KINDS AND SOURCES OF RISKS IN LIVESTOCK PRODUCTION AND MARKETING

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The purpose of this paper is to assess the price and production risk of livestock relative to crop production. The analysis will follow two separate thrusts. The first is a comparison of various crop and livestock activities in regard to historical price and income variability measures. The second is a determination of financial vulnerability on a whole farm basis of various crop, livestock, and crop-livestock settings. The benefits of diversification in moderating risk resulting from production and price variability will not be directly examined in this analysis. Similarly, price protection strategies such as forward pricing and contracts will not be included.

Generally, livestock has tended to receive less emphasis in risk analysis compared to crop production. The high risk of Great Plains agriculture, for example, is usually attributed to weather impacts upon crop and pasture yields rather than price and production variability of livestock activities. In the last decade, because of increased price variability, more emphasis has been placed on price variability of both crop and livestock products compared to previous time periods. Also, the benefits of diversification in some aspects of livestock production has been a long held and traditional principle of risk reduction. Other risk strategies such as hay reserve levels and herd inventory management have received emphasis in the past. Still, most agricultural risk analyses of recent years have generally been directed toward crop production rather than livestock.

A number of reasons account for our emphasis on crop risk relative to livestock risk. First, specialized livestock production units have less to gain from diversification than crop production settings in most cases. It is also more difficult to objectively analyze and compare risk in heterogeneous livestock activities compared to more homogeneous crop production alternatives. Finally, the inclusion of livestock activities in risk programming models has lagged because of the complexity of linking crop and livestock activities in regard to risk elements.

In this paper we address the two general risk concepts of (1) variability and (2) financial vulnerability resulting from disaster events. Historical variability indexes resulting from price and production variability are developed for selected crop and livestock activities. Programming models under a growth framework are developed for various representative farms in examining financial vulnerability over time. Some would argue that financial decisions relating to debt expansion are of more importance to business risk than are diversification issues or price protection strategies.

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Price and Net Returns Variability

In this section some estimates of livestock return variability are presented against a context of comparable cropping estimates. A number of studies (Bravo-Ureta and Helmers, Carter and Dean, Mathia, and Yaha and Adams) have estimated crop variability indexes for Nebraska, California, North Carolina, and Wyoming respectively. These studies have generally used aggregate data leading to some underestimate of actual farm variability. Often total variability is separated from random variability as determined from the variate difference method. Generally, such studies have emphasized crop enterprises.

The arguments for comparing enterprises according to random variability suggests that general price and production movements are predictable and only variability around such general trends should be considered risk. An extension of this is the use of random variance as a risk criterion in QP models (Adams, et al.). A nearly opposite observation is that while random variability may be diversifiable, the major sources of risk to the firm arise from the major trends. According to this view, even if general trends are predictable, this hardly eliminates financial problems which may arise from such trends. We tend to agree with the latter view that while the separation of total variance into a random component is useful, total variance is a better criterion to gauge variability of alternative enterprises. Again, the use of any variance concept as a risk measure is traditional and assumes both upward and downward deviations are useful to a risk criteria.

Variability indexes for net returns of agricultural crop enterprises can be expressed on any resource base; however, it is common to express variability on a per acre basis. For homogeneous (in terms of resource use) crops standard deviations can be used as a basis of comparison. For example, where irrigated crops are to be compared to dryland crops, standard deviations alone as a basis of comparison lead to a lack of dimension regarding the different investment intensities of the two types of crops. This problem becomes more dramatic when variance measures of livestock enterprises are to be compared to crop enterprises. Normalizing such standard deviations by mean yields or net returns is of some value in this respect. As discussed later, this does not necessarily eliminate comparison distortions arising among hetergeneous enterprises.

