Behavioral Responses of Farmers to Risk

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Optimal control and Monte Carlo simulation are used to measure farmers' risk attitudes. Discounting for the probablistic life expectancy of the firm, then comparing optimal capital structure to the observed, farmers in North Dakota internally rationed capital at a level implying a time preference of money 6.39 percent below the rate expected of a risk neutral participant.

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The use of financial leverage influences the growth and viability of the farm firm. An important determinant of farm financial structure is the decision maker's attitude toward the risk associated with debt financing. Many methods of determining decision maker risk characteristics have been developed in economic research.

Binswanger elicited risk preference in a gaming situation, but recognized that preferences may be different in non-gaming situations. Halter and Mason indicated a need for further empirical work after finding a wide range of risk attitudes among 44 Oregon farmers. King and Robison explored a method of measuring risk aversion functions in an experimental test under controlled conditions different from actual decision environments. This activity indicates interest in and the importance of measuring risk attitudes.

Modigliani and Miller (1958) demonstrated that firm market value in frictionless financial markets is unrelated to its capital structure. In their tax-revised model (1963) the tax deductibility of interest results in a zero equity border solution, implying 100 percent indebtedness. The impact of personal income tax offset the decreasing cost of indebtedness. Optimumization occurred at either boundary solution of zero equity or zero debt.

Baker and Hopkin explored the effects of leverage and liquidity on growth characteristics of the farm firm. They discussed three topics: 1) the influence of credit on the equilibrium position of the firm, 2) the implications of equilibrium for resource allocation, and 3) the dynamics of firm growth and achieving desired levels of income and net worth accumulation. They stated a basic proposition of farm finance:

> Capital management affects the rate of firm growth, through leverage, and the vulnerability of the firm, through liquidity. A farmer may earn a satisfactory rate, accumulate an equity in assets, and yet suffer from a low level of disposable income. On the other hand, to divert income from capital accumulation to consumption purposes may so retard a farmer's growth rate as to jeopardize his ability to survive in the dynamics of a capital using agriculture.

Baker and Hopkin, using this proposition, presented a model of leveraged farm growth. They used equity as a measure of growth stating that "equity seems to be a reasonable welfare proxy for the operator who owns assets of the firm, either totally, or subject to debt." The annual increment to equity is,

$$g=(r*A-i*D)*(1-t)*(1-c), \qquad (1)$$

where (r) is rate of return to assets,(i) is interest rate on debt, (t) is tax rate, (c) is firm earning consumption rate. Their model assumes: 1) The firm has constant returns to scale at different levels of debt and equity (rate of return on assets remains constant as debt-equity level increased), 2) The combined effects of (c) and (t) result in a constant value over debt-equity categories and 3) interest rate (i) is constant across debt-equity categories.

The economic environment in which farmers operate is constantly changing. Economic conditions observed in the 1980's are different from the 1970's. Unfortunately, many farmers experienced difficulty adjusting to changing macroeconomic factors that were beyond their control. They failed to correctly anticipate changes and implemented decisions based upon inaccurate expectations.

Many farmers structured their finances to take advantage of an inflationary environment in the 1970's. Some expected inflation to continue indefinitely at an accelerated pace; however, inflation abated in the early 1980's. These farmers experienced substantial financial problems because of their previous expectations and decisions.

Little research work has been conducted on how economic factors outside the control of the farm manager affect firm financial structure. For instance, how should a farmer adjust the farm financial structure to expected changes in interest rates and inflation? The ability of a farmer to successfully anticipate and adjust to economic forces external to the firm is critical to profitability and survival.

Purpose of the Study

Gabriel and Baker hypothesized the farmer engages in internal capital rationing to comply with a predetermined risk constraint. The decision maker subjectively discounts the value of the marginal product of capital used in the operation. The purpose of this study is to develop a theoretical framework and to empirically estimate a behavioral measure of producer discounting as a risk response.

