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Risk Balancing in an Integrated Farm Risk Management Plan

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ABSTRACT

Using optimization techniques in a simulation framework, this study demonstrates the synergy between risk balancing and alternative strategies in effectively reducing risk under changing farm conditions. Highly risk-averse farmers tend to prefer integrated risk-management plans, based on the diversification principle, that yield offsetting combinations of the risk-reducing benefits of most strategies and the profit-generating capacities of the others. The greater appeal of a more diversified plan usually downplays the risk balancing strategy as the farm utilizes credit reserves to implement other production and marketing plans considered essential to overall risk reduction. The farm, however, still realizes overall, though more regulated, reduction in its financial risk position.

Key Words: *business risk, expected utility-mean variance framework, financial risk, multiperiod quadratic programming model, Risk Balancing Hypothesis.*
JEL Classification: Q12, Q14

In the latter half of 1990s, major changes in federal policy towards agriculture included the "freedom to farm" provision of the Farm Bill and the shift from market-based to fixed, decoupled production and price support payments. The impacts of these institutional changes have been aggravated by downturns in commodity prices coinciding with the early years of the transition period. These downward price trends are believed to have resulted from high production and large carry-over stocks due to the bill's "freedom to farm" attribute. With significantly less cushion against market volatility under the new policy environment, farm incomes can become more depressed and unstable. Faced with nagging risks peculiar to the farming environment, farm operators devise various strategic plans for countering the effects of increasing income risk. These risk-management strategies could take the form of preventive production, marketing, insurance, or finance-related schemes that provide farmers with some safety net.

An intuitively appealing strategy for farmers is suggested by the risk-balancing hypothesis. The hypothesis contends that whenever exogenous shocks alter the farm's business risk conditions, expected utility-maximizing farmers might opt to make offsetting adjustments in the firm's financial structure (Gabriel and Baker; Barry; Barry and Robison). Risk balancing, as a risk-management strategy, has the potential to form synergistic relationships with other alternative strategies. Studies have shown that a farm's decision to incur additional debt may be influenced by, among others, its tenure position (Scott; Ellinger and Barry) and marketing activities (Barry and Baker; Turvey and Baker). Barry, Bierlen, and

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Sotomayor find empirical support for both the pecking order theory and a partial adjustment theory of capital structure. This latter theory is consistent with the risk-balancing concept where changes in the farm's business risk conditions will elicit adjustments in the farm's financial structure. These financial adjustments, defined using expected utility concepts, are equivalent to the adjusted target financial structure under the partial adjustment theory.

The implementation of an integrated strategic plan designed to regulate the magnitudes of both business and financial risks is supported by the results of the 1996 Agricultural Resource Management Survey (ARMS) conducted by the USDA (Harwood, *et al.*). The survey reveals that farmers adopt combined strategies. Decisions on the choice of strategies, however, are not homogenous across all farmers. Preferences for certain strategies are influenced by the decision-makers' risk attitudes and their risk-return tradeoffs that could be differentiated due to inherent structural, demographic or financial characteristics.

A related study provides econometric evidence suggesting that many farmers have employed the risk-balancing concept in the past (Escalante and Barry). These farmers are usually older, have higher proportions of rented acreage, and are less financially efficient than those that do not balance risks. The study's results also suggest compatibility between the risk-balancing strategy and such risk-management strategies as enterprise diversification, crop specialization, and marketing activities.

The purpose of this study is to determine the effectiveness of risk balancing as a risk-reducing strategy in a changing risk environment employing optimization techniques in a simulation framework. A multi-period quadratic programming model is developed and applied to a representative Illinois grain farm operating under the modified risk environment created by the 1996 Farm Bill. Two menus of strategic plans that include the risk-balancing strategy will be tested to determine which risk-management strategies form stronger synergistic relationships with risk balancing as a response to risk. The effects of changes in risk attitudes on the optimal menu of strategic plans will also be considered. The following sections provide the study's theoretical background, explain the development of the programming model, and present the results of this study.

Conceptual Framework

The risk-balancing hypothesis contends that exogenous shocks affecting a firm's business risk level could induce the firm to make offsetting adjustments in its financial leverage position.[1] The hypothesis suggests a risk-management strategy that requires abstinence from incurring additional financial obligations whenever business risks are too high. Conversely, upward adjustments in debt levels may be warranted whenever the level of business risk decreases. The underlying motivation for this balancing behavior is the restoration of optimal conditions that have been disrupted by external shocks affecting the firm's business risk condition.

The risk-balancing hypothesis can be derived under an expected utility-mean-variance framework.[2] The less structured, single proprietorship organization of most farm businesses provides greater appeal to the expected utility approach to capital structure theory that establishes the influence of the magnitude of risk and the decision-maker's risk attitude on farm leverage decisions. In this stochastic approach involving random payoffs, the decision-maker's preferences over strategies involving the choice variable(s) can be represented by a generalized mean-variance approximation to expected utility. Earlier studies have shown that a consistent ranking of alternatives under two-moment decision and expected utility models is possible under cer-

[1] For simplicity, *financial leverage* shall be used in this study to pertain only to debt financing. The farm's leasing contracts, though legitimately considered as another form of leveraging, are treated separately.

[2] Another approach is based on the analysis of a firm's equilibrium conditions and derives the additive (Gabriel and Baker) and multiplicative (Barry) relationships between business and financial risks. This method and the one used in this study are equivalent approaches and differ only in measurement concepts.

tain restrictions on the utility functional form and the random variable's probability distribution. Several studies have identified quadratic preferences and a normally distributed random variable as the prerequisite, yet implausible, conditions (Tobin; Feldstein; Hanoch and Levy; Markowitz). Freund explored an alternative outside the quadratic utility function by considering the negative exponential utility function. He has shown that this function, along with a normally distributed random variable, can yield the same decision problem statement as the others have established. Meyer further generalized the applicability of mean-variance analysis by developing a general economic decision model. His approach demonstrates the equivalence of preference orderings under the two-moment decision and expected utility maximization models using the location and scale parameter condition.

