Managing Risk by Coordinating Investment, Marketing, and Production Strategies

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This study of the farm firm integrates long run investment and financial decisions, and short-run production and marketing decisions into a single decision framework that includes both time and risk. The results suggest that the use of various strategies for managing market risks allow the entrepreneur to accept more risk in investing and producing; and that an integrated analysis of production, marketing and investment-financing alternatives is essential to make accurate recommendations about risk management strategies.

Risk management is receiving much more attention in the literature. Most studies focus on short-run production or marketing decisions; exceptions are studies of risk in farm growth models by Barry and Willman, Kaiser and Boehlje, Batterham, and Chen. This study adds long-run investment and financial decisions to broaden the scope of risk analysis. Specific problems analyzed are:

1. How big should the farm be? How much land, machinery, and feedlot should be added?
2. What should be produced? How much should a farmer diversify?
3. How should production be marketed? Can diversified marketing allow riskier investment or production?

No model can fully simulate the complex decision set facing farmers. But incorporating investment, production, and marketing options in one model yields further insights as to interactions among these decisions when risk is present. Model results show that considering a broader array of decision options allows more efficient risk management.

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Western Journal of Agricultural Economics, 8(2): 155–169

Theoretical Development

Objectives of the study required a theoretical decision model that combined risk and long-term planning. Review of the literature led to using a multiperiod quadratic program. The objective function maximized the expected utility of net worth by minimizing net worth variances for different expected net worth values. Key theoretical considerations will be briefly reviewed.

Risk

Risk refers to situations where several different outcomes are possible. Moreover, most definitions imply that a decision maker can assign probabilities to each possible outcome (Johnson). This study assumes farmers form personal probabilities (Friedman, Markowitz)—they act as if they know the actual probabilities. It is not important whether personal probabilities closely approximate actual values; what matters is that probabilities guide actions.

TABLE 1. Cattle Marketing Strategies.[a]

Production activities	Month Hedge Placed	Month Hedge Lifted
February–July Feeder	February	July
Steers and	February	June
February–July Feeder	April	July
Heifers	April	June
August–January Feeder	August	January
Steers and	August	December
August–January Feeder	October	January
Heifers	October	December
October–July Feeder	October	July
Steer Calves	October	June
	February	July
	February	June

[a] For the production activities, the first month notes when cattle are purchased; the second month when sold. Hedging is done with the contract whose maturity date is closest to the cash selling date, i.e., an August futures contract was used for February–June and February–July contracts. Hedges are always held for a time span less than or the same as the time span cattle are held.

Many decision criteria have been developed to evaluate risk (see Chen or Johnson for reviews); one that is widely used is maximizing expected utility (Luce and Raiffa). A decision maker assigns utility values to random events and selects the strategy with the highest expected utility (utility multiplied by probability and summed over all possible outcomes).

Empirical studies usually do not try to directly calculate expected utilities. Rather, expected utility problems are transformed into mean-variance or E-V analyses (Markowitz, Johnson). While such transformations are heavily criticized (Borch), E-V procedures are often used in agricultural studies based on assumptions of quadratic utility functions (at least over a range), normally distributed random events, or that mean-variance accurately approximates expected utility (Lin *et al.*, Officer and Halter).

A study assumption is that expected utility can be approximated by using mean-variance analysis. This allowed using quadratic programming (QP) to solve numerical problems.

Multiperiod Decision Making

Most investment studies use a multiperiod model to determine investment or disinvestment decisions (Boehlje and White). One problem with using this approach in risk models is that technical coefficients are fixed. For example, period to period transfers, say of cash, occur as if their expected values are realized. In reality, cash transfers would vary as crop yields or prices varied. Or the firm could go bankrupt during the first year.

Chance-constrained and recursive programming (Chien) are two possible alternatives. But both are cumbersome computationally and have other theoretical problems.[1] A multiperiod QP seemed most acceptable, with the understanding that model solutions are only first approximations to long-range planning. This follows Modigliani and Cohen's approach in which the primary objective of multiperiod planning is to get the best first year plan.

The Objective Function

Many multiperiod growth models maximize present values as an objective (Cocks and Carter). Alternatively, Lutz and Lutz suggest maximizing the return on owned capital to maximize ending capital. This model uses a net worth objective. More specifically, to incorporate risk, this model maximizes the expected utility of ending net worth. Net worth is measured at current market values to reflect the value of capital appreciation (Plaxico and Kletke), but possible tax liabilities arising from liquidation are ignored (Reid, Musser, and Martin). This approach recognizes that changes in asset value as well as annual income are both important economic outcomes of management decisions.