Brink and McCarl drew inferences about farmers' risk aversion based on differences between actual cropping decisions and the results of a linear programming model. They found low risk aversion and indicated studies of actual behavior instead of hypothetical situations are needed. They also expressed some doubt of their own ability to include farmer risk in their model. A theoretical framework that specifies observed behavioral responses to risk, rather than perceived conduct, is of interest to researchers and decision makers.

Collins (1985) provides an optimal control model to maximize the present value of future income consumption. This paper adds a risk attitude factor and adjusts the functional form of the model to fit empirical data gathered from a survey of farm financial charactoristics (North Dakota Crop and Livestock Reporting Service, 1986).

Collins used a Du Pont identity based concave return on equity over the leverage domain to determine income. Empirical data from the 1985 finance survey of North Dakota farmers and ranchers does not yield a concave function for RE. Table 1 profiles the financial returns of North Dakota farmers and ranchers. The data clearly indicates that net rate of return to assets and return to equity do not follow the pattern used by Collins. Net rate of return to assets remained relatively constant as debt/asset ratio approaches one. Consequently, return to equity is not a concave function of debt/asset ratio but exhibits a pattern of increasing rapidly as debt/asset ratio approaches one. Interest rates paid by farmers does not show a pattern of increasing as debt/asset ratio approaches one. The empirically observed relationships between returns and interest rates are embodied in the following optimal control framework.

The Model

The objective is to maximize expected present value of consumption of farm income for all generations of the farm. Farm income (I) is multiplied by rate of consumption (C). The exponent $e^{-h(t,D,E)}$ is a risk discount function. Debt and consumption are the control variables. Equity is the state variable. Expected present value of consumption is then,

Table 1. Financial Characteristics of Selected North Dakota Farms and Ranches by Debt-Asset Category

Number of Farms	Debt-Asset Category	Return to Assets Mean[a]	Return to Equity Mean[a]	Interest Rate Mean[b]
	Percent			
80	0-10	8.99	9.64	29.07
85	10-20	9.54	11.26	13.54
91	20-30	7.56	9.98	12.6
83	30-40	8.69	13.32	11.11
78	40-50	8.72	15.79	10.86
65	50-60	7.36	16.56	9.75
37	60-70	6.93	19.99	8.48
24	70-80	6.33	26.60	9.92
28	80-90	9.57	70.52	8.81
5	90-100	13.73	339.02	9.73

SOURCE: Farm Finance Survey, January 1986, North Dakota Crop and Livestock Reporting Service, February 1986.

[a]Returns are calculated as gross receipts minus production expenses including interest payments.

[b]Interest rate paid is defined from the survey as total farm interest paid divided by total farm liabilities as of January 1. Since this is a time of lowest debt, this interest rate is upward biased, especially for farmers with low indebtedness.

$$J = \int_{t=0}^{+\infty} e^{-h(t,D,E)} CI \qquad (2)$$

subject to the equity constraint,

$$\dot{E}(t)=[1-C]I \qquad (3)$$

and the initial state of the firm. Equation (8) is the motion of the state variable equity and describes the portion of farm income retained and added to equity in time t. A Hamiltonian function is formed from equations (2) and (3).

$$H(C,D,E,\lambda)=e^{-h(t,D,E)}CI + \lambda[1-C]I \tag{4}$$

The partial derivatives of the Hamiltonian with respect to the time variables C,D,E, and determine the solution to the control problem. Prior to solving for the risk attitude coefficient from the Hamiltonian, empirical values for the risk discount function need to be derived. The risk discount function $e^{-h(t,D,E)}$ which discounts income using the probability of insolvency is an integral part of the control framework solution for the risk attitude coefficient.

Risk Discount Function

Shepard and Collins demonstrated a statistically significant relationship between reported bankruptcies and debt as a proportion of physical farm assets. It is reasonable to presume farmers planning capital needs would want to consider the possibility of business failure. Probability of failing by time t is considered to be directly related to the firm's leverage position.

