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A CLARIFICATION OF FORWARD PRICING WITH YIELD RISK FROM A REGIONAL PERSPECTIVE

Larry A. Johnson

Development of the portfolio model of hedging with applications to include production variability were first developed by McKinnon. For a number of years, however, most theoretical and applied studies (Ward and Fletcher; Stein; Johnson; Peck) focused entirely upon price changes. Only in recent years have several authors again begun to address the yield risk factor in hedging (Rolfo, Grant 1985, Berck, Conroy and Rendleman, Miller and Kahl, Curtis, et. al.).

Rolfo used the McKinnon approach to include yield variability in an empirical study to determine optimum hedge levels for Cocoa producing countries. Berck included production risk in a revenue forecast equation to study hedging multiple crops using quadratic programming. Also, Karp developed a theoretical model of dynamic hedging with yield risk under an optimal control framework. Most framed hedging in a portfolio setting and viewed returns to the cash and futures positions as separate assets.

Grant (1985) extended McKinnon's theoretical model and provided further insight into the complexities of forward pricing with production uncertainty when he compared the theoretical actions of the firm both with and without a forward market. He concluded that firms facing just price risk and those facing both price and production risk behave similarly in the absence of forward markets. However, in the presence of a forward market the covariance between price and production affects a farmer's scale of production and the optimal forward position. He goes on to demonstrate the preference for hedging given different covariance relationships between farm level revenues and futures price.

The preferred levels of hedging given different price-yield relationships was first discussed by McKinnon. He states that the greater the output variability relative to price variability, the smaller will be the optimal forward sale; and, the more negatively correlated price and yield, the smaller will be the forward sale. McKinnon suggests that weather conditions affecting a particular farmer are likely to affect other farmers and that any particular farmer expects his own output to be positively correlated with the aggregate output of all farmers and negatively correlated with price. He derives a "pseudo" or "effective" elasticity of demand and suggests that as the effective elasticity of demand approaches one, hedging would be reduced. As the effective elasticity approaches zero, an increasing amount would be recommended.

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Conroy and Rendleman expand upon McKinnon's assertion of price-yield relationships and indicates that the effective elasticity is not a "true" elasticity since an individual farmer would have a negligible effect on price. Most farmers, however, could expect some degree of correlation between market price and their own output and this relationship would depend on their location relative to other producing regions. Farming areas far removed from the major producing region could expect low correlation between price and output; whereas, primary producing regions might expect high correlation between price and yield.

Reflecting back upon McKinnon's assertions regarding price-yield correlations and yield variability, primary producing regions may expect high negative correlation between price and yield which would suggest that optimal forward positions are likely to be small. Also, aggregation of production from numerous farmers over several regions suggest that individual farmers and local regions are likely to face more production variability than the variability of aggregate price levels. Higher production variability relative to price variability would again cause optimal forward sales to be small. Therefore, these observations suggest routine forward pricing by producers in the primary producing regions before yields are known are likely to be small. However, individual farms and/or regions where price variability is greater than production variability may forward price more. Also, there may be lesser producing regions facing a positive price-yield relationship that could obtain even greater reductions in income variation through routine forward pricing.

PURPOSE

The purpose of this paper is to determine the price-yield relationships of major and lesser producing regions of corn and soybeans and draw implications as to their possible influence on the desirability of forward pricing. The paper uses McKinnon's effective demand elasticities and minimum variance hedge ratios to determine theoretical levels of forward pricing assuming farmers can completely off-set year-to-year cash price changes through forward priced positions. The analysis then extends Rolfo's theoretical model to arrive at actual levels of forward pricing using futures markets transactions. The study determines the need for forward pricing on a state-by-state level and draws implications as to the resulting impact of forward pricing on farm-level income stability.

MODEL FORMULATION

Forward pricing is viewed here in terms of futures hedging. The analysis is performed based only upon mean and variance. Commodity options and/or utility functions addressing higher moments were not considered to simplify the analysis.

A Rolfo type formulation is used to demonstrate the derivation of the optimal forward position. The farmer is assumed to maximize a Von Neuman-Morgenstern utility function U defined on income. If income is normally distributed, a farmer's risk function can be expressed by the exponential function

$$U = 1 - e^{-\alpha\pi} \quad (1)$$

where,

U = utility of income,
 α = Arrow-Pratt risk aversion coefficient, and
 π = income.

