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SENSITIVITY OF EFFICIENCY FRONTIERS DEVELOPED FOR FARM ENTERPRISE CHOICE DECISIONS

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ABSTRACT

"Sensitivity of Efficiency Frontiers Developed for Farm Enterprise Choice Decisions." Bryan W. Schurle (Kansas State University) and Bernard L. Erven (The Ohio State University)

The sensitivity of efficiency frontiers in farm enterprise choice under risk is examined. With expected return levels held constant, substantial variation was found in farm organizations off the efficiency frontier. However, there was relatively little additional risk associated with suboptimal organizations. Expected return level substantially influenced the sensitivity of frontiers.

Sensitivity of Efficiency Frontiers Developed for Farm Enterprise Choice Decisions

The use of efficiency frontiers has become common in empirical studies of farm enterprise choice under risk. In these studies, mean-variance analysis is commonly used to develop frontiers. These frontiers are efficient in the sense that they represent a series of farm enterprise combinations, each enterprise combination having minimum risk (variance of returns) for a specified level of return. Anderson, et. al. provide an excellent discussion of the different types of frontiers and the different methods of deriving frontiers.

An efficiency frontier provides much useful information concerning the trade-off between risk and return. The procedure is particularly helpful when the interest is in enterprise choice alternatives for increasing returns when the risk among enterprises varies substantially. However, efficiency frontiers provide little information on near optimal enterprise combinations. Decision makers and researchers should be interested in farm plans slightly different from those on the frontier in terms of risk and return levels. The usefulness and uniqueness of the frontiers as a decision aid would be substantially reduced if these near optimal solutions are substantially different in terms of combination of enterprises. Other considerations such as management requirements may overshadow the difference in risk between near optimal enterprise combinations and the minimum risk enterprise combination on the frontier.

The frontier sensitivity issue has seldomly been addressed in empirical studies. In this paper, we report on the sensitivity of efficiency frontiers developed in a farm enterprise choice study. Specificially, we address the question of how much change in risk accompanies an enterprise combination change when expected return is held constant.

Problem Setting

The problem involves choices between cash grain crops (corn, soybeans, and wheat) and specialty crops (processing tomatoes and cucumbers) in Ohio. The budgeted net returns in Table 1 show the relatively high returns associated with tomatoes and cucumbers. However, farmers considering adding these enterprises or expanding current acreage have a major concern with their risk. Yields may vary substantially due to interactions of complex production technology, seasonal labor supply, and weather. Substantial yield variation results in much greater annual variation in returns for specialty crops than for grain crops (see Table 1).

Risk is an important factor in farmers' decisions because of the trade-offs between the higher returns and higher risk of the specialty crops and the lower returns and lower risk of the grain crops. The coefficient of variation (standard deviation of return divided by return above variable cost) quantifies these important differences in risk. Table 1 shows that the coefficients for the grain crops are substantially below those for tomatoes and cucumbers and that cucumbers are the most risky enterprise. Also, in spite of the greater standard deviation of net return for mechanically harvested tomatoes, the additional net return due to reduced harvesting costs results in a smaller coefficient of variation for mechanically harvested tomatoes than that for hand harvested tomatoes. It is these substantial differences among the crops which cause risk to be a major concern for farmers.

Enterprise diversification is a means by which farmers can reduce risk. The correlation coefficients between returns for different enterprises are shown in Table 2. Only hand and mechanically harvested tomatoes are significantly correlated. Wheat returns tend to be negatively correlated with other returns, but not at a significant level.

Model Formulation

Given the characteristics of this problem and the importance of risk in the enterprise decisions involved, an operational procedure was needed which permitted the handling of a complex set of enterprise alternatives, explicit treatment of risk and the development of practical farm enterprise choice guidelines. The modified linear programming alternative, the MOTAD model, proposed by Hazell was chosen.

The MOTAD model is easily solved with most linear programming algorithms having parametric options. The model minimizes the sum of the absolute values of the negative total gross margin deviations. This procedure minimizes the mean absolute deviation in net return for the total farm about the expected return for the total farm. The mean absolute deviation is a measure of dispersion of a distribution and thus it measures risk in a manner comparable to the variance used in quadratic programming. The results of the MOTAD model result in an EA frontier very similar to the EV frontier from quadratic programming (Thompson and Hazell). In cases where MOTAD has been used, researchers have been optimistic about its capabilities and usefulness (Schluter and Mount, Kennedy and Francisco).

The basic linear programming matrix models a 600 acre representative farm with the capacity to produce corn, soybeans, wheat, mechanically harvested tomatoes, hand harvested tomatoes and hand harvested cucumbers. Additional activities were also included for hiring labor, land preparation, and other support services. The constraints of the model included land, and the limiting factors of labor, machinery capacity and field time associated with critical spring planting and fall harvesting periods.

