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Using Non-Contemporaneous Data to Specify Risk Programming Models

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Specification of the variance-covariance matrix holds continuing interest for agricultural economists considering risk programming applications. This research examines alternative expected value-variance (E-V) frontiers constructed using contemporaneous and non-contemporaneous data and two statistical assumptions concerning crop prices and yields. Empirical examples from two locations for different crops illustrate the various assumptions. Considerable differences in the E-V efficient frontiers occur in both empirical settings.

Introduction

Agricultural economists have devoted considerable attention to the estimation of variance-covariance matrices for quadratic risk programming. Early applications such as Freund, used standard statistical sample estimators from historical data that were common in production economic studies at the time (Carter and Dean). The subsequent popularity of decision theory led to consideration of subjective estimates of the distribution parameters (Anderson, Dillon, and Hardaker). Difficulties in eliciting covariance estimates (Lin, Dean, and Moore) and fundamental conceptual problems with human capacity to formulate statistical estimates (Musser and Musser) have limited the use of these estimates. More recent developments concern the use of mean squared forecast error estimates with historical data rather than standard statistical estimates to better approximate subjective estimates (Peck: Young, 1980). Additionally, McSweeney, Kenyon, and Kramer demonstrated that forecast and sample estimates produce considerable differences in the shape and position of an E-V frontier. While the forecast estimators hold considerable merit for models predicting producer responses, the traditional sample estimators still have merit in farm management information research. In addition to these general methods of estimating variance-covariance matrices, other studies have considered the impact of more specific issues such as the appropriate length

for historical data and general detrending issues (Adams, Menkhous, and Woolery), errors in parameters (Schurle and Ervin), and residual errors (Dixon and Barry). Young (1984) reviewed these studies and others concerning different procedures for estimating the variance-covariance matrix.

All of these previous efforts used contemporaneous time series data on prices and yields to estimate variance-covariance matrices. Such studies are limited as the general price environment evolves. For example, Klinefelter, Sonka, and Baker; and Musser, Mapp, and Barry argue that time series of prices before 1973 have limited applicability to current price risk because fundamental changes in domestic agricultural policy and the general trade environment changed at that time. However, weather patterns and other biological processes that influence yield may have much longer cycles, so that longer time series of yields may be relevant. Especially with the recent popularity of physical process simulators in agricultural risk research (Musser and Tew), generation of lengthy time series of crop yields under constant technology conditions based on historical weather patterns is possible. Yield data from these models overcome many of the usual problems associated with long time series of crop yields from aggregate sources, and focus attention on crop price risk and the subsequent interrelationships with yield risk. In an early study using this type of data, Boggess, *et al.* assumed the price and yield of soybeans produced in Florida were independent. A subsequent article by Tew and Boggess re-examined the independence assumption concluding that it biased the variance estimates for all soybean production methods. However, these studies did not consider portfolio affects among crops or use non-contemporaneous data.

This research considers the impact of the use of

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non-contemporaneous data and alternative assumptions about the independence of crop prices and yields in a portfolio context of different crops. While this application considers estimates from historical data with sample statistics, the general procedures could be applied to estimates with forecast statistical methods and perhaps to subjective estimates.

Specification of Variance-Covariance Matrices

Variance-covariance matrices for risk programming applications are generally constructed from detrended time series of gross margins. Although, Adams, Menkhous, and Woolery demonstrate that detrending does not strategically affect the E-V frontier, the appropriate length of a historical series of price and yield data is a perennial problem in agricultural risk analysis. Statistical theory suggests extended data series reduce parameter estimation errors and decision theory suggests that the observations included in the series must be conceptually repeatable to be relevant for current decision applications. Since price data from before the early 1970's may not meet decision theory criteria and an extended time series of yield data may be necessary to accommodate weather patterns and biological processes, combinations of extended yield series and shorter price series appear to satisfy statistical and economic criteria.