Freund extended the exponential function to show that given a normal distribution of income with mean μ and variance σ^2 , the exponential function can be expressed as a mean-variance utility function where

$$E[U(\pi)] = E(\pi) - \alpha/2(\text{Var } \pi) \quad (2)$$

and assumes constant levels of risk aversion with increasing levels of income.

For the case of forward pricing with futures, income (π) becomes the combined incomes from both the cash position and the forward position. Assuming stochastic prices and yields, income (π) then becomes

$$\pi = [P_c Y] + [N_f Q(F - P_f)] \quad (3)$$

where,

π = combined income from the cash and forward positions,
 P_c = cash price,
 Y = actual yield,
 N_f = predetermined proportion of production forward priced,
 Q = predetermined level of output,
 F = forward price, and
 P_f = settlement or futures price.

Given that $Q(F - P_f) = \pi_f$, then, maximizing expected utility of historical mean revenue with respect to the predetermined level of forward pricing gives the optimum portion of forward pricing

$$N_f = E(\pi_f)/\alpha \text{Var} \pi_f - \text{cov}(P_c Y, \pi_f)/\text{Var} \pi_f. \quad (4)$$

If one assumes the forward market is efficient and the best predictor of future price levels, the first expression (the speculative component, see Rolfo) goes to zero and the optimum level of forward pricing then becomes

$$N_f = - \text{cov}(P_c Y, \pi_f) / \text{Var} \pi_f. \quad (5)$$

This expression, often described as the optimal or naive hedge, is simply the slope coefficient between cash income and futures profits and can be derived empirically using simple regression techniques. Since the variance of the future price is always positive the decision regarding whether or not to forward price and the absolute level to forward price depends upon the covariance of cash income and futures profits.

The optimal hedge simply gives the percentage of expected production that should be hedged to minimize the variance of total income over time. The model does not incorporate year-to-year price expectations nor does it consider information about upcoming revenue contained in the futures price quotations. Revenue expectations obtained from information on futures price can only be obtained if expected yields are realized.

DATA AND METHODS

Ideally, a study of this type would analyze farm level price-yield relationships across numerous regions and over a long time period. Lack of resources along with inadequate and inconsistent data, however, limited this approach. An analysis of regional differences in forward pricing was performed using state level data over the 50 year period 1936-85. A fifty year period was chosen in order to include an adequate number of national crop disasters and provide a relatively high degree of statistical significance. While not perfectly addressing hedging differences, it does provide general insight as to preferred hedge levels across states and across time.

The analysis derived the correlation coefficient, effective² demand elasticity measure¹, the "McKinnon" minimum variance hedge ratio², and the optimum hedge coefficient using cash and futures returns for both corn and soybeans. Individual state and U.S. average price and yield data were collected from U.S.D.A.'s Agricultural Statistics. Ideally, harvest prices would be used to reflect harvest sales. An adequate set of harvest prices were unavailable, however, so season average prices were used. Futures price data were collected from the Chicago Board of

¹McKinnon's effective demand elasticity is $\epsilon = (\delta X / \delta P)(P/X)$ where X is output and P is price.

²The minimum variance hedge ratio as defined by McKinnon is $\Omega = \epsilon + 1$, where Ω is the amount forward priced relative to production and ϵ is effective elasticity.

Trade's Annual Report. To be consistent with the season average cash price, an average of the midpoints of the range of high and low futures settlement prices for the first six months of the harvest season were used as a proxy for futures settlement price. The futures settlement price quoted on the fifteenth of April or the first trading day following the fifteenth was used as the forward price. The Producer Price Index used to deflate price levels was from the U.S. Statistical Abstract.

Prices were deflated and yields detrended so the analysis would reflect year-to-year changes in prices and yields. Each state's yield was regressed on time and detrended to reflect differences in each state's yield response to technology. U.S.D.A.'s season average price was used to represent each state's cash price.

Pearson's correlation coefficients were calculated and significance levels determined. Regression analysis was used to determine elasticity measures and hedge ratios along with significance levels for the t statistic and corresponding coefficients of determination. Results are presented in Figures 1 through 4. Figures 1 and 2 summarize price-yield correlation coefficients by state. The correlation coefficient, effective elasticity measure, "McKinnon" minimum variance ratio, and optimum hedge ratio are shown by state and listed from top to bottom in Figures 3 and 4.