[1] Chance constrained programming still would not provide variable outcomes in later years. Sequentially solving a series of QPs would do so, but it would be extremely difficult to relate a solution on subsequent frontiers with solutions on the initial frontier.

TABLE 2. Net Worth Contribution and Variability of Net Worth Contribution of Selected Activities.

Activity	Expected Net Worth Contribution First Year	Expected Net Worth Contribution Variance	Standard Deviation as a Percent of First Year Net Worth (Absolute Value)
Buy Land (1 Acre)	$1,554.48	$3,652.35	3.9%
Buy Machinery ($1 Machinery Capital)	.45	.0006	5.4
Buy Soybean Oil Meal (cwt)	−6.07	1.01	16.6
Grow Corn (Acre)	−49.54	317.31	36.0
Grow Corn Silage (Acre)	−48.88	196.28	28.7
Grow Soybeans (Acre)	−27.68	116.05	38.9
Build Feedlot (1 Head Capacity)	148.08	127.77	7.6
Cash Sale February Steers (Head)	114.36	992.72	27.6
Cash Sale August Steers (Head)	95.48	161.76	13.3
Cash Sale February Heifers (Head)	95.74	688.52	27.4
Cash Sale August Heifers (Head)	79.38	141.25	15.0
Cash Sale October Steer Calves (Head)	167.78	918.56	18.1
Cash Sale Corn (Bu)	1.29	0.11	25.7
Cash Sale Soybeans (Bu)	3.20	0.42	20.3

Model Details

The farms modeled were representative of those in northwestern Iowa, although not all possible events could be included. The QP code was solved entirely in computer memory, which severely limited the model's size. Consequently, some features initially considered were deleted—interest rate variability was excluded, only a four year horizon was used (adding a fifth year did not change the first year solution much), and some production activities (e.g., raising hogs or alfalfa) were not considered.

Firms studied were ongoing cash grain operations.[2] Half the initially owned land was mortgage free; the other half was purchased 10 years earlier, so the mortgage was half paid. At that time, land cost only about one fourth of current market value. Additionally, grain farmers have relatively low operating debt at the start of the planning period, February 1. So, the initial debt to asset ratio (based on market value of assets) was 8 percent. This seems unrealistically low, but was not unreasonable compared to actual farms being simulated. Moreover, a recent Census survey reports that more than 40 percent of U.S. farm operators had no debt at year-end 1979 (1979 Farm Finance Survey). The low ratio also allowed more flexibility to adjust credit to differing risk preferences.

The QP model resembles a LP model, except a variance-covariance matrix is added. A brief discussion of the structure follows; more detail is in Johnson.

Resource Restrictions

Resource limits resemble those in most linear programming models. Structural equations specify initial land, machinery, labor, cash, and crop inventories. Asset restrictions have the most complex structure. Initial land and machinery holdings are model determined, depending on risk preference. A key study assumption was

[2] The QP parametric routine provided many different solutions, each of which had a different risk preference. While the model used the same technical coefficients (as in an LP), each solution was considered representative of a different firm. Hence, the plural is used in discussing the model's composition.

TABLE 3. Abbreviated Covariance Matrix.

	Cash Grain Complex						Livestock Complex				
	Buy Land	Buy Machinery	Grow Corn	Grow Soybeans	Sell Corn	Sell Soybeans	Sell Feb. Steers	Sell Feb. Heifers	Sell August Heifers	Build Feedlot	Grow Silage
Cash Grain Complex											
Buy Land	3652.35	.81	−135.95	39.90	9.47	17.82	391.92	221.68	140.25	486.57	−131.09
Buy Machinery	.81	.0006	−.19	−.06	.006	.007	.50	.39	.16	.16	−.18
Grow Corn	−135.95	−.19	317.31	182.86	−4.81	−9.21	101.54	79.90	6.07	−66.84	239.99
Grow Soybeans	39.90	−.06	182.86	116.05	−2.50	−5.17	93.12	70.92	23.22	−23.19	136.43
Sell Corn	9.47	.006	−4.81	−2.50	.11	.20	1.32	1.18	−.14	2.06	−3.81
Sell Soybeans	17.82	.007	−9.21	−5.17	.20	.42	−3.63	−2.72	−1.67	4.33	−6.69
Livestock Complex											
Sell February Steers	391.92	.50	101.54	93.12	1.32	−3.63	992.72	818.19	201.42	9.62	−.71
Sell February Heifers	221.68	.39	79.90	70.92	1.18	−2.72	818.19	688.52	155.06	−13.05	−6.67
Sell August Heifers	140.25	.16	6.07	23.22	−.14	−1.67	201.42	155.06	141.25	29.69	−12.72
Build Feedlot	486.57	.16	−66.84	−23.19	2.06	4.33	9.62	−13.05	29.69	127.77	−38.04
Grow Silage	−131.09	−.18	239.99	136.43	−3.81	−6.69	−.71	−6.67	−12.72	−38.04	196.28