Equations are available that combine basic statistical parameters from non-contemporaneous price and yield series in constructing a variance-covariance matrix of gross margins. These equations were originally developed in the statistical literature by Goodman; and Bohrnstedt and Goldberger. Agricultural economics applications include Anderson, Dillon and Hardaker; Burt and Finley; Boggess *et al.*; and most recently Tew and Boggess. Assuming activity gross revenues are multivariate normal, which is sufficient for the consistency of E-V models with the theory of expected utility, the expected value and variance of gross revenue for the *i*th activity become

$$(1) \quad E(P_i Q_i) = E(P_i)E(Q_i) + \text{COV}(P_i, Q_i), \text{ and}$$

$$(2) \quad V(P_i Q_i) = E^2(P_i)V(Q_i) + E^2(Q_i)V(P_i) \\ + V(P_i)V(Q_i) + 2E(P_i)E(Q_i)\text{COV}(P_i, Q_i) \\ + \text{COV}^2(P_i, Q_i),$$

where *V*, *E*, and *COV* are the variance, expected value, and covariance operators, respectively. In addition, *E*² and *COV*² are the squares of *E*(.) and *COV*(.), and *P_i* and *Q_i* are price and quantity of the *i*th activity. An expression for the covariance between the gross revenues of the *i*th and *j*th crops is

$$(3) \quad \text{COV}(P_i Q_i, P_j Q_j) = E(P_i)E(P_j)\text{COV}(Q_i, Q_j) \\ + E(P_i)E(Q_j)\text{COV}(P_j, Q_i) \\ + E(Q_i)E(P_j)\text{COV}(P_i, Q_j) \\ + E(Q_i)E(Q_j)\text{COV}(P_i, P_j) \\ + \text{COV}(P_i, P_j)\text{COV}(Q_i, Q_j) \\ + \text{COV}(P_i, Q_j)\text{COV}(P_j, Q_i).$$

Equations (1) through (3) require explicit assumptions concerning statistical independence between price and yield distributions. In the economic theory of the firm under risk, the assumption of independence between price and yield distributions is often justified by assuming pure competition (Dillon). This justification assumes firm output is independent of output from other firms and aggregate output. Independence between the distributions seems unreasonable in regions that annually produce a major portion of aggregate output of a crop. This assumption may be more plausible in regions that are minor producers of a crop. Nevertheless, Tew and Boggess demonstrated that the assumption did affect the variance of gross revenue of soybeans in Florida.

If crop price and yield are independent, *COV*(*P_i*, *Q_i*) = 0, the last term in (1) and the final two terms in (2) will be zero. If these distributions are not independent, derived demand theory suggests that the covariance term would be negative for major producing areas. Determining the sign of the sum of the last two terms in (2) is necessary to demonstrate the effect of joint distributions on *V*(*P_i*, *Q_i*). Using the definitions of a covariance, $2E(P_i)E(Q_i)\text{COV}(P_i, Q_i) + \text{COV}^2(P_i, Q_i) = \text{COV}(P_i, Q_i)[2E(P_i)E(Q_i) + E(P_i)Q_i - E(P_i)E(Q_i)] = \text{COV}(P_i, Q_i)[E(P_i)E(Q_i) + E(P_i)Q_i]$. For economic data, *E*(*P_i*), *E*(*Q_i*), and *E*(*P_i*, *Q_i*) are all positive so the sum has the same sign as *COV*(*P_i*, *Q_i*). Therefore, an incorrect independence assumption overstates estimates of (1) and (2). Such an assumption would falsely indicate that the enterprise had a higher risk-return tradeoff than a correct assumption would indicate. Alternatively, in noncentral production areas the covariance term could be positive. In this situation, an incorrect assumption of independence results in lower expected values and higher variances and would again bias the results towards less risk aversion. Tew and Boggess illustrate both effects with reference to soybean production in Florida.

