A Structural Econometric Model of the World Wheat Market

Kenneth W. Bailey
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Abstract

This report presents an econometric model that can assess the effect of changing global policies and other conditions on world wheat trade. The model can reflect changes in U.S. farm programs on the rest of the world and U.S. wheat export levels. Changes in other factors, such as yields, exchange rates, and incomes, are also accounted for and result in changes in U.S. wheat export levels. The report focuses on the wheat sectors of the United States, Canada, Australia, Argentina, the European Community, and Japan. The report provides an assessment of the year-by-year effect of a change in the U.S. wheat price on world wheat trade.

Keywords: Wheat, econometric model, trade, dynamic elasticities.

Acknowledgments

I would like to thank Carlos Arnade, C. S. Kim, Mack Leath, Nancy Schwartz, and C. Edwin Young of the Economic Research Service for comments on earlier drafts. I would also like to thank Jim Sayre of the Economics Management Staff for editorial comments and Nadine Loften for composition assistance. Cover design by Carolyn Riley.

Author’s Note

I am reporting research which resulted from an Economic Research Service project that was to initially expand the USDA’s FAPSIM model into multiple world regions. The project evolved into the development of a stand-alone system of equations that could help explain world wheat trade. The project and subsequent analysis were also the subjects of my Ph.D. dissertation at the University of Minnesota.

The research in this study was outlined prior to my employment with ERS while I was a research assistant at the University of Minnesota. The model was developed at ERS while I was with the Agriculture and Trade Analysis Division. My experience at ERS helped me to significantly expand the empirical content of the model. My supervisors, J. Michael Price, Robert House, and Larry Deaton, provided much help and encouragement. William Meyers, Patrick Westhoff, and Michael Helmar of Iowa State University helped in the structuring of the trade model. I also received numerous comments from my dissertation committee at the University of Minnesota: James P. Houck (thesis advisor), Burt Sundquist, Willis Peterson, J. S. Chipman, and Edward Coen. This academic link helped shape this report.

1301 New York Avenue, NW
Washington, DC 20005-4788
June 1989
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Summary

This report presents an econometric model that can assess the impact of changing global policies and other conditions on world wheat trade. The model can reflect changes in U.S. farm programs on the rest of the world and U.S. wheat export levels. Changes in other factors, such as yields, exchange rates, and incomes, are also accounted for and result in changes in U.S. wheat export levels. The report focuses on the wheat sectors of the United States, Canada, Australia, Argentina, the European Community, and Japan. The report provides an assessment of the year-by-year effect of a change in the U.S. wheat price on world wheat trade.

This report presents a technical view of how supply, domestic use, trade, and prices are determined from one year to the next in each of these countries. The approach views each country separately and uniquely reflects their agricultural policies and production possibilities. The U.S. wheat sector reflects the effect of U.S. farm programs on U.S. area planted and domestic use. The behavior of the Canadian and Australian Wheat Boards in setting domestic prices is explained. The effect of the Common Agricultural Policy on supply and use in the European Community is explained. The Argentine wheat sector links U.S. prices and Argentine hyperinflation to Argentine production and export levels. The Japanese wheat sector explains Japanese supply and use conditioned on Japanese wheat and rice policies.

The model presented in this report is useful for both policy analysis and situation and outlook work. Emphasis was placed on developing a structural model that can quantitatively assess the impact of changing global farm policies on world wheat trade. The model results indicate that the elasticity of demand for U.S. wheat exports is -0.7 in the short run, -0.9 in the intermediate run, and -0.8 in the long run. For example, the results suggest that a sustained 10-percent increase in the price of U.S. wheat, f.o.b. gulf ports, will reduce U.S. wheat exports by 6.9 percent the first year, 8.6 percent by the fifth year, and 7.9 percent in the long run.
A Structural Econometric Model of the World Wheat Market

Kenneth W. Bailey

Introduction

U.S. agricultural policies must be analyzed within an international framework due to the interdependent nature of such policies via trade. This report presents a nonspatial equilibrium model of world wheat trade that focuses on the domestic and trade policies of the world’s major wheat exporters and Japan. The report presents a conceptual and empirical model of international wheat trade based on a thorough review of the structure of the world wheat market. The report also reviews recent estimates of price elasticities and summarizes area-response studies for the United States, Canada, Australia, the European Community (EC-10), and Argentina.

Most agricultural trade models are empirically weak and inadequate in reflecting the impact of changes in such policies on the U.S. position in global trade (60). Two-region trade models provide highly detailed U.S. commodity market models, but lack any credible interaction between the United States and the rest of the world (21, 52). Spatial equilibrium and Armington-type models provide a global perspective of commodity markets and endogenize trade flows between countries, but are not dynamic and fail to empirically reflect the impact of agricultural policies on trade (46, 55, 32). Non-spatial equilibrium trade models do not endogenize trade flows between countries, but do allow for a detailed assessment of country/commodity models within a dynamic framework (14).

This report represents an improvement to existing trade models, since it explicitly reflects agricultural policies in area-response, domestic demand, and price transmission equations. The model links a highly detailed U.S. wheat model with that of Canada, Australia, the EC, Argentina, and Japan. This model is useful to trade analysts interested in dynamic wheat trade models. The model is also useful to policymakers, since it provides an analytical framework within which to view the effects of changes in U.S. farm policy from an international viewpoint.

World Wheat Market

A brief introduction to the world wheat market is presented next in order to define the world’s major players. World wheat production averaged 507 million metric tons (mmt) over the period 1983/84-1986/87 (table 1). China was the largest producer, averaging 17 percent of world production, followed by the USSR (16 percent), the EC-12 (14 percent), the United States (13 percent), India (9 percent), Eastern Europe (8 percent), Canada (5 percent), Australia (4 percent), and Argentina (2 percent). These nine countries/regions averaged 87 percent of world wheat production.

World wheat exports averaged 96 mmt over the 4-year period. The United States averaged 34 percent of world wheat trade, followed by Canada (21 percent), the EC-12 (17 percent), and Australia (15 percent). These four exporters held 86 percent of the world export market share. Argentina held 7 percent of the world wheat market, which is approximately half Australia’s market share.

The world’s two largest producers, China and the Soviet Union, were also the world’s largest importers, accounting for almost 30 percent of world wheat imports. The USSR and China are followed by Japan (6 percent), Eastern Europe (4 percent), and the EC-12 (3 percent). These five major importers, however, accounted for only 42 percent of world wheat imports.

Some interesting conclusions can be drawn from the data presented in table 1. First, the four major exporters command a sizable portion of world wheat trade (86 percent over the 4-year period). They are all considered developed economies and all employ complex policy regimes to support and stabilize wheat production. Second, the Soviet Union is by far the world’s largest importer, accounting for 21 percent of world wheat imports over this period. The rest of the import market is from a large number of countries that each account for less than 10 percent of world wheat imports. Third, the EC is the only country or region that is a major producer, as well as a major exporter and importer. The EC produces a soft wheat for domestic use and exports, but must import harder wheats for blending.

2 Underscored numbers in parentheses refer to sources listed in the References.
Model Structure

The trade model presented in this report takes off from an earlier study by Devadoss and others (74). Devadoss presented a trade model similar to one developed earlier by Bredahl and others (6). The Devadoss model was unique in that excess supply and demand schedules were reduced to area-response equations, food, feed, and stocks demand equations, and price transmission equations. These latter equations were estimated individually and then aggregated via identities to form the excess supply and demand equations. Earlier studies estimated simple reduced form excess supply and demand schedules and, therefore, did not explicitly reflect market structure (34).

Table 1--Wheat and wheat flour: World trade and production

<table>
<thead>
<tr>
<th>Country or region</th>
<th>1983/84</th>
<th>1984/85</th>
<th>1985/86</th>
<th>1986/87</th>
<th>4-year average</th>
<th>Percentage of world total²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>81.4</td>
<td>87.8</td>
<td>85.8</td>
<td>90.3</td>
<td>86.3</td>
<td>17.0</td>
</tr>
<tr>
<td>USSR</td>
<td>77.5</td>
<td>68.6</td>
<td>78.1</td>
<td>92.3</td>
<td>79.1</td>
<td>15.6</td>
</tr>
<tr>
<td>EC-12</td>
<td>63.8</td>
<td>82.9</td>
<td>71.6</td>
<td>71.7</td>
<td>72.5</td>
<td>14.3</td>
</tr>
<tr>
<td>United States</td>
<td>65.9</td>
<td>70.6</td>
<td>66.0</td>
<td>56.8</td>
<td>64.8</td>
<td>12.8</td>
</tr>
<tr>
<td>India</td>
<td>42.8</td>
<td>45.5</td>
<td>44.1</td>
<td>46.9</td>
<td>44.8</td>
<td>8.8</td>
</tr>
<tr>
<td>E. Europe</td>
<td>35.4</td>
<td>42.1</td>
<td>37.1</td>
<td>39.6</td>
<td>38.6</td>
<td>7.6</td>
</tr>
<tr>
<td>Canada</td>
<td>26.5</td>
<td>21.2</td>
<td>24.3</td>
<td>31.4</td>
<td>25.9</td>
<td>5.1</td>
</tr>
<tr>
<td>Australia</td>
<td>22.0</td>
<td>18.7</td>
<td>16.1</td>
<td>16.1</td>
<td>18.2</td>
<td>3.6</td>
</tr>
<tr>
<td>Argentina</td>
<td>12.8</td>
<td>13.2</td>
<td>8.5</td>
<td>9.0</td>
<td>10.9</td>
<td>2.1</td>
</tr>
<tr>
<td>All others</td>
<td>61.3</td>
<td>60.9</td>
<td>67.6</td>
<td>74.8</td>
<td>66.1</td>
<td>13.0</td>
</tr>
<tr>
<td>World total</td>
<td>489.4</td>
<td>511.5</td>
<td>499.2</td>
<td>528.9</td>
<td>507.3</td>
<td>100.0</td>
</tr>
<tr>
<td>Exports:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>38.9</td>
<td>38.1</td>
<td>25.0</td>
<td>28.4</td>
<td>32.6</td>
<td>34.0</td>
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<td>Canada</td>
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<td>16.8</td>
<td>20.8</td>
<td>19.7</td>
<td>20.6</td>
</tr>
<tr>
<td>EC-12</td>
<td>15.5</td>
<td>18.5</td>
<td>15.6</td>
<td>15.0</td>
<td>16.2</td>
<td>16.8</td>
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<td>14.9</td>
<td>14.3</td>
<td>14.9</td>
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<tr>
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<td>6.1</td>
<td>4.3</td>
<td>7.0</td>
<td>7.3</td>
</tr>
<tr>
<td>USSR</td>
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<td>.5</td>
<td>.5</td>
<td>.5</td>
<td>.5</td>
<td>.5</td>
</tr>
<tr>
<td>All others</td>
<td>5.0</td>
<td>6.7</td>
<td>4.6</td>
<td>5.9</td>
<td>5.5</td>
<td>5.8</td>
</tr>
<tr>
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<td>107.0</td>
<td>84.6</td>
<td>89.8</td>
<td>95.9</td>
<td>100.0</td>
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<tr>
<td>Imports:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USSR</td>
<td>20.5</td>
<td>28.1</td>
<td>15.7</td>
<td>16.0</td>
<td>20.1</td>
<td>20.9</td>
</tr>
<tr>
<td>China</td>
<td>9.6</td>
<td>7.4</td>
<td>6.6</td>
<td>8.5</td>
<td>8.0</td>
<td>8.4</td>
</tr>
<tr>
<td>Japan</td>
<td>5.9</td>
<td>5.6</td>
<td>5.5</td>
<td>5.8</td>
<td>5.7</td>
<td>5.9</td>
</tr>
<tr>
<td>E. Europe</td>
<td>3.8</td>
<td>2.6</td>
<td>3.5</td>
<td>4.2</td>
<td>3.5</td>
<td>3.7</td>
</tr>
<tr>
<td>EC-12</td>
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<td>2.4</td>
<td>3.2</td>
<td>3.3</td>
</tr>
<tr>
<td>All others</td>
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<td>59.9</td>
<td>50.4</td>
<td>52.9</td>
<td>55.4</td>
<td>57.7</td>
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<tr>
<td>World total</td>
<td>102.0</td>
<td>107.0</td>
<td>84.6</td>
<td>89.8</td>
<td>95.9</td>
<td>100.0</td>
</tr>
</tbody>
</table>

¹July-June crop years.
²Country total as a percentage of world total using a 4-year average.

The model presented in this report is unique in its explicit treatment of agricultural policies. The model does not attempt to capture the imperfect nature of the world wheat market, yet does not presuppose a perfectly competitive market structure, since price-distorting policies are explicitly reflected in the model’s structure. These policies are included in the model’s supply, demand, and price transmission equations, and are thus implicitly reflected in the model solution and, hence, price formation. This is the approach suggested by Grennes and Johnson, who argued:

In terms of future research, we would expect a larger payoff to modeling the interdependence of national trade policies than to formulating more complex oligopoly models (24).

**International Model**

Nonspatial equilibrium trade models simultaneously solve regional supply and demand balances for one world market-clearing price. The term “nonspatial” refers to the fact that this type of model solves for the net trade position of each country or region, and lacks any source and destination trade flows (56). The nonspatial equilibrium model used in this report solves for the world price at the point where the world market clears. In other words, the model solves when a price is reached that sets world supply equal to world demand.

The general structure of the wheat trade model is presented below and in figure 1. The domestic supply and demand schedules are combined to form excess supply and demand schedules. Five equations describe the behavior of major exporters and importers and the world market-clearing conditions.

\[ ES_{j,t}(P_{j,t}) = AP_{j,t}(P^{e}_{j,t}) \times YLD_{j,t} + ST_{j,t-1} - DD_{j,t}(P_{j,t}) \]

(1)

\[ P_{j,t} = a_{j,t} + b_{j,t} \times \text{ER}_{j,t} \times P_{us,t} \]

(2)

\[ ED_{i,t}(P_{i,t}) = DD_{i,t}(P_{i,t}) + ST_{i,t-1} \times - AP_{i,t}(P^{e}_{i,t}) \times YLD_{i,t} \]

(3)

\[ P_{i,t} = a_{i,t} + b_{i,t} \times \text{ER}_{i,t} \times P_{us,t} \]

(4)

\[ P^{*}_{us,t} \text{ such that} \]

\[ \sum_{j} ES_{j,t}(P^{*}_{us,t}) - \sum_{i} ED_{i,t}(P^{*}_{us,t}) - \text{ROW}_{t} = 0 \]

(5)

where:

- \( ES = \) wheat excess supply
- \( P = \) border price
- \( AP = \) wheat area planted
- \( P^{e} = \) expected wheat price
- \( YLD = \) wheat yield
- \( ST = \) wheat ending stocks
- \( DD = \) wheat domestic demand
- \( a = \) trade margin
- \( b = \) exchange rate coefficient
- \( \text{ER} = \) exchange rate, currency for country \( i \) or \( j \) relative to U.S. dollars
- \( ED = \) wheat excess demand
- \( \text{ROW} = \) rest-of-the-world net trade
- \( j = \) subscript for major exporters
- \( i = \) subscript for major importers
- \( \text{us} = \) subscript for the United States

Excess supply for major exporters, equation (1), is determined via an identity that equals supply (area planted times yield plus beginning stocks) less domestic demand and ending stocks. Planted area is a function of an expected wheat price. The expected price in this study is equal to a lagged market price, since producer expectations are formed at planting, which occurs well in advance of the marketing year. The border price is determined in equation (2) via a price transmission equation which is linked to a world reference price, in this case the price of U.S. wheat, f.o.b. gulf ports. Internal prices are conditioned on these border prices, as well as on governmental policies that act to limit the influence of the variation in world prices.