Data for prices of both crop and livestock products are readily available. Crop yield data for historial variance studies generally uses aggregate averages. However, production variability data for livestock enterprises are the most limiting factor when constructing crop and livestock variability measures. Experimental data for livestock yields nearly always have treatment effects involved. Farm record summaries have a number of disadvantages with respect to securing livestock yield data, perhaps the largest being the nature of the cost data. When enterprise records are so used, the results of livestock yields are reflected in production and feed required. Such data may be incomplete, however, with respect to fixed costs since reported fixed cost payments may be far lower than a true economic level. Published budgets for livestock activities can be used to distinguish the levels of fixed and variable costs for a livestock unit and, in conjunction with farm record enterprise records, may provide the best source for livestock variance studies.

In this analysis, variance estimates for both price and net returns (over variable costs) for hogs (farrow to finish), finishing cattle, and cow calf enterprises are developed. These estimates are developed over the period 1975-81 from Kansas Farm Record Summaries. These variance measures are compared to similar crop variance measures previously estimated for various areas of Nebraska (Bravo-Ureta and Helmers).

Two variance indexes are developed. The first is a relative variance measure--the standard deviation divided by the mean with the quotient multiplied by 100. This measure is useful for comparing intensive versus extensive activities; however, this measure breaks down as a comparison standard when activities differ widely in the ratio of fixed and variable costs. For example, if returns over variable costs is the return measure, cattle feeding with a very high proportion of variable costs may have an average return over variable cost approaching zero. A cow calf activity involves a relatively low proportion of variable costs compared to cattle feeding. Hence, relative variance measures between these two enterprises under such a setting may be distorted. If all costs were included, it would be expected that mean net returns would approach zero for all activities. Interestingly, risk premium differences among enterprises are one reason why net returns, considering all economic costs, may not be zero for all activities. Other factors influence this also. In any event, because activities vary in their fixed-variable cost ratio, resulting in a possible distortion of risk based upon a relative variability concept (based upon the mean), an alternative relative variability measure is developed. This index is the standard deviation divided by the investment level for the activity, the quotient multiplied by 100. This risk criterion is less vulnerable to problems resulting from normalizing with mean net returns.

The two variance indexes for prices and net returns over variable costs are represented in Tables 1 and 2 respectively. The price and net return series are deflated by the CPI. The time series are not the same for all items and could be a source of distortion between the two classes of products. For most crops a 1951-76 period was analyzed while for livestock a 1975-81 series was examined. Both crop and livestock series are based on aggregate data.

In regard to price variability, livestock variability is greater than crop variability particularly when normalized by investment level rather than the mean. Two measures for fat cattle are developed. The first is raw selling prices and the second (gross margin) examines net sale margins after the price of purchased cattle is included. The second includes the element of purchase price variability thus increasing the overall price risk. Hog and fat cattle (gross margin) price variability is not reduced to the degree of crops and the cow calf activity as one compares the index based upon investment relative to the index based upon the mean. This indicates the relatively lower investment requirements for these two activities compared to the other enterprises.

We must conclude that product price variability is much higher for livestock activities relative to crop production under Nebraska-Kansas

TABLE 1.

Product Price Variability Indexes for Crop and Livestock Activities[1]

	A. Relative to Mean	B. Relative to Investment
Wheat	20.9	2.6
Corn	13.5	2.5
Alfalfa	19.7	3.6
Oats	10.6	1.0
Grain Sorghum	14.7	2.2
Soybeans	16.9	1.3
Hogs	24.4	18.3
Cow Calf	28.4	4.7
Fat Cattle	12.0	2.0
Fat Cattle (gross margins)	15.2	13.1

[1]Crop variability indexes developed from Bravo-Ureta and Helmers for 1957-76 and livestock variability developed from Kansas Farm Management Summaries, 1975-81.

TABLE 2.

