally tested for autocorrelation in the revenue series using the Ljung-Box Q-statistic and the results are presented in Table 1. There is no evidence of serial correlation in the residuals of the revenue series. Following these results, we specified the county revenue data generating process as:

(5) $R_t = \mu + \varepsilon_t;$ $\varepsilon_t \sim N(0, \sigma^2)$

where t is a time subscript, μ is a constant and ε is the error term. The assumption of normality in the error term is obviously restrictive. However, normality tests on the errors failed to reject the null hypothesis that the errors are normally distributed. The results of the Jarque-Bera (JB) test of normality are shown in Table 2 together with descriptive statistics of the revenue series. Based on the JB test results, we fail to reject the null hypothesis of normality.

Farm revenue distribution

Due to lack of adequate farm-level yield data, we estimated farm-level revenue distribution by adjusting the county level values to reflect what these values would be at the farm-level. Our assumption is that farm-level revenues would generally be directly related with county yield since farmers in a given county face similar technology, weather conditions, and prices. We specified the relationship between county-level and farm-level revenue as:

(6) $ln(R_t^f) = \eta + \alpha \, lnR_t^c + u_t;$

where t is a time subscript, η is a constant, α is a parameter to be estimated using the available

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farm and county data, u_t is a random term and superscripts f and c represent farm and county, respectively.

 The available farm-level yield data consist of eight years of Actual Production History (APH) data for Adair County of Iowa from 1985 to 1992. The data were available for several farms from the county and therefore the data set is a panel of annual farm yields that spans eight years. The farm yields were multiplied by the SWIA cash prices to obtain individual farm revenue. These were then used to estimate the model in equation 6 using pooled OLS. The results of this estimation are presented in Table 5.

Using the regression results to predict the farm-level revenue given the realization of county revenue, we used the specification:

(7) $\hat{R}_t^f = \hat{\delta} \exp(\hat{\eta} + \hat{\alpha} \ln R_t^c)$

where $\hat{\delta} = exp(u_t)$ and the hat indicates a fitted value. Under the assumption of normality the expected value of $exp(u_t)$ is $exp(\sigma^2/2)$ (Wooldridge). However, if we assume that u_t is independent of the explanatory variable, it is easy to obtain a consistent estimate for $\hat{\delta}$ without the assumption of normality (Wooldridge) which is the procedure we used.

Transition Probabilities

The probability density function for revenue faced by farmers at each decision time is represented by a discrete-time transition probability matrix that maps the stochastic revenue states from one decision period to the next. For *illustrative* purposes, assume two states of nature $\{R_1, R_2\}$ and one decision period, $t,$ for a farmer considering the purchase of an IR contract. The elements in the transition probability matrix, Π, mapping the states at t to the states at $t+1$ are given by

(8) Π $=$ $\begin{bmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{bmatrix}.$

As an example, the second element in the first row is computed as:

(9) $\pi_{12} = Prob(R_{t+1} = R_2 / R_t = R_1)$

where "prob (. | .)" indicates the conditional probability. Hence (9) gives the probability that state R_1 at t will be followed by state R_2 at $t+1$ and therefore the row elements in Π sum to one.

Given the specification in equations (5) and (6) and the assumption of normality, the density for individual farm revenue was specified as a univariate normal distribution. Using the normal

cumulative density we generated the probabilities of revenue being in any state, *j*, and used them to build the probability transition matrix since revenue was found stationary. That is, revenue realizations at *t+1* are independent of realizations at *t*.

Preliminary Results

We solved the model for three scenarios: (1) the farmer has debt only; (2) the farmer has insurance only; and (3) the farmer has both debt and insurance available to manage risk. We investigate each of these cases in turn.

Debt Only

Table 4 shows the optimal borrowing decision for a farmer who uses debt only to manage risk given current revenue and existing debt. The results show that a farmer who follows the optimal strategy uses debt to smooth consumption around expected revenue (*i.e.* $ 230 which is the mid-point of the range containing the mean). When the farmer's current revenue is below the mean, it is optimal to increase consumption through borrowing. Similarly, when current revenue is greater than the mean, the farmer saves or repays existing debt. For example, a farmer with no existing debt and current revenue of $ 70 borrows $140 while one with current revenue of $270 saves $20.