RESULTS

In general, the correlation coefficients and price-yield elasticity measures were consistent with the McKinnon minimum variance hedge ratios and suggest that the possibility of forward pricing of at least a minimum level to a relatively high level of production is recommended for both crops in all states considered. However, optimum hedge ratios as determined using actual futures markets transactions are greatly reduced, statistically insignificant, and even negative for several states. These results are consistent with those reported by Grant (1987) in a preliminary study of hedging across states. Some regional differences do occur for soybeans and particularly for corn suggesting that opportunities from routine forward pricing differ for producers in different states.

Soybeans

Negative price-yield correlations exist for all states analyzed with the exception of Wisconsin which is essentially zero and insignificant at the $\alpha = 10\%$ level. All effective elasticity coefficients are negative inelastic suggesting state level percentage price changes are greater than percentage yield changes. Negative correlation coefficients are significant at the $\alpha = 10\%$ level for most of the midwestern, delta, and southeastern states. Most of the

northern border states had insignificant price-yield correlation coefficients.

McKinnon's theoretical minimum variance hedge ratios are positive for all states analyzed ranging from 51% to 96% of production. As suggested by McKinnon, the more elastic the elasticity coefficient, the smaller the hedge ratio. Optimum hedge ratios as determined by the futures transaction, however, range from a long position of 19% in Alabama to a short position of 55% in Kansas. All optimum hedge ratios are insignificant with the exception of Kansas which has a significant t statistic at the $\alpha = 10\%$ level but a low coefficient of determination at .09.

The dispersion and recommended levels of forward pricing are consistent with production patterns. Soybean production is widely dispersed within the U.S. with most production occurring in the traditional corn-soybean belt. Therefore, weather patterns affecting any major producing region impacts total supply enough to create a price response. Price-yield relationships and recommended levels of forward pricing appear to be consistent across production regions.

Corn

Corn demonstrated distinct regional differences in price-yield relationships as evidenced by statistically significant negative correlation coefficients in the midwestern states and zero and/or positive correlation coefficients in the southeastern states and Kansas. Effective elasticity coefficients are both positive and negative depending upon location. McKinnon minimum variance hedge ratios varied from a low of 72% in Missouri to a high of 127% of production in Florida. Optimum hedge ratios as determined by futures profits are much less ranging from a long position of 3% in Nebraska to a short position of 28% in Indiana and Ohio. Optimal hedge ratios are significant for the t statistic at the $\alpha = 10\%$ level for Indiana, Ohio, and Michigan but the coefficients of determination are low with all being less than .15.

The results suggest that a significant negative relationship exists between price and yield in the major corn producing area. Again, yield changes in the region can greatly impact price and this lowers the potential level of forward pricing by farmers in that region. Forward pricing using futures markets transactions are less than theoretical levels and may be closer to observed levels of forward pricing. The relationship between price and yield are much different in lesser producing regions ranging from zero to slightly positive and suggests that higher levels of forward pricing might be applied. Optimum hedge ratios as determined through the use of futures transactions, however, does not indicate this may be the case.

SUMMARY AND CONCLUSIONS

This study uses McKinnon's theoretical evaluation of forward pricing and extends Rolfo's theoretical model of hedging using futures transactions by investigating state-level price-yield relationships and draws implications as to the effects upon preferred and actual levels of hedging. Generally the results imply that distinct price-yield differences exist across states and that these differences can greatly affect routine hedging decisions. Regional differences for corn are more distinct than for soybeans. Price-yield correlations and effective elasticity coefficients suggest that some lesser corn producing states have the potential for relatively high levels of routine forward pricing. Effective demand elasticities suggest at least some minimum level of forward pricing even in the major producing states.

Actual hedging results using futures transactions, however, suggest that the need for forward pricing is inconclusive. Part of the problem may be due to the volatile nature of the futures markets and the timing of forward positions thereby causing the statistical results to be insignificant. Efficiency of the futures markets capture changes in planting intentions and suggest that forward prices at planting are not as volatile as harvest prices and thus does not allow farmers to completely off-set year-to-year variations in cash income. Also, elasticity measures are derived from each state's cash price-yield relationship which would include basis variability and therefore may indicate a higher degree of negative correlation than that which is present when yields are compared to futures prices.

