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Intra-Enterprise Diversification: An Evaluation of
Variety Diversification as a Risk Management Tool

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The importance of risk in agriculture has recently been elevated by increased uncertainty in the agricultural economy. Better risk managing techniques are desired as management becomes an increasing portion of variable production inputs. For farm managers who exhibit risk aversion, this uncertainty is unwanted. For these individuals, risk management may become a major objective in the decision making process. A widely used method of controlling production risks is diversification of enterprises. The concept of diversification involves combining investments with less than perfectly positive correlations to reduce risk in the portfolio (Markowitz). Although enterprise diversification has received considerable attention, intra-enterprise diversification has received much less attention as a risk management tool. This study evaluates the use of crop variety diversification as a tool for management of production risk within the corn enterprise.

Conceptual Framework

The risk averse manager prefers less risk to more at a given level of return. This statement forms the basis for risk-return or E-V analysis which is simply the examination of the relationship between risk and return, including the relative trade-off's between changes in levels of risk and return.

Any point on the E-V frontier dominates all other points of similar risk but lower return, or of equal return and lower risk. Also, any point with both higher risk and lower returns is clearly inferior to a point on the E-V frontier. A rational investor would choose his investments so as to remain as close to the E-V frontier as possible.

The individual may invest a portion of the available funds in each of several investments, forming a portfolio. The investment opportunity set is then expanded to include the individual investment activities and an infinite number of combinations of investments in varying proportions. In practice, some indivisibility of assets exists so that the possible combinations do not occupy a complete area, but enough unique points are represented to accommodate most any investor's desires. The rational investor will be concerned only with combinations that lie on the efficient frontier of the investment opportunity set. This set is at least a linear combination of the individual activities represented as efficient and probably is convex away from the variance axis.

No risk reduction can be accomplished through diversification if the investments are perfectly positively correlated. Complete elimination of risk is possible if the investments are perfectly negatively correlated. Most investments covary with other investments to some extent but not perfectly, therefore some risk reduction is nearly always possible through the use of diversification.

The expected return, $E(r)$, of a combination of investments is simply the weighted sum of the $E(r)$'s of the individual investments. The variance of any combination is not a linear combination of the individual investment's variances, but rather, is a function of the correlation among the investments.

As the number of assets in a portfolio increases, the variance becomes more dependant on the level of covariance among the assets in the portfolio. In general, for an equally

weighted portfolio of "n" assets, the variance is given by:

$$V(p) = (1/n) \text{ ave. variance} + (1 - 1/n) \text{ ave. covariance}$$

As portfolio size becomes sufficiently large, the average variance term's contribution to portfolio risk approaches zero and the portfolio total variance approaches the average covariance of the assets in the portfolio. The limits to risk reduction through diversification depend on the correlation among the assets in the portfolio. Systematic inter-enterprise diversification is likely to provide more benefit than intra-enterprise diversification as the components of the former are likely to be less correlated than those of the latter.

The available assets are likely to covary positively because of widespread economic and social forces that affect all assets simultaneously and similarly. The part of the risk that is attributable to these forces is known as systematic risk and cannot be eliminated through diversification. Unsystematic risk is that variability that is unique to individual investments and is composed of such things as relative susceptibility to disease, weed or insect pressure, and weather. Unsystematic risk can be reduced through diversification.

Data

The data utilized in this study are from the Ohio Corn Variety Performance Trials performed by the Department of Agronomy at The Ohio State University. The data contain information about yield, standability, plant populations, planting rate, test weight and harvest moisture. The tests are conducted at two sites in each of three regions. There were 53

unique site-year combinations.

For any site-year observation, the varieties tested are exposed to a number of uncontrolled factors (weather, insects, soil type, etc.). Selection of varieties for study were restricted to common site-year occurrences so that the varieties were all exposed to the same set of uncontrollable factors. Hence, the variability for all varieties is partially caused by common uncontrollable factors.

A priori, it was felt that at least five varieties were needed to examine various portfolio combinations. The selection from all available varieties were made subjectively with emphasis given to apparent dissimilarities of varieties, recency of and continuity of the time series, and ability to maintain a large number of site-year observations with equal numbers of observations from each site. It was felt that dissimilar varieties would more clearly demonstrate the characteristics of diversification with the limited number of varieties. The group of varieties selected for study is comprised of five varieties with observations for 20 site-year locations.

Empirical Analyses

Means, variances and correlation coefficients of the selected varieties were calculated for the five varieties over 20 site-year combinations. As expected, these five varieties' returns are highly correlated, with correlation coefficients ranging from 0.72974 to 0.88759.