Collins (1985) formulated the probability of failing by time t with,

$$f(t,D,E)=1-e^{-\beta*t*D/E}, \tag{5}$$

where f(t,D,E) is the probability of failing by time t, $e^{-g(t,D,E)}$ is the probability of being solvent by time t, β is the estimated beta coefficient of risk for a specified real rate of interest, t is time, and D/E is the debt-equity ratio. The exponent discounts foregone future earnings due to firm failure. Interest rate (r) is added to discount earnings to present value. The attitudes of farmers to risk may differ from the direct impact of the probability of bankruptcy. Risk attitude factor (a) is included in the discount function. This risk attitude factor is easily interpreted. A factor of .05 discounts future expected earnings by 5 percent more than interest rates and backruptcy probability, suggesting higher risk aversion by the decision maker. A negative factor lowers the discount rate and suggests a risk preference by a producer wanting to take a chance on future earnings. The resulting discount function is

$$e^{-h(t,D,E)}=e^{-(r+a+\beta*D/E)t}. \qquad (6)$$

Monte Carlo Simulation Model

The Monte Carlo method is used to estimate beta coefficients. The Monte Carlo model is repeated 100 times to simulate changing equity of the firm over a 25 year time period. Farms are considered insolvent if a financial indicator falls below a predetermined level by t+n (e.g., equity falls below 20 percent of total assets at year 10). Cumulative probability distributions of solvency by time t are constructed for different investment options and economic environments.

Solvency regressed against time and debt-equity ratio yields estimates of beta.

$$S(t,D,E)=e^{-\beta*t*D/E} \qquad (7)$$

where S(t,D,E) is portion of farms remaining solvent at t, (β) is the estimated beta coefficient, (t) is time and (D/E) is debt-equity ratio. The dynamic equation of the Monte Carlo simulation is:

$$E(t)=A-(D(t-1)-((A)*(RA+SD*RN(t))*(1-C)-(r*D(t))-F)), \qquad (8)$$

where (E) is equity, (D) is debt, (A) is total assets (E+D), (RA) is expected rate of return to assets, (SD) is the standard deviation of returns to assets, (RN(t)) is a normally distributed stochastic disturbance generated for the Monte Carlo runs,(C) is the portion of earnings consumed, (r) is the rate of interest paid on debt and (F) is minimum family living expense.

The data required for the Monte Carlo model (Table 2) are from the January 1, 1986, farm finance survey of North Dakota farmers and ranchers. The estimated betas are presented in table 3.

Table 2. Farm Financial Data as of January 1, 1986

Item	Unit	Value
Mean Total Farm Assets[a]	(Dollars)	431,753
Mean Gross Return to Assets[a]	(Percent)	12.2
Mean Interest Rate Paid[a]	(Percent)	13.6
1985 Consumer Price Index[b]	(Percent)	3.4
Mean Real Gross Return to Assets	(Percent)	8.8
Mean Real Interest Rate Paid	(Percent)	10.2
Standard Deviation of Mean Gross Returns to Assets	(Percent)	9.8
Consumption Preference	(Percent)	5.0
Family Living Expense[c]	(Dollars)	17,007

[a]SOURCE: North Dakota Crop and Livestock Reporting Service, February 1986.
[b]SOURCE: Economic Committee of the Council of Economic Advisors, July 1986.
[c]SOURCE: North Dakota Vocational Agriculture Farm Business Management Program, 1985.

Table 3. Beta Coefficients and T-Statistics for Selected Real Rates of Interest and Debt-to-Equity Categories

Interest Rate(%)	Debt-to-Equity Category: 33 Percent		67 Percent		122 Percent	
	Beta(%)	t-value	Beta(%)	t-value	Beta(%)	t-value
0	0.31768	25.28	0.45587	19.75	0.62546	16.43
3	0.30548	10.01	0.65810	34.49	0.90524	33.77
5	0.34177	16.76	0.92422	28.47	1.76895	38.44
8	1.66903	38.49	2.83897	48.47	3.50110	33.13
10.2	5.44108	32.59	5.98953	112.44	5.85656	44.02

Solution of the Control Framework

A constant return on assets (RA) times equity E(t) and debt D(t) less interest rate (r) times debt (D(t)) and family living expenses (F) is used for income (I(t). In equation form,

$$I(t) = RA*E(t) + (RA-r)*D(t) - F. \qquad (9)$$

The equation of farm income and the risk discount function are used to find the solution to the control framework.