Figure 1 shows optimal consumption paths for the period between 1974 to 1993, for a representative farmer in Adair county. We computed the optimal consumption path assuming no debt and with debt available. Further, the farmer is assumed to have no existing debt coming into 1974. It is seen from the graph that borrowing and lending enables the farmer to smooth consumption across time. This is a well known fact and there is nothing new here.

Insurance Only

Figure 2 shows the optimal insurance coverage decision for a farmer using actuarially insurance only to manage risk given current revenue outcomes. The farmer is assumed to start with no existing insurance coverage. These results show that at low revenues the farmer may not buy insurance coverage while full coverage is taken at high revenues. This result differs from the static solution in which the farmer always takes full coverage of actuarially fair insurance. The reason the dynamic solution differs from the static solution is that the premium for next period's coverage is a drain on current consumption. This implies that at low revenues the farmer's disutility of foregoing current consumption to buy insurance is higher than the expected discounted utility from future consumption with insurance. Hence, in the absence of debt, actuarially fair insurance will be used less often than we might think from using a purely static analysis.

Figure 3 shows optimal consumption paths over 1974-1993 for the farmer when only insurance is used for risk management assuming no existing coverage. As expected, the figure shows that insurance protects the farmer's consumption from falling below a given level. Compared to the case of debt only, however, the insurance instrument clearly provides less consumption smoothing.

Figure 4 shows the expected optimal insurance coverage paths for cases when the premium is actuarially fair and when it is actuarially unfair with wedge factors of 1.3 and 1.6, again assuming debt is not available.[1,2] The figure shows that a premium wedge reduces coverage. If the premium is actuarially fair, the farmer expects to take out full coverage (because revenue will, on average, equal its mean value). With a wedge of 1.3 (*i.e.* 30% higher than the actuarially fair premium) the expected coverage .74 while it is about .58 when the wedge is 1.6. In part, the reason for this is that a wedge essentially raises the premium which is equivalent to reducing current revenue if insurance coverage is taken out.

Insurance and Debt

Table 5 shows optimal borrowing and insurance decisions for a farmer who has both debt and insurance available to manage risk, given current revenue and debt states. Again, we assume that the farmer has no existing coverage. When a farmer has both insurance available, full coverage of actuarially fair insurance is taken out at all current revenue states. Thus, with debt the insurance choice reverts to the static result of full insurance at all current revenue states (even at very low revenue states). This also suggests that debt and insurance are complementary risk management instruments whereby debt enables the farmer to take full coverage at low revenues. This is because the farmer can use debt to pay for full coverage of actuarially fair insurance at low revenue realizations.

Compared to the results presented in Table 4, a farmer who has both insurance and debt borrows more at each current revenue state than when no insurance was available. It appears the additional debt is taken out to finance the insurance premium so that current consumption levels can be maintained.

Optimal consumption paths for the representative farmer using both insurance and debt to manage risk are presented in Figure 5. The figure shows that using both debt and insurance leads to more consumption smoothing than when insurance only is used and is at about the same level of

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[1]   The expected optimal path shows how the controlled dynamic process evolves over time starting from some initial state. Given the state transition function, g, the optimal policy function, x^*, and the transition probability matrix, P^*, the path taken by the controlled state from an initial point, s_1, the expected optimal is computed path by iterating on the transition equation, $S_{t+1} = g(s_t, x^*(s_t), P_t^*)$ assuming that the optimal policy is followed.

[2]   A wedge is a loading factor which makes the insurance premium actuarially unfair and is usually applied to account for administrative costs.

smoothing when debt only is available. The coefficients of variation (CV) for the consumption paths are: 0.26 when no debt or insurance are available, 0.06 when debt only is available, 0.18 when insurance only is available and 0.06 when both debt and insurance are available to the farmer. These CVs suggest that use of insurance and/or debt to manage risk leads to 31% reduction in extant risk when insurance only is available and 77% reduction when debt only or both debt and insurance are available. This result underscores the importance of including debt in the portfolio of risk management instruments when modeling farmers' risk management behavior.