Indexes of Variability of Net Returns Over Variable Costs for Crop and Livestock Activities[1]

	A. Relative to Mean	B. Relative to Investment
Northeast Nebr. (corn)	41.43	5.2
Northeast Nebr. (soybeans)	53.89	6.3
Central Nebr. (irr. corn)	35.65	15.8
Central Nebr. (alfalfa)	78.13	6.2
Northwest Nebr. (wheat)	42.21	5.4
Northwest Nebr. (irr. corn)	41.92	5.2
Northern Nebr. (irr. corn)	46.63	10.0
Northern Nebr. (alfalfa)	293.39	5.0
Eastern Nebr. (irr. corn)	31.07	5.8
Eastern Nebr. (grain sorghum)	30.29	5.4
Southern Nebr. (irr. corn)	39.38	5.0
Southern Nebr. (wheat)	50.16	4.5
Southwest Nebr. (irr. corn)	38.10	6.0
Southwest Nebr. (wheat)	46.41	4.7
Southeast Nebr. (wheat)	43.82	5.4
Southeast Nebr. (alfalfa)	63.16	4.9
Hogs	55.9	10.6
Cow Calf	151.9	5.1
Fat Cattle	-1670.7	11.0

[1]Crop variability indexes developed from Bravo-Ureta and Helmers for 1951-76 for alfalfa, corn, wheat and 1957-76 for grain sorghum and soybeans. Livestock variability indexed developed from Kansas Farm Management Summaries, 1975-81.

conditions. Certainly, this indicates why a high degree of interest exists in price protection strategies for livestock.

It can be seen from Table 2 that relatively little heterogeneity in variability exists among the various crops with respect to net returns. For the various selected areas of Nebraska, the two crops with the greatest acreage are selected for comparison. Obviously, both price and production variability are contributing factors to net returns variability. It should not be concluded that yield variability can be exactly determined by subtracting price variability from net return variability. However, as a general tendency, net returns variability for crop production includes a sizable yield variability component while this is far less true for livestock. This can be found by examining net returns versus price indexes for index B.

As we have mentioned, the variability index based on mean net returns can lead to distortion when activities vary in fixed-variable cost differences or budget assumptions. Generally, we prefer to gauge relative variability based on the index B, the index based on investment levels. In this case, few differences exist among crops and little difference in variability is seen between irrigated and dryland production.

It can be seen that net return variability for hogs (10.6) and fat cattle (11.0) fall at the upper end of the range of crop variability with the cow calf activity at the lower end. The cow calf activity defined by the Kansas summaries is not a range livestock activity. Rather, substantial feed purchases are made each year as variable costs probably in excess of range practices.

This should not be interpreted to mean that variable feed yields for range conditions are less than under non range conditions, only that the meeting of those deficiencies is more likely to be met from hay reserves and not through purchased feed. In a full accounting sense a meeting of feed deficiencies through hay reserves (above normal needs) does not reduce risk but rather only reduces variable cost differences over time. At the same time it may be expected that production variability under range conditions would be higher than under the setting analyzed for the cow calf enterprises. Thus, a comparable range activity would be expected to yield comparable variability indexes compared to the cow calf estimates shown. These influences of high variable costs for the cow calf and fat cattle enterprises lead to a very high (151.9) index for cows and the "blow up" (-1670.7) of the fat cattle activity for the variability index related to mean returns. As we shall discuss later, where financial vulnerability is of importance, the variability index based on mean returns may be more reflective of risk compared to the other index (B). This relates more to a fixed-variable cost issue than the relative variability differences. Yet from a variance concept alone, it appears that the livestock activities tend to fall in the range of crop activities in regard to total net return variability.

In summary, based upon risk as defined in a variance context, we conclude that:

1) Price variability is relatively more influential in explaining enterprise risk for livestock relative to crops. Similarly, crop yield variability is sizable under Nebraska conditions while livestock yield variability is minor.

2) Net returns (above variable cost) variability for livestock tends to be comparable to crop production (Nebraska context). For cattle feeding and hogs variability tends to be higher than most crop activities and cow calf variability tends to be comparable to most crops.

Programming Analysis

Procedure

While the previous discussion relates to a variance aspect of risk, the following discussion will center arouund the impact of variability on the financial status of the farm firm. To some degree this emphasis could be considered a safety-first concept, although there appears to be some lack of uniformity regarding a safety-first risk definition.

