Estimation of Wheat Acreage Response Functions for the Northwest

John R. Winter and James K. Whittaker

Acreage response functions for wheat are fitted to aggregate data and pooled time-series and cross-sectional data for the Northwest. It was hypothesized that the pooled data approach provides a useful alternative to using aggregate data since it requires fewer time-series observations for reliable parameter estimation and it does not require the assumption of constant acreage response elasticities throughout the region. The results of this study verify this hypothesis as well as indicate that regional response elasticities for Northwest wheat acreage may differ greatly from national estimates.

In the Northwestern states of Oregon, Washington and Idaho, fifty percent of all planted acreage is sown to wheat (1975-1977 average). The importance of wheat in the Northwest indicates that the responsiveness of wheat acreage to changes in product prices and government programs has a significant regional impact on farm income, demand for storage and marketing facilities, and the regional balance of payments. National estimates of wheat acreage responsiveness to various independent variables may not be appropriate for discerning or predicting changes in regional wheat acreages. If a given region's response to changes in independent variables differs from the national response, then the use of national models to determine regional impacts on farm income and demand for storage and marketing facilities will give misleading results.

In 1973, Hoffman developed acreage response functions for five wheat producing regions of the U.S. Generally, his models were successful both in terms of explaining a large proportion of regional variation in wheat acreage and in determining the structural response to various independent variables. However, for the Northwest region, his model failed to meet expectations in terms of R^2 and the significance levels of the estimated coefficients.[1]

The objective of this paper is to estimate a regional wheat acreage response function for the Northwest and compare parameter estimates to those from national models. Results of two approaches are compared. First, the parameters of an aggregate regional model are estimated using annual time series observations from 1954 to 1977. One disadvantage of estimating an aggregate acreage response model is the need for a fairly lengthy time series (usually a minimum of twenty observations) in order to have sufficient degrees of freedom for reliable parameter estimation. Unfortunately, the parameter estimates from data spanning several major policy regimes are somewhat suspect. In this analysis, 1954 was chosen as the first time series observation for the aggregate model, because it is the first post-war year following a major wheat policy change and, in addition, it provides a sufficient number of observations for parameter estimation. The observations are re-

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[1]Hoffman defined the Northwest region to include Washington, Oregon, Idaho, Nevada, California, and Arizona.

gional totals or weighted regional variables. The aggregate model implicitly assumes that the acreage response elasticities are homogeneous across the three states. If this assumption is not valid, aggregation error and bias are inherent in the estimated coefficients.

The second approach uses pooled time-series and cross-sectional data for parameter estimation. The estimation period for this model is 1964 to 1977. The year 1964 was chosen as the starting point for these data since it, too, was the first year after a major change in the government programs for wheat.

There are two major advantages of using pooled data. The first is that pooling enables the researcher to estimate the parameters of a model using a shorter historical time period than is necessary for an aggregate regional model. In addition to the disadvantage already mentioned, measuring the effects of changes in technology is a common problem in supply analyses. The longer the time period under analysis, the greater the chance of significant changes in technology. While shortening the time period used for parameter estimation likely will not eliminate the effects of changing technology, it should greatly reduce the problem. The second advantage of pooled data is that it enables the researcher to relax the assumption that acreage response elasticities are constant throughout the region being studied.

Following sections of the paper discuss the specification of the aggregate and pooled models and then present and compare empirical results for the two regional models.

Model Specification

The aggregate regional wheat acreage model used in this analysis is similar to the model presented by Houck, *et al.* However, a risk variable is added following the formulation used by Lin. The model is specified as follows:

$$(1)\quad AW_t = f(PW_{t-1}, EWSP_t, WD_t, Risk_t);$$

where, AW_t = acres of wheat planted for the region in year t, in thousands of acres; PW_{t-1} = regional price of wheat in year t−1, in dollars per bushel[2]; $EWSP_t$ = wheat price support rate weighted by percent of wheat acreage eligible for this payment in year t, in dollars per bushel[3]; WD_t = voluntary wheat diversion payment rate weighted by percent of wheat acreage eligible for this payment in year t, in dollars per bushel; and $Risk_t$ = moving average of the standard deviation of the regional gross income per acre from wheat for the three previous years.[4]

The model specification for the pooled-data model is similar to the aggregate model with the addition of binary variables for Washington and Idaho. The model specification is:

$$(2)\quad AW_{i,t} = g(PW_{i,t-1}, EWSP_t, WD_t, Risk_{i,t}, BW, BI);$$

where, $AW_{i,t}$ = acres of wheat planted for state i in year t, in thousands of acres; $PW_{i,t-1}$ = price of wheat for state i in year t−1, in dollars per bushel; $EWSP_t$ = wheat price support rate weighted by percent of wheat acreage eligible for this payment in year t, in dollars per bushel; WD_t = voluntary wheat diversion payment rate weighted by the percent of wheat acreage eligible for this payment in year t, in dollars per bushel; $Risk_{i,t}$ = moving average of the standard deviation of

[2]The regional wheat price was calculated as the sum of the lagged state wheat prices, with each state price weighted by the proportion of regional wheat acreage attributed to the state in that year.