The implications of independence on (3) are not as directly apparent. Economic theory suggests that market interrelationships cause *COV*(*P_i*, *P_j*) > 0, and relationships in response to environmental conditions cause *COV*(*Q_i*, *Q_j*) > 0. Both relationships are assumed to hold in all situations in this research. However, independence assumptions related to

$\text{COV}(P_i, Q_i) = 0$ could imply $\text{COV}(P_j, Q_i) = 0$ and/or that $\text{COV}(P_i, Q_j) = 0$. If both relationships are zero the second, third, and sixth terms of equation (3) all are zero. The aggregate affect on (3) of non-zero covariances depends on the derived demand characteristics of the individual commodities. For example, should crop i and crop j have a negative cross-price relationship a reduction in aggregate output of crop i would cause an increase in P_j without a corresponding reduction in yield so that $\text{COV}(P_j, Q_i)$ and $\text{COV}(P_i, Q_j)$ would be negative and (3) would be overstated if the three terms were zero. Alternatively, the two commodities may have a positive cross-price relationship, in which case (3) would be understated.

Data and Variance-Covariance Matrix Computations

Equations (1), (2), and (3) are used to calculate four variance-covariance matrices and corresponding expected values. One matrix, M_1 , using contemporaneous price and yield data for 1973 to 1981, is computed in a manner that reflects standard practices in risk programming methodology (i.e., dependence was assumed for M_1). A second matrix, M_2 , is computed using the same data, but individual crop prices and yields are assumed independent. Two more matrices, M_3 and M_4 , are calculated using crop price data from 1973 to 1981 and yield data from 1960 to 1981. Additionally, M_3 and M_4 incorporate dependence and independence assumptions, respectively. Calculation of the covariances

between prices and yields required by M_1 and M_3 used contemporaneous data from 1973 to 1981. Data from Georgia and from Kentucky are used in the empirical analysis. Corn and soybeans are included for both states and wheat and cotton are included for Georgia. State average price data and multicounty yield data are used because farm-level data series of sufficient length were not available. The Georgia data were from USDA sources (Georgia Crop Reporting Service). Data for the Kentucky example are obtained by using average farm data from the Kentucky Farm Business Management Groups in the Ohio Valley Portion of the state.

Results

The four variance-covariance matrices for the Georgia data are reported in Table 1. Variances of soybeans, cotton, and wheat in the dependent matrices, M_{1G} and M_{3G} , are lower than the corresponding values for the independent matrices, M_{2G} and M_{4G} , resulting from a negative covariance term in (2). Corn had a positive covariance term and therefore an opposite pattern. In addition, the variance and covariance terms are generally lower for the matrices that use non-contemporaneous data. This pattern arises from the distribution moments of long-term yields used to construct the non-contemporaneous matrices that were lower than the corresponding contemporaneous values. Several severe droughts during the 1970's caused $V(Q_i)$, $\text{COV}(Q_i Q_j)$, $V(P_i Q_i)$, and $\text{COV}(P_i Q_i, P_j Q_j)$ to be greater with a shorter yield time series. The drought

Table 1. Gross Revenue Variance-Covariance Matrices Constructed With Alternative Assumptions on Crop Prices and Yields in Georgia^a

Matrix	Soybeans	Corn	Cotton	Wheat
M_{1G} (dependent, contemporaneous)	1059.53	723.78 3056.55	6.07 2723.25 3161.90	277.15 370.65 260.57 95.38
M_{2G} (independent, contemporaneous)	1338.92	805.42 2042.48	416.41 1488.64 3599.15	319.87 282.54 85.24 256.10
M_{3G} (dependent, non-contemp.)	956.22	594.51 2666.89	-757.52 2038.10 3606.32	98.76 291.00 218.74 240.03
M_{4G} (independent, non-contemp.)	1235.62	676.16 1652.82	-347.19 803.48 4043.54	191.49 202.89 43.41 400.74

^aContemporaneous matrices included yields and prices from 1973 to 1981 while non-contemporaneous matrices included prices from 1973 to 1981 and yields from 1960 to 1981.

had less effect on wheat because of its different production period. Therefore, the variance of wheat would not necessarily decrease in an extended time frame. The results for cotton variance may be attributed to the large decline in cotton acreage during the non-contemporaneous study period since presumably a decline in observations used in the estimation of distribution parameters causes an increase in variance on a per acre basis.