Mean yield is an appropriate measure of return for this analysis. The commodity nature of corn prevents varietal price

differentiation. Historic price fluctuations affect variability of returns, but do not affect the yearly yield distribution. Price at harvest is simply a scaling factor and its exclusion leaves the ordinality of the results intact.

All unique combinations of the five varieties were considered in equally weighted portfolios. Portfolio mean and variance were simulated using yield data for 20 site-year locations. Additionally, a 20 year time series of the "market" average was included as a benchmark for a "fully diversified" portfolio. The E-V mapping of these portfolios is presented in Figure 1.

The combination of risky varieties tends to reduce risk at the expense of return. The ranges of both risk and return are reduced as more varieties are added to the portfolio. In all but two cases, two variety portfolios display less risk than either of the individual varieties. Of the three variety portfolios, only two have portfolio risk greater than the least of the component varieties. In all four variety portfolios, risk was reduced below the level offered by any single variety. In general, the potential for overall risk reduction through diversification is available and reduction below the level suggested by averaging is always possible.

Mathematical Programming Formulation:

Thus far, no attempt has been made to maximize return at any given level of risk or minimize risk for some level of return. We have only made arbitrary equal allocations of resources among the choices and described rules for evaluating the results. Quadratic programming is an optimization technique which allows the enterprise manager to choose proportions of

one or several varieties in combination to maximize portfolio efficiency. As the number of activities, n , increases, the number of objective terms increases on the order of $n(n+1)$, making the solution computationally more difficult and susceptible to error.

Minimization of total absolute deviation, MOTAD, closely parallels the quadratic programming approach, but utilizes a simpler linear programming algorithm. Hazell (1971) originally used a measure of mean absolute deviation as a measure of risk. A more appealing version would be to measure and penalize only for negative deviations. However, it can be shown that the conclusions reached will be similar whether considering total deviations or only total negative deviations from the mean. The net negative deviations, measured in bushel per acre per year is:

$$Y = \min [(C_i - C) * X_i , 0]$$

The formulation used in this study is to maximize net return subject to a parametrically varied constraint on the sum of the net negative deviations over time.

MOTAD5

The initial MOTAD model (MOTAD5) was formulated without recognition of investment indivisability constraints. A constraint (SUM-Y), which represents the total negative deviations of the portfolio, is parametrically varied to represent different levels of risk aversion. Parametric changes in the maximum value of SUM-Y were determined by basis changes. This formulation allows us to trace out the E-V frontier of the entire numerically available activity

opportunity set.

The lowest level to which SUM-Y may be reduced without causing infeasibility is 137.763. The upper critical limit for this model is 100 percent variety "A" with the associated mean of 156 bu./acre and a sum of negative deviations over time of 173.41. The efficient frontier produced by this model is presented graphically in Figure 2, and is labeled MOTAD5.

The E-V frontier for any risk/return level below that offered by 100% "A" is composed of only two varieties, "A", and "C". The minimum level of risk is associated with a portfolio of only two varieties. Combinations of "A" and "C" dominate all other possible combinations of the five selected varieties.

It is evident that risk reduction is possible only at the expense of increasing amounts of return. Changes in the rate of change of the objective function occur whenever there is a change in basis. The five activities which are considered did not change membership in the basis over the relevant ranges.

MOTAD5B

A logical follow-up analysis to the initial MOTAD5 model is one where activity indivisibility constraints are imposed. In this formulation (MOTAD5B), each of the five varieties is forced to be included in a proportion of .1 or greater.

Because the model forced even the riskiest portfolio to be well diversified (i.e. to include all available activities), little absolute risk reduction was observed. In effect, the model locates an E-V efficient frontier which is inferior to the frontier offered by the "best" combinations of the five varieties (Figure 2).

The portfolio with the highest return and associated level of risk is composed of the maximum amount feasible of the high risk and return variety "A" and minimum amounts of the other varieties. Yield is maximized at 150.212 bu./acre given an unrestricted level of negative deviations. Higher levels of risk may be taken on but will not result in further compensation. The lower relevant limit occurs where the slope of the E-V frontier is infinite. In the case of the five variety portfolio, the minimum risk level attainable at any level of returns is 145.9505 units of total negative deviations from the mean. The greatest level of return which may be achieved at any level of total negative deviation is 152.132. The relevant portions of the E-V set therefore lie between the points of 152.32 bu./acre return and 145.9505 units of total negative deviations.

In order to reduce portfolio risk from the maximum relevant level, an increasing portion of "C" must be included. The solution becomes infeasible before levels of the other three activities increase.

Parametric changes in the maximum value of SUM-Y were chosen at one unit. Risk is reduced at the expense of return, but only at a decreasing rate for each additional unit of return sacrificed. This confirms the notion that accepting higher risk at initial low levels of risk is accompanied by greater increases in $E(r)$ than accepting additional risk from an initially higher level.