Freund's results have been more prominently used in studies that prescribe an optimal capital structure level for farm enterprises (Barry, Baker and Sanint; Collins; Featherstone, *et al.*). Under this approach, a firm's optimal leverage model starts with the following decision problem:

$$(1) \quad \underset{\delta}{\text{Max}}\ E(U(W)) = E(r_e) - 0.5\rho\sigma_e^2$$

where **E(U(W))** is the expected utility of wealth, $\mathbf{E(r_e)}$ is the expected (or the mean) rate of return on equity, σ_E^2 is the variance of the rate of return on equity and ρ is either the coefficient of absolute risk aversion (Freund) or its relative measure counterpart (Pulley).[3]

The solution to the optimal leverage problem can be obtained from the model's first-order conditions (FOC):

$$(2) \quad \delta^* = 1 - \frac{\sigma_a^2\rho}{\bar{r}_a - i}$$

where the choice variable δ is the firm's leverage or debt-to-asset ratio, $\bar{r}_a$ is the rate of return on total assets, σ_a^2 is the variance of the rate of return on assets, and i is the cost of borrowing.

The risk-balancing hypothesis can be verified using comparative static analysis. Calculating the partial derivatives of equation (2) with respect to the mean and variance of the rate of return on assets (Collins):

$$(3) \quad \frac{\partial\delta^*}{\partial\sigma_a^2} = \frac{\rho}{\bar{r}_a - i} \leq 0 \qquad \text{if } \bar{r}_a \geq i;$$

$$(4) \quad \frac{\partial\delta^*}{\partial\bar{r}_a} = \frac{\rho\sigma_a^2}{(\bar{r}_a - i)^2} \geq 0 \quad \text{if } \bar{r}_a \geq i.$$

These results confirm the contention that exogenous shocks aimed at reducing the level of business risk by pressuring (separately or simultaneously) the mean and variance of the rate of return of assets to increase and decrease, respectively, could induce an increase in the firm's leverage position. Conversely, movements in these business risk variables to the opposite direction (thereby increasing the coefficient of variation) could result in a decrease in the firm's debt level.

The Simulation-Optimization Framework

This analytical framework is designed to determine the effectiveness of the risk-balancing strategy in reducing risk under an integrated risk-management strategic approach. Different iterations of the model consider various combinations of risk-management strategies applied to different levels of risk aversion in order to determine the marginal effects of the respective strategies on the farm's risk position. Moreover, sensitivity analyses were conducted to explore the influence on business and financial decisions of increasing the amount of risk in the programming model and then specifying a higher initial level of indebtedness.

The Optimization Framework

This study will use the quadratic programming (QP) model developed by Markowitz, which

[3] The objective function is parameterized using the following definitions for the expected return and variance of the rate of return on equity: $\bar{r}_e = \bar{r}_a P_a - iP_i$; $\sigma_e^2 = \sigma_a^2 P_a^2$ where P_a and P_i are the proportions invested in risky (total) assets and risk-free asset, respectively.

is equivalent to Freund's formulation, represented by the following matrix formulation:

$$\max_{X} U'X - 0.5\Omega X'\sigma X$$

$$\text{Subject to:} \quad AX \geq, \leq B, \qquad X \geq 0.$$

In the above notation, X is a matrix of activity levels, U is a matrix of returns associated with each activity level, Ω is the risk-aversion parameter, σ is the variance-covariance matrix, A is the matrix of technical coefficients and B is the matrix of resource limits.

The objective of this QP framework is the maximization of expected utility of an outcome variable. Under this framework, activity levels (X) are chosen based on a decision rule that minimizes the variance given an expected level of the outcome variable. The objective function has two components: a linear and a quadratic component. The quadratic portion introduces a risk dimension through the risk-aversion parameter (ρ) and the magnitude of risk associated with certain activity levels captured in the variance-covariance matrix (Ω). The linear portion accounts for the net changes in final wealth regardless of risk considerations. Under conditions of risk neutrality, therefore, the model takes on a linear form since the decision-maker's zero risk-aversion level cancels out the quadratic term.

This study assumes a five-year planning horizon and considers final wealth as its outcome variable. The magnitude of this variable is determined by the value of farmland, equipment, and the cash balance at the end of the planning horizon with deductions for the remaining principal balances for all financing incurred during the planning period.

The model's empirical properties resemble previous multi-period programming models (Barry and Willmann; Gwinn, Barry, and Ellinger) that define a large matrix of activities and constraints where sub-matrices along the main diagonal elements correspond to the time periods and off-diagonal elements provide information on transfers among the model's activities. The major activities include production and marketing, land and machinery investments, related borrowing alternatives, farmland leasing under share rent and cash rent conditions, short-term borrowing, off-farm investments, liquidity management, and consumption and taxation. The constraints establish limits on land availability, machinery requirements, off-farm investments, consumption and borrowing levels.

To capture the timing of certain cash flows within a particular year, the model has two sub-periods in its cash transfer equations. The farm's borrowing activities depend largely on the levels of its credit reserves. Lenders determine a farm's borrowing capacity based on the quality of collateral available and the farm business income and cash generating potential. The unused portions of farm's credit reserves represent the amount that lenders are still willing to lend to the farm under present financial conditions. Thus credit reserves provide important information on alternative sources of liquidity for the farm to utilize whenever unexpected changes in business plans require additional fund inflows to the business. The levels of credit reserves are determined by liquidity changes in the balance sheet, income expected in the coming year, changes in debt level, and changes in asset values (Gwinn, Barry and Ellinger).