[3]For a detailed account of the construction of these variables under each policy regime, see Houck, *et al.* One reviewer questioned the economic rationale of this policy variable formulation. The variables formulated by Houck *et al.* were chosen for this study because they are the most prevalent in the literature. For alternative policy variable formulations, see Lidman and Bawden, Just (1973), and Danin.

[4]Regional gross income per acre was calculated as the sum of the state per acre gross incomes with each weighted by the proportion of regional wheat acreage attributable to the state in that year.

per acre gross income for state i for the previous three years; BW = binary intercept shift variable for Washington (=1 if the observation is for Washington, and 0 otherwise); and BI = binary intercept shift variable for Idaho, (=1 if the observation is for Idaho, and 0 otherwise).

The lagged price of wheat is assumed to be a proxy variable for producers' price expectations at planting time. The coefficient on this variable is expected to be positive; that is, an increase in the expected price of wheat with all other variables remaining constant is hypothesized to result in an increase in planted wheat acreage.

Likewise, the coefficient of the wheat support rate is hypothesized to be positive. This variable may be viewed as a guaranteed minimum price for wheat. If this guaranteed price is increased with all other variables remaining constant, planted acreage is expected to increase.

The weighted voluntary diversion payment rate is hypothesized to be negatively correlated with planted wheat acreage. This variable represents an alternative to wheat production; that is, leaving the land idle in order to receive the diversion payment. As the price of this production alternative increases, one would expect a shift from wheat production to diversion.

As producers are generally assumed to be risk averse [see, for example, Just (1974) and Lin], the coefficient of the risk variable is expected to be negative. An increase in the variability of per acre gross income from wheat production is hypothesized to induce a decrease in wheat acreage planted.

The shift variables in the pooled-data model account for differences in the mean planted wheat acreage among the three states. The coefficients on these variables represent differences in planted acreage between Oregon and each of the other states. Since both Washington and Idaho produce more wheat than Oregon the coefficients on both shift variables are expected to be positive.

Both the aggregate model and the pooled-data model are estimated using a double logarithmic functional form. The pooled-data model implicitly assumes that the relationship between wheat acreage and the independent variables is the same for all three states. If this equation were estimated in the linear functional form, this assumption implies that a given change in an independent variable would change acreage of wheat equally in all three states. Since planted wheat acreage varies considerably among the three states, it is not reasonable to assume that the change in acreage from some given change in price is equal across states. The double logarithmic functional form enforces the more reasonable assumption that the acreage elasticities are equal across states. Therefore, the double logarithmic functional form was used for parameter estimation in the pooled-data model. The aggregate model was also estimated in double logarithmic form to maintain comparability to the pooled-data model.

Empirical Results

Aggregate Model

The ordinary least squares (OLS) estimates of the parameters of equation 1 in double logarithmic form are presented below.[5]

$$\text{(3)}\quad \text{LnAW}_t = \underset{(128.7)}{8.11} + \underset{(1.46)}{.094}\ \text{LnPW}_{t-1} - \underset{(-.299)}{.032}\ \text{LnWD}_t + \underset{(4.50)}{.508}\ \text{LnEWSP}_t + \underset{(1.34)}{.032}\ \text{LnRisk}_t$$

$$R^2 = .716 \qquad DW = 1.77$$

All coefficients have the anticipated sign except for the risk variable, but it is not significant at the five percent level of probability. Only the weighted support price coeffi-

[5]Numbers in parentheses below the estimated coefficients are t-values and DW is the Durbin-Watson statistic.

cient is significant at five percent. The estimated elasticity of planted acreage with respect to the weighted wheat support price is .508 which is very similar to Houck, *et al.*'s national estimate of .58. The estimated elasticity with respect to wheat price is .094, which is much smaller than national estimates obtained by Nerlove (his estimates were in the range .35 to .48) and by Houck, *et al.* (.39). However, this coefficient is not significant in the model estimated here. The Durbin-Watson statistic indicates that serial-correlation is not a problem.