Table 2 presents the four corresponding variance-covariance matrices for the Kentucky data. The variances for soybeans offer an interesting contrast to the Georgia estimates. For example, the variances calculated with the dependency assumption (M_{1K} and M_{3K}) are larger than the corresponding elements in the independent matrices (M_{2K} and M_{4K}). Recall the soybean variances for the Georgia example showed the opposite effect. The Kentucky relationships result from a positive covariance between soybean price and yield. The non-contemporaneous assumption produces variances slightly larger than the corresponding estimates produced using the contemporaneous assumption as a result of marginally larger yield variances over the longer period.

The variances of corn in the dependent matrices are lower than in the independent matrices. This pattern arises from a negative covariance between corn price and yield. Unlike Georgia, Kentucky is very close to the corn belt. Thus, a negative covariance implied by derived demand theory seems plausible. The variances for corn under the non-contemporaneous assumption are much larger than the corresponding contemporaneous values. Several severe droughts prior to 1973 caused the yield variance to increase relative to the seemingly stable growing period of 1973–81. The covariances in the dependent matrices (M_{1K} and M_{3K}) are much lower than the in M_{2K} and M_{4K} . Negative covariance terms between soybean price and corn yield make the entire second term in equation (3) neg-

ative and between corn price and soybean yield cause the third term in equation (3) also to be negative. In addition, the covariances in the non-contemporaneous matrices (M_{3K} and M_{4K}) are smaller than in the corresponding contemporaneous matrices because of lower expected yields for both crops and a much lower covariance between crop yields.

Parametric solutions obtained using the various assumptions for Georgia are illustrated in Figure 1 for a representative farm firm in the southern portion of Georgia (Musser, Mapp, and Barry; Musser and Stamoulis). Although the composition of the portfolios with each basis for alternative formulations of the problem are similar, the important aspect of the results is that the variance of the portfolios are not similar. The highest portfolio variances occur under the independent, contemporaneous assumptions (M_{2G}), and the lowest portfolio variances occur under the dependent, non-contemporaneous assumption (M_{3G}). The variances of M_{2G} are nearly twice those of M_{3G} with approximately the same expected returns. The dependency assumption has less effect on the portfolio variance than the contemporaneous assumption (i.e., M_{1G} is closer to M_{3G} than M_{4G} in Figure 1).

Parametric solutions for the different assumptions are illustrated in Figure 2 using a representative farm firm in the Ohio Valley region of the state. Again portfolios for the contemporaneous matrices (M_{1K} and M_{2K}) are quite similar. However, the initial solution of M_{1K} contained much less soybean and slightly more corn acreage than the corresponding initial solution of M_{2K} . Again the E-V coordinates of the solutions are very different reflecting the differences in the initial portfolio of the corresponding elements of the matrices. The composition of the non-contemporaneous matrices (M_{3K} and M_{4K}) is different with the dependent matrix (M_{3K}) having a smaller portion of the portfolio devoted to corn acreage. In this case, the

Table 2. Gross Revenue Variance-Covariance Matrices Constructed With Alternative Assumptions on Crop Prices and Yields in Kentucky^a

Matrix	Soybeans	Corn
M_{1K} (dependent, contemporaneous)	1502.00	153.45 884.77
M_{2K} (independent, contemporaneous)	1448.57	694.73 1962.33
M_{3K} (dependent, non-contemp.)	1583.00	-8.76 3142.36
M_{4K} (independent, non-contemp.)	1533.45	456.62 4064.06

^aContemporaneous matrices included yields and prices from 1973 to 1981 while non-contemporaneous matrices included prices from 1973 to 1981 and yields from 1960 to 1981.

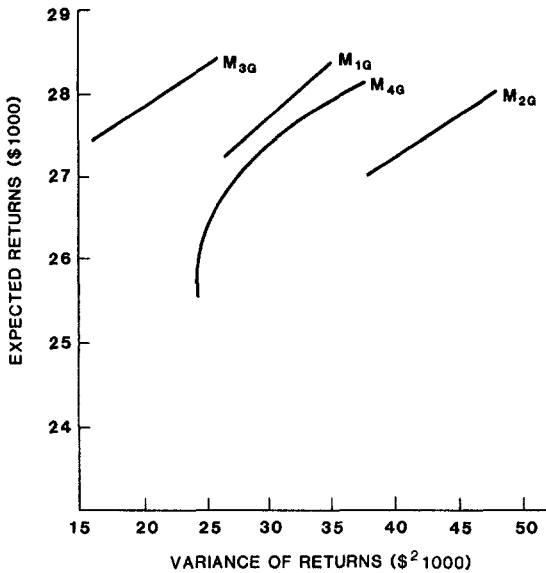


Figure 1. E-V Frontiers for the Various Dependency and Temporal Data Assumptions for the Representative Farm in Georgia.

dependency assumption has more effect on the portfolio variance than the temporal assumption.