The Simulation Procedure

Different scenarios of farm business-decision-making conditions will be simulated in this analysis by introducing several versions of the QP model. The analysis starts with a base case where the attributes of a representative farm are modeled, including provisions for the implementation of a risk-balancing strategy. Subsequently, the base case is modified with the introduction of risk-management strategies expected to complement or supplement the risk-balancing strategy.

The base case actually reflects some additional risk-management alternatives that include modest crop diversification (as farmers generally regard the combination of corn and soybeans as diversification, albeit limited, in response to business risks), off-farm investments, insurance (crop, liability and other forms), holdings of liquidity, restraints on farm size, and continued participation in government programs. The base case is developed as a cash-leasing farm, although share leasing is dominant among Illinois farmers. The growing importance of cash leasing and the reduced value farmers associate with the risk-reduction benefits of share leasing (Barry, *et al.*) warrant a separate treatment for the share leasing strategy.

This analysis explores the compatibility of two other risk-management strategies with the risk-balancing strategy: share leasing of farmland and entering into forward contracts as a form of marketing strategy. These two strategies are introduced to expand the risk-management strategic profile of the base farm that is expected to balance business and financial risks as well as engage in cash leasing and invest in non-farm assets. These strategies are standard practices of the typical North Central Illinois grain farm. Strategies to further diversify crop production (beyond the corn-soybean combination) and farm enterprises were not included in this model based on the findings of a related study (Escalante and Barry) that indicate the compatibility of crop specialization with the risk-balancing strategy. Moreover, another study (Barry, Escalante and Bard) suggests the lack of significantly extensive enterprise diversification as a risk-reducing strategy for North Central grain farms. Thus, this analysis will look at two scenarios with varied menus of risk-management strategies:[4]

- *The Base Farm* employs the standard strategies (debt financing, cash leasing, off-farm investments, and others as explained earlier); and
- *The Complete Farm* enters into both share leasing and forward (marketing) contracts in addition to the set of standard strategies.

These menus of strategic plans will be evaluated by comparing the relative variability of net worth "solution" levels. The preferred plan is the one that yields the lowest level of relative variability. In addition to this decision criterion, the resulting profitability and liquidity positions defined by the prescribed solutions of the models will also be considered.

The Representative Farm Conditions

The simulation-optimization analysis will be applied to a representative grain farm whose conditions define the initial resource, financial condition, and operating levels for the two farm models considered in this study. In the simulation procedures, each model will then either restrict or expand the production, marketing, and financing alternatives for the representative farm.

This model's representative farm is an Illinois grain farm operating in the North Central region of the state that produces corn and soybeans in a 50/50 rotation.[5] The financial and demographic attributes of this study's case farm represent the average farm characteristics and conditions of a subset of 1004 grain farms operating in the North Central region of the state that maintained certified usable financial records under the Illinois Farm Business Farm Management (FBFM) system in 1998. During this year, the average NC grain farm was operating a total of 862 tillable acres of farmland—153 acres owned, 241 acres cash rented, and 468 acres share rented.

As of December 31, 1998, the farm's assets had a fair market value of $1,019,959, which

[4] Two additional models were actually considered in the original study that introduce the share leasing and forward contracting options one at a time (Escalante). However, identical results for the forward contracting and base farm models were obtained in the risk-neutral case as both models recognize the additional costs of the forward contracting option. As risk aversion was introduced, the models' results only differed slightly from each other. The results noted in the share leasing and complete farm models also provided the same slight transition in diversity and risk efficiency of production plans. Hence, this analysis focuses only on the base and complete farm models.

[5] The Illinois FBFM system defines grain farms as those where the value of the feed fed was less than 40 percent of the crop returns and where the value of feed fed to dairy or poultry was not more than one-sixth of the crop returns.

includes $209,253 worth of machinery and equipment and farmland value of $376,496. The farm's assets were financed by current ($130,561), intermediate ($43,775) and long-term ($108,117) debts as well as the farm's equity funds ($737,507). Based on these figures, the firm's debt-to asset ratio is 0.28.

The farm operator is 49 years of age and belongs to a family of three. The family's annual living expenditures in 1998 were $31,729, excluding income taxes. That year, the farm generated a net farm income before tax of $20,171 plus a net non-farm income before tax of $13,180.

The macroeconomic projections used in this analysis were based on the Food and Agricultural Policy Research Institute's (FAPRI) outlook for U.S. agriculture during the five-year planning period (1999–2003). Its macroeconomic projections reflect a modest economic growth for the world economy due to short-term difficulties arising from the Asian financial crisis and the devaluation of the Russian ruble and Brazilian real. This lower world economic activity is expected to lead to a decline in the demand for agricultural products from the U.S. that manifests itself as a downward pressure for prices of agricultural commodities.

FAPRI expects inflation (measured by changes in the Consumer Price Index, CPI) to be low while Gross Domestic Product (GDP) growth declines a bit during the same five-year period. The three-month T-Bill yield settles at 4.5 percent during the last three years of the five-year planning period.

The other data specifications of the programming model were obtained from various sources. Data on yield and production costs were obtained from estimates provided in the *1998 Summary of Illinois Business Records* prepared by University of Illinois Extension. The Illinois Farm Business Farm Management (FBFM) system, the Illinois Agricultural Statistics Service (IASS), and the Economic Research Service of the United States Department of Agriculture (USDA-ERS) provided the data on land prices, cash rents, wages, machinery costs, and interest rates for operating, intermediate, and long-term loans.