The approach followed in this section is to estimate impacts of price and production variability on the financial position of firms for various crop, livestock, and crop-livestock situations. This will be done through programming each situation using expected values and then observing the "worst year" impacts of joint price and yield distributions. The price and yield distributions are examined for the historical period 1972-81.

In examining agricultural risk, we believe it is important to place the setting in a growth context. That is, diversification studies alone ignore the risk dimension relating to debt expansion. Profit potential leads to firm expansion and provides the means to increased net worth. Without profit potential, the firm can neither grow nor retire existing debt. At the same time, growth can increase the vulnerability of the firm to financial insolvency if the firm expands using debt resources.

MOTAD and QP models do not adequately incorporate a time related growth framework for risk decision making. That is, assuming constant risk aversion, increased net worth should enable the firm to choose riskier enterprise mixes. The emphasis of MOTAD and QP on variance does not provide for such a decision framework. As an alternative, we will describe a model designated as PARC (polyperiod annual risk constraint) which does so provide and analyze its decisions compared to other programming models. The PARC model is discussed in more detail later.

The "worst year" analysis whereby price and yield distributions are used to calculate resulting financial outcomes from model activity levels could be analyzed under a non optimizing (simulation) framework or where activity levels are determined from optimizing models (LP, MOTAD, Recursive risk constraints, or PARC). Advantages lie in using a polyperiod model. First, changing activity levels in response to changing financial positions are determined directly from such a model. Second, polyperiod programming provides an acceptable framework for analyzing investments under income tax. Finally, a polyperiod model is useful where complex linkages between activities and inventories occur.

Finally, some discussion is included in regard to the method of disaggregating activities in risk models. The models which are examined here provide for disaggregation of activities. The disaggreagation method applies to MOTAD models equally as well as to the PARC framework.

Representative Farms

Four representative situations are examined in this paper:

1) a grain-livestock farm in southeast Nebraska,
2) an irrigated cash grain farm in southcentral Nebraska,
3) a cow calf ranching unit in northcentral Nebraska, and
4) a commercial cattle feeding operation.

Each situation was assumed to intially own one million dollars of assets with $400,000 of liabilities ($600,000 of net worth).

The grain-livestock farm was assumed to own 592 acres of land along with machinery and livestock facilities to total one million dollars. Two thousand eighty hours of operator labor was assumed available. Dryland corn, soybeans, grain sorghum, and wheat could be grown and farrow to finish hogs could be raised. A limit of 100 sow units on sow capacity was assumed.

For the irrigated cash grain farm, 370 acres of land was owned which with crop machinery resulted in one milion dollars of assets. Irrigated crops were corn, soybeans, and grain sorghum and 2,080 hours of operator labor was assumed available.

The cow calf operation was a 3,428-acre ranch with 286 cows initially. The pasture requirements assume one ton of hay per cow is purchased annually. Again, 2,080 hours of operator labor was assumed available.

The cattle feeding operation assumes labor is hired and that initial assets are in the form of cash which along with borrowing capacity enable the feedlot to purchase cattle and feed.

A 25 percent equity (net worth to asset) ratio is assumed to be an insolvency limit. While liquidation or partial liquidation would realistically be used under such circumstances, it is considered a business failure target in this analysis.

Opportunity for growth is provided from earnings and borrowing capacity. Initially, $1,400,000 of capital could be borrowed ($600,000 X 3/1 - $400,000). One-year notes were at four percent (real rates) while a rate of three percent was charged for five year notes. A savings account paid 2.5 percent.

Unlimited labor was assumed available for hire at $10 per hour. Renting of land was possible for all three land based farms. Cows could be purchased and pasture rented for the ranching situation. No limits were placed on the number of steers purchased.

Data

A 1972-81 time frame was employed in the analysis in determining variation for each activity. Budgets for each activity were secured from Bitney, et al. for each year. Crop yields were secured from county averages from Nebraska Agricultural Statistics. Feed efficiency variation for cattle feeding was provided by Dr. Wallace Koers and variability in calf weights from Kearl. There was no provision for variation in hog feed efficiency. Historical livestock and crop prices were used to correspond to the 1972-81 period.