Note: The complete matrix was 56 × 56—too large to report.

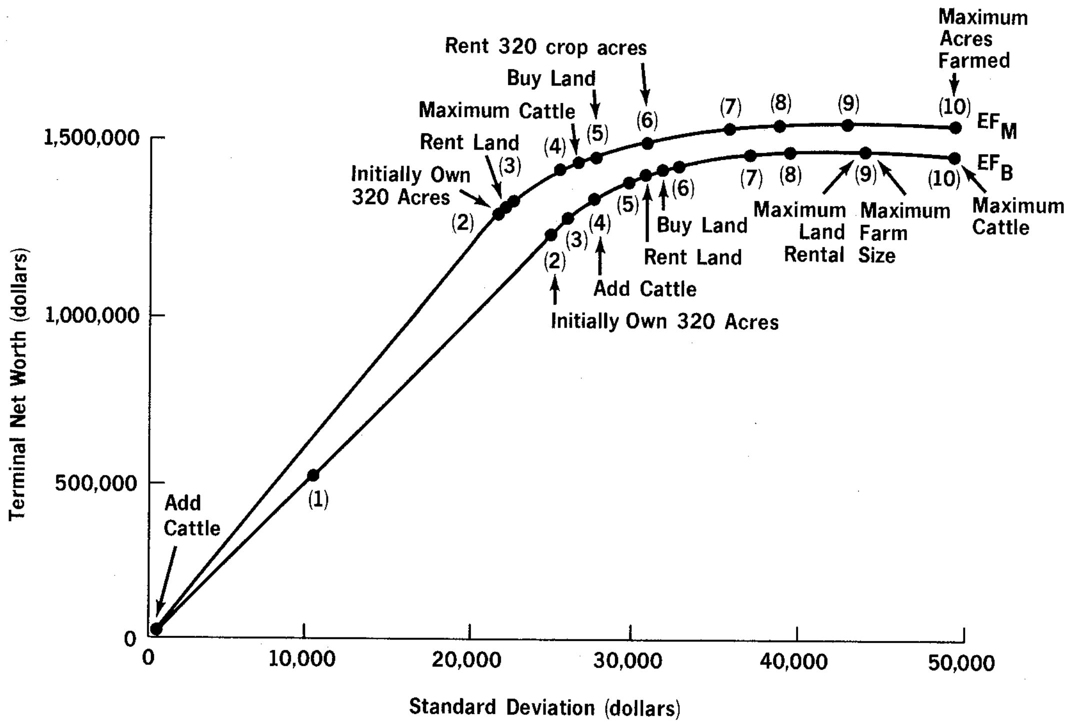

Figure 1. Efficiency Frontier for the Basic Model (EF_B) and the Marketing Model (EF_M).

that farmers with different risk preferences might start with different asset structures. The model also allows subsequent land, machinery, and feedlot investment.

Cash can be transferred forward; crops are sold or fed to cattle in the next year. Grown crops are not fed until the following year to limit model size. Debt equations limit total borrowing (short, intermediate, and long-term) to no more than 50 percent of a firm's equity in land, machinery, and feedlot facilities. Borrowing activities are specified to finance land, machinery, or feedlot facilities.

Activities

Initial size activities determine the beginning machinery and farmland owned (and debt), with acreage ranging from zero to 320 acres. Activities for investment, financing, production, marketing, input supply (including land rental), and accounting are specified in each period. Investment activities are used to purchase land, buy machinery, add feedlot space, and invest off-farm. Costs of capital purchases increase each year, reflecting historical cost increases during the 1966 to 1977 period.