Several activities were used to represent each enterprise in the model. For example, corn and soybeans could be planted in any of six spring time periods and harvested in any of the three fall time periods. This resulted in 18 activities to represent corn and 18 to represent soybeans. Likewise, tomatoes harvested by machine were represented by 13 activities and tomatoes harvested by hand were represented by 10 activities. The returns associated with activities varied depending on the estimated yield for each planting and harvesting period combination.

The data used in the risk analysis were collected from three farms which are close geographically and operated by excellent managers. Yield and price data on each crop were collected for an eight year period. Trends in these data were removed prior to analysis and costs were assumed to be constant over the eight year period. Year to year deviations in gross margins (gross revenue - variable costs per acre) were calculated for each enterprise from these modified data.

The data allowed development of gross margin deviations for each enterprise. However, time-series data on yields were not available for each activity (representing different planting and harvesting dates) in the model. Consequently, the same gross margin data were used for each activity of an enterprise even though some activities representing an enterprise were less profitable than others due to less than optimal planting and harvesting dates.

These data were included in the following MOTAD model formulation:

(1) Minimize $\sum_{h=1}^{s} y_h^-$

such that

(2) $\sum_{j=1}^{n} (c_{hj} - g_j)\, x_j + y_h^- \geq 0$ (for h=1,2,...,s)

and

(3) $\sum_{j=1}^{n} f_j x_j = I$ (for I = 0 to unbounded)

(4) $\sum_{j=1}^{n} a_{ij} x_j \leq b_i$ (for i=1,2,...,m)

(5) $x_j,\ y_h^- \geq 0$ (for all h, j).

where

y_h^- = absolute values of the negative total gross margin deviations;

c_{h_j} = the gross margin (gross revenue per acre - variable costs per acre) for the $_j$th activity on the $_h$th observation;

g_j = the average gross margin for the $_j$th activity;

x_j = the level of the $_j$th activity (usually in acres);

f_j = the expected gross margin of the $_j$th activity;

I = the expected net return ;

a_{ij} = the technical requirements of the $_j$th activity in the $_i$th constraint;

b_i = the $_i$th constraint level;

s = the number of years;

n = the number of activities in the basic LP model;

and

m = the number of constraints in the basic LP model.

This model minimizes risk for each level of I (total returns above variable costs) specified in equation (3). The model minimizes risk as measured by the sum of the absolute values of the negative total gross margin deviations. Essentially this minimizes variance of returns to the farm measured by the estimator of variance

$$D\left[\frac{\pi s}{2(s-1)}\right]^{\frac{1}{2}}$$

where s is the number of years in the sample and D is the estimated mean absolute deviation in returns to the farm. In order to minimize risk while achieving a specified return level, the model selects enterprise combinations that are least risky (as measured by variance in annual returns) and/or that have negatively (or less positively) correlated returns. Return to the farm (I) is parameterized resulting in a minimum risk farm organization for each specified level of return. The return, risk coordinates can be graphed as in Figure 1 to show the efficiency frontier facing a farm manager with a given resource base. The decision maker can then choose an enterprise combination and return-risk situation which is consistent with his risk preference and goals. If the farm plan chosen is off the frontier, there is an increase in risk with no compensating increase in return or a decrease in return with no compensating decrease in risk.

Results

In the first phase of the analysis, both cash grain and specialty crop enterprises were allowed to enter the model. The resulting efficiency frontier is illustrated in Figure 1. Net return above variable costs was varied in $5,000 intervals. There is a specific farm plan associated with each point on the frontier. However, for purposes of brevity, only selected farm plans for the frontier are shown in Table 3. This table also shows the coefficient of variation and the standard deviation of net return for the farm.

It can be readily observed from Table 3 that diversification has a major impact on risk and net return. The more diversified farm plans have lower levels of net return and risk. The trade-off between returns and risk is captured by the coefficient of variation. As net return decreases, the coefficient of variation is reduced which shows that risk per dollar of expected return is reduced.

Farm plans change considerably along the frontier. The frontier and accompanying table of detailed farm plans permit a farm decision maker to evaluate the trade-offs between return and risk for his particular situation. Individual choice among diversification strategies is likely to be unique because of the influence of risk preference, goals, capital position and management capability.

Sensitivity of Frontier

We have shown the impacts of changes in enterprise combinations on both return and risk. We turn now to the sensitivity of the frontier which has been generated. Are there enterprise combinations substantially different from those in Table 3 for each level of return which have inconsequential increases in risk? If there are, the approach we used for investigating enterprise choice under risk has not identified all the enterprise combinations of interest to decision makers.