Conclusions

This study examines the methodological issue of using non-contemporaneous data series to specify the expected values and variance-covariance matrix necessary for quadratic risk programming in a portfolio context. This approach allows the use of extended crop yield data with shorter, more relevant price data. The moments of the component distributions are related to the moments of a gross revenue distribution and illustrated for typical crops in two states. Four variance-covariance matrices and corresponding expected values are developed for each example. The data are subsequently incorporated into quadratic risk programming models and parametric solutions are generated. Enterprise organizations for the same expected portfolio returns are similar but the variances of gross revenue are much different. Similar differences could exist in many risk programming applications except when prices are nonstochastic.

Given these differences in results, the appropriate assumptions for risk research are important. Theoretically, the non-contemporaneous assumption has considerable merit because yield distributions evolve more slowly than price distributions. This assumption combines the statistical efficiency of larger samples with the decision theory principle

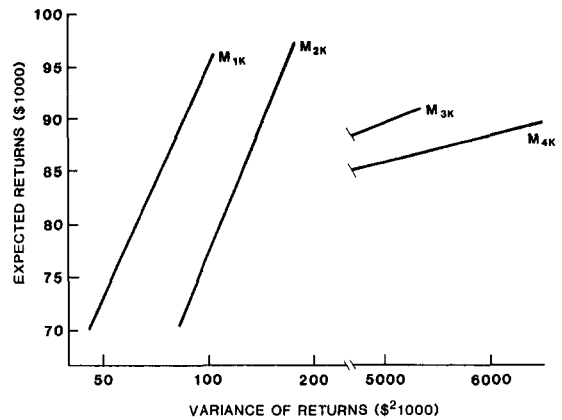


Figure 2. E-V Frontiers for the Various Dependency and Temporal Data Assumptions for the Representative Farm in Kentucky.

of recent information for current decisions. Therefore, yield data have longer usefulness in specification of current gross revenue distributions than price data. Rather than truncating the gross revenue series at the time pricing environments change, yield data generally can be used for the entire period that has data available for the current production environment.

The methods presented in this paper for non-contemporaneous data are only applicable to quadratic risk programming models and cannot be adapted to linear risk programming methods such as MOTAD in which deviations rather than distribution parameters are necessary. Thus, the procedures presented in this research demonstrate one situation where the methods are not substitutes. Similarly, these methods are not applicable to stochastic dominance techniques. Unless other methodology is developed, quadratic programming appears to have an advantage in the use of non-contemporaneous data sources. Nevertheless, the statistical methods for using non-contemporaneous data require explicit assumptions concerning the statistical dependency of yields and prices. An assumption of independence in areas that are minor producers of commodities is theoretically plausible. Although the effect of the small positive covariances in the Georgia empirical analysis confirmed earlier research that the assumption can influence variance of income of enterprises, both data applications demonstrated the importance of the covariance terms between crops [i.e., $\text{COV}(P_i Q_i, P_j Q_j)$] in correctly calculating the covariance between revenues. Earlier studies of the independence assumption in combining distribution parameters such as Tew and Boggess had not incorporated this effect. Certainly,

an assumption of dependence provides more generality for empirical analysis since this assumption accommodates independence as well. While the use of non-contemporaneous price and yield data were illustrated in the study with traditional sample statistics and historical data, the general methods are applicable to other methods of estimating variance-covariance matrices. Application to the forecast error approach is quite straightforward. For subjective methods, decisions on the length of time series is not relevant, but combining moments of price and yield distributions is still important. Furthermore, decision makers may be able to specify individual price and yield distributions better than revenue distributions because they correspond to separate marketing and production decisions.

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