Activity returns were deflated by the CPI. Fixed costs for depreciable assets were included as costs for each activity. While it is true that asset replacement can often be delayed in economically adverse times, a true accounting of costs in terms of asset values requires fixed asset use to result in cost. Of course, where a repayment structure is assumed, this cannot be directly delayed because of adverse times and this holds for non depreciable assets (land) as well as machinery and livestock facilities. For the most part we believe producer behavior treats the use of fixed assets as a cost and hence, our economic models should reflect this behavior.

PARC

Linear programming solutions for each farm were determined using before-tax wealth maximization over a ten-year period. The LP polyperiod model requires no further elaboration.

The PARC (polyperiod annual risk constraint) model examines variability annually and adjusts optimum activity levels in accordance with the variability. The objective function is before-tax wealth and is maximized subject to the usual constraints. In addition, for each activity year, 10 years (1972-81) of MOTAD-type deviations are embedded. In association with a 25 percent equity minimum the model maximizes wealth taking account of the impact of the deviations on owner equity. The "worst year" dictates the influence of the deviations and the activity levels result in a plan where no deviation results in an equity position below 25 percent. Obviously, the activity levels are far different from a linear programming solution in terms of financial vulnerability. It has been shown by Atwood, et al. that PARC results in solutions less risky in a safety-first sense compared to MOTAD solutions.

The PARC model uses expected values in determining growth; that is, annual deviations only act to constrain the solution. The obvious advantage of PARC in risk analysis is its ability to change activity organization in response to changing financial status. Thus, as growth and increased net worth occur, the firm is better enabled to accept riskier plans (riskier in the sense of bad events). Variance *per se* is not an issue in PARC models in regard to income-risk tradeoffs. Rather, a tradeoff occurs between equity levels and wealth. Higher required equity levels constrain growth and thus wealth. Risk is embodied in terms of the impact of bad events--the elements in the lower tail of the distribution.

For these farm situations the model is a 10-year model. The inclusion of 10 years of deviations and the 10-year length of the model are coincidental, the number of deviation years need not equal the model length.

A detailed discusssion of the PARC model cannot be completed here. Neither can the potential risk analyses potential of PARC be described. However, we feel a wide scope of risk research is possible with a PARC framework.

Disaggregation of activities is required whenever the decision to sell output or transfer output to another period is endogenous to the model. The approach of this paper is to make decisions each period based on expected values of yields and prices. The impact of the deviations from expected values can then be determined for each of the potential outcomes. The decisions made in succeeding years are tied to previous years' decisions only through expected values. However, the activity mix of year one may be constrained by the potential outcomes for year one. To the extent that the activity mix in year one is thus modified, the year two activities may be indirectly impacted by the year one potential outcomes.

Disaggregation of activities involves requiring the production activities to "purchase or sell" output at the observed prices so that the expected output is achieved. The expected output can then either be sold or transferred to the next period. The amount of price or "valuation" deviation is the amount the observed price varies from the expected price. With this method, the decisions made in following time periods based upon expected values are feasible even with yield shortfalls.

The impact on the firm's potential net worth is the same whether the activities are aggregated or disaggregated. An example of the concept is given in the following discussion. Table 3 contains sample data for two observations. The mean yield and weighted price are used as the expected

TABLE 3.

Corn Sample Data

Observations	Yield	$ Price/Bushel	Variable $ Cost/Acre
1	140	$2.50	$120
2	120	$3.00	$120
Expected Value	130	$2.7308[1]	

[1]The expected price is the bushel weighted average price.

values. The data is for one acre of corn. The observed yields in the two years are 140 and 120 bushels per acre respectively. The price in the years were $2.50 and $3.00 per bushel. The resulting gross revenue for observation 1 is 140 bushels/acre X $2.50/bushel or $350.00. Gross revenue in observation 2 was $360.00. The variable cost per acre was $120.