Excess demand for major importers, equation (3), is determined via an identity that is equal to domestic demand plus ending stocks less supply. The border price for importers, equation (4), is determined via a price transmission equation.

The world market-clearing condition, equation (5), is satisfied when an equilibrium world price \( P^{*}_{us} \) is determined that sets world supply equal to world demand. Since the U.S. border price is the world reference price, the model is cleared through the U.S. market by setting U.S. excess supply equal to the world demand for U.S. exports. This is
diagrammed in figure 1, where EDi and ESj represent excess demand and supply schedules in local currencies for world importers and export competitors. Substituting the price transmission equations into these schedules then determines EDi and ESj, which are denominated in U.S. dollars. Market-clearing conditions are then met when an equilibrium world price $P_{us}^*$ is determined that equates U.S. excess supply (ESus) with the import demand facing the U.S. market (EDrow), where the latter is equal to the horizontal sum of the excess demand for all importers (EDi) less the excess supply for the non-U.S. world exporters (ESj).

Domestic Model

A conceptual model of domestic supply and demand is specified according to neoclassical producer and consumer theory. The domestic model provides a theoretical basis for the excess supply and demand schedules that are used in the international model.

Domestic Supply Block

The domestic supply block is specified as follows:

Supply:

$$SUP_t = PRD_t + IMP_t + ST_{t-1}$$  \(6\)

Production:

$$PRD_t = AP_t * YLD_t$$  \(7\)

Area planted:

$$AP_t = AP(P^*_t, P^{^c}_t, W_t, G_t, Z_t, AP_{t-1})$$  \(8\)

where the supply of wheat (SUP) is equal to production (PRD) plus imports (IMP) plus beginning stocks (ST_{t-1}), and wheat production is equal to area planted (AP) times yield (YLD). Producer decisions to plant are determined from the first-order conditions of profit maximization for wheat production. Wheat area planted is, therefore, a function of the expected price of wheat ($P^*_t$), the expected price of a crop substitute ($P^{^c}_t$), a production cost index for wheat ($W_t$), a variable reflecting governmental commodity programs ($G_t$), a variable that reflects all other area-inducing variables ($Z_t$), and a lagged dependent variable. An increase in the own

---

**Figure 1**

Solution of the World Wheat Trade Model

---
price shifts the demand for land for wheat production to the right, whereas an increase in the substitute price has the opposite effect. The lagged dependent variable was used in the specification, since it is assumed that producers adjust to changes in market information over time rather than instantaneously.

**Domestic Demand Block**

The domestic demand block is specified as follows:

Per-capita consumer demand:

\[
PCCD_t = PCCD(P_t, PCY_t)
\]

Total consumer demand:

\[
CD_t = POP_t \times PCCD_t
\]

Seed demand:

\[
SD_t = SD(AP_{t+1}, ISV_t)
\]

Feed demand:

\[
FD_t = FD(P_t, P_{st}, LPI_t, LN_t)
\]

Total ending stocks:

\[
ST_t = ST(SUP_t, P_t, AP_{t+1})
\]

Consumer demand is determined from the first-order conditions for utility maximization. Per-capita consumer demand for wheat (PCCD) is, therefore, a function of the market price of wheat (P) and per-capita income (PCY); total consumer demand for wheat (CD) is equal to population (POP) times per-capita consumer demand.

Seed use is a derived demand function that is solved simultaneously with land use from the profit-maximizing conditions of wheat production. It should thus have the same specification as an area-response function. However, researchers have noted that seed use is a small component of domestic demand and have specified it as a function of area planted (22, pp. 36-37). Seed demand for wheat (SD) in period t is thus specified as a function of wheat area planted (AP) in period t+1 and an index reflecting the use of improved seed varieties (ISV). It is hypothesized that seed use decreases as improved seed varieties are adopted, since the improved germination rates will result in producers’ using lower seeding rates.

Feed demand is derived from the profit-maximizing conditions of livestock production. Livestock feed demand for wheat (FD) is thus a function of the market price of wheat (P), the market price of a substitute livestock feed (P_{st}), a livestock price index (LPI), and livestock numbers (LN). It is hypothesized that as the price of P_{st} increases, producers will substitute wheat in livestock feed rations and the demand for wheat will increase. It is also hypothesized that as livestock prices and numbers increase, the demand for feed and thus wheat will increase.

Stock behavior is described via a speculative inventory model that employs a rational expectations price component (22, pp. 19-25). Total ending stocks for wheat (ST) is thus a function of carry-in plus production (SUP), the market price of wheat (P), and wheat area planted in period t+1 (AP).

**Domestic Market-clearing Identity**

The following equation describes the market-clearing conditions that form the basis for the excess supply and demand equations for the individual countries:

\[
EQ_t = PRD_t + ST_{t-1} - CD_t - SD_t - FD_t - ST_t
\]

where:

\[
EQ = \text{excess supply if } EQ>0, \text{ or}
\]

\[
EQ = \text{excess demand if } EQ<0.
\]

Excess supply is defined as production (PRD) plus total beginning stocks (ST_{t-1}) less consumer demand (CD), seed demand (SD), feed demand (FD), and total ending stocks (ST); excess demand merely reverses all signs. The domestic markets clear when the difference between domestic supply and domestic demand equals net trade. Countries are exporters if EQ>0, are importers if EQ<0, and are self-sufficient if EQ=0.

**Modeling Approach**

The following approach was taken in estimating individual equations in country-specific markets:

1. Develop a data base from individual country sources,
2. Review the market structure and impact of governmental policies on the sector, and
3. Review econometric studies of each country’s wheat sector.

Data in most cases were obtained directly from individual country government sources. Market structure was reviewed in order to provide a basis for model specifications that link government policies with supply and use. Econometric
studies of the wheat markets of the world's major exporting countries were reviewed and are presented in appendix A.

**Estimation Techniques**

The simultaneous wheat trade model was estimated over the period 1960/61-1986/87 via ordinary least squares (OLS). The OLS estimation technique may lead to biased and inconsistent parameter estimates when there exists a right-hand-side endogenous variable in the system. However, OLS was chosen over other estimators for two reasons.

First, the model is nonlinear in the variables, which precludes the use of instrumental variables in two-stage least squares (2SLS) and three-stage least squares (3SLS) techniques. Johnston notes that a necessary condition under which 3SLS is asymptotically more efficient than 2SLS is that the complete modeling system is correctly specified (31, p. 489). Hence, the possibility of misspecification would deny any advantage of 3SLS over 2SLS, and a nonlinear specification would preclude the use of 2SLS.

Second, other full-information techniques are not guaranteed to represent an improvement over OLS when the model may not be correctly specified (13). The possibility of misspecification increases as a modeling system becomes larger and more detailed. Individual parameter estimates under these techniques are sensitive to the specification of the entire model system. A misspecified equation will distort the variance-covariance matrix of errors between equations, which would affect all parameter estimates in the system. Another concern with full-information techniques is that in order to apply them with standard computer packages, one must limit the degrees of freedom for the complete system to a common sample period, which may result in a loss of information.

One problem with using an OLS estimator with time series data occurs if there is serial correlation in the error structure. The existence of serial correlation will not affect the unbiasedness and consistency of OLS parameter estimates, but will render them inefficient, thus allowing one to make invalid inferences regarding the precision of the OLS estimates. One way to correct for the presence of serial correlation is to use the Cochrane-Orcutt (CO) procedure, which iteratively solves for the correlation coefficient r for errors of adjacent time periods (11).

One problem with the CO procedure is that it must eliminate the first observation of the transformed equation. This reduces the variance matrix of the disturbance term to an (n-1)x(n-1) matrix. Prais and Winsten modified the CO procedure to retain the first observation and thereby improve the efficiency of the estimator (44). This is particularly important in small sample sizes.

Neither correction for autocorrelation was used, however, since it is questionable as to whether the corrections improve the relative efficiencies of the estimated parameters over OLS. Chipman proved that the Prais-Winsten version of the CO estimator is less efficient than OLS as the number of observations approaches infinity and the value of the autocorrelation coefficient, rho, approaches 1 (10). Kramer employed an alternative definition of the CO estimator and concluded that the greatest lower bound to the efficiency of the CO estimator relative to the OLS estimator is zero (37). This, of course, implies that the variance of the parameter estimates under OLS is less than that estimated with the CO correction and that one should be wary of using CO at all. These two studies apply to a special model of linear trend, but they suggest what one may expect in more practical cases.

**Estimation Results**

The estimated equations, identities, and variable descriptions are presented in appendixes B and C. Variables were generally maintained in an equation when (1) they were theoretically and conceptually appropriate, (2) the estimated coefficients had the correct sign, and (3) the "t" ratios were statistically significant within a 90-percent confidence interval. Variables with a less than 90-percent confidence interval were maintained in some cases, but they were included only if the first two conditions were satisfied. All variables have correct a priori signs and most are statistically significant within a 90-percent confidence interval.

**United States Submodel**

The United States is the world's leading exporter of wheat, accounting for an average of 34 percent of world wheat exports over the period 1983/84-1986/87 (table 1). This share has expanded in recent years from 29 percent in 1985/86 to an estimated 41 percent in 1987/88, reflecting the implementation of the Food Security Act of 1985 (62, May 1988, p. 43). The United States ranks fourth in the world as a major producer, behind China, the Soviet Union, and the...
The United States averaged 13 percent of world wheat production over the period 1983/84-1986/87.

The U.S. wheat submodel is presented below and in figure 2. The supply block consists of production plus total beginning stocks. Production is equal to area harvested times yield per harvested acre. Harvested acreage is a linear function of total planted area (planted program acreage plus nonprogram acreage). Planted acreage is estimated behaviorally as a function of lagged market prices and governmental program variables. The demand block consists of domestic demand and total ending stocks. Domestic demand consists of food, feed, and seed use; total ending stocks consist of commercial, Commodity Credit Corporation (CCC) owned, and farmer-owned reserve (FOR) stocks. The submodel is closed via a market-clearing identity that sets exports equal to supply less domestic demand and stocks. A price equation is used to link the U.S. wheat season average farm price to the export price, f.o.b. gulf ports. Elasticities are computed at the mean for select variables and are compared with those reported by other researchers in tables 2 and 3. A review of U.S. area-response studies is contained in appendix A.

**U.S. Wheat Total Program Acreage**

Wheat acreage in the United States is reported as either program or nonprogram acreage. Program acreage consists of acres planted in the program and diverted and/or set-aside acres. Nonprogram acreage consists of acres planted outside the program. Total planted acreage is equal to planted program plus nonprogram acres.

Two equations were specified to behaviorally explain program and nonprogram acreage. Both were specified as a function of (1) expected net returns for wheat program participants, (2) expected net returns for wheat nonprogram participants, (3) expected market net returns for substitute...
commodities, and (4) national wheat allotment/base acres. It is hypothesized that grain sorghum and cotton are the major competitors for wheat production resources.

Expected wheat returns were computed for both minimum and maximum diversion participants (eqs. 3 and 4, app. B). The diversion program was voluntary in most years when it was offered; hence, producers had the option of meeting minimum acreage requirements or voluntarily diverting the maximum acreage. The variable used in the acreage-response specifications to reflect net returns for program participants is the maximum of expected returns for minimum and maximum diversion participants. It was hypothesized that a producer deciding whether or not to join the program will consider the highest net returns under all diversion options relative to market net returns. The expected net returns for minimum and maximum program participants is generally specified as follows:

\[
\begin{align*}
\text{Table 2—U.S. wheat program and nonprogram acreage-response elasticities} & \\
\hline 
\text{Item} & \text{Current study} & \text{Bancroft study} \\
& 1962-86 & 1959-79 (5) \\
\hline 
\text{Total program acreage:} & & \\
\text{Expected program net returns for wheat} & 0.58 & 0.47 \\
\text{Expected market net returns for wheat} & -0.62 & -0.38 \\
\text{Expected market net returns for cotton} & -0.19 & - \\
\text{Wheat base acreage} & 0.45 & - \\
\text{Total nonprogram acreage:} & & \\
\text{Expected program net returns for wheat} & -1.48 & - \\
\text{Expected market net returns for wheat} & 1.23 & 0.29 \\
\text{Expected net return for sorghum} & - & -0.31 \\
\text{Wheat base acreage} & 0.58 & - \\
\hline 
\end{align*}
\]

\text{— = not applicable.} \\
\text{1Shortrun elasticity evaluated at the mean.} \\
\text{2Program acreage includes both acreage planted and diverted.}

\[
\begin{align*}
\text{ENRMPP} &= (\text{EPF}\*\text{EY} - \text{VC})*(1-\text{DRMIN}) - \text{SP}\*\text{PY}\*\text{PB} + \text{DP}\*\text{PY}\*\text{DRMIN} \\
\text{ENRXPP} &= (\text{EPF}\*\text{EY} - \text{VC})*(1-\text{DRMAX}) + \text{SP}\*\text{PY}\*\text{PB} + \text{DP}\*\text{PY}\*\text{DRMIN} + \text{ADP}\*\text{PY}\*(\text{DRMAX}-\text{DRMIN}) \\
\end{align*}
\]

where:

\[
\begin{align*}
\text{ENRMPP} &= \text{expected net returns for minimum program participants, per acre} \\
\text{EPF} &= \text{expected farm price, per bushel} \\
\text{EY} &= \text{expected yield per acre} \\
\text{VC} &= \text{variable cost per acre} \\
\text{DRMIN} &= \text{minimum diversion rate, percent of base} \\
\text{SP} &= \text{certificate or expected deficiency payment, per bushel} \\
\text{PY} &= \text{program yield per acre} \\
\text{PB} &= \text{percent of the base eligible for support} \\
\text{DP} &= \text{diversion payment, per bushel} \\
\text{ENRXPP} &= \text{expected net returns for maximum program participants, per acre} \\
\text{DRMAX} &= \text{maximum diversion rate, percent of base} \\
\text{ADP} &= \text{additional diversion payment, per bushel} \\
\end{align*}
\]

These variables reflect the program and market returns net of variable production costs for producers participating in the governmental farm programs. The expected net returns for market participants for wheat and substitute commodities is specified as follows (eq. 5, app. B):

\[
\begin{align*}
\text{ENRNPP} &= \text{EPF}\*\text{EY} - \text{VC} \\
\end{align*}
\]

where:

\[
\begin{align*}
\text{ENRNPP} &= \text{expected net returns for nonprogram or market participants, per acre} \\
\text{EP} &= \text{expected farm price, per acre} \\
\text{EY} &= \text{expected yield per acre} \\
\text{VC} &= \text{variable cost per acre} \\
\end{align*}
\]

See equations 1-5 in appendix B for the computation of the expected net returns per acre for wheat program and nonprogram participants. See appendix table 6 in Bailey (2, p. 346) for the historical series.
The expected farm price used in this report is the higher of the lagged season average farm price or the loan rate (eq. 1, app. B). The expected yield is defined as trend yield.