Figure 6 shows the expected optimal path for coverage when both debt and insurance are used. The figure shows that at an actuarially fair premium, full coverage is taken. However, a wedge on the premium drastically reduces coverage. In the case of a farmer using insurance only, coverage was still taken with a premium wedge even though it was reduced. However, with an option to use debt, a wedge eliminates the incentive to take any insurance coverage. Thus, the farmer opts to substitute debt for insurance rather than pay the actuarially unfair premium. Intuitively, because the revenue distribution is completely stationary, the farmer expects next period's revenue to revert to its mean value and may therefore choose partial, rather than full coverage if the premium is actuarially unfair.

Conclusions

This paper develops a *stylized* model and uses it to explore optimal risk management behavior in a dynamic framework. The model pertains to the case of a risk averse farmer who can use revenue insurance and debt instruments to manage risk, subject to a credit constraint. A discrete time, discrete state and discrete control space dynamic programming approach is applied to an example farm from Adair County in Iowa to determine optimal consumption, insurance, and borrowing/lending decisions. The model is solved numerically in a time separable expected utility framework with results that provide three key messages concerning farmers' risk management behavior.

First, a farmer using insurance only to manage risk may not take full coverage of actuarially fair insurance at low revenue realizations. This finding has the implication that, in the absence of debt actuarially fair insurance will be used less often than we might expect from using a purely static analysis. Second, if debt is available, full coverage of actuarially fair premium is taken because, as it appears, the farmer borrows to pay for the premium at low revenues. Third, when both insurance and debt instruments are available, premium wedges at reasonable levels have larger impact on insurance because they eliminate incentives for taking insurance coverage. These results underscore the need to include debt in the portfolio of risk management instruments when analyzing farmer's risk management behavior.

This paper used a simple stylized model that limits generalization of the results. First, only individual revenue insurance was considered with indemnification index based on realized farm revenue. Thus, basis risk is eliminated when in practice it is present given the way the insurance