Financial activities include short-term, intermediate-term, and long-term borrowing. Short term funds augment cash flow and can finance down payments on asset purchases. Intermediate-term credit finances 75 percent of farm machinery purchases and feedlot capacity costs. Repayment is completed in four years for machinery and seven years for feedlots. Long-term credit finances 80 percent of land purchase costs; repayment is completed in 20 years.

Crop production activities include corn,

TABLE 4. Four Year Investment Plan for the Basic Model.

	Solutions			
	(1)	(2)	(3)	(4)
Terminal Net Worth ($)	502,684	1,244,741	1,278,718	1,332,641
Initial Net Worth ($)	310,782	707,684	712,452	712,452
Change in Net Worth ($)	191,902	537,057	566,266	620,189
Net Worth Change Due to Price Appreciation ($)	172,951	426,455	442,554	497,350
Percent Change Due to Price Appreciation (%)	90	79	78	80
Standard Deviation of Terminal Net Worth ($)	9,960	24,559	25,370	27,183
Standard Deviation as Percent of Net Worth Change (%)	5.2	4.6	4.5	4.4
Land (Acres)				
Initial Owned Land	130	320	320	320
Farm Size—Year 1	130	320	320	320
Farm Size—Year 2	130	320	384	389
Farm Size—Year 3	130	320	382	445
Farm Size—Year 4	130	320	334	397
Land Rented—Year 1	0	0	0	0
Land Rented—Year 2	0	0	56	15
Land Rented—Year 3	0	0	48	48
Land Rented—Year 4	0	0	0	0
Land Purchased—Year 1	0	0	0	0
Land Purchased—Year 2	0	0	8	54
Land Purchased—Year 3	0	0	5	23
Land Purchased—Year 4	0	0	0	0
Total Land Purchased	0	0	13	77
Feedlot Investment (head—capacity added)				
Year 1	0	0	0	0
Year 2	113	279	270	280
Year 3	0	0	0	0
Year 4	0	0	0	0
Total Capacity Added	113	279	270	280
Debt Utilization ($)				
New Borrowings—Year 1	17,541	27,328	27,487	27,480
New Borrowings—Year 2	43,635	156,480	164,744	291,808
New Borrowings—Year 3	44,783	91,509	53,966	181,790
New Borrowings—Year 4	23,856	53,708	50,953	117,998

corn silage and soybeans, with separate activities for corn and soybeans on rented land. Crop coefficients came from Northwest Iowa planning budgets (McGrann *et al.*). Yield and price variability are included in crop production activities.

Cattle feeding activities include yearling steers (purchased at 650 pounds and fed 150 days to 1150 pounds) and heifers (purchased at 550 pounds and fed approximately 150 days to 950 pounds); and steer calves (purchased at 450 pounds and fed 180 days to 1150 pounds) which are placed in October. Yearling steers and heifers are placed in February or August.

Initially, the model required sales of all crops or livestock on cash markets, but additional marketing activities were added later. For grains, these included storage with cash or hedged sales and hedging

TABLE 4. (Continued).

Solutions					
(5)	(6)	(7)	(8)	(9)	(10)
1,370,873	1,414,035	1,458,269	1,480,966	1,491,127	1,496,999
712,452	712,452	712,452	712,452	712,452	712,453
658,421	701,583	745,817	768,514	778,674	784,546
524,024	540,329	576,475	572,767	544,427	518,787
80	77	77	75	70	66
28,870	31,854	36,221	40,181	43,428	50,470
4.4	4.5	4.9	5.2	5.6	6.4
320	320	320	320	320	320
320	562	589	628	730	729
521	539	541	580	682	681
474	491	493	532	634	633
426	443	445	484	586	585
0	237	190	225	341	341
124	133	96	136	252	277
48	48	48	88	204	229
0	0	0	40	156	181
0	5	78	83	68	68
77	81	47	41	42	17
29	37	0	0	0	0
0	0	0	0	0	0
106	123	125	124	110	85
34	83	137	164	167	168
235	235	203	209	206	347
23	0	0	58	186	287
0	0	0	0	0	11
292	318	340	431	559	813
39,964	67,159	175,897	310,506	310,560	310,573
363,660	351,643	319,597	314,332	313,583	313,787
214,734	233,304	158,857	207,847	323,619	374,060
150,175	161,405	169,013	229,808	312,995	479,432

growing crops. Cattle marketing strategies are identified in Table 1.