Declining Government Contract Payments

Imbedded in the calculation of projected crop revenues are the declining contract payments for corn production. As mandated by the 1996 Farm Bill, federal disbursements for contract payments for corn production will continue to decline until the expiration of the FAIR Act in 2002. The program payments are "decoupled" which means that the size of payment is no longer dependent on the amount of crop production or the level of market price (Knutson, *et al.*). Given the fixed amount of aggregate government payments, the payment rate per acre will then depend on the number of acres enrolled in the program and will be further reduced by the provision that sets a maximum coverage of 85 percent of the enrolled acreage. Specifically, the payment rate for each unit of crop is calculated by dividing total expenditure limit by the product of total crop contract acreage, 85 percent and the stipulated farm program yield (Knutson, *et al.*). This study uses FAPRI estimates of contract payment levels for corn obtained from projected corn contract acreage and USDA data on the total expenditure limits and farm program yield. While the FAIR Act will expire in 2002, FAPRI's projections assumed that support would continue beyond the seven-year transition period at the 2002 levels.

Sources of Risk

The variance-covariance matrix captures the various sources of risk in this programming model. Historical data on the decision variables are analyzed in terms of their variability as well as the correlation between variables that altogether define the matrix entries. The historical values used in the derivation of the complete variance-covariance matrix are summarized in Table 1.

The base farm model has seven sources of risk: land values (ACBUY), equipment costs (EQBUY), agricultural real estate interest rates (FINLAND), equipment loan interest rates (MEDCRED), operating loan interest rates (SHTCRED), gross margins per cash rented acre (ACRENT), and gross margins per acre

Table 1. Historical Values of the Decision Variables Used in the Variance Covariance Matrix, 1985–1998

Year	ACBY[1] ($)	EQBY[2] ($)	FINLND[2] (Percent)	MEDCR[4] (Percent)	SHTCR[5] (Percent)	ACRNT[6] ($)	ACPRD[7] ($)	SHLSE[8] ($)	CTRCT[9] ($)
1985	1,381	224	9.57	13.70	13.00	113.25	223.35	111.68	239.55
1986	1,232	208	9.39	12.20	11.50	38.39	138.29	69.15	153.24
1987	1,149	192	9.62	11.50	10.80	116.71	202.41	101.20	136.59
1988	1,262	182	9.78	11.70	11.20	22.30	111.50	55.75	107.90
1989	1,388	174	10.02	12.80	12.60	120.47	214.77	107.38	217.12
1990	1,405	169	10.11	12.30	11.70	97.79	197.19	98.59	213.35
1991	1,459	166	9.36	11.30	10.40	82.31	183.21	91.61	174.99
1992	1,536	161	8.51	9.30	8.80	110.53	213.83	106.92	241.87
1993	1,548	155	8.00	8.70	8.10	141.77	244.67	122.34	200.38
1994	1,694	151	8.41	8.60	8.40	135.35	234.85	117.43	246.71
1995	1,863	147	8.74	10.30	10.00	182.32	285.02	142.51	163.17
1996	2,064	143	8.83	9.70	8.60	161.03	267.03	133.51	280.55
1997	2,210	139	8.52	9.80	9.90	99.77	208.77	104.38	203.32
1998	2,380	135	8.27	9.30	9.60	25.11	136.11	68.05	186.15
Mean	1,612.2	167.57	9.08	10.80	10.33	103.58	204.36	102.18	197.49
Stdev	380.53	26.38	0.69	1.63	1.55	48.49	49.39	24.70	47.43
CV	0.2360	0.1574	0.0762	0.1506	0.1504	0.4681	0.2417	0.2417	0.2402

[1] Illinois farmland values per acre.
[2] Durable equipment index, 1948 = 100.
[3] Agricultural real estate loan interest rates.
[4] Agricultural non-real estate interest rates for equipment loans.
[5] Agricultural non-real estate interest rates for operating capital loans.
[6] Gross margins per cash rented acre.
[7] Gross margins per acre at open market prices.
[8] Gross margins per (50-50) share rented acre.
[9] Gross Margins per acre under forward contract market prices.

based on open market prices, in the absence of forward contracts or hedges (ACPROD). Two additional sources of risk are added to the complete farm model: share leasing risk, represented by gross margins per share leased acre (SHLEASE), and forward contracting risk, represented by gross margins calculated using forward contract prices (CNTRCT).

This study analyzes these variables' contributions to the amount of risk in the model based on their historical values over a 14-year period, 1985 to 1998. Historical land values and cash rent levels in Illinois were obtained from the annual summaries prepared by the IASS. USDA-ERS provides information on durable equipment indexes (based on 1948 prices) and average agricultural real estate loan interest rates during the 14-year period.

The summary in Table 1 provides some important implications. Share leasing and forward (marketing) contracts produce gross revenues that are less volatile than those obtained under the base case scenario. Barry, *et al.* have shown that share leasing arrangements indeed could reduce risk by the proportion of the landlord's share in the contract. In this case, the variability of gross margins is reduced by 50 percent relative to that of cash leasing due to the 50–50 share leasing arrangement.

Forward contracts are also regarded as risk reducing, but costly, marketing schemes. Forward contracts reduce price risk by transferring some of the risk to the buyer with whom the farmer enters a contract. This contract then requires the payment of a premium to the new risk bearer, otherwise he/she would not be willing to enter into such an arrangement. Townsend and Brorsen confirm this expectation by establishing that the cost of forward contracting hard red winter wheat is indeed not zero. Based on annualized weekly data on harvest delivery forward contract and spot prices in Illinois, forward contracting results in relatively lower gross margins than open market operations with a slight reduction in relative variability (Table 1). The downplaying of the variability effect can be attributed to the aggregation procedure involved in annualizing forward contract prices.