Table 4 shows a matrix with the corn production activity disaggregated. disaggregated. The corn production acivity requires $120 of operating capital in the first year first period. The activity expected yield is 130 bushels of corn in the first year second period. The entries under the deviations are calculated by multiplying the yield deviation from the expected yield by the observed price. For deviation 1 the amount is +10 bushels X $2.50/bushel = $25.00. The deviations 2 entry is -10 X 3.00 = -30.00. The entries in the sell corn and transfer corn are identical in their impact on net worth. However, one converts the asset to cash and the other values the asset at market value. The expected value of prices is $2.7308/bushel with observation 1 being 23.08 cents lower and observations 2 being 26.92 cents higher. These amounts are the deviation entries.

TABLE 4.

Disaggregated Matrix

Row Constraint	Row	Grow Corn	Sell Corn	Transfer Corn	Transfer OPERATE CAPITAL
L	OP CAP11[1]	120.			
L	OP CAP12		-2.7308		1.0
L	Short-term assets			-2.7308	-1.0
L	Corn12	-130.	1.0	1.0	
E	Deviation1	25.00	-.2308	-.2308	
E	Deviation 2	-30.00	.2692	.2692	
L	OP CAP21				-1.0
L	CORN21			-1.0	

[1]The numerical codes 11 indicate first year first period; 12 indicates first year second period, etc.

The gross revenue for outcome 1 if the corn is sold is (1 acre X $25.00/acre) + (130 expected bushels/acre X $2.73.08/bushel) + (130 bushels/acre X -$.2308 price deviation/bushel) = $350 per acre. For outcome 2 the gross revenue would be (1 acre X -30.00/acre) + (130 bushels/acre X 2.7308/bushel) + (130 bushels/acre X $.2692/bushel) = $360.00 per acre. The two amounts are the same as shown above for the aggregated observations.

The impacts on net worth are identical if the expected yields are transferred through the transfer activity. The main difference is that inventories are transferred rather than cash balances. The expected yield of 130 bushels per acre would then be available for sale or use as an input in the future.

Programming Results

In this section the linear programming and PARC solutions for each farm situation are presented. These solutions provide the base upon which to conduct the worst year analysis of the next section where the distribution of financial outcomes after year 1 are determined. By so doing, the relative risk of various crop and livestock settings are assessed.

In Table 5 the results for year 1 for LP and PARC solutions are presented. The initial large borrowing capacity ($1,400,000) provided for large initial growth in year 1. Thereafter, annual growth was far less. With the limited resource constraints of the models, the solution resulted in a high degree of specialization. PARC solutions, as constructed under this model, will not include diversification for the purpose of deviation minimization but will be diversified where such diversification is helpful in moderating disaster events.

It can be seen that PARC solutions restrain the growth of three firms as PARC anticipates potential bad events. This restriction comes at minimal loss in net worth for the grain livestock farm, more loss in net worth for the cattle feeding operation and still greater net worth loss for the cash grain farm. Due to declining profitability under higher levels of expansion, the ranching firm did not expand to the degree of the other farms leading to no difference in the LP and PARC solutions.

Worst Year Analysis

Given the LP and PARC activity levels, the results of the 10 possible events corresponding to the 10 deviations of the PARC model are calculated and presented here. The PARC model by definition will not allow equity positions to fall below 25 percent. Such is not necessarily the case for LP solutions and, while not included here, not necessarily for MOTAD solutions.

In Table 6 the impacts of annual variability on the financial position of the firm at the end of programming year 1 are presented. While it is tempting to examine the variability of equity asset ratios between LP and PARC, the setting of the PARC model is a safety-first risk framework. Hence, it is more appropriate to examine the number of consequences where the equity asset ratio falls below .25. Four such cases occur for the southeast grain livestock farm followed by two and seven, respectively, for the cash grain and cattle feeding unit. In no case does the cow calf operation encounter financial difficulty because its growth is more limited than the other farms.

TABLE 5.