contracts are designed. Second, the data showed that revenue is completely stationary and normally distributed and is therefore mean reverting. In cases where this is not true, results may differ from those presented here. A natural extension of this work will be to allow for basis risk and also include other insurance designs in the model as well as other risk management instruments. In addition, the normality assumption of the revenue distribution will be relaxed. In spite of these limitations, the economic implications of these results should still hold when the model is expanded to accommodate more variables and insurance designs used in practice.
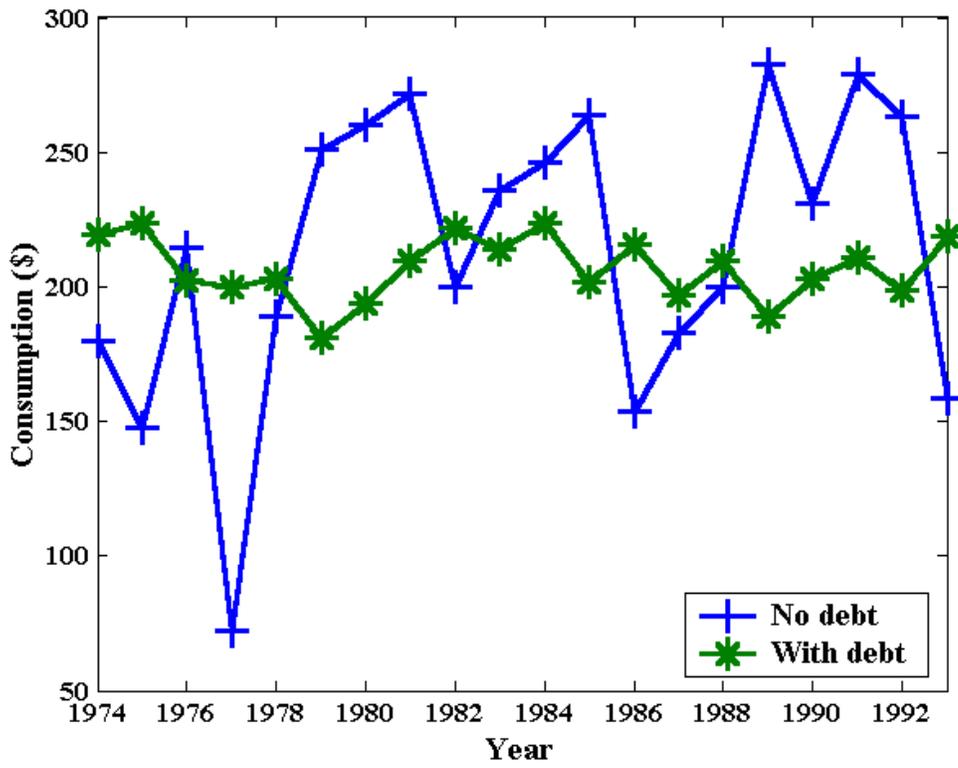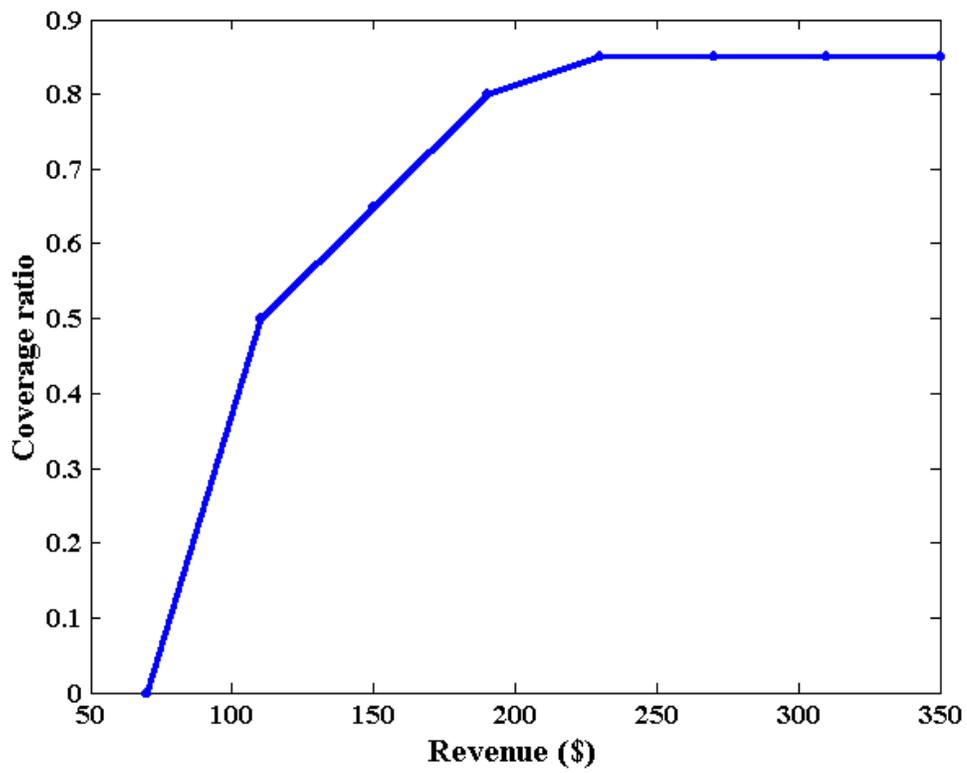
Figure 1.   **Optimal consumption paths in the absence of insurance**