Further research should include a more detailed analysis of the futures transactions. The analysis should include farm level yields within the different regions to determine whether the possibility exists for forward pricing within the region. Also, the analysis should be performed over different time periods. The results are very sensitive to the time period considered due to the infrequent nature of climatic disasters. Finally, other crops should also be analyzed to determine whether these patterns are consistent.

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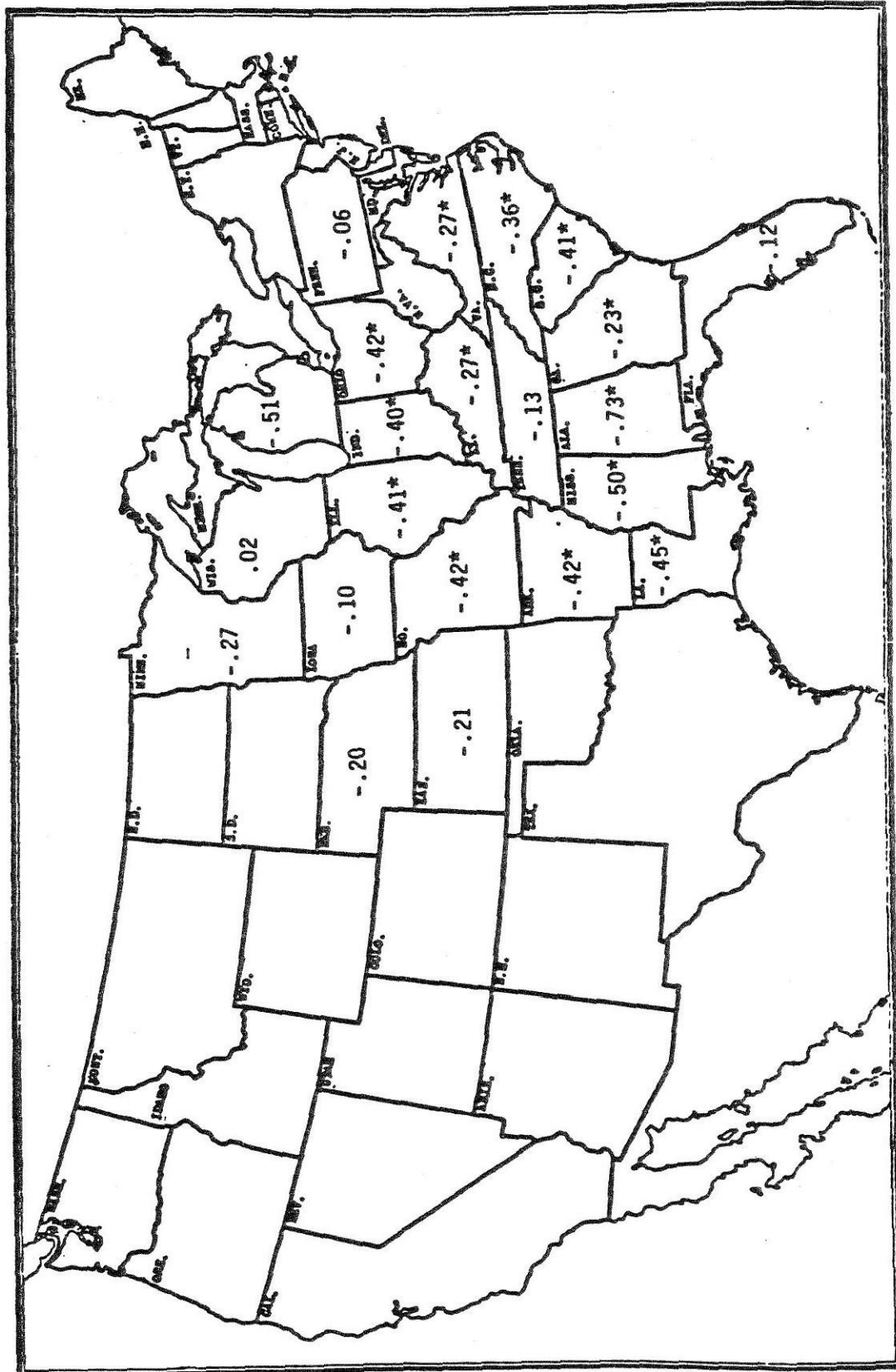
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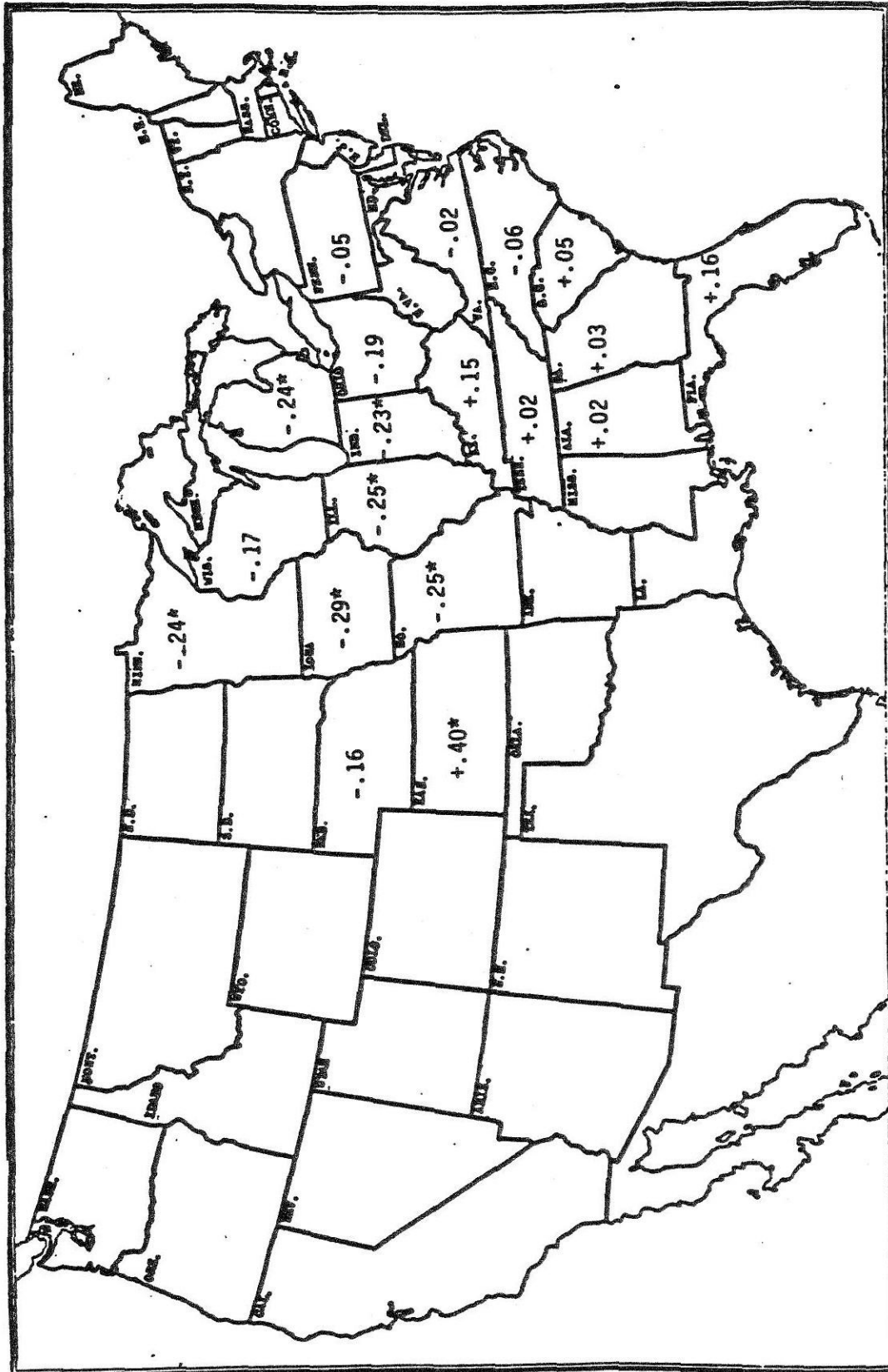
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Figure 1. State Level Price-Yield Correlation Coefficients¹ For Soybeans.