Total U.S. wheat program acreage was, therefore, estimated as a function of real expected net returns for wheat program participants and nonprogram or market participants, real expected market net returns for cotton, the national wheat allotment/base, and a dummy variable that equals 1 for years when there was a farm program (eq. 6, app. B). All estimated parameters have correct signs and are statistically significant within a 90-percent confidence interval. The estimated elasticities with respect to expected program and nonprogram returns for wheat are 0.58 and -0.62, respectively, compared with 0.47 and -0.38 reported by Bancroft (table 2) (5). These elasticities are similar in magnitude but

Table 3—Summary of U.S. wheat demand elasticities

<table>
<thead>
<tr>
<th>Item</th>
<th>Current study 1960-86</th>
<th>Gardiner 1961-80 (23)</th>
<th>Devadoss and others 1965-84 (14)</th>
<th>Gallagher and others 1950-74 (22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food use:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat farm price^2</td>
<td>—</td>
<td>-0.02</td>
<td>-0.14</td>
<td>—</td>
</tr>
<tr>
<td>Rye wholesale price</td>
<td>—</td>
<td>0.08</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Personal disposable income</td>
<td>-0.18</td>
<td>-0.51</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Personal consumption expenditures</td>
<td>—</td>
<td>—</td>
<td>0.55</td>
<td>-0.31</td>
</tr>
<tr>
<td>Population</td>
<td>1.14</td>
<td>—</td>
<td>—</td>
<td>1.00</td>
</tr>
<tr>
<td>Feed use:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat farm price^2</td>
<td>-.97</td>
<td>-3.22</td>
<td>-.35</td>
<td>-3.29</td>
</tr>
<tr>
<td>Corn wholesale price</td>
<td>—</td>
<td>1.47</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Sorghum farm price</td>
<td>—</td>
<td>—</td>
<td>.87</td>
<td>1.62</td>
</tr>
<tr>
<td>Steer and heifer fed slaughter</td>
<td>1.06</td>
<td>—</td>
<td>1.02</td>
<td>—</td>
</tr>
<tr>
<td>Cattle numbers</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Livestock price index</td>
<td>-.73</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Fed cattle price</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Seed use:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat acreage planted</td>
<td>1.21</td>
<td>—</td>
<td>—</td>
<td>1.02</td>
</tr>
<tr>
<td>Commercial inventories:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat farm price^2</td>
<td>-.59</td>
<td>-0.59</td>
<td>—</td>
<td>-1.70</td>
</tr>
<tr>
<td>Wheat production</td>
<td>.39</td>
<td>—</td>
<td>—</td>
<td>1.34</td>
</tr>
<tr>
<td>Wheat commercial inventories lagged one period</td>
<td>.10</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>CCC inventories</td>
<td>-.22</td>
<td>—</td>
<td>—</td>
<td>-.34</td>
</tr>
<tr>
<td>Farmer-owned reserve inventories</td>
<td>-.16</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>CCC inventories</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat farm price</td>
<td>-.25</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Wheat loan rate</td>
<td>.25</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Wheat production</td>
<td>.37</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

= not available.

^Shortrun elasticities evaluated at the mean.

^Gardiner used a wholesale price.
opposite in sign, suggesting the relative strength of these variables has a significant influence on program acres. The variable for market returns for cotton was statistically significant, and the computed elasticity suggests that a 10-percent increase in this variable will decrease program acreage 1.9 percent. As noted earlier, the wheat base was entered in this specification as a separate regressor. The statistical results indicate that program acreage is positively correlated with the wheat base. The estimated elasticity suggests that a 10-percent increase in the wheat base will result in a 4.5-percent increase in program acres, assuming other price variables remain unchanged.

**U.S. Wheat Planted Program Acreage**

Planted wheat program acreage is equal to total program acreage less diverted acreage. This is similar to total program acreage times 1 minus the actual diversion rate (eq. 7, app. B). The actual diversion rate must be endogenized if planted program acres are to be completely endogenized in the system. It needs to be accounted for in those years in which (1) a voluntary diversion program is announced, and (2) an additional diversion rate above a minimum rate is announced. The historical data reveal that the actual diversion rate was very close to the announced rate for those years in which no additional diversion was allowed. A program allowing additional diversion was implemented in 12 of the 25 crop years included in the study, from 1962/63-1986/87. The actual diversion rate rose above the minimum announced rate in 8 of these 12 years. It was then attempted to behaviorally explain additional diversion in these 8 years by analyzing the expected program returns for maximum diversion participants relative to minimum diversion participants. The data, however, revealed that expected net returns for maximum diversion participants were greater than that of minimum participants in only 3 of these 8 years. Hence, the actual diversion rate cannot be explained behaviorally, and it will be assumed to be an exogenous variable in this study.\(^6\)

**U.S. Wheat Nonprogram Acreage**

Nonprogram wheat acreage was hypothesized to have the same specification as that of program acreage, but with opposite signs for the wheat variables. Hence, nonprogram wheat acreage was estimated as a function of the expected market returns for wheat, expected program returns for wheat, wheat base acres, and a dummy variable that equals 1 for years in which a wheat program was in effect (eq. 8, app. B).

All parameter estimates are statistically significant within a 99-percent confidence interval. The elasticities with respect to market and program returns for wheat are 1.23 and -1.48, respectively. These are much larger than those computed for program acreage (table 2). Bancroft reported an elasticity of 0.29 with respect to expected wheat market returns, which is much smaller than that calculated in this study. One possible reason for this is that Bancroft may have underestimated the impact of market returns for wheat on nonprogram acreage, since program acreage was included in the specification as a separate regressor. Program acreage was specified earlier as a function of both market and program returns for wheat, thus its presence in the nonprogram equation creates a problem of multicollinearity.

The estimated coefficient for wheat base acres is statistically significant, and the estimated mean elasticity suggests that a 10-percent increase in this variable will increase nonprogram acreage by 5.8 percent. The sum of this elasticity and that of wheat program acreage with respect to the wheat base (0.45) is slightly greater than 1. This indicates that a 10-percent increase in the wheat base will likely result in a 10.3-percent increase in total wheat acreage as land is substituted away from other crops into wheat production.

The estimated coefficient for the wheat program dummy variable indicates that nonprogram wheat acreage increased 48.5 million acres in years when there was no wheat program, assuming all other variables remain the same. This coefficient is expected to be an important adjustment to the simulation model for those years in which there will be no farm programs.

**U.S. Wheat Harvested Acreage**

Wheat harvested acreage was specified as a function of total planted acreage and a dummy variable (DUM83) to account for drought conditions in 1983/84 (eq. 10, app. B). Total planted acreage is equal to the sum of planted program and nonprogram acreage. The statistical results indicate that an average of 89 percent of planted acreage was harvested. The results also indicate that the 1983 drought reduced harvested acreage approximately 6.3 million acres.

**U.S. Wheat Per-capita Food Use**

Food use was estimated in this study on a per-capita basis in order to avoid problems of multicollinearity between population and income. Per-capita wheat food use was estimated as a function of the real wheat farm price and real per-capita disposable income (eq. 14, app. B). Real per-capita disposable income is defined as U.S. personal disposable income divided by a U.S. personal consumption expenditures deflator and U.S. residential population. Dummy variables

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\(^6\) An examination of State-level production cost data may provide insight into endogenizing the diversion rate when a minimum-to-maximum voluntary diversion rate is announced.
were included in the specification to reflect an upward shift in food use beginning in 1975/76 and unexplained outliers.

The statistical results produced an insignificant parameter estimate for the real price of wheat and a negative, but significant, parameter estimate for real per-capita income. These results are similar to those reported by Gallagher and others (22). They dropped the wheat price from their specification and concluded that wheat is an inferior good in the United States, since a declining wheat food consumption is correlated with a rising real income.

The elasticity of food use with respect to real personal disposable income computed in this study is -0.18, compared with -0.31 reported by Gallagher and others (table 3). Devadoss and others reported a positive income elasticity of 0.55 (14). This result seems inconsistent with previous estimates and may be due to the fact that they did not estimate wheat food use on a per-capita basis.

U.S. Wheat Feed Use

The USDA’s FAPSIM model specified wheat feed use as a function of steer and heifer slaughter, wheat and corn farm prices, and a livestock price index (21). Steer and heifer slaughter was included in the specification as a proxy for livestock numbers since fed cattle are the major consumers of wheat for feed purposes. This specification was employed in this report (eq. 16, app. B).

Attempts to include both the real price of corn and sorghum—the major competitors for wheat in livestock feed rations—resulted in statistically insignificant parameter estimates. Wheat feed use was therefore estimated as a function of steer and heifer slaughter, the real wheat farm price, and a real livestock price index.

All parameter estimates have correct signs and are statistically significant within a 90-percent confidence interval. The results suggest an own-price elasticity of -0.97 (table 3), compared with elasticities that range from -0.35 reported by Devadoss and others to -3.29 reported by Gallagher and others (22). This specification was used in the model to account for unexplained outliers.

All parameter estimates are statistically significant within a 90-percent confidence interval. The estimated own-price elasticity for commercial stocks is -0.59, which compares with -0.59 reported by Gardiner (23) and -1.70 reported by Gallagher and others (22) (table 3). This suggests that U.S. commercial wheat stockholders are significantly less responsive to unexpected prices than they were prior to the world price instability of the 1970’s and 1980’s. The statistical results also suggest that a 10-percent increase in wheat production will increase wheat commercial ending stocks 3.9 percent and that a 10-percent increase in commercial carry-in stocks will increase carry-out by an estimated 1 percent. And finally, a 10-percent increase in CCC and FOR wheat ending stocks will reduce commercial wheat ending stocks by 3.8 percent.

U.S. Wheat Seed Use

Wheat seed use (WSEDUS) in period t is specified as a function of wheat area planted (WAPTUS) in period t+1 (eq. 17, app. B). Dummy variables were included in the specification to account for an upward shift in seed use beginning in 1983/84 and an unexplained outlier. All parameter estimates have correct signs and are statistically significant within a 95-percent confidence interval. The estimated elasticity for seed use with respect to area planted is 1.21, which compares with 1.02 reported by Gallagher and others (table 3).

U.S. Wheat Commercial Ending Stocks

U.S. commercial wheat stocks are hypothesized to be a function of current production, the wheat farm price, area planted in the next period, and a lagged dependent variable. Gallagher hypothesized that expectations of next period’s price are equal to current prices modified by area planted in period t+1 (22, pp. 19-25). Area planted is a proxy for expected production in period t+1. CCC and FOR stocks are also included in the specification, since it is assumed that an increase in these variables will reduce commercial stocks.

Commercial ending stocks for wheat were therefore estimated as a function of wheat production plus a lagged dependent variable, the real farm price of wheat, and the sum of CCC and FOR wheat stocks (eq. 18, app. B). Wheat area planted and expected wheat production (area planted times trend yield) in period t+1 were both tested in the specification but were dropped, since they produced insignificant parameter estimates and lowered the t-value for the real wheat price. Dummy variables were included in the specification to account for unexplained outliers.

All parameter estimates are statistically significant within a 90-percent confidence interval. The estimated own-price elasticity for commercial stocks is -0.59, which compares with -0.59 reported by Gardiner (23) and -1.70 reported by Gallagher and others (22) (table 3). This suggests that U.S. commercial wheat stockholders are significantly less responsive to expected prices than they were prior to the world price instability of the 1970’s and 1980’s. The statistical results also suggest that a 10-percent increase in wheat production will increase wheat commercial ending stocks 3.9 percent and that a 10-percent increase in commercial carry-in stocks will increase carry-out by an estimated 1 percent. And finally, a 10-percent increase in CCC and FOR wheat ending stocks will reduce commercial wheat ending stocks by 3.8 percent.

Because of the nature of the reported data, seed used to plant wheat for the t+1 crop year is credited to domestic use in the t crop year. This is because planting occurs before the beginning of the new crop year.
U.S. Wheat CCC Ending Stocks

CCC-owned stocks are defined as grain forfeited to the CCC by producers after the 9-month loan period. It is hypothesized that CCC-owned stocks increase as the market price falls relative to the loan rate, since producers would have a greater incentive to forfeit their grain under loan. It is also hypothesized that CCC-owned stocks increase with production, since the volume of grain under loan would expand with an increase in production. Hence, CCC-owned ending stocks for wheat were estimated as a function of the ratio of the wheat farm price to the wheat loan rate, wheat production, a lagged dependent variable, and a dummy variable to account for an unexplained outlier (eq. 19, app. B). The farm-loan price ratio lagged one period was tested in the specification, but produced a statistically insignificant parameter estimate.

All parameter estimates are statistically significant within a 95-percent confidence interval. The statistical results suggest that a 10-percent increase in the wheat farm price will result in a 2.5-percent decrease in CCC ending stocks (table 3). A similar increase in the wheat loan rate will result in a 2.5-percent increase in CCC ending stocks. Also, a 10-percent increase in wheat production will result in a 3.7-percent increase in CCC ending stocks.

U.S. Wheat Market-clearing Identity

An identity representing the U.S. excess supply function is also used to clear the domestic wheat market. U.S. wheat net exports are set equal to wheat production plus wheat beginning stocks less wheat food, feed, seed use, and total ending stocks (eq. 21, app. B).

U.S. Wheat Season Average Farm Price

The season average farm price is linked to the U.S. wheat gulf ports price via a domestic price transmission equation (eq. 22, app. B). The model links foreign border prices to the U.S. gulf ports price, since competitors and importers are more likely to face the gulf ports price than the farm price, which is nonlocational specific. The U.S. wheat submodel, however, was estimated as a function of the wheat farm price since it is an average of State farm prices and therefore reflects domestic prices. The results indicate an elasticity of 1, which reflects a perfect degree of price transmission between the U.S. wheat season average farm price and the gulf ports price.

Canadian Submodel

Canada, like the United States, is a major producer and exporter of wheat on the world market. Canada is second to the United States as the world's leading exporter and is the world's seventh-leading producer (table 1). Canada accounted for 21 percent of world wheat exports and 5 percent of world wheat production over the period 1983/84-1986/87.

The Canadian wheat submodel is presented below and in figure 3. The supply block consists of production plus beginning stocks. Production is equal to area planted times yield per planted hectare. The demand block consists of domestic demand plus total ending stocks. Domestic demand is equal to food, feed, and seed use. The market-clearing identity closes the Canadian wheat submodel and sets Canadian wheat exports equal to an excess supply identity. The U.S. wheat loan rate determines Canadian Wheat Board (CWB) prices, and the U.S. wheat gulf ports price determines Canadian feed, food, and export prices. Mean elasticities are computed for select variables and are compared with those reported in major studies in tables 4-6. A review of Canadian area-response studies is contained in appendix A.

Canadian Wheat Area Harvested

Prior to estimating a Canadian wheat area-response function, one must identify the proper area-inducing price and its expectations operator, an appropriate measure of the cost of production, and the impact of expectations of the marketing quota system on the expected price and area planted.

The expected CWB total realized price for wheat is assumed to be the proper area-inducing price. This price is a function of the wheat initial, adjustment, interim, and final payments. The producer knows the initial payment at planting and forms expectations of the adjustment, interim, and final payments. The model specifies the expected wheat total realized price as the sum of the initial payment, the adjustment and interim payments lagged one period, and the final payment lagged two periods. Barley enters the model as a competing crop for wheat production resources. The barley expected total realized price has the same specification as that used for wheat. Krakar and Paddock, and Bailey subtracted CWB handling charges and freight from the expected prices in order to approximate a farm-level price (36, f). However, the estimated elasticities with respect to handling charges and freight were extremely low, so these variables were dropped from the current specification.
Canadian wheat area harvested was therefore estimated as a function of the expected total realized price of wheat and barley, dummy variables reflecting the “Lower Inventories for Tomorrow” program, and a lagged dependent variable (eq. 23, app. B). A third dummy variable was included in the specification to reflect the increase in plantings in 1985/86 due to 2 previous years of drought that severely lowered stocks. All price variables were deflated by a lagged fertilizer price index, which was used as a proxy for the cost of production.

