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RISK-RETURN ASSESSMENT OF IRRIGATION DECISIONS IN HUMID REGIONS: AN EXTENSION

Bernard V. Tew and William G. Boggess

Abstract

The risk effects of irrigation scheduling in a sub-humid climate have been well documented recently using approximations of the variance of net returns. A method to determine the exact variance of net returns assuming only multivariate normality is presented. The approximation technique in contrast to the method presented in this research was shown to have a non-uniform effect on the variance of net returns of each schedule.

Key words: exact variance, risk, irrigation scheduling.

The recent work by Boggess et al. demonstrates the importance of irrigation scheduling with respect to various types of risk in a sub-humid climate. The empirical results of the article were derived using an approximation of the variance of net returns. Boggess et al. represents net returns (π) for each irrigation schedule in equation (2) of their recent study using an approximation procedure developed by Burt and Finley. The random variables used by Boggess et al. to represent expected net returns which are preserved in this study include: price of soybeans (P); crop yield using irrigation schedule i , (Y_i); price of irrigation water (R); and the amount of water applied using schedule i , (X_i). The purpose of this note is to present an alternative calculation method. Expressions for the expectation and variance are developed and used to calculate these statistics for several simulated irrigation schedules for the purpose of comparison.

METHODOLOGY

Goodman; Bohrnstedt and Goldberger; and, recently in the agricultural economic literature, Anderson et al. derived expressions for the ex-

pectation and variance of a product under very general assumptions. Since expected value-variance analysis was used by Boggess et al., an assumption of multivariate normality was added to simplify this analysis. The resulting expressions are:

$$(1) E(\pi) = E(P)E(Y_i) + \text{Cov}(P, Y_i) - E(R)E(X_i) - \text{Cov}(R, X_i)$$

and

$$(2) V_i = V(PY_i) + V(RX_i) - 2\text{Cov}(PY_i, RX_i)$$

where the variances of net revenue and cost are:

$$(3a) V_{PY} = [E(P)]^2 V_Y + [E(Y_i)]^2 V_P + V_P V_Y + \text{Cov}^2(P, Y_i)$$

and

$$(3b) V_{RX} = [E(R)]^2 V_X + [E(X_i)]^2 V_R + V_R V_X + \text{Cov}^2(R, X_i).$$

The covariance between two products is:

$$(4) \text{Cov}(PY_i, RX_i) = E(P)E(R)\text{Cov}(Y_i, X_i) + E(P)E(X_i)\text{Cov}(Y_i, R) + E(Y_i)E(R)\text{Cov}(P, X_i) + E(Y_i)(X_i)\text{Cov}(P, R) + \text{Cov}(P, X_i)\text{Cov}(Y_i, R).$$

The variance of net returns is formulated by incorporating the independence assumptions of Boggess et al., and expanding equation (2) to include the reduced forms of equations (3a), (3b), and equation (4).¹ That expression is:

$$(5) V_i = [E(P)]^2 V_Y + [E(Y_i)]^2 V_P + V_P V_Y + [E(R)]^2 V_X + [E(X_i)]^2 V_R + V_X V_R - 2[E(P)E(R)\text{Cov}(Y_i, X_i) + E(Y_i)E(X_i)\text{Cov}(P, R) + \text{Cov}(P, R)\text{Cov}(Y_i, X_i) + \text{Cov}(P, R)(\text{Cov}(Y_i, X_i))].$$

Equations (1) and (5) are used for this analysis.

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¹The analysis implicitly assumed that an individual farmer follows a fixed irrigation strategy based on soil water threshold. Thus, there was no interaction between soybean price and irrigation applied, between water costs and irrigation application, or between yield and water costs. For applications using observed data based on profit maximizing behavior, one would expect that $\text{Cov}(P, X) > 0$, $\text{Cov}(R, X) < 0$, and $\text{Cov}(Y, R) < 0$.

RESULTS

Expected net returns and variance of net returns were calculated for the same irrigation schedules presented in Boggess et al. The relative contribution of each component random variable to the variance of net returns was analyzed by normalizing equation (5) as described by Burt and Finley. While the general trends reported in the earlier study were also apparent in this research, several interesting points originated from a comparison of the variance and covariance terms. The component variance terms largely remained unchanged; however, the covariance and, consequently, the variance of net returns terms were substantially different. For low frequency strategies, the covariances remained negative but were approximately three times larger in absolute value. For high frequency strategies, the covariances were positive and slightly larger than the earlier approximations.

Because the calculations presented in this research changed the variance of net returns of each schedule in a nonuniform manner, the "smoothing" effect of the Burt and Finley approximation was removed. An explanation for this nonuniform change can be found in the relationship between the individual component random variables and the covariance. The sum of the covariance terms was negative for low levels of irrigation and increased steadily as the level of irrigation increased. The negative covariance arose from a negative correlation between yield and water applied. For low-frequency schedules, drought damage to the crop has occurred before the threshold was reached. However, when the threshold was reached, the water applied was relatively effective. Since the low thresholds were reached more often in dry years than in wet years, there was a tendency for low yields to be accompanied by relatively large applications of irrigation water and vice versa. As the threshold was increased, less stress occurred before irrigation was initiated.

CONCLUSIONS

The procedures employed in this note provide expressions for calculating the variance of net returns as a function of four random variables. This method differs from the earlier method primarily in the addition of several covariance terms. However, the specific independence assumptions of the Boggess et al. article which eliminated some of the covariance terms were retained in this analysis to illustrate the impact of the remaining covariance terms.

The methodology developed in this note allows analysis and/or elimination of the effects of various independence assumptions that are often used by agricultural decision analysts. Since agricultural economists are increasingly using analytical techniques such as biophysical simulation (Musser and Tew) to synthesize data series and noncontemporaneous data series in risk decision analysis, the appropriateness of independence assumptions is suspect. For example, in this analysis consider inclusion of such an assumption between crop price and quantity. In areas that do not annually account for a large portion of aggregate crop output, the independence assumption seems reasonable and unlikely to cause decision errors. However, in other areas of the country, farm level yields may correlate more closely with aggregate output and subsequently price. Another potential application of the methodology occurs when the independence assumption between input price per unit and the quantity of input used is relaxed (see Tew for such an application). In situations with similar characteristics to the two previous examples, substantial errors in the estimation of net returns (expected value) and risk (variance) could result in risk inefficient management decisions. Further avenues of research employing the methodology developed here include comparative investigations of the various independence assumptions on other crops and in other production areas.

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