The variance and covariance terms are derived using both historical time-series data and expected values of the choice variables during the planning period (Gwinn, Barry and Ellinger). This approach, which adjusts risk terms associated with assets and liabilities to correspond to end-of-period values, is consistent with the model's goal of optimizing the value of final wealth at the end of the planning period. The derivation starts with the calculated coefficient of variation (CV) measures for the choice variables in Table 1. Annual standard deviations for each variable for each year in the planning period are then calculated by holding the historic CV level constant and considering the projected annual values in the five-year period. Thus a variable's standard deviation adjusts to its expected level while its relative variability remains unchanged from year to year in the planning period.

The other component required in the calculation of covariance entries is the degree and direction of the correlation relationship between variables. Table 2 summarizes these measures and provides information on the statistical significance of the correlation coefficients. Thomas, *et al.* suggest that insignificantly correlated variables may be disregarded as sources of risk since their resulting covariance estimate will not significantly affect the optimal solution to the problem. Gwinn, Barry, and Ellinger have argued for the retention of these uncorrelated pairs of variables by pointing out that "a zero correlation is only one point along the -1 to $+1$ range of admissible correlation values and therefore has no more stature than any other correlation value (p. 46)." This study, therefore, retains all variables.

The estimated signs of the covariance entries among assets (and income-generating activities) and among liabilities (and cost-generating activities) will be unchanged when entered into the matrix. Lower correlations are more preferred among assets or among liabilities and thus would potentially lower total risk in the model. On the other hand, higher correlations between assets and liabilities result in greater risk reduction. In this case the opposite of their estimated signs are entered into the model to account for the reversal of

Table 2. Matrix of Correlation Coefficients Between Decision Variables and Probability Values (Prob > |R|)

	ACBY	EQBY	ACPRD	FINLND	SHLSE	CTRCT	ACRNT	MEDCR	SHTCR
ACBY	1								
EQBY	−0.8020								
	(0.001)	1							
ACPRD	0.2231	−0.2995	1						
	(0.443)	(0.298)							
FINLND	−0.6689	0.6507	−0.3159	1					
	(0.009)	(0.012)	(0.271)						
SHLSE	0.2230	−0.2994	1.000	−0.3159	1				
	(0.444)	(0.298)	(0.000)	(0.271)					
CTRCT	0.3859	−0.2785	0.5960	−0.2856	0.5960	1			
	(0.173)	(0.335)	(0.025)	(0.322)	(0.025)				
ACRNT	0.1215	−0.2579	0.9888	−0.2390	0.9888	0.5193	1		
	(0.679)	(0.373)	(0.000)	(0.411)	(0.000)	(0.057)			
MEDCR	−0.6191	0.8104	−0.2874	0.9051	−0.2874	−0.2613	−0.2495	1	
	(0.018)	(0.000)	(0.319)	(0.000)	(0.319)	(0.367)	(0.390)		
SHTCR	−0.5164	0.7393	−0.3472	0.8620	−0.3472	−0.3090	−0.3173	0.9726	1
	(0.059)	(0.003)	(0.224)	(0.000)	(0.224)	(0.282)	(0.269)	(0.000)	

Table 3. Farm Production Plans and Profitability Conditions Under Different Levels of Risk Aversion, Five-Year Averages

Activity/Variable	Risk Neutral	Low	Moderate	High
Base Farm Model				
Farm Size (Acres)	2,135.10	1,271.09	1,001.99	451.46
Cash Rented Acres	1,982.10	1,115.77	824.40	257.59
Land Purchases (Acres)	0	11.60	13.95	20.63
Equipment Purchases ($)	118,829	39,517	8,826	0
Net Farm Income ($)	60,318	54,456	50,664	26,206
Off-Farm Income ($)	0	0	0	399
Return on Assets (%)	5.44	5.62	5.48	3.22
Return on Equity (%)	7.44	6.81	6.39	3.66
Complete Farm Model				
Farm Size (Acres)	4,630.00	2,051.64	891.97	436.69
Cash Rented Acres	0	0	0	2.71
Share Rented Acres	4,477.00	1,854.51	655.72	226.94
% Forward Contracted	0	0	0	36.46
Land Purchases (Acres)	0	15.13	21.88	28.62
Equipment Purchases ($)	304,514	83,108	50	0
Net Farm Income ($)	127,320	81,522	55,764	26,792
Off-Farm Income ($)	0	0	0	482
Return on Assets (%)	7.49	6.95	5.98	3.28
Return on Equity (%)	12.82	9.31	6.87	3.72

the preferred correlation relationship between these activities. In terms of implications for risk efficiency, among the preferred pairs of variables are the negative correlations between equipment costs (EQBUY) and such variables as land values (ACBUY) and gross margins at open market prices (ACPROD) as well as its positive correlations with equipment loan interest rates (MEDCRED) and operating loan interest rates (SHTCRED).

Levels of Risk Aversion

Previous studies in risk analysis establish the limits for allowable levels of the coefficient of absolute risk aversion. Lemieux, Richardson and Nixon utilized values for the risk-aversion parameter that range from −1E–05 to 1.5E–05. The simulation model in the Gwinn, Barry, Ellinger study utilized risk-aversion coefficients that were within the same range.