Partial derivative with respect to the control variable consumption (C):

$$\frac{dH}{dC} = e^{-h(t,D,E)} I - \lambda I = 0 \qquad (10)$$

Solving for lambda yields:

$$\lambda = e^{-h(t,D,E)} \qquad (11)$$

Partial derivative with respect to the control variable debt:

$$\frac{dH}{dD}=e^{-h(t,D,E)}C(h_D I + I_D + [1-C]I_D = 0,^1 \qquad (12)$$

substituting (10) for lambda and rearranging,

$$C = \frac{I_D}{I\bar{h}_D}. \qquad (13)$$

Partial derivative with respect to the state variable equity (E):

$$\frac{dH}{dE}=e^{-h(t,D,E)}C(h_E I + I_E) + [1-C]I_E = -\dot{\lambda}. \qquad (14)$$

substituting (10) for lambda and rearranging,

$$e^{-h(t,D,E)}[C(h_E I + I_E) + (1-C)I_E] = -\dot{\lambda}. \qquad (15)$$

The expression $-\dot{\lambda}$ is equated with the partial derivative of lambda with respect to time and solving for debt and equity. First, the derivative of lambda with respect to time is:

$$\frac{d}{dt} = \dot{\lambda} = -e^{-h(t,D,E)}h_t. \qquad (16)$$

This expression is multiplied by a negative one and equated with (15) and equation (13) is substituted for C. Then the steady state D/E can be derived. The transversality condition $\lim_{t\to\infty} = 0$ is satisfied as long as $h_t > 0$. From the solution it is apparent that D/E at optimum is constant.

$$\frac{D}{E} = \frac{r+a-RA}{RA-r-\beta} \qquad (17)$$

The risk attitude factor (a) can now be calculated for any specific circumstance. At optimal debt-equity ratio or steady state the risk attitude is measured by (a),

$$a=(RA-r)(1+D/E)-\beta^{*}D/E. \qquad (18)$$

Coefficients were estimated using data from table 2 and the beta (β) values from the Monte Carlo simulation in table 3. The results are presented in table 4.

Table 4. Risk Aversion Coefficients for Selected Real Rate of Interest and Selected Debt-Equity Categories

Interest Rate	Debt-to-Equity Category: 33 Percent	67 Percent	122 Percent
	(percent)		
0	11.6097	14.3405	18.7615
3	7.6154	9.2057	11.7529
5	4.9350	5.6950	6.2528
8	0.4925	-0.5810	-2.5300
10.2	-3.7270	-6.3980	-10.3640

The risk attitude coefficient describes a farmer's net return to his farm resources for a given set of financial returns, cost, and leverage. This return is composed of the expected gross return to assets minus the real rate of interest and a risk premium for solvency.

The farmer's return rises with leverage if his risk adjusted interest rate (real interest rate plus risk premium) is less than his anticipated return to assets. A farmer's aversion to financial risk rises with leverage. The farmer must receive a higher return to offset rising financial risk due to leverage.

However, if the risk adjusted interest rate is greater than anticipated return to assets the net return to farm resources becomes negative. A farmer must be willing to subsidize his operation with outside resources to maintain a certain level of debt.

The results of this analysis describe the behavior of farmers in the 1970's and the early 1980's. The real rate of interest was generally below the rate of returns accumulating to farm assets. The positive gap between returns and interest cost provided the incentive to accumulate debt because of a larger anticipated return. Real rate of interest rose markedly in 1981. Returns to assets became less than interest cost causing considerable financial problems for many farmers.

Endnotes

1. Variables with subscripts are partial derivatives.

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