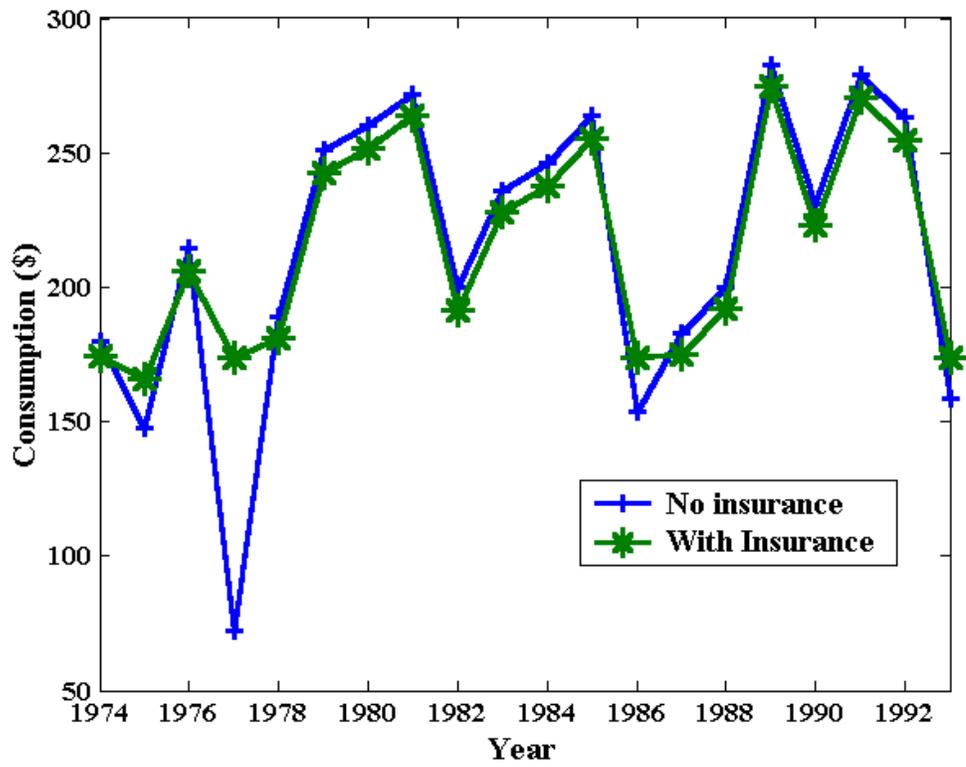**Figure 2.** **Optimal insurance coverage in the absence of debt**

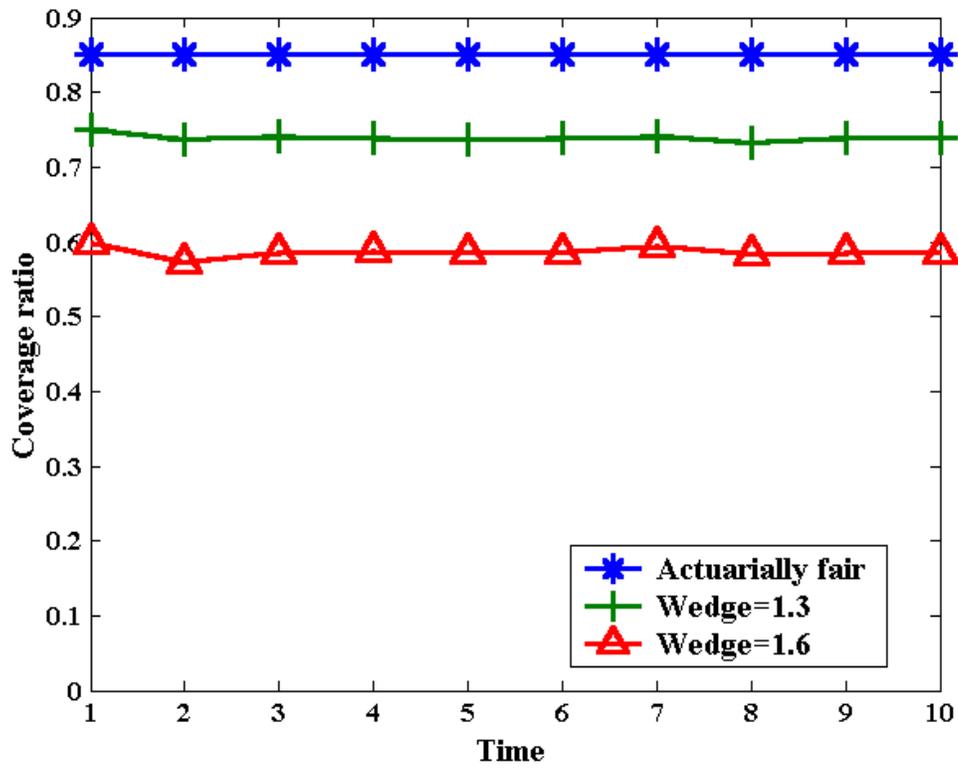**Figure 3.** **Optimal consumption paths in the absence of debt**