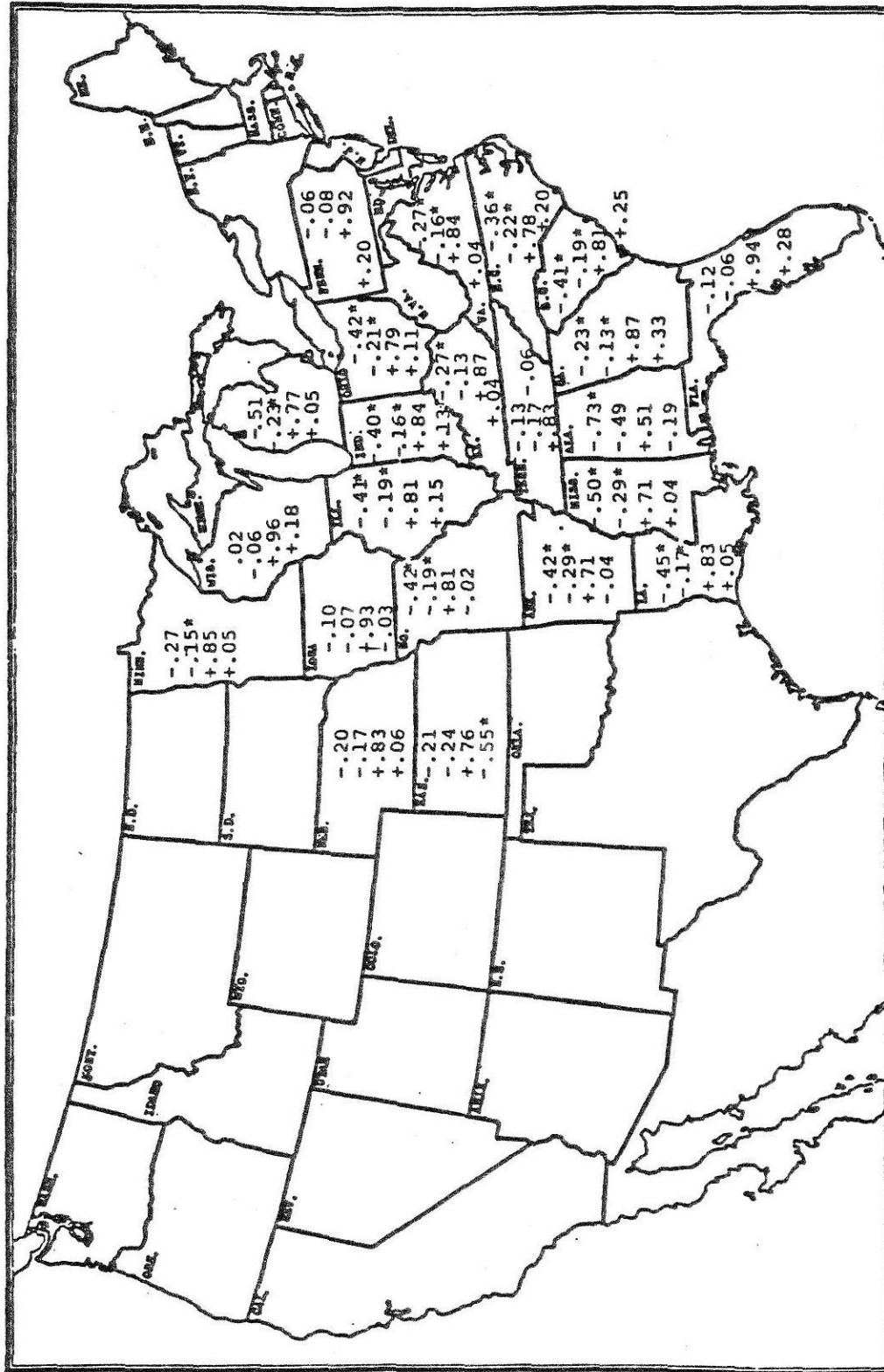
1. * indicates significant at $\alpha = .10$ for Pearson correlation coefficient.