MOTAD4

We now turn to a problem which may be more typical of the

crop variety choice; optimization among a set of similar varieties. Variety "A" can be said to "stochastically dominate" the other varieties. Even with its relatively high risk, it is represented in the lowest risk efficient portfolio because of its high expected return. Elimination of this variety from the activity set leaves four similar varieties to choose among. This model was formulated as MOTAD4.

A similar set of choices is often faced by farmers when selecting seed corn varieties. That is, they wish to select seed based on several criteria. The choices may be readily reduced to a limited set of similar varieties that exhibit the desired characteristics yet, it is probably not apparent that one variety dominates the others or what combination should be selected for optimal results.

Ranges were again located for the relevant portion of the E-V frontier (Figure 2). It was found that our measure of risk could not be reduced below 155.06915 units. Inspection reveals an upper relevant point corresponding to 100% "B" with associated $E(r)$ and SUM-Y of 148.26 and 200.58 respectively.

Again, a single variety portfolio is shown to provide the highest risk/return combination. Furthermore, moving away from this point toward lower $E(r)$ and lower deviations requires the addition of a second variety into the portfolio. By incorporating more "C" into the mix, risk may quickly be reduced to the level offered by either "D" or "E" alone with a substantially higher expected return. At the level of risk offered by a single variety portfolio of "C", an optimal combination of "B" and "C" provide only .26055 bu./acre higher

$E(r)$. The relatively small return advantage to diversification is in this case due to the initial similarity in $E(r)$ between "B" and "C".

Three varieties are required to be held in a portfolio in order to reduce risk below the level offered by "B", "C", or a combination of "B" and "C". Variety "E"'s introduction into the portfolio maintains efficiency for reduced risk. Moving to areas of still lower risk forces "B" out of the optimal basis and introduces "D". Notice that through this progression from 200 to 160 units of negative deviation, only 1.5 bushels of expected yield were sacrificed. Because the value to the individual of reducing variability of returns is dependant upon the individual's utility function, no attempt is made to relate the desirability of these rates of risk/return exchange.

The lowest relevant range of the E-V frontier clearly dominates either "E" or "D" alone but includes portions of both. This suggests that highly risk averse managers will nearly always hold a portfolio rather than a single asset even at very low levels of individual asset risk.

Summary and Conclusions:

Variety diversification offers an additional risk management tool that can be used in addition to enterprise diversification to better manage risk. By improving the opportunity set associated with an individual enterprise, the overall portfolio comprised of all enterprises is, by necessity, improved. It is therefore in the manager's best interest to apply the concepts of diversification to the greatest extents practical. This does not imply that all rational investors are fully

diversified; it may be that the individual is relatively less risk averse than most and would prefer to hold a fairly risky portfolio. What is suggested is that the individual increase his awareness of the available opportunity set in order to increase his effectiveness as a decision maker.

Combining similar varieties usually allows the reduction of risk below the level offered by the least risky of the individual varieties. This association is more apparent when the varieties have initial similar levels of risk. This fact makes the process of diversifying especially appealing to the manager who must choose among similar varieties. It appears to be relatively costless in terms of $E(r)$ to diversify. Therefore, a farm manager would likely moderate risk and not lose large portions of $E(r)$ by diversifying.

It was shown that required ratio of return sacrificed to risk reduced increases as more risk is eliminated from the portfolio until the point is reached at which no risk may be reduced regardless of the amount of return sacrificed. Alternately, repeatedly accepting additional risk increases the expected return, but at a decreasing rate. This fact again stresses the need to match an individual's risk return preferences to the E-V frontier in order to maximize utility. Because individual risk return preferences differ, selection of a utility maximizing portfolio is left to individual choice.