Net cash sale prices are extensions (for 1978–81) from 1966 through 1977 linear trends. So expected prices changed with time. For hedging strategies, the price was the cash selling price plus profits or losses on futures transactions (i.e., cash selling price plus futures selling price less futures buying price less commissions). Again trends were used to compute expected values. Similar procedures were used to obtain expected gross margins for cattle feeding activities.

Input purchasing activities are used to rent land and buy labor services and feed supplies (both stochastic activities). Finally, accounting activities provide for consumption and the payment of income taxes.

Variance-Covariance Matrix

Personal probabilities (entered as variances and covariances in the model) for prices and yields were estimated using deviations from historical trends. This assumes farmers based probabilities on past

TABLE 5. The First Year Production Plan for the Basic Model.

	Solutions									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Total Crop Acres	132	300	300	300	300	527	553	588	684	684
Total Cattle Fed	0	0	0	0	34	166	274	329	335	336
Crop Plantings (% of Total Acres)										
Corn Grain	56	56	56	56	55	55	57	48	43	49
Corn Silage[a]	14	14	14	14	14	10	9	8	7	8
Soybeans	30	30	30	30	31	35	34	44	50	43
Cattle Programs (% of Cattle Fed)										
Yearling Steers—February[b]	0	0	0	0	0	0	0	50	50	50
Yearling Steers—August[b]	0	0	0	0	0	0	0	0	0	0
Yearling Heifers—February[b]	0	0	0	0	0	50	50	0	0	0
Steer Calves—October[b]	0	0	0	0	100	50	50	50	50	50

[a] Corn silage is fed the following year; hence it shows up in solutions when no cattle are fed in the first period. Table 3 shows that feedlot capacity is added in the second year in all solutions.
[b] The month indicates the time of placement.

history—the same trends used to compute expected prices and yields. An autoregressive vector model (Johnson) was first used; this allowed variances to change over time just as prices did. But some variances exploded—that on growing corn increased from $27.65 in the first year to $433.08 in the second. And expected values were volatile.

While theoretically correct, the autoregressive vector model didn't seem practical. Farmers would not likely expect variances (and covariances) to increase dramatically over time. A simpler approach was to compute a covariance matrix based on historical deviations from trend.[3] This covariance matrix was used in each planning year; that is, variances and covariances did not increase with time.

Using deviations from trend led to much smaller variances than calculating variances on the raw data. For example, the regression on Northwest Iowa land prices removed 99 percent of the original variability. In raw terms, land prices have such a high variance because they increased so fast. But, if decision makers knew land prices increased rapidly and expected that to continue, that source of variation should be removed. In reality, absolute variances are not particularly important; rather, relative comparisons are more critical.

The following random variables were included in the model: asset purchase prices (land, machinery, and feedlot), crop production (yield variabilities), and marketing activities (prices). A matrix of time series deviations for all variables was developed and matrix manipulation gave the variance-covariance matrix used in the QP.

Table 2 gives standard deviations as percents of first year expected values (the coefficient of variation); the higher the percent, the riskier the activity. While cattle feeding has large variances, its coefficients of variation are similar to those for selling crops. However, this ignores diversification possibilities arising from covariance relationships. Table 3 shows an abbreviated covariance matrix for key activities. Ways of diversifying to lower risk are hard to identify by inspection; however, some possibilities are suggested.

[3] A historical time series was computed for each random activity based on deviations from trend. Variances and covariances were computed for each activity from the historical series.

For example, land has a relatively low variance and a negative correlation with growing corn. In low risk solutions, one might expect emphasis on corn production, either for sale or feeding in the next period. Another observation is that building feedlots and feeding cattle are positively correlated. So cattle feeding is riskier than its variance alone would indicate.

In summary, each random activity had a net worth value in the objective function and variances and covariances for the appropriate periods. Each activity's solution level determined its contribution to the expected value and variance of ending net worth. Variances and covariances were calculated for all activities directly affecting net worth, except for the financial activities. The extreme interest rate movements since early 1980 suggest these should also be included in any future modeling.

TABLE 6. Comparisons of Selected Marketing Strategies with Cash Selling Alternatives.

	Expected Net Worth Contribution	Variance
Corn (Bushel):		
Sell Cash at Harvest	$ 1.29	$ .11
June–March Hedge	1.11	.04
August–June	1.35	.13
Soybeans (bushel):		
Sell Cash at Harvest	3.20	.42
June–March Hedge	3.08	.12
Sell Cash in June	3.83	.71
February Yearling Steers (Head)		
Cash	114.36	992.18
April–June Hedge	119.43	520.12
April–July Hedge	116.70	574.87

Empirical Results

The parametric quadratic program calculated risk efficient solutions for each basis change. Results are summarized below.