All estimated coefficients were statistically significant within a 95-percent confidence interval. Elasticities were calculated at the mean. The elasticity with respect to the expected realized price of wheat is 0.33, compared with 0.38 reported by Devadoss and others and 0.35 reported by Meilke (table 4) (14, 39). The elasticity with respect to the expected realized price of barley is -0.35, compared with -0.40 reported by Meilke. Hence, the elasticities computed

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Footnote: The “Lower Inventories for Tomorrow” program, otherwise known as Operation LIFT, was a 1-year Canadian Government program that reduced seeded area by half in 1970 from 10.1 million hectares in 1969 in order to deal with excess stock conditions.

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Figure 3

Canadian Wheat Submodel
in this study are close to measures reported by other researchers.

**Canadian Wheat Food Use**

Canadian wheat for food and industrial use represents the wholesale demand for wheat, and shifts with respect to the retail demand for wheat products (bread and bakery goods). Wheat food use was originally specified on a per-capita basis as a function of the real mill price of wheat and real per-capita income. This represents the theoretical specification presented earlier. The statistical results, however, did not support this specification. Hence, Spriggs’ specification was used, and food use was estimated in an aggregate form as a function of the real wheat milling price and real personal disposable income (eq. 27, app. B) (58). Dummy variables were incorporated into the specification to account for unexplained outliers. All estimated coefficients have correct signs and are statistically significant within a 90-percent confidence interval.

The elasticity of food use with respect to the milling price was estimated to be -0.08, compared with -0.03 from the Spriggs study (table 5). The elasticity with respect to income was calculated to be 0.24, compared with 0.10 reported by Spriggs. One explanation for this difference

| Table 4—Summary of Canadian wheat area-response elasticities¹ |
|-----------------|-------------|-------------|-------------|-------------|---------------|
| Item            | Current study | Bailey 1968-84 | Krakar and Paddock 1968-83 | Devadoss and others 1965-84 | Meilke 1949-74 |
|                 | 1965-86      | (1)         | (36)          | (14)         | (39)          |
| Area-inducing prices: |
| Wheat—        |             |             |              |              |               |
| CWB initial price | 0.25       | 0.29       | 0.46         | —            | 0.53          |
| CWB final price  | .04         | .02        | .06          | —            | .08           |
| CWB initial plus final price | .33        | —          | —            | 0.38         | .35           |
| Barley—       |             |             |              |              |               |
| CWB initial price | -.28       | -.25       | -.06         | —            | -.69          |
| CWB final price  | -.04        | -.03       | —            | —            | -.05          |
| CWB initial plus offboard price | —          | —          | —            | -.30         | —             |
| CWB initial plus final price | -.35       | —          | —            | —            | -.40          |
| Offboard price  | —            | —          | -.05         | —            | —             |
| Handling costs: |
| Wheat         | —            | -.01       | -.01         | —            | —             |
| Barley        | —            | .01        | 0            | —            | —             |
| Freight rate  | —            | 0          | -.02         | —            | —             |
| Wheat beginning stocks | —            | -.03       | —            | —            | —             |

— = not available; CWB = Canadian Wheat Board.

¹Shortrun elasticities evaluated at the mean.
may be that Spriggs included population as a separate regressor, which robbed the income variable of explanatory power, since the two are highly correlated.

**Canadian Wheat Feed Use**

Wheat for feed use is a function of the price of feed wheat, the price of a substitute feed, and livestock prices and numbers. Offboard prices were used to represent feed prices for wheat instead of CWB prices, since the offboard markets deal primarily with feed quality grains. Barley is assumed to be the major competitor of feed wheat in livestock rations. The major consumers of feed-quality wheat in Canada are hogs and poultry.

Wheat for feed use was estimated as a function of the real offboard price of wheat and barley, the real price of hogs, and the number of hogs on farms (eq. 28, app. B). Poultry numbers and prices were not included in the specification because of a lack of appropriate data. Dummy variables were included in the specification to account for unexplained outliers. All estimated coefficients have correct signs and are statistically significant within a 95-percent confidence interval.

### Table 5—Summary of Canadian wheat demand elasticities

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Food use:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat mill price</td>
<td>-0.08</td>
<td>-</td>
<td>-0.03</td>
<td></td>
</tr>
<tr>
<td>Personal disposable income</td>
<td>.24</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Personal consumption expenditures</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>-</td>
<td>-</td>
<td>.10</td>
<td>.47</td>
</tr>
<tr>
<td>Feed use:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat offboard price</td>
<td>-1.03</td>
<td>-0.12</td>
<td>-0.07/-0.59</td>
<td>-.60</td>
</tr>
<tr>
<td>Barley offboard price</td>
<td>.61</td>
<td>-</td>
<td>.23/</td>
<td></td>
</tr>
<tr>
<td>Corn price</td>
<td>-</td>
<td>-</td>
<td>- / .49</td>
<td></td>
</tr>
<tr>
<td>Wheat beginning stocks</td>
<td>-</td>
<td>-</td>
<td>.32/</td>
<td></td>
</tr>
<tr>
<td>Wheat production</td>
<td>-</td>
<td>.06</td>
<td>- /</td>
<td></td>
</tr>
<tr>
<td>Hog price</td>
<td>.73</td>
<td>-</td>
<td>.21/</td>
<td>.60</td>
</tr>
<tr>
<td>Cattle price</td>
<td>-</td>
<td>.68</td>
<td>- /</td>
<td></td>
</tr>
<tr>
<td>Hog numbers</td>
<td>.72</td>
<td>-</td>
<td>.29/</td>
<td></td>
</tr>
<tr>
<td>Seed use:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat area planted</td>
<td>1.04</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total ending stocks:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat export price</td>
<td>-.25</td>
<td>-.18</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wheat production</td>
<td>.70</td>
<td>.61</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wheat carry-in</td>
<td>.50</td>
<td>.49</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wheat area planted, next period</td>
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<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wheat expected production, next period</td>
<td>-</td>
<td>-.60</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

---

1 Shortrun elasticities evaluated at the mean.

2 Krakar estimated feed use for western and eastern Canada.
The results indicate a direct-price elasticity of -1.03 for the offboard price of wheat, compared with much lower estimates of -0.12 from Devadoss and others and -0.60 from Spriggs (table 5). The cross-price elasticity with respect to the price of barley is 0.61 and compares with 0.14 reported by Spriggs. The elasticity of feed use with respect to the price of hogs is 0.73 and compares with 0.60 reported by Spriggs. The results also indicate the dependent variable is sensitive to the number of hogs on farms, suggesting a 10-percent increase in hog numbers will increase the demand for feed wheat 7.2 percent. Again, the magnitude of these elasticities across various studies depends heavily on the specification used and the period in which the coefficients were estimated.

**Canadian Wheat Seed Use**

Canadian wheat seed use was estimated as a function of wheat area harvested in the next period and trend (eq. 29, app. B). The estimated coefficients have correct signs and

<table>
<thead>
<tr>
<th>Table 6—Summary of Canadian wheat price elasticities¹</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Wheat offboard price:</td>
</tr>
<tr>
<td>Wheat initial payment</td>
</tr>
<tr>
<td>Wheat adjustment payments</td>
</tr>
<tr>
<td>Wheat export price—</td>
</tr>
<tr>
<td>Wheat export price—</td>
</tr>
<tr>
<td>U.S. wheat gulf ports price</td>
</tr>
<tr>
<td>Canadian-U.S. exchange rate</td>
</tr>
<tr>
<td>Wheat production plus beginning stocks</td>
</tr>
<tr>
<td>Wheat ending stocks</td>
</tr>
<tr>
<td>Wheat initial payment:</td>
</tr>
<tr>
<td>U.S. wheat loan rate</td>
</tr>
<tr>
<td>U.S. wheat farm price</td>
</tr>
<tr>
<td>Canadian-U.S. exchange rate</td>
</tr>
<tr>
<td>U.S. wheat beginning stocks</td>
</tr>
<tr>
<td>Wheat initial payment lagged one period</td>
</tr>
<tr>
<td>Wheat stocks-to-use ratio</td>
</tr>
<tr>
<td>Wheat final payment:</td>
</tr>
<tr>
<td>Wheat initial payment</td>
</tr>
<tr>
<td>Wheat offboard price</td>
</tr>
<tr>
<td>Wheat realized price:</td>
</tr>
<tr>
<td>U.S. gulf ports price</td>
</tr>
<tr>
<td>Canadian-U.S. exchange rate</td>
</tr>
<tr>
<td>Wheat export price:</td>
</tr>
<tr>
<td>U.S. gulf ports price</td>
</tr>
<tr>
<td>Canadian-U.S. exchange rate</td>
</tr>
<tr>
<td>Wheat beginning stocks</td>
</tr>
<tr>
<td>Wheat exports</td>
</tr>
</tbody>
</table>

— = not available.

¹Shortrun elasticities evaluated at the mean.
are statistically significant within a 99-percent confidence interval. The statistical results indicate that farmers used an average 0.096 metric tons of wheat per hectare for seeding. The results also indicate that a 10-percent increase in wheat area harvested in period t+1 will increase seed use 10.4 percent in period t (table 5). The coefficient for trend suggests that Canadian producers have reduced national seed use an average 2,260 metric tons each year over the historical period due to improved seed varieties.

**Canadian Wheat Total Ending Stocks**

Wheat total ending stocks were estimated as a function of the CWB selling quotations for wheat, wheat total beginning stocks plus production, and wheat area harvested for the coming crop year (eq. 30, app. B). As the export price of wheat rises, the CWB is hypothesized to increase the marketing quota for wheat and move more grain into export positions, thus lowering stock levels. Also, as planting during the last few months of the t crop year increases, the CWB is hypothesized to reduce current stock levels by lowering export prices and increasing exports in order to make room for a larger expected harvest in the t+1 crop year. Dummy variables were included in the specification to account for an unprecedented 56-percent rise in the export price of wheat in 1972, and the enormous buildup in wheat stocks prior to the imposition of the LIFT program in 1967 and 1968. Attempts to deflate the export price by the Canadian consumer price index resulted in a statistically insignificant coefficient; hence, the nominal price was retained. All variables are statistically significant within a 99-percent confidence interval.

The statistical results indicate an own-price elasticity of -0.25, compared with -0.18 reported by Devadoss and others. The estimated elasticity with respect to wheat production is 0.70, compared with 0.61 reported by Devadoss and others. The estimated elasticity with respect to carry-in stocks is 0.50, compared with 0.49 reported by Devadoss and others (table 5). The statistical results also indicate that as wheat plantings in May for the coming crop year increase by 10 percent, the CWB responds by reducing current yearend inventories by 9.1 percent. The elasticities estimated in this report compare favorably with those reported by Devadoss and others, since the specifications and historical time periods are very similar.

**Canadian Wheat Market-clearing Conditions**

The Canadian wheat market-clearing conditions set exports equal to production plus carry-in, less food, industrial, feed, and seed use, less total ending stocks (eq. 31, app. B).

**Canadian Wheat and Barley Prices**

The estimated equations for the Canadian offboard, initial, and total realized prices for wheat and barley and the mill and export quotation prices for wheat are presented in appendix B (eqs. 32-41). The elasticities for these estimated equations are presented in table 6. A detailed description of the specifications for these equations may be found in two earlier USDA studies (1, 3).

**Australian Submodel**

Australia is the world’s fourth-leading exporter of wheat, just behind the United States, Canada, and the EC-12 (table 1). Australia accounted for 15 percent of world wheat exports over the period 1983/84-1986/87. Australia is also a major producer of wheat, accounting for just under 4 percent of world wheat production over the same period.

The Australian wheat submodel is presented below and in figure 4. The supply block consists of production less on-farm balance and permit feed wheat, plus total beginning stocks. Production is defined as area planted times yield per planted hectare. The demand block consists of domestic demand plus total ending stocks. Domestic demand consists of food and feed use. The Australian wheat market-clearing identity sets exports equal to an excess supply identity. The price block consists of equations that link U.S. prices to Australian prices. The U.S. loan rate determines the Australian minimum support price; the U.S. wheat gulf ports price determines the Australian domestic and export prices. Select elasticities computed at the mean are compared with those reported in major studies in tables 7-11.

**Australian Wheat Area Planted**

Decisions to plant wheat in Australia are conditioned on the proper area-inducing price as well as a number of variables unique to Australia. A review of previous Australian wheat area-response studies is presented in appendix A.

A number of area-inducing price variables were considered for use in the area-response equation. The average net returns to growers (lagged two periods), the export price (lagged one period), and the initial price for wheat were all tested. These variables produced insignificant parameter estimates and were therefore dropped from the specification. The Australian Wheat Board’s (AWB) guaranteed price for wheat was then tested and proved highly significant in the model specification. This price represents a substantial
portion of average net returns to growers, and farmers have a great deal of information on what that price will be prior to planting.

Wool and beef compete with wheat for production resources. It is assumed that at planting time, Australian farmers must decide what portion of their land will be planted to wheat, and what will be planted to pasture for grazing sheep and cattle. Land use in the Australian wheat-sheep zone is dependent on the expected relative prices of wheat, wool, lamb, and cattle. Recently, however, in some parts of western Australia, wheat area has been competing with alternative crops such as lupines, field peas, and oats.

Wheat area in Australia was therefore modeled as a function of the AWB guaranteed price for wheat, the price of Australian greasy wool and beef, both lagged one period, and a lagged dependent variable (eq. 42, app. B). Dummy variables were included in the specification to reflect the years following drought years and the one year the marketing quota system was restrictive. Attempts to deflate the guaranteed price by the Australian Bureau of Agriculture and Resource Economics (ABARE) prices paid index and the Australian consumer price index rendered the estimated coefficient statistically insignificant. Hence, the ratio of the guaranteed price to the greasy wool and beef prices was used. The drought variable was included in the specification to reflect the empirical observation that wheat area increased the year following a severe drought. Farmers increased their wheat area in order to increase their cash flow following a year in which yields were significantly reduced. All estimated coefficients were statistically significant within a 90-percent confidence interval.

The direct-price elasticity calculated from the area-response equation is 0.13, compared with 0.39 reported by Dewbre and others, 0.77 reported by Vincent and others, and 0.18 reported by Powell and Gruen (table 7) (15, 64, 43). The estimated cross-price elasticity with respect to the price of wool is -0.07, compared with -0.10 reported by Dewbre and others, -0.25 reported by Vincent and others, and -0.11 reported by Powell and Gruen. The cross-price elasticity

Figure 4

Australian Wheat Submodel
with respect to the price of beef is -0.06, compared with -0.04 reported by Dewbre and others and -0.11 reported by Vincent and others. The magnitude of the elasticities reported in table 7 depends heavily on the functional form and substitute commodities used in the estimation. They do suggest, however, that the elasticities estimated in this study are reasonable.

**Australian Wheat Yield**

Australian wheat yield was estimated as a function of trend (eq. 43, app. B). Australian wheat yields are highly variable and have had very little upward trend over the past 27 years (0.007 metric tons per year). Less than 1 percent of the variation in wheat yields was explained by the trend variable. The mean of wheat yields over the historical period is 1.27.

**Australian Wheat Food Use**

Australian wheat per-capita food use was estimated as a function of the real AWB human consumption price and real per-capita household disposable income (eq. 46, app. B). Dummy variables were included in the specification to account for a shift from a December/November to an October/September Australian crop year.