The values of the risk-aversion parameter to be used in this study are consistent with the levels used in those previous studies. Aside from the risk-neutral case, this study will consider three classes of the risk-averse decision maker (low, moderate, and high levels of risk aversion) to verify the effects of risk aversion on the choice of optimal plans. The low risk-aversion category considers parameter values ranging from 4E–11 to 3E–08 to capture decisions of farmers that are almost risk neutral. The intermediate case of a moderately risk-averse farmer is assumed to have risk-aversion coefficients ranging from 4E–08 to 3E–06. Finally, the case of a highly risk-averse farmer is associated with risk-aversion parameter values from 4E–06 to 4E–05.

Programming Results

Table 3 reports the farm production plans and profitability conditions for the two farm scenarios under different levels of risk aversion as prescribed by the General Algebraic Modeling System (GAMS) programs. Generally, lower farm incomes tend to be associated with higher levels of risk aversion in the farm models. This ties up with the trends in farm sizes where highly risk-averse farmers tend to operate smaller farms, thus limiting the farm's potential for greater absolute levels of profitability. These results are consistent with the findings of other studies employing optimization techniques (Gwinn, Barry and Ellinger).

The Risk-Neutral Solutions

In the absence of risk considerations in the risk-neutral case, the solutions suggest that an optimizing risk-neutral farm would prefer share leasing to the cash leasing option. This optimal decision is not influenced by profitability considerations since the farm normally pays a higher share rent and cash rented land usually generates higher net margins.[6] The preference for share rented land reflects liquidity differences between the two production schemes. Under cash renting, the farm's disbursements in the first cash transfer period cover the full amount of production costs plus half of the cash rents payable to the landlord. In contrast, under share leasing the farm disburses only its share (half) of the production costs in the same period. Under both cases, the farm recovers returns in the second transfer period. In all models, the GAMS solutions produce binding first cash transfer constraints. This suggests that at the first cash transfer period the farm is constrained to expand its size under a production plan that involves cash renting given its liquidity position and financial resource endowments. In contrast, under share leasing the farm is able to expand considerably as long as it could afford the cash operational requirements in the first cash transfer period.

The results for the risk-neutral case confirm that the share leasing strategy indeed expands the farm's income potential. The Complete Farm model had larger farm acreage, about twice the size of the solution to the Base Farm model.

Increasing Risk Aversion

Across all levels of risk aversion, the rates of asset and equity returns follow the same trend observed in the absolute income levels across both farm models. The Complete Farm model registers higher profitability measures than the Base Farm model in both percentage (returns) and absolute terms. The Complete Farm model also tends to have wider margins between the returns measures in the low- and high-risk aversion classes. This margin usually ranges from 3.7 percent to 6.0 percent, compared to a range of 2.4 percent to 3.2 percent in the Base Farm model. Income from off-farm investments normally shows up in the optimal portfolio only under conditions of high levels of risk aversion.

Farm size becomes smaller as the farmer becomes increasingly risk averse. The Complete Farm model has a wider size gap between its farm size solutions in the two extreme risk-aversion classes. The model experiences 78.72 percent shrinkage in farm size as the solution in the low risk aversion class of 2052 acres is reduced to 437 acres in the high-risk aversion class. The shrinkage rate in the Base Farm model is relatively lower at 64 percent.

In the absence of the share leasing option, the farm starts to use less of cash rented farmland as the level of risk aversion increases. As the share leasing option is introduced, cash renting is not included in the production plan for the low and moderate risk-aversion categories. This activity shows up very minimally (around three acres) in the high-risk aversion category. All these results confirm the dominance of share over cash leasing in terms of both risk and liquidity (cash flow structure) considerations.

The inferior return structure of the forward contracting option is validated by the exclusion of the strategy in the optimal production plans of the Complete Farm model at the low and moderate risk-aversion categories. The model's high-risk aversion class, however, starts to recognize the risk reducing benefits of the strategy by allocating 36.46 percent of farm production on average to forward contracts.

Land purchases tend to increase modestly as risk aversion increases. The attraction to increase land acquisition activities to the risk-

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[6] In 2000, the farm realizes estimated net margins of \$80.32 per acre under a 50–50 share leasing arrangement and \$92.74 per acre under a cash-leasing contract (Escalante, p. 78, 74).

Table 4. Debt-Related Measures Under Different Risk-Aversion Levels, Five-Years Averages

Variable	Risk Neutral	Low	Moderate	High
Base Farm Model				
Unused ST Credit Reserves (%)	50.56	91.57	94.39	92.39
Unused IT Credit Reserves (%)	14.40	54.39	71.16	80.60
Unused LT Credit Reserves (%)	80.32	85.09	86.89	88.53
Liquidity Ratio	2.50	3.88	4.17	3.27
Debt-to-Asset Ratio	0.2694	0.1759	0.1390	0.1170
Complete Farm Model				
Unused ST Credit Reserves (%)	34.50	80.51	92.76	87.91
Unused IT Credit Reserves (%)	7.25	39.38	80.53	80.45
Unused LT Credit Reserves (%)	77.01	86.34	89.89	89.23
Liquidity Ratio	1.34	1.90	2.52	2.30
Debt-to-Asset Ratio	0.4141	0.2518	0.1234	0.1169

averse decision-maker lies in the lower historical relative variability of land values compared to the other production alternatives (Table 1).

Risk-Balancing Solutions

The farm's borrowing decisions under different levels of risk aversion and menus of risk-management strategies are summarized in Table 4. The results indicate the farm's increasing tendency to regulate its financial risk position, translated as a risk-balancing strategy, as risk aversion becomes greater. This is demonstrated by the declining debt-to-asset (D/A) ratios as the risk-aversion class becomes higher. The Complete Farm model registers a wider gap in the leverage positions of the two extreme risk-aversion classes. From a D/A ratio of 0.4141 in the risk-neutral case, the figure drops to 0.1169 for the class of highly risk-averse decision makers.