The Basic Model

First, the basic model (with cash sales only) was solved to generate efficiency frontier EF_B in Figure 1. This frontier is linear until point (2), since solutions differ only in initial machinery and landholdings. Consequently, expected net worth and its standard deviation increase proportionally.

As commonly assumed in risk studies, solutions higher on the frontier represent plans chosen by less risk averse decision makers. Solution (1) is the lowest risk; solution (10), the highest risk. In moving from solution (1) to solution (5), ending net worth increases 173 percent while standard deviation increases 190 percent; significant net worth gains are made with nearly proportionate risk increases. Between solutions (5) and (10), net worth increases 9 percent but standard deviation increases 75 percent. Thus, at higher risk solutions, a decision maker must accept increasingly greater risk for only limited gains in expected net worth.

The four year investment plan. Table 4 presents detailed data for the ten solutions enumerated in Figure 1. These solutions indicate risk efficient investment plans, given present knowledge of the future. In reality, second through fourth year investments may not occur because a farmer might revise his investment plan based on first year results and other new information. Nonetheless, the four-year solutions show the initial expansion plan.

Clearly, risk attitudes are reflected in farm size. In the lowest risk solution, (1), only 130 acres are farmed which is well below the maximum allowed, and no expansion occurs. Thus, staying small is one way to reduce risk. For solutions (2) through (10), initial firm size is the same, but annual production and expansion plans differ considerably. As one moves from solutions (2) through (10), first year acreage increases from 320 to 729, new borrowings increase from $27,328 to

TABLE 7. Four Year Investment Plans for the Marketing Model.[a]

	Solutions		
	(2)	(3)	(4)
Terminal Net Worth ($)	1,312,018	1,354,458	1,430,021
Initial Net Worth ($)	705,035	712,452	712,452
Change in Net Worth ($)	606,983	642,006	717,569
Net Worth Change Due to Price Appreciation ($)	489,018	514,597	544,045
Percent Change Due to Price Appreciation (%)	81	80	76
Standard Deviation of Terminal Net Worth ($)	21,092	21,894	24,845
Standard Deviation as Percent of Net Worth Change (%)	3.5	3.4	3.5
Land (Acres)			
Initial owned land	320	320	320
Farm Size—Year 1	320	432	478
Farm Size—Year 2	403	513	539
Farm Size—Year 3	430	465	491
Farm Size—Year 4	394	417	443
Land Rented—Year 1	0	112	158
Land Rented—Year 2	28	126	112
Land Rented—Year 3	36	48	48
Land Rented—Year 4	0	0	0
Land Purchased—Year 1	0	0	0
Land Purchased—Year 2	55	67	107
Land Purchased—Year 3	19	30	16
Land Purchased—Year 4	0	0	0
Total Land Purchased	74	97	123
Feedlot Investment (Head—Capacity Added)			
Year 1	251	247	318
Year 2	0	0	0
Year 3	22	36	49
Year 4	0	0	0
Total Capacity Added	273	283	367
Debt Utilization ($)			
New Borrowings—Year 1	142,222	147,340	206,167
New Borrowings—Year 2	218,369	234,322	347,820
New Borrowings—Year 3	158,587	175,988	222,738
New Borrowings—Year 4	161,491	168,496	184,975

[a] Solution (1) data are excluded since results cannot be compared.

$310,573, and feedlot capacity increases from zero to 168 head.

Cattle feeding is relatively risky; moreover, the gains from diversifying cattle feeding with other activities were somewhat limited due to covariance relationships shown in Tables 2 and 3. In this model, cattle are not fed in the first year until solution (5), but cattle feeding facilities are constructed and used in the second year for all solutions. At higher risk solutions (5) through (7), small feedlots with less than a 150 head capacity are added in the first year.

Firm expansion in most solutions is generally diversified between rented land, purchased land, and feedlot capacity throughout the planning horizon. In most solutions, purchased land is substituted for share-leased land over time. Purchased land is more profitable, but it uses more capital and adds more variability. Hence, total acres farmed generally decline over time. Feedlot investment is also riskier, but

TABLE 7. (Continued).