<table>
<thead>
<tr>
<th>Item</th>
<th>Current study</th>
<th>Dewbre and others</th>
<th>Vincent and others</th>
<th>Powell and Gruen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>0.13</td>
<td>0.39</td>
<td>0.77</td>
<td>0.18</td>
</tr>
<tr>
<td>Barley</td>
<td>-</td>
<td>-.12</td>
<td>-.08</td>
<td>-</td>
</tr>
<tr>
<td>Oats</td>
<td>-</td>
<td>-.03</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sorghum</td>
<td>-</td>
<td>-.02</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Coarse grains</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-.07</td>
</tr>
<tr>
<td>Wool</td>
<td>-.07</td>
<td>-.10</td>
<td>-.25</td>
<td>-.11</td>
</tr>
<tr>
<td>Sheep</td>
<td>-</td>
<td>-</td>
<td>-.08</td>
<td>-</td>
</tr>
<tr>
<td>Beef</td>
<td>-.06</td>
<td>-.04</td>
<td>-.11</td>
<td>-</td>
</tr>
</tbody>
</table>

With respect to the following expected prices:

- = not available.

All estimated coefficients are statistically significant within a 99-percent confidence interval with the exception of the real AWB human consumption price. This variable was maintained in the specification, since it does have the correct sign and is theoretically appropriate. The results show a negative coefficient for real per-capita household disposable income, which suggests that wheat in Australia is an inferior good. This result is consistent with estimates reported by Spriggs, Ryan, and Brennan (57, 50, 7). The associated elasticity suggests that a 10-percent increase in real per-capita household disposable income will reduce wheat food use 3.5 percent (table 8).

**Australian Wheat Feed Use**

The Australian Bureau of Statistics reports wheat for feed end uses in three categories: (1) stockfeed, (2) balance kept on farms, and (3) stockfeed wheat sold under permit. The balance kept on farms consists of harvested wheat retained by producers for onfarm feed and seed uses. One problem with econometrically estimating Australian wheat feed use is that a reliable series for the percentage of onfarm retention used for feed purposes is not available. Another problem is that stockfeed wheat sold under permit is a new series that began in 1984 with the implementation of the eighth stabilization plan. Hence, because of these two problems, stockfeed use under category (1), above, will be explained behaviorally in the model, and categories (2) and (3) will be assumed exogenous. Spriggs and Brennan noted that most

<table>
<thead>
<tr>
<th>Item</th>
<th>Current study</th>
<th>Ryan (50)</th>
<th>Meyers (41)</th>
<th>Spriggs (57)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat human consumption price</td>
<td>-0.04²</td>
<td>-0.40</td>
<td>-0.17</td>
<td>-0.47</td>
</tr>
<tr>
<td>Retail price potatoes</td>
<td>-</td>
<td>-</td>
<td>.05</td>
<td>-</td>
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<tr>
<td>Household disposable income</td>
<td>-.35</td>
<td>-</td>
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<tr>
<td>Private consumption</td>
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<td>-.62</td>
<td>-.14</td>
</tr>
<tr>
<td>expenditures</td>
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<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Population</td>
<td>1.36</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

With respect to:

- = not available.

²Shortrun elasticities evaluated at the mean.

1Shortrun elasticities.
wheat sold by the AWB for domestic livestock feed use is processed and then consumed by the intensive livestock industries (pigs, layers, and poultry). Wheat used for livestock feed is therefore modeled as a derived demand function and shifts to the right in response to an increase in intensive livestock production. Wheat is also consumed in the extensive livestock industries (sheep and cattle), especially during drought years when producers substitute wheat for sparse pastures (57).

Australian wheat feed use was therefore modeled as a function of the ratio of the AWB stockfeed price to the Australian Barley Board feed price, an intensive livestock index, the pork saleyard price deflated by the Australian consumer price index, and a dummy variable reflecting drought years (eq. 48, app. B). Barley is the major competitor of wheat in livestock feed rations; hence a wheat/barley price ratio was used in the specification. Spriggs' index of intensive livestock production was also used in this specification as a proxy for total livestock production (57, p. 41). Spriggs did not specify a livestock price index; hence the pork sale yard price was used in this specification.

Table 9—Summary of Australian wheat feed demand elasticities

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat feed price</td>
<td>-2.24</td>
<td>-2.37</td>
<td>-2.76</td>
<td>-0.73</td>
</tr>
<tr>
<td>Barley feed price</td>
<td>2.24</td>
<td>—</td>
<td>1.26</td>
<td>.73</td>
</tr>
<tr>
<td>Other feedgrains price</td>
<td>—</td>
<td>1.58</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Intensive livestock index</td>
<td>1.93</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Pork price</td>
<td>1.27</td>
<td>—</td>
<td>.71</td>
<td>—</td>
</tr>
<tr>
<td>Poultry price</td>
<td>—</td>
<td>—</td>
<td>.36</td>
<td>—</td>
</tr>
<tr>
<td>Egg price</td>
<td>—</td>
<td>—</td>
<td>1.40</td>
<td>—</td>
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<tr>
<td>Beef price</td>
<td>—</td>
<td>—</td>
<td>.34</td>
<td>—</td>
</tr>
<tr>
<td>Pork production per sow</td>
<td>—</td>
<td>—</td>
<td>-3.00</td>
<td>—</td>
</tr>
</tbody>
</table>

All estimated coefficients have correct signs and are statistically significant within a 99-percent confidence interval with the exception of the coefficient for DROUGHT. This variable was retained in the specification because it is conceptually appropriate, has the correct sign, and has an 84-percent confidence interval. An alternative measure of the impact of drought conditions on extensive livestock should be considered in a future study. The direct-price elasticity is -2.24, which compares favorably with -2.37 reported by Meyers and -2.76 reported by Ryan (table 9). The cross-price elasticity with respect to barley is 2.24, compared with 1.26 reported by Ryan and 0.73 reported by Spriggs. The elasticity with respect to the price of pork is 1.27, compared with 0.71 estimated by Ryan. And finally, the elasticity with respect to Spriggs' intensive livestock production index is 1.93.

Australian Wheat Total Ending Stocks

Australian wheat ending stocks were specified in a manner similar to the Canadian wheat ending stocks specification. It is hypothesized that as the world price rises, the AWB makes more grain available for exports, thus lowering ending stocks. Likewise, as world prices fall, so also do exports, thus raising ending stocks. It is also hypothesized that as area planted for the t+1 crop year increases, the AWB reduces ending stocks in order to increase available storage for the larger expected harvest.

Spriggs hypothesized an inverse relation between stocks and the world price. Spriggs specified a hyperbolic function that simultaneously reflected a minimum AWB desired carryover

Table 10—Summary of Australian wheat ending stock elasticities

<table>
<thead>
<tr>
<th>Item</th>
<th>Current study 1960-85</th>
<th>Devadoss and others 1965-84</th>
<th>Spriggs 1949-73</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat feed price</td>
<td>-0.60</td>
<td>-0.43</td>
<td>-0.84</td>
</tr>
<tr>
<td>Wheat beginning stocks</td>
<td>.50</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Wheat production per sow</td>
<td>2.15</td>
<td>1.39</td>
<td>—</td>
</tr>
</tbody>
</table>

— = not available.

1 Shortrun elasticities evaluated at the mean.
2 Barley, oats, sorghum, and corn.
3 A measure of technological change.
and a minimum accepted AWB price. Such a specification was tested and provided statistically significant coefficients, but produced elasticities much lower than those estimated by Spriggs. A simple linear specification was therefore retained. The Australian wheat export price was used to reflect movements in the world price; attempts to deflate it by the Australian consumer price index rendered it statistically insignificant. Area planted in period t+1 was also tested in the specification but proved statistically insignificant.

Australian wheat ending stocks were therefore estimated as a function of beginning stocks plus production and the Australian wheat export price (eq. 49, app. B). Attempts to account for the unprecedented stock levels in 1968 and 1969 using dummy variables rendered the export price insignificant. These variables were therefore not retained in the specification. All parameter estimates are statistically significant within a 99-percent confidence interval.

The own-price elasticity computed from the results is -0.6, compared with -0.84 reported in the Spriggs study and -0.43 reported by Devadoss and others (table 10). The elasticity with respect to wheat production is 2.15, compared with 1.39 reported by Devadoss and others. The results also suggest that a 10-percent increase in wheat beginning stocks will increase ending stocks 5 percent.

Table 11—Summary of Australian wheat price transmission elasticities

<table>
<thead>
<tr>
<th>Item</th>
<th>Current study 1960-86</th>
<th>Devadoss and others 1964-85 (14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guaranteed minimum price</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S. wheat loan rate2</td>
<td>0.20</td>
<td>—</td>
</tr>
<tr>
<td>Guaranteed minimum price lagged one period</td>
<td>.42</td>
<td>—</td>
</tr>
<tr>
<td>Human consumption price</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S. wheat gulf ports price</td>
<td>.63</td>
<td>—</td>
</tr>
<tr>
<td>Australian-U.S. exchange rate</td>
<td>.63</td>
<td>—</td>
</tr>
<tr>
<td>Annual average export price</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S. wheat gulf ports price</td>
<td>.86</td>
<td>.97</td>
</tr>
<tr>
<td>Australian-U.S. exchange rate</td>
<td>.86</td>
<td>.97</td>
</tr>
</tbody>
</table>

— 5 not available.

*1Shortrun elasticities evaluated at the mean.
*2Evaluated over the period 1979-86.

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**Australian Wheat Market-clearing Identity**

The Australian wheat market-clearing identity sets exports equal to production plus carry-in less onfarm use, permit feed, food and feed use, and ending stocks (eq. 50, app. B)

**Australian Wheat Guaranteed Minimum Price**

The formula for the Australian wheat guaranteed minimum price (GMP) has been legislated every fifth year under the wheat stabilization plans. The GMP was set by the Minister of Primary Industries under the first six stabilization plans according to the cost of production (1948-78).11 The GMP varied little under the first five stabilization plans, but grew 56 percent under the sixth stabilization plan. The AWB set the GMP under the seventh and eighth stabilization plans (1979-present) using a formula equal to 95 percent of the net average of (1) market returns from the previous 2-3 years, and (2) estimated market returns for the current year.

It was assumed that the GMP is based on expectations of the world market price and that the AWB adjusts to changes in the latter over time. The GMP must be set conservatively by the AWB since the Australian Government is liable for any pool deficits (the difference between the GMP and the pooled price). It was also assumed that the AWB has had a varied response to changes in the expected world market price under the various stabilization schemes, particularly the sixth, seventh, and eighth. Hence, the Australian wheat GMP was specified as a function of the U.S. wheat loan rate and U.S. wheat beginning stocks in order to reflect AWB expectations of the world market price (eq. 51, app. B). A lagged dependent variable was included in the specification to reflect a lag in the response of the AWB to changes in the expected world price. Dummy variables were also included to test for shifts in the intercept and estimated coefficients over the following three time periods: (1) 1960-73 (the third through fifth stabilization plans), (2) 1974-78 (the sixth stabilization plan), and (3) 1979-86 (the seventh and eighth stabilization plans).

The dummy variables for the three time periods proved statistically significant. U.S. wheat beginning stocks proved statistically insignificant in all three time periods, and the U.S. wheat loan rate proved statistically significant in the last time period only. This suggests that the AWB was responsive to world market prices under the seventh and eighth stabilization plans only. The lagged dependent variable proved statistically significant, suggesting the AWB does not instantaneously adjust to changes in the world price, but rather partially through time.

*11Called the "guaranteed price" under the first five stabilization plans and the "stabilization price" under the sixth stabilization plan.
All estimated coefficients were statistically significant within a 99-percent confidence interval. A direct price elasticity of 0.20 was computed over the mean of the time period 1979-86 (table 11).

**Australian Wheat Human Consumption Price**

The Australian wheat human consumption price, otherwise known as the HCP, was estimated as a function of the lagged U.S. wheat gulf ports price, the lagged U.S. wheat export subsidy, and the lagged Australian-U.S. exchange rate (eq. 52, app. B). The HCP is fixed by the Australian Government at the start of the marketing year. It was hypothesized that the AWB did consider the world price in setting the HCP, but that a structural change occurred in 1979 when, for the first time, the price was formally linked to the world price under the seventh stabilization plan. The formula under the seventh stabilization plan intended to raise the HCP 20 percent above the Australian wheat export price.

The statistical results revealed an upward shift in the HPC because of the estimated coefficient for the U.S. wheat gulf ports price. All variables proved statistically significant within a 99-percent confidence interval. An elasticity of price transmission of 0.63 was estimated for this equation from the statistical results (table 11).

**Australian Wheat Export Price**

The Australian wheat annual average export price was estimated as a function of the U.S. wheat gulf ports price, the U.S. wheat export subsidy rate, and the Australian-U.S. exchange rate (eq. 53, app. B). All estimated coefficients were statistically significant within a 99-percent confidence interval. An elasticity of price transmission of 0.86 was computed from the statistical results, which is a less-than-perfect degree of price transmission (table 11).

**Australian Barley Board Feed Price**

The Australian Barley Board feed price for barley was estimated as a function of the U.S. barley farm price, the Australian-U.S. exchange rate, and a lagged dependent variable (eq. 54, app. B). Spriggs noted that the Australian Barley Board (ABB) feed price—otherwise known as the HCP for feed barley—varied monthly in accordance with changing market conditions (57, p. 41). This is unlike the GMP, which is set once, well before the start of the wheat marketing year. The ABB feed price was therefore specified as a function of the U.S. farm barley price, which is a proxy for the world barley price. It was also hypothesized that the ABB did not instantaneously adjust to changes in world market conditions; hence a lagged dependent variable was also incorporated in the specification.

All estimated coefficients were statistically significant within a 99-percent confidence interval. Dummy variables were incorporated into the specification to account for unexplained outliers. An elasticity of price transmission of 0.39 was computed from the statistical results and suggests that the ABB has significantly insulated producers from variation in world barley prices.

**European Community Submodel**

The EC-12 is the world's third leading exporter and producer of wheat, accounting for 17 percent of the world wheat export market and 14 percent of world wheat production (table 1). These export figures, however, tend to exaggerate the EC position in the world wheat market, since they include intra-EC trade. The EC is unique in that it is a common market and exports to itself. In fact, it is the world's fifth major importer of wheat. The EC typically produces lower quality wheat and imports higher quality wheat for blending purposes. EC-12 exports net of imports, therefore, represent almost 14 percent of the world wheat export market. The EC would then rank behind Australia as the world's leading exporter.

An EC-10 wheat submodel is presented below and in figure 5. The major limitation of any EC grain model is data, since only limited time series and country coverage are available for econometric estimation. A U.S. Department of Agriculture statistical data base was available for the EC-10 from 1960-85; hence, an EC wheat model excluding Spain and Portugal was estimated (26). The data base provided area, yield, production, producer prices, and exchange rates on a country-by-country basis; feed, nonfeed, ending stocks, and net exports were available at the EC-10 level.

Meilke and de Gorter's study is one of a few econometric studies of the EC wheat sector available for review and was therefore referenced heavily in this section (40). Their method of aggregating producer prices to the EC-10 level was used after initially comparing it with that employed by Herrlihy and others.