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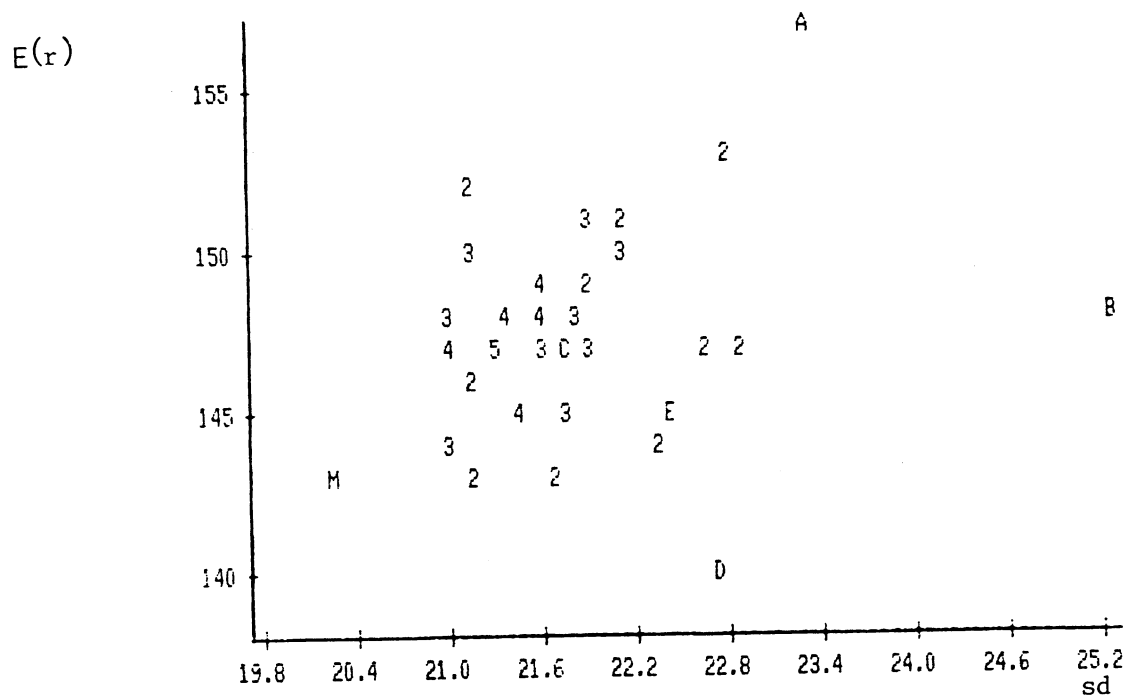


Figure 1: E-V Combinations for Various Sized Portfolios of Corn Varieties.

A-E Single Varieties
 1-5 Portfolio of Size Indicated
 M Market Portfolio

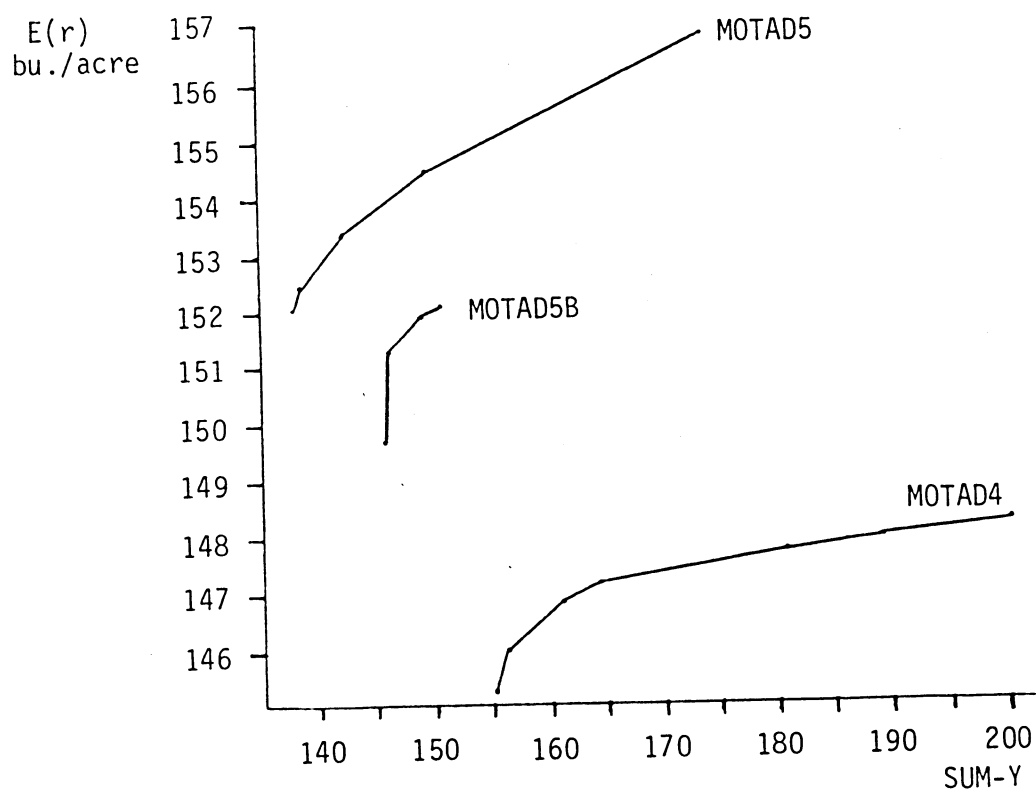


Figure 2: $E(r)$ - SUM-Y Frontiers; MOTAD analyses