Pooled-Data Model

The OLS estimates of equation 2 in double logarithmic form are presented below.

$$
\begin{aligned}
(4)\ LnAW_{i,t} = \ & \underset{(96.2)}{6.71} + \underset{(4.53)}{.299}\, LnPW_{i,t-1} \\
& + \underset{(2.50)}{.246}\, LnEWSP_t - \underset{(-.049)}{.013}\, LnWD_t \\
& - \underset{(-1.85)}{.049}\, LnRisk_{i,t} \\
& + \underset{(27.11)}{1.03}\, BW + \underset{(5.78)}{.222}\, BI
\end{aligned}
$$

$$R^2 = .962$$

It was suggested earlier in the paper that the pooled-data model allows the researcher to relax the assumption that acreage response elasticities are constant throughout the three state region. If the elasticities are not constant, the parameter estimates of equation 4 are biased due to model misspecification. In order to test the assumption of elasticity homogeneity across states, variables were created by multiplying the binary intercept shift variables by the wheat, wheat support, and wheat diversion price variables. The wheat price elasticity shift variable for Washington was found to be statistically significant, and equation 4 was then re-estimated with this variable ($BWLnPW_{i,t-1}$) included. The results are presented as equation 5.

$$
\begin{aligned}
(5)\ LnAW_{i,t} = \ & \underset{(100.3)}{6.68} + \underset{(5.31)}{.376}\, LnPW_{i,t-1} \\
& - \underset{(-2.30)}{.157}\, BWLnPW_{i,t-1} \\
& + \underset{(2.60)}{.242}\, LnEWSP_t - \underset{(-.110)}{.029}\, LnWD_t \\
& - \underset{(-2.37)}{.060}\, LnRisk_{i,t} + \underset{(19.53)}{1.13}\, BW + \underset{(6.17)}{.367}\, BI
\end{aligned}
$$

$$R^2 = .967$$

All of the coefficients in equation 5 have the anticipated signs and all are significant at the five percent level of probability except the coefficient for the weighted price of wheat diversion (WD). The only coefficients that exhibit a major change when compared to those in equation 4 are those for wheat price (PW) and the intercept shifter for Washington (BW). These changes were anticipated because these coefficients were previously based on a model that excluded the elasticity shift variable.

The error terms from equation 5 were initially assumed to be serially correlated and heteroskedastic, and a method suggested by Kmenta (pp. 509-10) was employed to obtain consistent estimates of the first order autocorrelation coefficient for each of the three states. None of the estimates were statistically significant. Therefore, serial correlation is not a problem in this study. Estimated variances of the error terms were calculated for each state (Kmenta, pp. 510-11), and the original data were transformed to adjust for heteroskedasticity. Ordinary least squares was then applied to the transformed data to obtain asymptotically efficient estimates of the parameters in the acreage response function. The results of this regression are virtually identical to those in equation 5 and therefore are not presented. The fact that the parameters and the standard errors did not change significantly indicates that heteroskedasticity was not a major problem.

For Oregon and Idaho, the estimated elasticity of planted acreage with respect to expected price is .376 for the pooled model. The estimate for Washington is .219 (.376−.157). These estimates are considerably larger than the .095 estimated for the aggregate region, but are in line with the national estimates made by Nerlove and Houck, *et al.*

The regional estimate of the elasticity of planted acreage with respect to the weighted support rate for the pooled-data model is .242. This estimate is considerably smaller than either national estimates or the estimate from the aggregate regional model. The estimated elasticity of weighted wheat diversion is −.029 for the pooled-data model and is virtually identical to the aggregate model estimate, but again is not statistically significant. The estimated elasticity of the risk variable is −.06 for the pooled model as opposed to .032 for the aggregate model. The pooled data estimate of this coefficient is, however, identical to the estimate made by Lin for Kansas. The sign on this coefficient is consistent with the assumption of risk averse behavior by producers. The magnitude of the estimated risk coefficient suggests that a 10 percent increase in the three year moving average of the standard deviation of per acre gross income from wheat production induces a .6 percent reduction in planted acreage.

The aggregate and pooled-data models were also compared with respect to their abilities to correctly predict regional acreages during the time period 1964 to 1977. The prediction errors were calculated by transforming the residuals from equations 3 and 5 to the original units of measurements (acres) and dividing these transformed residuals by the actual planted acreages. The aggregate model had an average prediction error of 6.5 percent. The prediction error for the pooled-data model was 5.8 percent, a reduction of 11 percent over that of the aggregate model.

The differences between regional and national estimates of the acreage response elasticities support the hypothesis that the use of national models for regional analysis may give misleading results, and greater emphasis should be placed on regional acreage response functions. Furthermore, the results of this study indicate that the use of the pooled time-series and cross-sectional data approach to acreage response function estimation is clearly a viable alternative to the previously used aggregate approach.

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