The EC-10 supply block consists of production plus beginning stocks; production is equal to total area harvested times yield per harvested hectare. The EC-10 demand block consists of feed and nonfeed (food) use and total ending stocks. An EC-10 market-clearing identity sets net exports equal to excess supply. The EC is unique in that domestic prices are unrelated to the world price. The import price, however, is related to the U.S. price and is weakly related to ending stocks. Select elasticities computed at their mean values are compared with those reported in major studies and are presented in tables 12-14.
EC Wheat Area Harvested

There are two basic approaches that were considered in estimating a wheat area-response equation for the EC-10: (1) estimating an aggregate EC-10 area-response equation and (2) estimating separate area-response equations for each member country. There are a number of problems involved with the former approach. First, not all countries joined the EC at the same time; hence, a number have faced different prices over the historical period. Second, producers do not face “common” agricultural policy prices because of monetary compensatory amounts (MCA’s) that maintain different price supports in each member country. Third, aggregation will involve a loss of information as the variation in individual country variables is submerged in aggregate variables. Both approaches were therefore tested. The statistical results suggest that the country-level approach was marginally better than the aggregate approach, but involved a much more complex model. The aggregate EC-10 wheat area-response equation was therefore used in this study. The country-level equations may be found in an earlier study (2). Table 13 contains the elasticities for the aggregate and country-level equations.

A major consideration in estimating an EC-10 area-response equation was to isolate the proper area-inducing price. Two techniques were tested for aggregating EC-level own- and cross-prices from country-level producer prices. The first approach aggregated EC-level producer prices for wheat and barley using the method outlined by Herlihy and others (26). They converted national prices to ECU’s (European currency units) using annual August/July exchange rates, and then aggregated across countries by taking a weighted sum using 1960-85 production shares. An expected real gross returns per hectare variable was computed by lagging

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Figure 5

EC-10 Wheat Submodel

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12 MCA’s are the difference between the official exchange rate and green rates.
the EC-level producer price one period, multiplying by a 3-year moving average yield, and then deflating by a lagged EC fertilizer price index. The second approach constructed country-level expected price variables and then aggregated using mean production shares computed over the historical period. This was the approach used by Meilke and de Gorter (40). Expected area-inducing variables were constructed for each country by multiplying the lagged producer price by a 3-year moving average yield, deflating by a lagged fertilizer price index (which equalled 100 in 1980), and then converting to ECU’s using the 1980 national currency/ECU exchange rate. These country-level prices were then aggregated using mean production shares as weights (see table 12).

Both approaches were tested in the EC-10 wheat area-response equation. The approach developed by Meilke and DeGorter provided better statistical results and was therefore used in this study. EC-10 wheat area was therefore estimated as a function of the expected gross returns for wheat and barley and a lagged dependent variable (eq. 55, app. B). The results produced explanatory variables that had a 1-percent significance level, but produced an adjusted R of only 0.407. The Durbin test failed to reject the hypothesis of a nonautocorrelated error structure. The statistical results produced an own-price elasticity of 0.77 and a cross-price elasticity with respect to barley of -0.85 (table 13). This compares with 0.34 and -0.75 for wheat and barley in the Meilke and de Gorter study. A specification using both one- and two-period lags on the real gross returns variables for wheat and barley rendered the own-price variables statistically insignificant.

### Table 12—Weights used in the computation of EC-10 aggregate prices

<table>
<thead>
<tr>
<th>Country</th>
<th>Production weights</th>
<th>Exchange rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wheat (WWi)</td>
<td>Barley (BWi)</td>
</tr>
<tr>
<td>Belgium/Luxembourg</td>
<td>0.0236</td>
<td>0.0205</td>
</tr>
<tr>
<td>Denmark</td>
<td>.0170</td>
<td>.1546</td>
</tr>
<tr>
<td>France</td>
<td>.4201</td>
<td>.2831</td>
</tr>
<tr>
<td>Ireland</td>
<td>.0083</td>
<td>.0307</td>
</tr>
<tr>
<td>Italy</td>
<td>.1676</td>
<td>.0189</td>
</tr>
<tr>
<td>Netherlands</td>
<td>.0183</td>
<td>.0101</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>.1370</td>
<td>.2674</td>
</tr>
<tr>
<td>West Germany</td>
<td>.1672</td>
<td>.1944</td>
</tr>
<tr>
<td>Greece</td>
<td>.0407</td>
<td>.0202</td>
</tr>
</tbody>
</table>

### EC-10 Wheat Yield

EC-10 wheat yield was estimated as a function of trend (eq. 56, app. B). The results indicate that EC-10 wheat yields have increased at a rapid rate of 0.107 metric tons per hectare each year over the historical period, compared with 0.023 in Canada and 0.007 in Australia. Trend alone explained 90 percent of the variation in EC-10 wheat yields, which suggests that, despite a drought in 1984/85, weather has less of an impact on EC-10 wheat yields than in other countries such as Canada and Australia.

### EC-10 Wheat Food Use

Nonfeed use consists predominantly of food use, but also seed, waste, and dockage. Per-capita food use is theoretically a function of the real price of wheat and real per-capita income. Real per-capita gross domestic product (GDP) was used as a proxy for personal disposable income, since the latter was unavailable. A real EC-10 wheat producer price was not included in the specification, since it produced a wrong sign and was statistically insignificant. This result is attributed to the relative stability of wheat per-capita food use in the EC over the historical period. Meilke and de Gorter employed a weighted average of the wheat threshold.

### Table 13—Summary of EC wheat area-response elasticities

<table>
<thead>
<tr>
<th>Item</th>
<th>Expected price</th>
<th>Expected yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wheat</td>
<td>Barley</td>
</tr>
<tr>
<td>Current study, 1963-85:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC-10</td>
<td>0.77</td>
<td>-0.85</td>
</tr>
<tr>
<td>Belgium/Luxembourg</td>
<td>.64(^2)</td>
<td>-.89</td>
</tr>
<tr>
<td>Denmark</td>
<td>1.01</td>
<td>-1.30</td>
</tr>
<tr>
<td>France</td>
<td>.60</td>
<td>-.59</td>
</tr>
<tr>
<td>Greece</td>
<td>.43</td>
<td>-.53</td>
</tr>
<tr>
<td>Ireland</td>
<td>1.32</td>
<td>-1.20</td>
</tr>
<tr>
<td>Italy</td>
<td>.35</td>
<td>-.47</td>
</tr>
<tr>
<td>Netherlands</td>
<td>.92</td>
<td>-1.02</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1.21</td>
<td>-.92</td>
</tr>
<tr>
<td>West Germany</td>
<td>.29(^2)</td>
<td>-.20(^2)</td>
</tr>
<tr>
<td>Gardiner, 1967-80 (23):</td>
<td>.25</td>
<td>—</td>
</tr>
<tr>
<td>Meilke and DeGorter, 1964-81 (40):</td>
<td>.34 (=)not applicable.</td>
<td>= not applicable.</td>
</tr>
<tr>
<td>EC-10</td>
<td>.34</td>
<td>-.75</td>
</tr>
</tbody>
</table>

\(^1\)Shortrun elasticities evaluated at the mean.
\(^2\)Statistically insignificant within a 90-percent confidence interval.
price and the EC-10 wheat producer price in their per-capita food use equation. The weights were determined by the share of total EC-10 food use from domestic and foreign sources. Their statistical results produced a highly inelastic own-price elasticity (-0.09) that was statistically insignificant within a 90-percent confidence interval. Such a specification was not considered in this study, since the series Meilke and de Gorter used for imports net of EC intra-trade is not based on the same crop year as the supply-demand balance sheet.

EC-10 per-capita wheat food use was therefore estimated as a function of real per-capita GDP (eq. 59, app. B). The statistical results produced a negative coefficient for real GDP, which indicates that wheat is an inferior good in the EC-10. An income elasticity of -0.16 was estimated, which compares with -0.12 reported in the Meilke and de Gorter study (table 14).

### Table 14—Summary of EC wheat demand elasticities

<table>
<thead>
<tr>
<th>Item</th>
<th>Current study</th>
<th>Meilke and de Gorter 1968-82, EC-10 (40)</th>
<th>Devadoss and others 1965-84, EC-9 (14)</th>
<th>Gardiner 1967-80, EC-9 (23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food use:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat price</td>
<td>—</td>
<td>-0.09</td>
<td>—</td>
<td>-0.27</td>
</tr>
<tr>
<td>Corn price</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>.22</td>
</tr>
<tr>
<td>Personal consumption expenditures</td>
<td>—</td>
<td>-.12</td>
<td>—</td>
<td>-.26</td>
</tr>
<tr>
<td>Income</td>
<td>-0.16</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Population</td>
<td>1.16</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Feed use:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat price</td>
<td>-1.92</td>
<td>-1.37</td>
<td>-3.11</td>
<td>-.84</td>
</tr>
<tr>
<td>Barley price</td>
<td>1.98</td>
<td>1.13</td>
<td>6.04</td>
<td>—</td>
</tr>
<tr>
<td>Corn price</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>.65</td>
</tr>
<tr>
<td>Soybean meal price</td>
<td>—</td>
<td>—</td>
<td>.08</td>
<td>.09</td>
</tr>
<tr>
<td>Denaturing premium</td>
<td>.41</td>
<td>.17</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Livestock units</td>
<td>1.43²</td>
<td>—</td>
<td>4.37</td>
<td>—</td>
</tr>
<tr>
<td>Income</td>
<td>—</td>
<td>1.23</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Wheat production</td>
<td>1.12</td>
<td>.52</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Total ending stocks:</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Wheat price—</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Producer</td>
<td>-.61</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Wholesale</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>-1.47</td>
</tr>
<tr>
<td>Intervention</td>
<td>.64²</td>
<td>—</td>
<td>—</td>
<td>2.14</td>
</tr>
<tr>
<td>C.i.f. Rotterdam</td>
<td>-.03²</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Denaturing premium</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>-.19</td>
</tr>
<tr>
<td>Wheat production plus</td>
<td>1.85</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>beginning stocks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial ending stocks:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government stocks</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Wheat production plus</td>
<td>—</td>
<td>-.21</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>beginning stocks</td>
<td>—</td>
<td>1.36</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

— = not applicable.

¹Shortrun elasticities evaluated at the mean.
²Statistically insignificant within a 90-percent confidence interval.
using 1980 exchange rates, and then aggregating to the EC level using the weights in table 12 (see eq. 64, app. B). Meilke and de Gorter deflated the wheat and barley producer prices by the price of hogs. The producer price of hogs was therefore tested as a deflator and as a separate real price. This price produced negative elasticities and was therefore dropped from the specification. One would expect a priori that a livestock price would be positively correlated with feed use, since a rise in this price would increase the demand for livestock numbers and, hence, feed demand. Wheat production was also included in the specification since Meilke and de Gorter hypothesized that producer prices do not adequately reflect the scarcity of grain in the EC because of the intervention price mechanism. An EC wheat feed subsidy, the denaturing premium, was also included in the specification as a separate regressor, as suggested by Meilke and de Gorter, since the quantity of feed wheat actually subsidized is not known.

All parameter estimates are statistically significant within a 95-percent confidence interval, with the exception of the intercept and livestock numbers. The estimated own-price elasticity is -1.92, which compares with -1.37 from Meilke and de Gorter, -3.11 from Devadoss and others, and -0.84 from Gardiner (table 14). The estimated cross-price elasticity with respect to the barley price is 1.98, which compares with 1.13 from Meilke and de Gorter and 6.04 from Devadoss and others. The direct- and cross-price elasticities estimated in this report are much closer to those reported by Meilke and de Gorter, since the two feed-use specifications are similar. The elasticity with respect to the denaturing premium is 0.41 and was computed at the mean of the period 1960-72, since this subsidy ended in 1972. This compares with a much lower elasticity of 0.17 reported by Meilke and de Gorter, which may have been estimated at the mean of the complete sample period. The elasticity with respect to livestock numbers indicates that a 10-percent increase in beef, veal, hog, sheep, and goat numbers will increase wheat demand for feed use by 14.3 percent. The elasticity with respect to wheat production is 1.12, which is much larger than the 0.52 reported by Meilke and de Gorter.

**EC-10 Wheat Total Ending Stocks**

EC-10 wheat total ending stocks were estimated as a function of the ratio of the EC-10 wheat producer price to the wheat intervention price, the ratio of the wheat c.i.f. import price to the wheat intervention price, and wheat production plus beginning stocks (eq. 62, app. B). Meilke and de Gorter hypothesized that government ending stocks should increase as production increases and decrease as producer prices rise relative to intervention prices. Under the latter scenario, producers would market their grain on the EC market rather than to the intervention agencies. Meilke and de Gorter also hypothesized that stocks should decline as the EC export price rises relative to the intervention price, since smaller restitition payments would be needed to export stocks. The wheat c.i.f. import price at Rotterdam was used in this study as a proxy for an EC export price, since a complete series for the wheat f.o.b. Rotterdam price was unavailable.

The estimated coefficients for the ratio of the EC-10 wheat producer price to the wheat intervention price and for production plus beginning stocks both have correct signs and are statistically significant. The coefficient for the ratio of the c.i.f. wheat price to the wheat intervention price has the correct sign, but is statistically insignificant. The c.i.f. price was maintained, however, since it is theoretically appropriate and maintains some degree of responsiveness between EC-10 exports and world prices. The statistical results suggest elasticities of -0.61 for the producer price and 0.64 for the intervention price (table 14). The statistical results also suggest that a 10-percent increase in wheat production plus carry-in will increase wheat ending stocks 18.5 percent.

**EC-10 Wheat Market-clearing Identity**

The EC-10 market-clearing identity sets wheat exports net of imports equal to production plus carry-in, less total consumption and ending stocks (eq. 63, app. B).

**Wheat c.i.f. Import Price**

The EC wheat import price was estimated as a function of the U.S. wheat gulf ports price, the U.S. wheat export subsidy, and the U.S.-EC exchange rate (eq. 65, app. B). A dummy variable was included in the specification to account for the unprecedented increase in world prices in 1973/74. An elasticity of price transmission of 0.79 was computed, which indicates a less than perfect degree of price transmission.

**Argentine Submodel**

Argentina, the world’s fifth-leading wheat exporter, accounted for 7 percent of the world wheat market over the period 1983/84-1986/87 (table 1). Argentina is also the world’s ninth-leading wheat producer.

The Argentine wheat submodel is presented below and in figure 6. The supply block consists of production plus
beginning stocks. Production is defined as harvested area times yield. The demand block consists of domestic demand plus total ending stocks. Domestic demand is equal to food plus feed use. The Argentine wheat market-clearing identity sets exports equal to excess supply. The U.S. wheat gulf ports price determines the Argentine wheat f.o.b. export price, which then determines the Argentine producer price. Select elasticities computed at the mean are compared with those reported by other researchers in tables 15-17. A review of Argentine wheat area-response studies is presented in appendix A.

**Argentine Wheat Area Planted**

Argentine wheat competes with corn, sorghum, sunflower, and cattle for land and other production resources. Calendar-year wholesale prices lagged one period for wheat, corn, sorghum, and sunflower were tested as area-inducing prices. The calendar-year average price of steers in the Liniers market was used to test for wheat substitution with beef production. The wholesale price of nonagricultural goods was used to deflate all prices and was considered a proxy for production expenses.

The statistical results revealed a strong substitution between wheat and sunflower, and no substitution with corn, sorghum, or cattle. Argentine wheat area planted was therefore estimated as a function of the real wholesale price of wheat lagged one period, the real wholesale price of sunflower lagged one period, a dummy variable to account for an unexplained outlier in 1970/71, and a lagged dependent variable (eq. 66, app. B).

All parameter estimates are statistically significant within a 99-percent confidence interval. The statistical results suggest a direct-price elasticity of 0.32, compared with 0.48 reported by Wainio during Argentina’s market-oriented years 1958-72 and 1977-80 (table 15) (65, 66). The results also suggest a cross-price elasticity with respect to sunflower of -0.50, compared with -0.47 reported by Wainio during market-oriented years.