The sensitivity question was investigated by restricting each enterprise in turn, to zero acres. This forces different enterprise combinations than those shown for the frontier in Figure 1. A separate frontier was developed for each enterprise restriction. The restrictions cause an increase in risk and result in all new frontiers being to the right of the original frontier. These new frontiers are represented as unconnected points in Figure 1.

Table 4 shows the enterprise combinations from each of the frontiers for one return level, $95,000. This is a relatively low level of return characterized by much diversification as all three grain crops, tomatoes and cucumbers are included. After subtracting the $97,000 fixed cost of land and machinery, there is a -$2,000 return to operator labor and management.

There are substantial differences in the enterprise combinations shown in Table 4. Corn varies from 114 to 442 acres, soybeans from 142 to 453 acres, wheat from 60 to 158 acres and hand harvested tomatoes and cucumbers from 0 to 67 acres in the plans where each is allowed. These differences would be extremely important to a farmer. For example, the third enterprise combination in the table consists of corn and wheat only, while the minimum risk combination includes corn, soybeans, wheat and a substantial amount of hand harvested tomatoes. These two enterprise combinations are extremely different from a farmer's viewpoint because tomatoes are included in one combination and not the other. Most importantly, these significant enterprise combination changes resulted in little additional risk at this return level. The next to last column in Table 4 shows that the increase in standard deviation of net return varied from $690 to a maximum of $3,500. These are relatively small increases in comparison to the expected return level of $95,000.

The results of sensitivity analysis on the middle portion of the frontier showed similar results. However, for the highest portion of the frontier enterprise specialization caused either of two results when risk sensitivity was investigated. First, a frontier developed with a certain restriction may not reach the high return levels under consideration. This has implications for decision making in that return potential is limited if certain enterprises are not allowed in the enterprise combinations. A second result occurring in some situations was that the restriction placed on an enterprise did not change the enterprise combination radically from the minimum risk enterprise combination. Thus small differences between enterprise conbinations were often accompanied by very small differences in risk.

Summary

Results of the sensitivity analysis indicate that major enterprise combination changes may be accompanied by little additional risk. The increases in risk seem slight relative to the level of expected return. This result causes concern over the usefulness of the model in fine tuning farm organizations. It may be more appropriate to investigate only the more general trends in return, risk, and enterprise combinations with this model.

These findings must be interpreted in light of the fact that there were 8 years of data and that the sensitivity of risk was investigated for this set of data only. Other data sets would allow a more thorough investigation of the sensitivity of frontiers. In addition, more complete data would allow a more precise specification of the risk associated with each activity representing an enterprise. Nevertheless, with the available data in this study there was basis to question the usefulness of this technique in assessing the impacts of fine adjustments in enterprise combinations.

References

Anderson, Jack R., John L. Dillion, and J. Brian Hardaker. Agricultural Decision Analysis. Ames: Iowa State University Press, 1977.

Hazell, P. B. R., "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning Under Uncertainty." Amer. J. Agr. Econ. 53 (1971):53-62.

Kennedy, J. O. S., and E. M. Francisco. "On the Formulation of Risk Constraints for Linear Programming." J. Agr. Econ. 25 (1974):129-144.

Schluter, Michael G. G., and Timothy D. Mount. "Management Objectives of the Peasant Farmer: An Analysis of Risk Aversion in the Choice of Cropping Patterns, Surat District India." Occasional Paper No. 78, Department of Agricultural Economics, Cornell University, 1974.

Thompson, K. J., and P. B. R. Hazell. "Reliability of Using the Mean Absolute Deviation to Derive Efficient E, V Farm Plans." Amer. J. Agr. Econ. 54 (1972):503-506.