Across all levels of risk aversion the transition from the risk neutral to the low-risk-aversion case usually entails a significant drop in the leverage ratios. At this point the influence of risk and risk attitudes on the solutions is primarily reflected in farm size adjustments with very modest signs of diversification of farm production plans, usually a few incremental acres of acquired land. Thus, the farm's leverage ratio freely decreases to regulate the resulting financial risk conditions. Under high levels of risk aversion, however, the farm's tendency to balance risks is tempered by the pressure to increase diversification of production plans, especially as the risk-reducing effects of non-profitable strategic alternatives such as forward contracting are starting to be recognized. Thus, the transition to high levels of risk aversion does not entail a reduction in leverage ratios as significant as that observed in the first levels of transition. In this case, reductions in debt-to-asset ratios are contemplated along with tendencies to reduce overall farm size and diversify allocation of farm production or marketing among other alternative plans.

Utilization rates of long-term credit reserves remain about the same in both models. The Base Farm model tends to have a higher proportion of unused short-term credit reserves than the Complete Farm model. This could be due to the smaller farm size solutions in the Base Farm model that require smaller operational cash outlays.

Final Net Worth Solutions

Table 5 presents a summary of the levels of the farm's final net worth under different levels of risk aversion for each farm model. The summary also includes the corresponding levels of risk (presented in terms of standard deviation measures) as determined by the variance-covariance matrix and the solution levels for the various decision variables.

In both models the results indicate declin-

Table 5. Final Net Worth and Risk Levels Under Different Risk-Aversion Levels ($)

Variable	Risk Neutral	Low	Moderate	High
Base Farm Model				
Final Net Worth	865,590	836,280	817,320	695,030
Standard Deviation	658,988	374,561	336,452	101,622
Coefficient of Variation	0.7613	0.4479	0.4117	0.1462
Complete Farm Model				
Final Net Worth	1,200,600	971,610	842,820	697,960
Standard Deviation	967,088	431,837	233,150	84,976
Coefficient of Variation	0.8055	0.4445	0.2766	0.1217

ing levels of final net worth as the decision-maker becomes increasingly risk averse. Consistent with the risk efficiency paradigm, the standard deviation measure of risk also declines with the final net worth values. The more conservative business plans often employed by the class of highly risk-averse farmers require smaller farm operations that result in relatively lower returns. This ultimately is translated to smaller increments in the retained earnings portion of the farm's net worth. Such calculated business decisions therefore ensure greater stability in the farm's net worth positions across the planning horizon.

In terms of measures of relative variability (CV), the Complete Farm model's CVs for the low-, moderate-, and high-risk aversion categories dominate the results from the other farm model. Thus, the risk-reducing benefits from both share leasing and forward contracting (as prescribed for the Complete Farm model) can collectively bring down the level of relative variability of ending net worth levels.

Increase in Risk

The analysis is extended by introducing an arbitrary increase in the level of risk in the programming model. This analysis focuses on the Complete Farm model that offers more opportunities for substitution and/or complementation of a larger number of risk-management alternatives.

In this analysis, a 50-percent increase in the historical CV levels is assumed. This change directly affects the levels of the standard deviations of the decision variables. The results of this analysis are compiled in Table 6 for the three classes of risk-averse decision makers. The results indicate a downsizing of farm operations in response to increases in risk, especially for the high-risk-averse decision maker. Before the increase in risk this class of farmers was operating 437 acres (Table 3). This size is reduced to 370 acres as risk is increased by 50 percent. Forward contracting starts to show up early in the solutions as the moderate category already starts to consider to forward contract 10.3 percent of farm production.

Leverage conditions gradually improve for the first class of risk aversion as the D/A ratio decreases from 0.2518 (the level before any change in risk, Table 4) to 0.1885. The third class of risk aversion also exhibited the same trend (from 0.1169 to 0.1153). Again, the magnitude of these risk-balancing adjustments depend on the farm's inclination to reduce size and widely allocate production and marketing among alternative plans as greater risk aversion starts to weigh the risk-reducing benefits of all strategic options.

The utilization rates of credit reserves as well as liquidity positions remain fairly unchanged under the new risk conditions. The levels of ending net worth, however, decrease as a result of the smaller farm sizes prescribed by the solutions.

Increase in Initial Level of Indebtedness

Another sensitivity analysis involves the modification of the farm's initial level of indebtedness to determine how production plans and risk balancing are altered in response to ad-

Table 6. 50% Increase in Risk, Programming Results for the Complete Farm Model Across Different Classes of Risk-Averse Farmers

Variable	Risk Neutral	Low	Moderate	High
Farm Size (acres)	4,630.00	1,408.11	891.82	369.75
Cash Rented Acres	0	0	0	0
Share Rented Acres	4,477.00	1,188.66	655.69	164.01
Land Purchases (Acres)	0	19.17	21.84	52.74
% Forward Contracted	0	0	10.30	37.90
Net Farm Income ($)	127,320	67,888	55,676	22,428
Off-Farm Income ($)	0	0	0	590
Final Net Worth ($)	1,200,600	903,440	842,380	676,140
Std Dev of Net Worth	967,088	335,014	245,993	83,944
CV of Net Worth ($)	0.8055	0.3708	0.2920	0.1242
Liquidity Ratio	1.34	2.09	2.53	2.31
Debt-Asset Ratio	0.4141	0.1885	0.1234	0.1153
Unused ST Credit Reserves (%)	34.50	85.95	92.76	86.37
Unused IT Credit Reserves (%)	7.25	55.00	80.54	80.31
Unused LT Credit Reserves (%)	77.01	88.46	89.89	89.06
ROA (%)	7.49	6.53	6.00	2.79
ROE (%)	12.82	8.07	6.86	3.17

ditional sources of financial strain. This analysis is again applied to the Complete Farm model using the same three classes of risk aversion.