Figure 6

**Argentine Wheat Submodel**
Argentine Wheat Area Harvested

Argentina reports both area planted and harvested. Area planted is explained behaviorally and area harvested is estimated as a simple linear function of planted area. The latter specification, however, produced a highly autocorrelated error structure. Argentine wheat area harvested was therefore estimated as a function of wheat area planted, trend, and a dummy variable to explain a severe drought in 1980/81 (eq. 67, app. B). All parameter estimates are statistically significant within a 99-percent confidence interval.

Argentine Wheat Per-capita Domestic Use

Domestic use of wheat consists of food and feed use. Argentine wheat feed use typically represents only 3-4 percent of domestic use. For this reason, feed use and food use were combined and per-capita domestic use was explained behaviorally. Per-capita domestic use was estimated as a function of real per-capita gross domestic product (eq. 71, app. B). Dummy variables were used in the specification to account for an unprecedented increase in feed use as a percentage of domestic use in 1975/76 and a downward shift in the error structure beginning in 1976/77. Dummy variables were also used to account for unexplained outliers in 1969/70 and 1972/73. Real f.o.b. export and wholesale prices were tested in the specification but were dropped after producing wrong signs and insignificant parameter estimates. Argentine wheat domestic use is therefore perfectly inelastic with respect to wheat prices.

The statistical results suggest the parameter estimates are significant within a 90-percent confidence interval. An income elasticity of -0.23 was computed at the mean and suggests that wheat in Argentina is an inferior good (table 16).

Table 15—Summary of Argentine wheat area-response elasticities

<table>
<thead>
<tr>
<th>Item</th>
<th>Current study 1961-85</th>
<th>Wainio(^2) 1946-79 (65)</th>
</tr>
</thead>
<tbody>
<tr>
<td>With respect to:(^3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat price</td>
<td>0.32</td>
<td>0.48</td>
</tr>
<tr>
<td>Sunflower price</td>
<td>-.50</td>
<td>-.47</td>
</tr>
<tr>
<td>Corn price</td>
<td>—</td>
<td>.02(^*)</td>
</tr>
<tr>
<td>Flaxseed price</td>
<td>—</td>
<td>-.10(^*)</td>
</tr>
<tr>
<td>Beef price</td>
<td>—</td>
<td>.10(^*)</td>
</tr>
</tbody>
</table>

\(^*\) = not applicable.
\(^3\)Shortrun elasticities evaluated at the means.
\(^4\)For the market-oriented years only.
\(^5\)The current study used wholesale prices, Buenos Aires. Wainio used data reported from the Buenos Aires Grain Exchange.
\(^6\)Statistically insignificant at a 90-percent confidence interval.

Table 16—Summary of Argentine wheat demand elasticities

<table>
<thead>
<tr>
<th>Item</th>
<th>Domestic use(^2)</th>
<th>Ending stocks(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>With respect to:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross domestic product</td>
<td>0.23</td>
<td>—</td>
</tr>
<tr>
<td>Population</td>
<td>1.24</td>
<td>—</td>
</tr>
<tr>
<td>Production</td>
<td>—</td>
<td>0.99</td>
</tr>
</tbody>
</table>

\(^2\)Shortrun elasticities evaluated at the mean.
\(^3\)1960/61-1986/87.
\(^4\)1965/66-1986/87.

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"reference price" times the tax rate. The wholesale price is therefore conditioned on four factors: (1) the f.o.b. wheat export price, Buenos Aires, (2) the Argentine-U.S. exchange rate, (3) the "reference price," and (4) the ad valorem tax rate. The real wheat wholesale price was therefore estimated as a function of the ad valorem tax rate, and the f.o.b. export price times the exchange rate deflated by the wholesale price index (eq. 75, app. B). The tax rate was included in the specification as a separate variable, since a complete time series for the reference price was unavailable. A dummy variable was included in the specification for those years when the margin between the net f.o.b. price and the wholesale price was negative. Dummy variables were also included for 1974/75 and 1975/76, years of the second Peron administration, when the margin was unusually large (67).

All parameter estimates are statistically significant within a 99-percent confidence interval. The estimated elasticities suggest that a 10-percent increase in the ad valorem tax rate will reduce the real wheat wholesale price by 21 percent (table 17). Likewise, a 10-percent increase in the real wheat f.o.b. export price will increase the dependent variable 10.1 percent.

**Argentine Wheat Export Price**

The Argentine wheat f.o.b. export price is linked to the U.S. wheat gulf ports price. The gulf price was computed on a June/May crop year, while the Argentine f.o.b. price is quoted on a calendar-year basis that is close to the December/November Argentine crop year. Hence, the Argentine wheat export price was estimated as a function of the U.S. wheat gulf ports price less export subsidies (eq. 76, app. B). The gulf price in both the t-1 and t time periods was used since the U.S. and Argentine crop years are exactly 6 months apart. Dummy variables were included in the specification to account for a sharp rise in the Argentine wheat export price in 1980/81 and 1981/82 that resulted from the U.S. embargo against the USSR.

The estimated parameter estimates are statistically significant within a 95-percent confidence interval. The results suggest an elasticity of price transmission between the United States and Argentina of 0.51 in period t-1 and 0.38 in period t, which sum to 0.89 (table 17). This is consistent with Westhoff, who reported an elasticity of price transmission of 0.82 (67). This suggests that the border price is less than fully transparent to changes in world prices. The statistical results also suggest that Argentine wheat export prices were above U.S. prices during the 1980 U.S. embargo against the USSR by US$39.67 per metric ton in 1980/81 and US$23.24 in 1981/82.

**Japanese Submodel**

Japan is the world's third-leading wheat importer following the Soviet Union and China and averaged almost 6 percent of world wheat imports over the period 1983/84-1986/87. The Japanese wheat submodel is presented below and in figure 7. Japanese wheat supply is equal to production plus beginning stocks; production is defined as area harvested times yield. The demand block consists of total demand, which is equal to domestic demand plus ending stocks. Domestic demand consists of feed and nonfeed use. The Japanese wheat market-clearing identity sets imports equal to total demand less supply. The U.S. wheat gulf ports price determines the Japanese c.i.f. import price, which in turn conditions the wheat resale price.

**Japanese Wheat Area Planted**

Japanese wheat area substitutes primarily with rice production. The producer price of wheat relative to rice declined in the 1960's and early 1970's and began to rise significantly in the mid-1970's. This is similar to the pattern of land use over the same period. The producer price of wheat relative to rice, therefore, is an important determinant of wheat area. Government-sponsored rice diversion programs are also hypothesized to determine wheat area in Japan. Rice surpluses in the early 1970's resulted in government

<table>
<thead>
<tr>
<th>Item</th>
<th>Current study 1961-86</th>
<th>Westhoff 1966-84 (67)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wholesale price:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Export tax</td>
<td>-0.21</td>
<td>—</td>
</tr>
<tr>
<td>F.o.b. export price</td>
<td>1.01</td>
<td>—</td>
</tr>
<tr>
<td>F.o.b. export price:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S. gulf ports price2</td>
<td>0.89</td>
<td>0.82</td>
</tr>
</tbody>
</table>

— = not applicable.
1 Shortrun elasticities evaluated at the mean.
2 The sum of periods t and t-1.
programs that offered rice producers diversion payments for switching from paddy cultivation to wheat and other crop production.

Diversion payments to wheat production proved statistically insignificant in the Japanese wheat acreage-response specification. Japanese wheat area was therefore estimated as a function of the ratio of wheat and rice producer prices lagged one period and a lagged dependent variable (eq. 77, app. B). All variables are statistically significant within a 5-percent significance level. The direct- and own-price elasticities are 0.52 and -0.52 for wheat and rice.

**Japanese Wheat Per-capita Consumption**

Japan uses wheat primarily for food or milling purposes. Japanese wheat feed use has declined as a percentage of total consumption from 6 percent in the early 1960’s to just 2 percent in the 1980’s. Food and feed use were therefore aggregated, and total domestic consumption was estimated behaviorally in this report.

Coyle hypothesized that Japanese consumers substitute between rice and wheat consumption depending on relative prices and income (72). The Japanese government purchases wheat and rice from producers at the producer price and resells it to wholesalers at the resale price. Coyle therefore used the resale prices of wheat and rice in his specification of per-capita wheat demand.

Coyle’s specification was reestimated for this study with similar results. Japanese per-capita wheat use was estimated as a function of the wheat and rice resale prices, each deflated by the Japanese consumer price index (eq. 81, app. B). All the estimated coefficients for the specification proved statistically significant, with the exception of the income variable. The own-price elasticity of -0.18 is identical to that reported by Coyle. The cross-price elasticity with

---

**Japanese Wheat Submodel**

![Japanese Wheat Submodel Diagram]

- Supply
  - Area
  - Yield
  - Production
  - Beginning stocks

- Imports

- Domestic demand
  - Feed and nonfeed use
  - Ending stocks

- CPI index

- Resale price

- C.i.f. import price

- Japanese-U.S. exchange rate

- U.S. Gulf ports price

---

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respect to rice is 0.12, compared with 0.16 reported by Coyle.

Japanese Wheat Ending Stocks

Japanese wheat stocks are held for pipeline purposes only, since most of Japan's wheat is imported. Japanese wheat ending stocks were therefore estimated as a function of production plus carry-in stocks and domestic use (eq. 83, app. B). Stocks are hypothesized to be positively correlated with imports, which are in turn determined mainly by domestic demand.

Japanese Wheat Market-clearing Conditions

Japanese wheat imports, net of any exports, are set equal to domestic use plus ending stocks less production and carry-in (eq. 84, app. B).

Japanese Wheat Producer Price

The Japanese wheat and rice producer prices are set by the government. Producers are guaranteed these prices on all government sales. Young states that decisions to set the wheat producer price in the past had been affected by movements in the agricultural parity price (APP) index—a measure of the returns to wheat production relative to its cost—as well as a need since 1974 to encourage wheat production (68). Young estimated the wheat producer price as a function of the lagged dependent variable, the APP index, and carry-in rice stocks. Rice stocks were used as a proxy for the rising cost of rice programs, which produced incentives on the part of the government to increase the wheat producer price in hopes of reducing rice seeded area. Rice stocks proved statistically insignificant, however, in Young's specification.

The Japanese wheat producer price was therefore estimated in this report as a function of the cost of wheat production, a lagged dependent variable, and a dummy variable to account for an unexplained outlier in 1977/78 (eq. 85, app. B). The cost of wheat production was used as a proxy for the APP. All variables are statistically significant at a 10-percent significance level with the exception of the wheat cost-of-production variable. It was maintained, however, since it has the correct sign and a t-value greater than 1.

Japanese Wheat Resale Price

The Japanese Government also sets the resale price that millers must pay for wheat. The Japanese Government purchases wheat from producers and then resells it to millers at a price below the producer price, but above the world price. That means the Japanese Government subsidizes producers the difference between the producer price and the resale price, and taxes consumers the difference between the resale price and the import price. For that portion of domestic use that is imported, the government profits from the difference between the c.i.f. import price it pays for wheat and the resale price it charges millers.

Young hypothesized that the Japanese wheat resale price is positively correlated with the consumer price index, the wheat c.i.f. import price, and a lagged dependent variable. This specification was employed here with all variables statistically significant within a 90-percent confidence interval (eq. 86, app. B). The elasticity for the wheat resale price with respect to the consumer price index is 0.24, compared with 0.23 reported by Young; the elasticity with respect to the wheat c.i.f. import price is 0.08, compared with 0.06 reported by Young; and the elasticity with respect to the lagged dependent variable is 0.56, compared with 0.61 reported by Young.

Japanese Rice Producer Price

Young noted that the Japanese rice producer price is influenced heavily by the income compensation-cost of adjustment formula. This formula adjusts the rice producer price for changes in urban wage rates and the cost of producing rice. The formula was designed to equilibrate urban and rural incomes. Young therefore estimated the Japanese rice resale price as a function of the lagged dependent variable, the APP index, and carry-in rice stocks. Beginning rice stocks, however, proved statistically insignificant in Young's specification.

Both the cost of rice production and the consumer price index proved statistically insignificant in equations estimated for this study. The rice producer price was therefore estimated as a function of the lagged dependent variable and dummy variables that account for the enormous increases in rice prices after 1973/74 (eq. 87, app. B).

Japanese Rice Resale Price

Japan is self-sufficient in rice production and purchases rice from producers at prices well above world prices, and then resells it to millers at the resale price. The margin between the producer price and the resale price has been large, suggesting high government expenditures on the rice program. This margin has, however, narrowed considerably in recent years, suggesting consumers now pay for a greater portion of the rice program cost.

Young specified the Japanese rice resale price as a function of the consumer price index, the rice producer price, and a lagged dependent variable. Young included the rice
producer price in the specification, since increases in this price are passed on to consumers.

The Japanese rice resale price was therefore estimated as a function of the consumer price index lagged one period, the rice producer price, and a lagged dependent variable (eq. 88, app. B). All variables are statistically significant within a 10-percent significance level. The elasticity with respect to the consumer price index is 0.22, compared with 0.21 reported by Young. The elasticity with respect to the rice producer price is 0.26, compared with 0.38 reported by Young. And finally, the elasticity with respect to the lagged dependent variable is 0.50, compared with 0.39 reported by Young.

Japanese Wheat Import Price

The Japanese wheat c.i.f. import price was estimated as a function of the U.S. wheat gulf ports price, the U.S. wheat export subsidy rate, and dummy variables that account for the increase in the gulf ports price relative to the Japanese wheat import price in 1972/73 and 1973/74 (eq. 89, app. B). The elasticity of price transmission between the United States and Japan was estimated to be 0.96.

World Importers

The model thus far has accounted for the world’s major wheat exporters and Japan. While these countries account for the trade-distorting polices of the major industrialized economies that produce and/or trade wheat, they do not reflect the important trade effects of the centrally planned importers and the rest-of-the-world importers. These countries were thus included in the model, but were not estimated in this report. The data and model specifications for these countries were provided by the Center for Agricultural and Rural Development (CARD) and are part of the FAPRI/CARD world wheat trade model.¹⁵

Centrally Planned Economies

The centrally planned economies (CPE) submodel consists of the Soviet Union, China, and Eastern Europe. These three importers have averaged 57 percent of world wheat imports over the period 1983/84-1986/87. They were therefore included in the model in order to account for a significant portion of the world import market.

Soviet Union

The Soviet Union is by far the world’s largest wheat importer, averaging 21 percent of world wheat imports over the period 1983/84-1986/87 (table 1). The Soviet Union has also been the world’s second-leading wheat producer, averaging 16 percent of world production over the same period.

CARD estimated Soviet wheat stocks and net imports behaviorally and determined domestic use via an identity. Wheat area harvested and yield were considered exogenous. The change in Soviet wheat stocks was estimated as a function of the change in Soviet wheat production. Import demand for Soviet wheat imports was estimated as a function of the ratio of the U.S. wheat gulf ports price to the price of Saudi light crude oil, and Soviet wheat production. Wheat imports are inversely related to the world wheat price and Soviet production. The price of crude oil was included in the specification as a proxy for hard currency earnings.

China

China is the world’s leading wheat producer and the second major wheat importer, averaging 17 percent of world wheat production and 8 percent of world wheat imports over the period 1983/84-1986/87 (table 1). CARD endogenized wheat area harvested and domestic use plus the change in ending stocks. Yield was considered exogenous and net imports were determined via an identity that equaled domestic use plus stock change minus production. Area harvested was estimated as a function of an aggregate grain price index and a lagged dependent variable; domestic use plus the change in stocks was estimated as a function of wheat production and a Chinese measure of income.