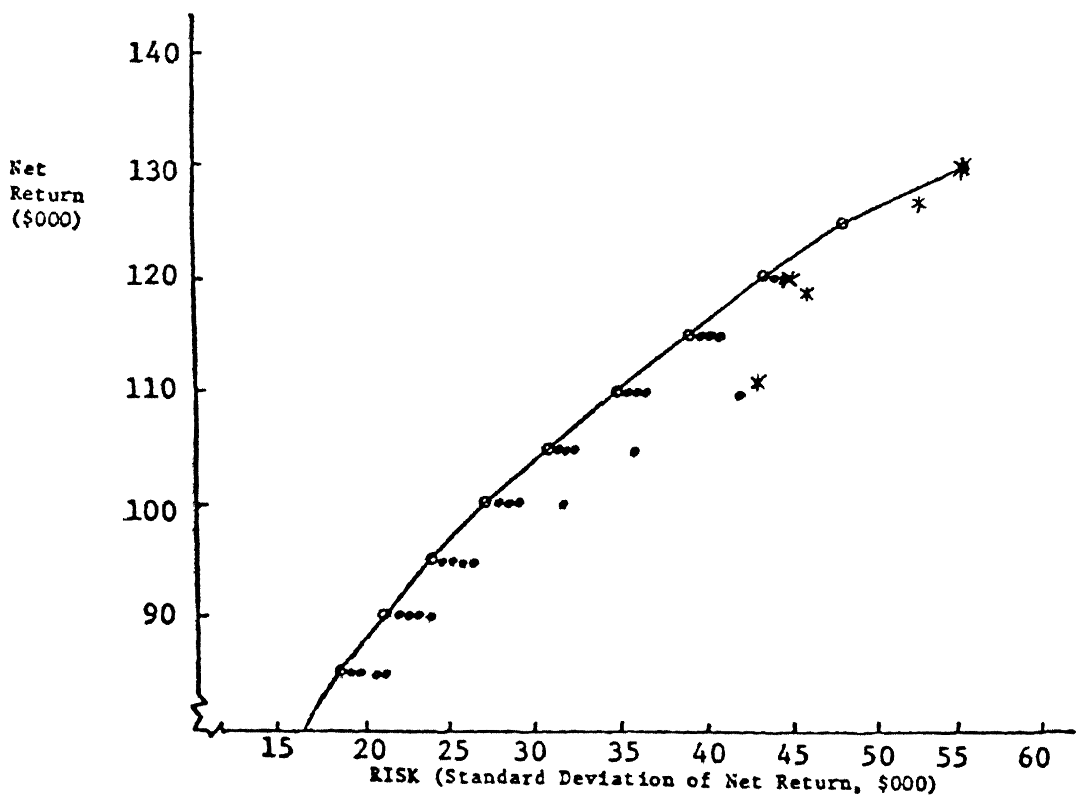

Figure 1. Efficiency frontier (connected points), unconnected points representing near optimal frontiers, and stars representing end points of near optimal frontiers.

Table 1. Descriptive Statistics for Alternative Enterprises

Enterprise	Return Above Variable Cost Per Acre	Standard Deviation of Return	Coefficient of Variation
Corn	$172	$ 50	.29
Soybeans	122	39	.32
Wheat	90	28	.31
Mechanically harvested tomatoes	593	344	.58
Hand harvested tomatoes	335	268	.80
Cucumbers	250	272	1.09

Table 2. Correlation Coefficients Between Gross Margins for Different Enterprises*

	Soybeans	Wheat	Mechanically Harvested Tomatoes	Hand Harvested Tomatoes	Cucumbers
Corn	.45 (.26)	-.03 (.95)	.57 (.13)	.34 (.59)	-.08 (.84)
Soybeans	-	.44 (.27)	.40 (.32)	.51 (.19)	.25 (.55)
Wheat	-	-	-.35 (.60)	-.00 (.99)	-.17 (.69)
Mechanically Harvested Tomatoes	-	-	-	.72 (.04)	.50 (.21)
Hand Harvested Tomatoes	-	-	-	-	.05 (.89)
Cucumbers	-	-	-	-	-

*Levels of significance are in parenthese below the correlation coefficients.

Table 3. Enterprise Combinations of Grain and Specialty Crops

Return[a] ($000)	Corn (acres)	Soybeans (acres)	Wheat (acres)	Mechanically Harvested Tomatoes (acres)	Hand Harvested Tomatoes & Cucumbers (acres)	Standard Deviation of Net Return ($000)	Coefficient of Variation
85	221	144	230	0	5	19	.22
95	186	274	99	0	41	24	.25
105	245	302	0	15	39	31	.29
115	341	172	0	27	60	39	.34
125	437	75	0	72	16	48	.38
130	483	0	0	85	32	56	.43

[a]Return above variable costs. The estimated fixed cost of land and machinery for this representative farm is $97.000.

Table 4. Enterprise Combinations Which Result in a Net Return of $95,000.

Enterprise Restriction	Corn (acres)	Soybeans (acres)	Wheat (acres)	Mechanically Harvested Tomatoes (acres)	Hand Harvested Tomatoes & Cucumbers (acres)	Standard Deviation of Net Return ($000)	Change in Standard Deviation ($000)	Coefficient of Variation
None (Minimum risk)	186	274	99	0	41	23.91	-	.25
No Corn	0 (-186)[b]	453 (+179)	60 (-39)	21 (+21)	66 (+25)	27.41	3.50	.29
No Soybeans	442 (+256)	0 (-274)	158 (+59)	0	0 (-41)	25.58	1.67	.27
No Wheat[a]	114 (-72)	362 (+88)	0 (-99)	0	67 (+26)	25.12	1.21	.26
No Hand Harvested Tomatoes	311 (+125)	142 (-132)	137 (+38)	9 (+9)	0 (-41)	24.60	.69	.26

[a]56 acres were rented out

[b]numbers in parentheses are changes in acres from minimum risk enterprise combination.