LP and PARC Solutions (Year 1) for Four Representative Farms

	LP	PARC
Southeast Nebr. Grain Livestock		
Hogs (cwt)	3188	3188
Soybeans (acres)	5974	3390
Net Worth (1000 $)	702	699
Capital Borrowed (1000 $)	1800	1239
Southcentral Nebr. Cash Grain.		
Soybeans (acres)	4718	2686
Net Worth (1000$)	725	692
Capital Borrowed (1000 $)	1800	1173
Cattle Feeding		
Cattle (no.)	1697	1317
Net Worth (1000$)	610	603
Capital Borrowed (1000 $)	1800	1489
Cow Calf		
Calves Sold (cwt.)	1348	1348
Net Worth (1000 $)	631	631
Capital Borrowed (1000 $)	520	520

TABLE 6.

Potential Equity/Asset Ratios for Year 1
for Four Representative Farms for LP and PARC Solutions

Outcome	Southeast Grain-Livestock		Southcentral Cash Grain		Cattle Feeding		Cow Calf
	LP	PARC	LP	PARC	LP	PARC	LP and PARC
1	.32	.39	.25	.34	.25	.28	.55
2	.41	.46	.32	.39	.21	.25	.58
3	.26	.35	.33	.40	.24	.28	.53
4	.08	.25	.10	.25	.34	.36	.51
5	.43	.46	.34	.41	.21	.25	.52
6	.33	.39	.28	.37	.23	.27	.53
7	.26	.34	.28	.36	.23	.27	.55
8	.24	.32	.27	.36	.21	.25	.56
9	.23	.31	.31	.38	.24	.28	.55
10	.21	.30	.15	.28	.28	.31	.53
Average	.277	.357	.263	.354	.244	.280	.541

One must remember that it is conceivable to place some growth limits on the linear programming solutions. Such limits could be rather simple and less sophisticated than the PARC model but such reductions on growth would reduce financial risk. For example, if such a limit were imposed on cattle feeding, the linear programming solution could be one where no or few outcomes result in the equity ratio falling below .25. More importantly, it is obvious that where such ratios would fall below 25 percent, the magnitude would be small. Such is not the case for the grain farms. The grain livestock farm reaches an equity asset ratio of .08 in year 4 while the cash grain farm achieves a .10 and .15 in years 4 and 10, respectively. Thus, the severity of decline of the equity ratio is important, suggesting that the grain farms encounter more financial risk than the livestock farms.

It should be mentioned that year 4 corresponds to 1975 a year with low crop yields and relatively low crop prices.

Conclusions

The two aspects of risk discussed in this paper, variance and disaster occurrence, cannot necessarily be reconciled. The historical variance measures indicate livestock production incurs a substantial level of price variability but relatively less production variability. Cropping agriculture is involved with both risk aspects. From a disaster or worst year standpoint, crop production appears to involve much greater risk than livestock production. This conclusion is different from our original hypothesis. It should be emphasized that the historical setting of agricultural prices over the programming period strongly contributed to the programming results. That is, in the first half of the 1972-81 period, soybean prices were high and thus led to soybeans dominating the solution. At lower soybean prices, a more diversified crop production pattern would likely have resulted. This result could moderate the "worst year" risk of the soybean enterprise, particularly in the linear programming solution. Similarly, we would expect that MOTAD or diversification solutions would have reduced the "worst year" influences compared to the linear programming solution. Again, however, it is our judgement that the crop farms would still experience more disaster risk compared to the livestock situations.

Finally, we find the PARC model as a potentially useful tool in normative risk analysis for farms, in addition to its potential as a research tool in risk analysis. As we have seen, PARC models have the potential of limiting financial insolvency at varying costs in terms of growth. The PARC model employed here is constructed around the worst event occurring. Should the solutions resulting from such a framework be viewed as too conservative, it is possible to modify the model accordingly in various ways. It remains to be seen what form of risk behavior (variance or safety first or a mixture) is most closely related to farm operator behavior.

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