Figure 4.   **Expected optimal path for insurance coverage in the absence of debt**
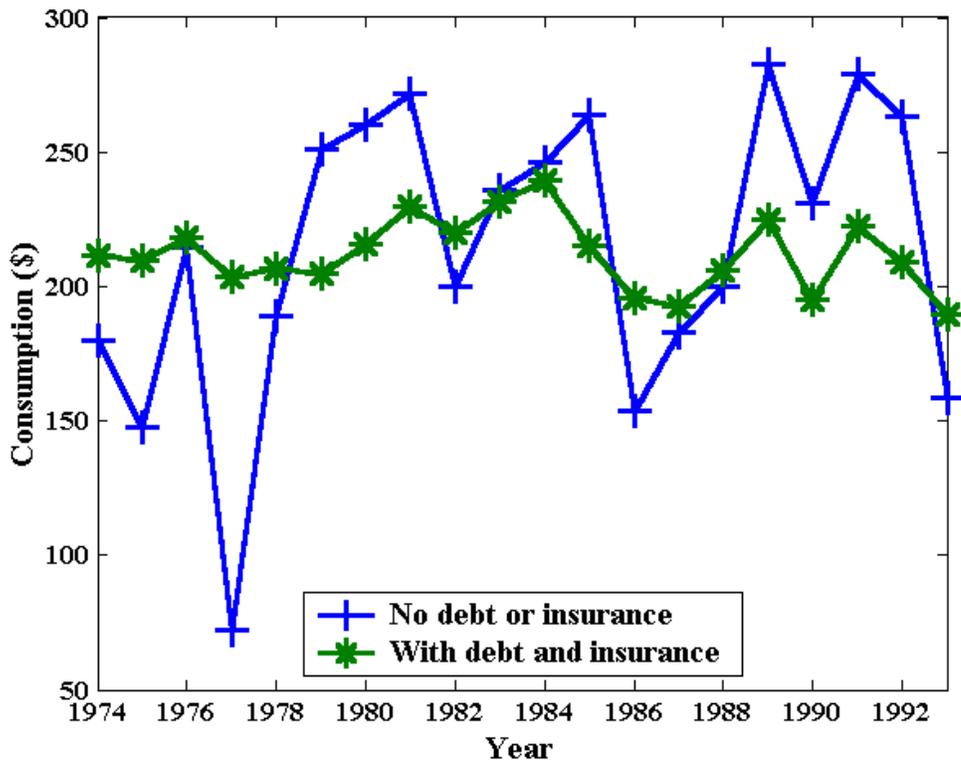
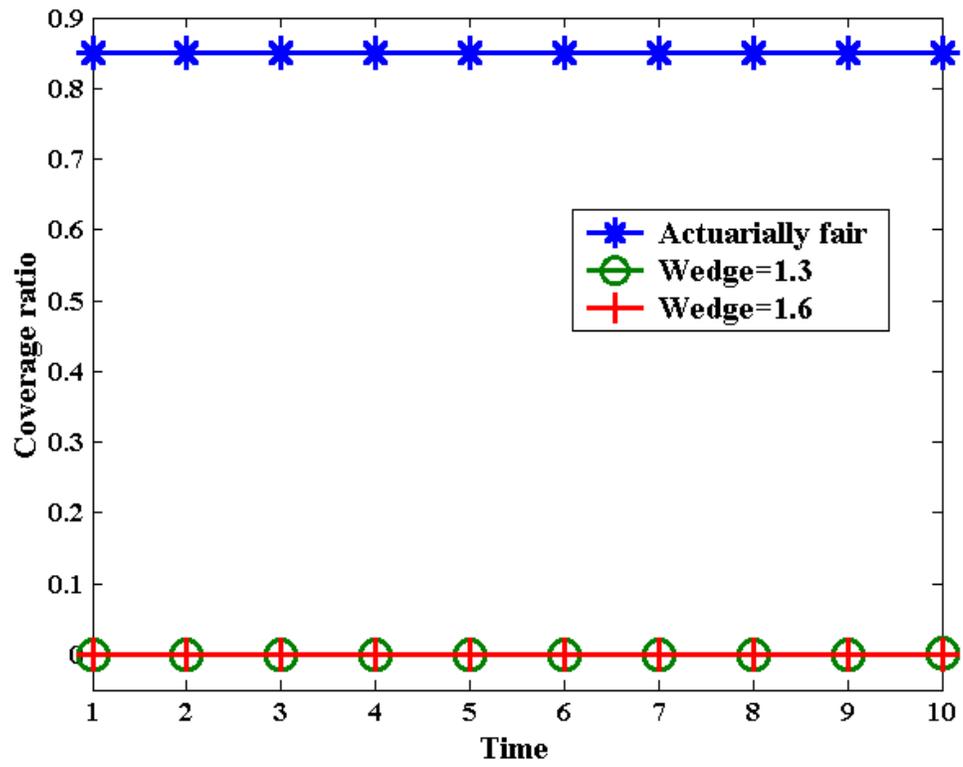**Figure 5.**   **Optimal consumption paths with debt and insurance**