Solutions					
(5)	(6)	(7)	(8)	(9)	(10)
1,466,476	1,497,103	1,529,572	1,543,958	1,553,694	1,560,772
712,452	712,452	712,452	712,452	712,452	712,452
754,024	784,651	817,120	831,506	841,242	848,320
557,868	560,264	557,967	564,697	565,950	556,581
74	71	68	68	67	66
27,357	30,466	35,303	38,666	42,690	48,881
3.6	3.9	4.3	4.7	5.1	5.8
320	320	320	320	320	320
597	706	723	722	721	731
549	658	773	775	781	793
501	610	725	727	733	745
453	562	677	679	685	697
265	341	341	341	341	341
115	220	341	341	341	341
48	155	263	256	261	293
0	107	215	208	213	245
12	45	62	61	60	70
102	73	50	53	60	62
19	17	31	37	32	0
0	0	0	0	0	0
133	135	143	151	152	132
326	216	179	184	186	163
0	107	150	125	109	86
90	112	133	159	185	294
0	0	0	0	26	150
416	435	462	468	506	693
290,932	312,985	311,586	311,593	311,601	310,480
335,672	321,754	315,890	316,228	316,573	313,102
275,793	292,628	339,293	361,830	359,029	357,662
197,613	212,944	232,288	235,842	284,683	470,322

more profitable, so it replaces some land purchases at higher risk solutions.

Land prices increase rapidly in the model, significantly affecting results. First, most of the net worth gain is asset appreciation (largely land)—90 percent in solution (1), 66 percent in solution (10). Second, appreciating land prices expanded borrowing capacity, which favored further land purchases. Even when borrowing ability was enhanced by land appreciation, credit was fully utilized in the first two years of solutions (7) through (10). When model specifications were changed so that asset appreciation did not affect net worth or borrowing capacity, no land is purchased; expansion is confined to feedlot facilities and land rental. This approach, however, ignores the value of asset appreciation in increasing borrowing ability.

Relatively small ratios of standard deviation to net worth changes (less than 7 percent) reflect using deviations from trend which removed much of the original variation, especially on land. When the model was rerun with asset appreciation excluded from net worth, these ratios were much higher, ranging from 7 to 29 percent.

TABLE 8. The First Year Production and Marketing Plan for the Marketing Model.[a]

	Solutions								
	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Total Crop Acres	300	405	448	560	662	678	677	676	686
Total Cattle Fed	351	372	506	597	430	331	353	377	326
Crop Plantings (% of Total Acres Planted)									
Corn Grain	89	92	57	54	43	43	43	44	45
Corn Silage	11	8	10	9	7	7	7	6	5
Soybeans	0	0	33	37	50	50	50	50	50
Disposition of Corn (% of Total Bushels Raised)									
Fed to Cattle	26	26	100	100	100	100	100	78	59
Sold June–March Hedge	74	74	0	0	0	0	0	0	0
Sold August–June Hedge	0	0	0	0	0	0	0	22	41
Disposition of Soybeans (% of Total Bushels)									
Sold June–March Hedge	0	0	100	100	82	9	0	0	0
Sold in June—Cash	0	0	0	0	18	91	100	100	100
Cattle (% of Total Fed)									
Yearling Steers—February[b]									
Sold April–June Hedge	0	0	0	0	0	0	0	0	50
Sold April–July Hedge	0	0	0	16	50	54	52	50	0
Yearling Steers—August[b]									
Sold October–December Hedge	28	34	37	45	50	40	32	24	0
Yearling Heifers—February[b]									
Sold April–July Hedge	72	66	63	39	0	0	0	0	0
Steer Calves—October[b]									
Sold Cash	0	0	0	0	0	6	16	26	50

[a] Solution (1) data are excluded since results cannot be compared.
[b] The month indicates the time of placement.

The first year production plan. Table 5 presents first year cropping and livestock production plans for the solutions in Table 4. Corn and corn silage are produced primarily to feed cattle in the next period. At low risk solutions (1) through (4), soybeans (the riskier crop) are only 30 percent of acreage planted, which is well below the 50 percent maximum. Between solutions (5) and (9), soybeans increase to the 50 percent maximum. Without the upper limit, which reflected a rotation plan to control disease and limit erosion, soybean acreage probably would be higher. But complete, continuous soybean production does not seem technically feasible for Northwestern Iowa farms. Soybeans decline in solution (10) to increase corn grain production for more cattle feeding in the second period.