The farm's initial D/A ratio of 0.28 (in 1998) is doubled to 0.56. This adjusts the initial liabilities level to $566,306 and initial equity level to $454,354. The resulting programming solutions under this scenario are presented in Table 7.

Only the risk-neutral case demonstrated the downsizing response to the higher level of initial debt. The other risk-aversion classes reacted otherwise. Compared to the original sce-

Table 7. 100% Increase in Initial Debt-Asset Ratio, Programming Results for the Complete Farm Model Across Different Classes of Risk-Averse Farmers

Variable	Risk Neutral	Low	Moderate	High
Farm Size (acres)	3,396.29	2,051.63	891.98	417.45
Cash Rented Acres	0	0	0	30.44
Share Rented Acres	3,243.29	1,875.43	676.94	234.01
Land Purchases (Acres)	0	6.88	22.72	0
% Forward Contracted	0	0	8.47	36.73
Net Farm Income ($)	103,336	98,838	73,070	46,792
Off-Farm Income ($)	0	0	23	1,076
Final Net Worth ($)	935,030	775,740	646,900	485,510
Std Dev of Net Worth	739,796	534,786	242,922	115,390
CV of Net Worth ($)	0.7912	0.6894	0.3755	0.2377
Liquidity Ratio	1.3501	1.4669	1.4471	2.5905
Debt-Asset Ratio	0.4269	0.3618	0.2516	0.2514
Unused ST Credit Reserves (%)	37.65	63.01	70.03	66.42
Unused IT Credit Reserves (%)	9.25	26.92	59.80	58.54
Unused LT Credit Reserves (%)	63.04	63.54	71.64	60.77
ROA (%)	9.58	9.16	8.28	6.05
ROE (%)	15.19	14.58	11.60	8.43

nario, farm size remains unchanged for the two lower classes of risk aversion. A slight downsizing is observed in the third class (417 acres from the original level of 437 acres) but this change is not as large as those realized in the previous sensitivity analyses involving increases in the magnitude of risk.

As in the other sensitivity analyses, allocations for forward contracting by the moderate-risk-aversion class depart from the trend in the original scenario. Also, the land purchase decisions in this scenario deviate from the earlier trends. No land is purchased by the highly risk-averse farmer and additional cash rented acreage is used. These decisions are most likely based on liquidity (cash flow) considerations. The financing measures provide the important clues. The programming solutions here yield higher D/A ratios (0.2514 to 0.3618) and proportions of unused credit reserves that are significantly lower than the original levels reported in Table 4 (26.92 percent to 71.64 percent here compared to 39.38 percent to 92.76 percent in Table 4).

Based on the results of both sensitivity analyses, decisions by risk-averse farmers generally lean towards downsizing of operations in response to increases in business risk while greater financial stress that may be due, for example, to high levels of initial indebtedness could elicit changes in portfolio composition (shifting of alternative production and marketing plans) without necessarily adjusting the size of farm operations. In either of these situations, the expected utility maximizing decision-maker makes prudent financial decisions that minimize risk for given levels of expected returns. As in the previous cases, these downward financial adjustments designed to balance risks are tempered by the highly risk-averse farmer's inclination towards greater diversification of production and marketing plans.

Concluding Comments

The results of this study reinforce the expected synergy between risk balancing and alternative risk-management strategies. Under both risk neutrality and increasing degrees of risk aversion, a farmer's optimal strategic plan contains a menu of strategies that involves risk balancing demonstrated by consistent downward adjustments in the farm's leverage position and such compatible strategies as cash leasing, share leasing, and forward contracting. The risk-neutral solutions, which do not take into account risk and the farmer's risk attitudes, recognize the expansion possibilities under the Complete Farm model arising from the favorable cash flow structure of share renting activities. Across all levels of risk aversion the Complete Farm model solutions are dominant in terms of income and returns levels after external financing costs are accounted for while the results for the Base Farm model indicate stronger liquidity position.

As the farmer becomes increasingly risk averse, the Complete Farm model offers a more diversified production portfolio that effectively results in the least variability of net worth while sustaining its strong profitability position and maintaining a fairly acceptable liquidity position. The effectiveness of the diversification scheme is based on the offsetting combinations of the risk-reducing mechanisms of most of these strategies and the profit-generating capacities of the other strategies. The greater appeal of the risk benefits of diversification—especially to the most risk-averse decision-maker—usually results in the downplaying of the risk-balancing strategy as the farm utilizes some credit reserves to accommodate certain farm production and marketing plans deemed essential to overall risk reduction. The overall financial risk position still decreases although at a more regulated and compromising manner. Thus, an integrated strategic profile that entails strategies designed to regulate both business and financial risk positions has greater appeal to the highly risk-averse decision-maker in search of highly risk-efficient farm solutions yielding the greatest tradeoffs between risk and return.

This preference for the Complete Farm model that offers greater opportunities to achieve greater risk efficiency under high levels of risk aversion confirms the contention of the USDA-ARMS survey that farmers are generally inclined towards combining strategies in addressing risky conditions.

This study demonstrates the practical relevance of reducing risk under an integrated risk-management approach. The results obtained in this analysis consider projected conditions that are influenced by the modified risk environment of the late nineties. The use of an integrated strategic plan will be especially appealing to the most risk-averse decision-maker operating under the most uncertain conditions similar to those existing at the beginning of the 21st century.

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