Figure 6.   **Expected optimal path for insurance coverage when debt is available**

Table 1.   **Ljung-Box Q-test for autocorrelation in the revenue series Adair County**

Order of lag	AC coefficient	p-value
1	0.1988	0.3388
2	0.0564	0.6087
3	-0.1031	0.7367
4	-0.1533	0.7515
5	-0.0744	0.8384
6	-0.1376	0.8488

Table 2.   **Jarque-Bera (JB) test of normality in the revenue series for Adair County**

mean	min	max	std. dev	skewness	kurtosis	JB	p-value
210.89	76.14	274.37	51.09	-0.83	3.20	2.305	0.316

Table 3.   **Pooled OLS results for the logarithm of farm-level revenue on the logarithm of county-level revenue Adair County**

No. of obs	dependent Variable	η	α	R^2	F	Prob > F
640	$\ln R_t^f$	-0.3582 (0.1586)[*] 0.027	1.0654 (0.0293) 0.000	0.4920	1322.72	0.000

* Figures in parenthesis are standard errors and below them are the p-values

Table 4. **Optimal debt in the absence of insurance**

Revenue	Existing Debt ($/acre)						
	0	**100**	**200**	**300**	**400**	**500**	**600**
($/acre)							
70	140	240	340	440	540	620	680
110	120	220	320	400	500	600	680
150	80	180	280	380	480	560	660
190	40	140	240	340	440	540	620
230	0	100	200	300	400	500	600
270	-20	60	160	260	360	460	560
310	-60	40	140	220	320	420	520
350	-80	0	100	200	300	400	480

Note: Negative indicates savings.

Table 5. **Optimal debt and insurance choices**

Revenue	Existing debt ($/acre)											
	0		**100**		**200**		**300**		**400**		**500**	
($/acre)												
	Debt	**Cov.**	**Debt**	**Cov.**	**Debt**	**Cov.**	**Debt**	**Cov.**	**Debt**	**Cov.**	**Debt**	**Cov.**
70	160	**0.85**	260	**0.85**	360	**0.85**	460	**0.85**	560	**0.85**	660	**0.85**
110	120	**0.85**	220	**0.85**	320	**0.85**	420	**0.85**	520	**0.85**	620	**0.85**
150	80	**0.85**	180	**0.85**	280	**0.85**	380	**0.85**	480	**0.85**	580	**0.85**
190	40	**0.85**	140	**0.85**	240	**0.85**	340	**0.85**	440	**0.85**	540	**0.85**
230	20	**0.85**	120	**0.85**	220	**0.85**	320	**0.85**	420	**0.85**	500	**0.85**
270	-20	**0.85**	80	**0.85**	180	**0.85**	280	**0.85**	380	**0.85**	480	**0.85**
310	-60	**0.85**	40	**0.85**	140	**0.85**	240	**0.85**	340	**0.85**	440	**0.85**
350	-80	**0.85**	20	**0.85**	100	**0.85**	200	**0.85**	300	**0.85**	400	**0.85**

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