Cattle feeding occurs only in the riskier solutions. At medium risk solutions, yearling heifers placed in February (which have a lower variance than steers) are fed in conjunction with the riskier calf program. This keeps the feedlot filled all year. At higher risk solutions (8) through (10), February yearling steers replace heifers because they are more profitable. Because the covariances among feeding programs were positive, the model utilized the following strategy: emphasize corn production in low risk solutions, and add more soybeans and start cattle feeding as risk aversion decreases.

The Marketing Model

Figure 1 also shows the marketing model (EF_M) efficiency frontier. This model adds storage and hedging options for grains, and hedging for cattle (refer to Table 1). A farmer who would prefer solution (5), for example, on EF_B would prefer solution (5) on EF_M.[4] EF_M rotates outward from EF_B indicating it provides a more risk efficient set of farm plans. Expected values and variances for marketing strategies were calculated in the same manner as for cash selling strategies. Table 6 shows that these marketing strategies increase expected returns, lower variances, or both, relative to cash sales.

The four year investment plan. Table 7 presents data for the marketing solutions enumerated in Figure 1. The most obvious benefit of marketing strategies is that one can farm more land, borrow more money, feed more cattle, and generate more net worth with less risk. In all solutions ending net worth is larger when additional marketing strategies are allowed. Benefits are greatest in low to medium risk solutions.

Net worth growth is also less dependent upon asset appreciation. Both cattle feeding and crop planting generally occur on a larger scale which allows more accumulated earnings. Part of the acreage increase comes from buying more land, but rented land is also increased.

Differences in cattle feeding are significant. In the marketing model, cattle are added in the first year throughout the horizon. Even at low risk solutions (2) through (4), relatively large feedlots are constructed. This suggests that effective marketing strategies make cattle feeding more desirable for low risk farmers.

At high risk solution (10), the marketing model includes more crop planting, but less cattle feeding. In that solution, use of high profit, high risk corn and soybean marketing strategies offer higher returns than increased cattle feeding.

The first year production and marketing plan. Table 8 shows first year cropping and livestock plans of the marketing model. Again, these data show that adding marketing strategies allows farming on a larger scale. In low risk solutions (2) and (3), no soybeans are planted due to their high price variability. At high risk solutions (6) through (10), maximum soybean acreage is planted in response to high soybean profits. In solutions (4) through (8), corn is grown only to feed cattle. However, in solutions (9) and (10), when expected profits are the main concern, corn is sold using the profitable, but risky, August–June hedge.

In low risk solutions, soybeans are sold using the June–March hedge, even though expected returns are about \$0.75 per bushel below June cash sale. The June cash strategy is not used much until solution (7) due to its high variability.

In low risk solutions (2) through (4), yearling heifers are placed early in the year and yearling steers later in the year. These options have the smallest variability in expected return. At higher risk solutions, more profitable, but riskier feeding programs are used. These include the steer

[4] Due to the small number of solutions obtained in the linear segment of the marketing model, a comparable solution to solution (1) of the basic model was not generated. We chose solutions on EF_M that were above and to the left of those numbered the same on EF_B. By inspection, we tried to select solutions where slopes along the frontier were the same. In other words, a farmer whose utility indifference curve was tangent to solution (5) on EF_B would also be tangent to solution (5) on EF_M. Since we did not work with specific utility functions, we cannot precisely say that a solution on EF_M is most preferred to the like numbered solution on EF_B.

calf program and February placements of yearling steers.

Conclusions

Model structure and size limitations prevented using a number of desirable marketing-financing strategies. Still, model results suggest significant risk management possibilities.

1. Both solution sets show that differences in risk attitudes lead to differences in farm size. Farmers can reduce risk by operating smaller farms.
2. Cattle feeding is a rational addition, even for moderately risk averse farmers. Hedging strategies, which increase expected returns and/or lower variability, increase the desirability of cattle feeding for all levels of risk aversion.
3. Market strategies allow one to accept more risk in investing and producing. Risk reducing marketing strategies are particularly beneficial to more risk averse farmers.
4. Corn is less risky than soybeans, but limited soybean acreage often occurs even in low risk solutions.
5. Feeding heifers seems less risky than feeding steers. The most profitable but riskiest programs are February yearling steer placements and October steer calf placements.

The numerical results of this study suggest that integrating the analysis of production, marketing, and investment alternatives is essential before making recommendations about risk management strategies. Analyzing only one dimension (such as marketing or production) does not account for the significant interrelationships among the various areas of a farm business.

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