Figure 2. State Level Price-Yield Correlation Coefficients¹ For Corn.



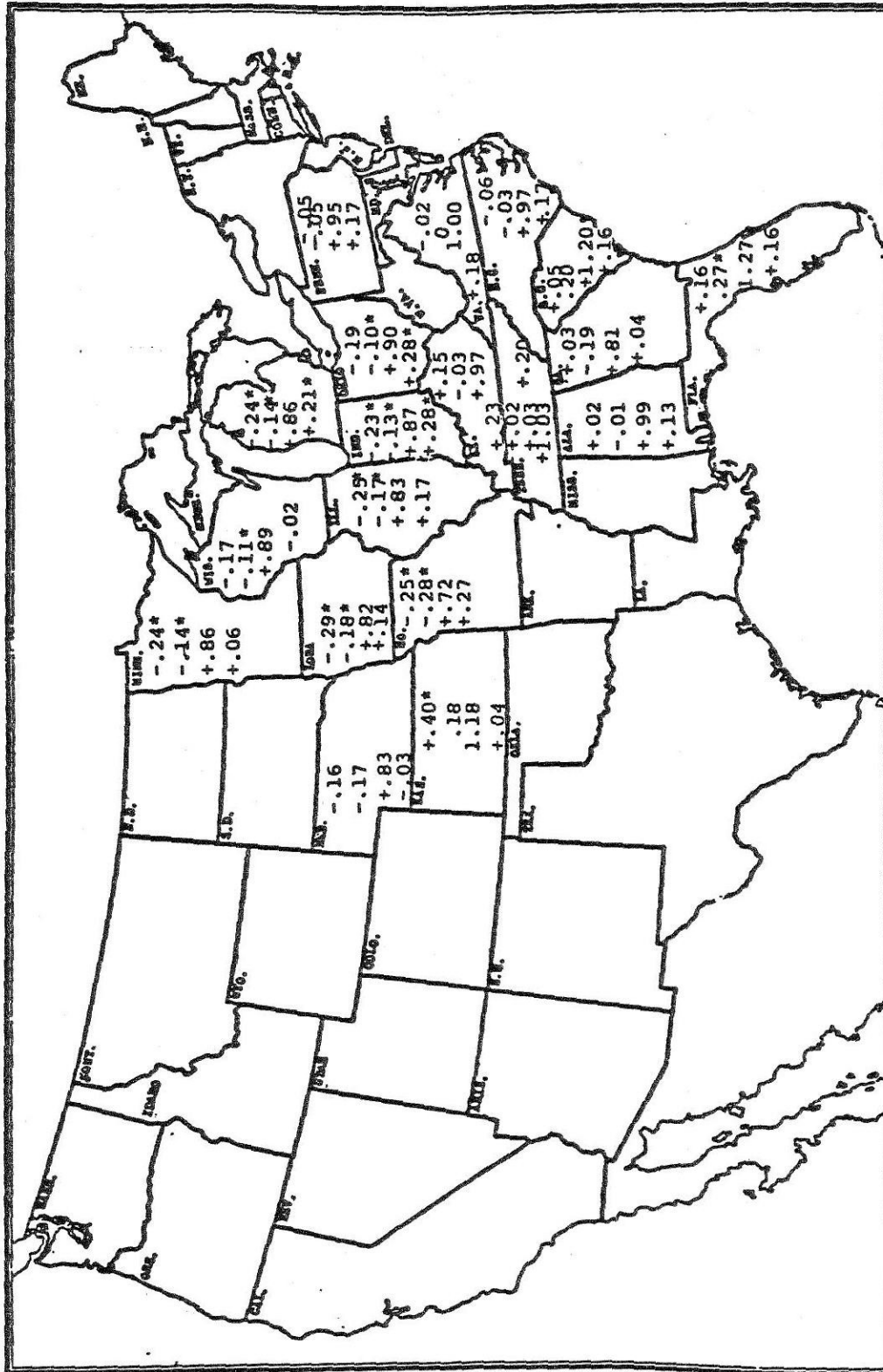
1. * indicates significant at $\alpha = .10$ for Pearson correlation coefficient.

Figure 3. State-by-State Summary¹ of Correlation Coefficients² Effective Elasticity Coefficients³, McKinnon Hedge Ratios³, and Optimum Hedge Ratios³ for Soybeans.



1. Coefficients are listed from top to bottom as the correlation coefficient, effective elasticity coefficient, McKinnon hedge ratio, and hedge ratio.
2. * indicates significant at $\alpha = .10$ for Pearson correlation coefficient.
3. * indicates significant at $\alpha = .10$ for standard t statistic.

Figure 4. State-by-State Summary¹ of Correlation Coefficients² Effective Elasticity Coefficients³, McKinnon Hedge Ratios³, and Optimum Hedge Ratios³ for Corn.



1. Coefficients are listed from top to bottom as the correlation coefficient, effective elasticity coefficient, McKinnon hedge ratio, and hedge ratio.
2. * indicates significant at $\alpha = .10$ for Pearson correlation coefficient.
3. * indicates significant at $\alpha = .10$ for standard t statistic.