CARD’s specification for Chinese wheat imports is perfectly inelastic with respect to the world wheat price. This specification was empirically tested by estimating Chinese wheat imports as a function of the U.S. wheat gulf ports price. The estimates over the historical period produced results that were statistically insignificant. Thus, Chinese wheat imports were considered unrelated to the world wheat price and were determined by internal factors. Therefore, in order to simplify the world wheat model presented in this report, Chinese wheat imports were considered exogenous to the model.

Eastern Europe

Eastern Europe—Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Rumania, and Yugoslavia—is the world’s sixth-largest wheat producer and fourth-largest wheat importer. Eastern Europe averaged 8 percent of world

¹⁵ These equations will be published in a forthcoming CARD publication (personal communication with Michael Helmar, Pre-doctoral Research Associate, CARD).
wheat production and 4 percent of world wheat imports over the period 1983/84-1986/87 (table 1).

CARD endogenized wheat domestic use and the change in wheat stocks for Eastern Europe. Imports net of exports were determined via an identity. Production was estimated as a function of wheat yields, domestic use was estimated as a function of production and real income, and the change in wheat stocks was estimated as a function of production and domestic use. The wheat import demand function for Eastern Europe is similar to that of China in that it is perfectly inelastic with respect to the world wheat price. Thus, for this model, Eastern European net imports were considered exogenous.

Rest-of-the-World Importers

CARD accounted for the rest of the world via four regional reduced form net import demand equations. Such an equation should theoretically be a function of the current and lagged world wheat price, a weighted exchange rate index, and some aggregate measure of real income denominated in a common currency. CARD did not include any exchange rate indices in its regional equations, given the problems involved in constructing a weighted index. CARD developed equations for the following four regions: (1) Other Western Europe, (2) High Income East Asia, (3) Other Asia, and (4) Africa and Middle East. Other Western Europe includes Austria, Finland, Iceland, Norway, Sweden, and Switzerland. High Income East Asia is composed of Hong Kong, Singapore, South Korea, and Taiwan. Other Asia includes all Asia less the High Income East Asia countries and Japan, China, and India.

CARD estimated Other Western Europe wheat imports as a function of a lagged U.S. gulf ports price. High Income East Asian imports were estimated as a function of the gulf price and real income for the region. Other Asia imports were estimated as a function of the lagged gulf price and real income for the region. Africa and Middle East imports were specified as a function of the ratio of the gulf price to the U.S. corn farm price, and the world crude oil price. Corn is an import substitute to this region and the world crude oil price is a measure of income. Thus, both variables are positively correlated to net imports.

Market-clearing Conditions

The conditions that set world supply equal to world demand and determine the world wheat reference price—defined here as the U.S. wheat gulf ports price—are presented below. Recall that a nonspatial equilibrium model is solved when a world price is determined that sets world supply equal to world demand. The world market in this study is cleared through the United States by setting the U.S. wheat excess supply function equal to the excess demand from the rest of the world facing the United States. The U.S. market was chosen partly as a matter of convenience and because the United States accounts for the largest share of world wheat exports. The market-clearing identity in the U.S. submodel represents the U.S. wheat excess supply function and represents U.S. export levels at various world prices. The excess demand function from the rest of the world facing the United States is part of the world market-clearing conditions and is simply the horizontal sum of the excess demand functions of all importers less the excess supply of our major export competitors. The world market is thus cleared when a gulf ports price is found that sets the U.S. excess supply equal to the excess demand facing the United States. This is analogous to the intersection of ESUS and EDworld in figure 1, which determines equilibrium trade and world price Pw.

One problem in solving the world market-clearing condition is that the world demand function facing the United States must be on a June/July crop year since it intersects with the U.S. wheat excess supply function and determines U.S. wheat net exports and the gulf ports price. This equation must therefore reconcile the differences in the crop years for all non-U.S. countries and regions in the world. A simple averaging procedure was employed in this study, since monthly exports for all countries and regions over the historical period were not available. Hence, if a country/region’s supply and demand balance is on a July/June crop year, a simple weight of (1/12) is used for period t-1 and (11/12) is used for period t in order to adjust the country/region’s net trade to a June/July crop year.

The world market-clearing conditions described above determine world trade and the U.S. wheat gulf ports price. These equations work simultaneously as follows. First, an initial gulf ports price (usually a lagged price) is fed into the country/regional submodels for the United States and the rest of the world and determines domestic and border prices and net trade volumes. These trade levels (except U.S. exports) are then used to determine the demand facing the U.S. market at the initial price (eq. 90, app. B). Another equation determines a quantity NET, which is the difference between the U.S. wheat excess supply function and the world demand for wheat facing the United States at the initial price (eq. 91, app. B). If this difference is zero, an equilibrium has been reached. If it is positive (negative), then a synthetic world price equation is used to determine a lower (higher) gulf price (eq. 92, app. B) (23). This price is then fed back into the model system and a new value of NET is then determined for the second iteration. This process then continues iteratively until an equilibrium price is reached that sets NET equal to zero (world supply equal to world demand).
Cumulative dynamic elasticities were therefore used in order to show the period-by-period response of country/region level excess supply and demand functions to a sustained change in the world price.\textsuperscript{16} According to Pindyck and Rubinfeld (42), “A dynamic elasticity would tell how the demand for a good would change over time in response to a change in price or in consumers’ incomes.” They defined a dynamic elasticity as follows:

\[
E_p(r) = - \frac{P_t}{Q_t} \frac{Q_{t+r} - Q_t}{dP_t}
\]  \hspace{1cm} (18)

where \( E \) is a dynamic elasticity for quantity \( Q \) with respect to price \( P \), \( dP_t \) is a change in price occurring in period \( t \), and \( Q_{t+r} - Q_t \) is the change in quantity over \( r \) periods.

Dynamic elasticities were computed in this report using the world wheat model as follows. First, all exogenous variables were fixed at 1985/86 levels from 1986/87 through 2025/26. The model was then simulated over this period in order to determine the baseline simulation path for the endogenous variables. The model was then shocked by raising the wheat gulf ports price 20 percent in 1986/87, sustaining this price over the period 1986/87-2025/26, and simulating the model over the 40-year period. This computes the shocked simulation path. The dynamic elasticities were then computed by (1) computing the percentage change in net trade for each country/region with respect to the baseline simulation path, and (2) dividing this change by the 20-percent increase in the gulf ports price.

The results are presented in table 18. The U.S. wheat export demand elasticity increases from -0.69 in the first period to -0.86 by the fourth period and declines to -0.79 in the long run. This result is surprising in that it suggests very little change in the demand for U.S. wheat beyond the first period. U.S. wheat excess supply is inelastic and increases from 0.2 in the first period to 0.46 in the third period and then declines to 0.44 in the long run. This range is comparable to the elasticity of excess supply for Argentina. Australian wheat excess supply is highly inelastic, since its only link to the world price is through the human consumption price, which is statistically insignificant in the food-use equation. Canadian wheat excess supply is relatively more elastic and increases from 0.37 in the first period to 2.7 in the long run. This cumulative increase results from the lagged impact of the wheat final price on decisions to plant wheat. The excess supply of the EC is not affected by changes in the world price. Japanese wheat import demand is only marginally responsive to the world price since the c.i.f. import price has only a marginal impact on the resale price. The rest of the import demand elasticities reported in table 18 are stable because of a lack of any dynamic structure.

\textsuperscript{16} For a discussion of dynamic elasticities and multipliers, see (31, pp. 8-11) and (42, pp. 391-401).
Model Validation

The complete modeling system is validated in this section by computing measures of goodness of fit. A methodology for simulating the model over the historical period is discussed first, statistical measures of goodness of fit are discussed next, and the validation statistics are presented and discussed.

Kost described the process of validating structural econometric forecasting models (34). He noted that a model must be simulated over the historical period before any validation statistics can be computed. Kost proposed two methods for dynamically simulating a simultaneous system of equations. The first approach is called static simulation. Actual values of both the exogenous and the lagged endogenous variables are used to solve for the current endogenous variables over the historical period. The second approach is called dynamic simulation. This approach also uses actual values for the exogenous variables but differs from the static approach, since it employs the actual value of the lagged endogenous variables in the first period only and then uses the solved values thereafter. The dynamic approach more completely reflects the dynamic and simultaneous nature of a structural econometric modeling system.

This latter approach was therefore used to simulate the world wheat model over the historical period.

Salathe, Price, and Gadson used three goodness-of-fit measures to validate the USDA’s Food and Agricultural Policy Simulator model (52). They are the mean absolute relative error (MARE), Theil’s inequality coefficient, and the percent turning point error (PTPE).\(^{17}\)

The MARE is defined as follows:

$$\text{MARE} = \frac{1}{n} \sum_{t=1}^{n} \left| \frac{y_t - \hat{y}_t}{y_t} \right|$$

where \(y_t\) is the actual value in year \(t\), \(\hat{y}_t\) is the model estimate in year \(t\), and \(n\) is the number of years in the historical simulation period. The MARE measures the degree of simulation error. The MARE is less misleading than the mean percentage error, which allows positive and negative errors to cancel each other out. One problem with the

\(^{17}\) See Pindyck and Rubinfeld for a more detailed description of the MARE and Theil U statistic (42, pp. 360-67).

Table 18—Cumulative dynamic elasticities for wheat\(^1\)

<table>
<thead>
<tr>
<th>Item</th>
<th>Simulation period(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>U.S. export demand(^3)</td>
<td>-0.692</td>
</tr>
<tr>
<td>Excess supply:</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>.199</td>
</tr>
<tr>
<td>Canada</td>
<td>.369</td>
</tr>
<tr>
<td>Australia</td>
<td>.207</td>
</tr>
<tr>
<td>Argentina</td>
<td>0</td>
</tr>
<tr>
<td>Excess demand:</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>0</td>
</tr>
<tr>
<td>Soviet Union</td>
<td>-.212</td>
</tr>
<tr>
<td>Other Western Europe(^4)</td>
<td>0</td>
</tr>
<tr>
<td>Africa and Middle East</td>
<td>-.335</td>
</tr>
<tr>
<td>High Income East Asia</td>
<td>-.125</td>
</tr>
<tr>
<td>Other Asia</td>
<td>0</td>
</tr>
</tbody>
</table>

\(^{1}\) With respect to a sustained change in the U.S. wheat gulf ports price.

\(^{2}\) Period 1: shortrun elasticity; period 5: intermediate run elasticity; and period 40: longrun elasticity.

\(^{3}\) Elasticity of demand for imports facing the United States with respect to the U.S. wheat gulf ports price.

\(^{4}\) Other Western Europe was a net exporter in 1985.
MARE is that while it is bound from below by zero, it has no upper bound.

One measure of Theil's inequality coefficient is presented below:

\[
U = \frac{\sqrt{\sum_{t=1}^{n} (y_t - \bar{y})^2}}{\sqrt{\sum_{t=1}^{n} y_t^2 + \sum_{t=1}^{n} \bar{y}^2}}
\]

Unlike the MARE, Theil's inequality coefficient is bound between zero and one (59). When \( U = 0 \), the actual and simulated values are the same for all periods and there is a perfect simulation. When \( U = 1 \), simulated values are zero (non-zero) when actual values are non-zero (zero), or simulated values are positive (negative) when actual values are negative (positive).

The following definition of percent turning point error was used in this study:

\[
\text{TPE}_t = \begin{cases} 
0 & \text{if } \frac{y_t - y_{t-1}}{y_t - y_{t-1}} > 0 \\
1 & \text{else}
\end{cases}
\]

\[
\text{PTPE} = \frac{1}{n} \sum_{t=1}^{n} \text{TPE}_t
\]

The PTPE provides a measure of how well the modeling system predicts turning points over the simulation period. Kost notes that a simulation has four possible outcomes with respect to turning points for each period \( t \): a turning point will exist and the model will either predict or not predict one; or no turning point will exist and the model will either predict or not predict one.

The model validation statistics for the MARE, Theil U, and PTPE are presented in table 19. The validation statistics are not presented for every endogenous variable in the system, but rather for those deemed most important to the modeling system. The MARE and the Theil U statistics are less than 0.15 and 0.9, respectively, for U.S. wheat net exports and the gulf ports price. The PTPE for U.S. net exports and the gulf ports price are high: 35.3 and 29.4 percent, respectively. Validation statistics for these two variables are important, since they represent the cumulative effect of all other endogenous variables.

### Table 19—World wheat model validation statistics

<table>
<thead>
<tr>
<th>Item</th>
<th>MARE</th>
<th>Theil U</th>
<th>PTPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program area</td>
<td>0.071</td>
<td>0.066</td>
<td>17.65</td>
</tr>
<tr>
<td>Nonprogram area</td>
<td>0.234</td>
<td>0.057</td>
<td>29.41</td>
</tr>
<tr>
<td>Food use</td>
<td>0.012</td>
<td>0.008</td>
<td>41.18</td>
</tr>
<tr>
<td>Feed use</td>
<td>0.335</td>
<td>0.093</td>
<td>17.65</td>
</tr>
<tr>
<td>Seed use</td>
<td>0.075</td>
<td>0.047</td>
<td>29.41</td>
</tr>
<tr>
<td>Ending stocks</td>
<td>0.113</td>
<td>0.056</td>
<td>5.88</td>
</tr>
<tr>
<td>Net exports</td>
<td>0.134</td>
<td>0.069</td>
<td>35.29</td>
</tr>
<tr>
<td>Gulf ports price</td>
<td>0.147</td>
<td>0.088</td>
<td>29.41</td>
</tr>
<tr>
<td>Canada:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area harvested</td>
<td>0.044</td>
<td>0.030</td>
<td>17.65</td>
</tr>
<tr>
<td>Food use</td>
<td>0.121</td>
<td>0.021</td>
<td>41.18</td>
</tr>
<tr>
<td>Feed use</td>
<td>0.099</td>
<td>0.066</td>
<td>41.18</td>
</tr>
<tr>
<td>Seed use</td>
<td>0.054</td>
<td>0.034</td>
<td>23.53</td>
</tr>
<tr>
<td>Ending stocks</td>
<td>0.095</td>
<td>0.043</td>
<td>29.41</td>
</tr>
<tr>
<td>Exports</td>
<td>0.100</td>
<td>0.063</td>
<td>41.18</td>
</tr>
<tr>
<td>Offboard price</td>
<td>0.144</td>
<td>0.067</td>
<td>17.65</td>
</tr>
<tr>
<td>Initial price</td>
<td>0.075</td>
<td>0.035</td>
<td>11.76</td>
</tr>
<tr>
<td>Export quotation</td>
<td>0.157</td>
<td>0.085</td>
<td>41.18</td>
</tr>
<tr>
<td>Australia:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area planted</td>
<td>0.092</td>
<td>0.046</td>
<td>11.76</td>
</tr>
<tr>
<td>Food use</td>
<td>0.032</td>
<td>0.021</td>
<td>41.18</td>
</tr>
<tr>
<td>Feed use</td>
<td>0.428</td>
<td>0.183</td>
<td>41.18</td>
</tr>
<tr>
<td>Seed use</td>
<td>0.788</td>
<td>0.216</td>
<td>23.53</td>
</tr>
<tr>
<td>Ending stocks</td>
<td>0.138</td>
<td>0.064</td>
<td>17.65</td>
</tr>
<tr>
<td>Exports</td>
<td>0.121</td>
<td>0.066</td>
<td>35.29</td>
</tr>
<tr>
<td>Guaranteed minimum</td>
<td>0.038</td>
<td>0.017</td>
<td>47.06</td>
</tr>
<tr>
<td>minimum price</td>
<td>0.189</td>
<td>0.105</td>
<td>58.82</td>
</tr>
<tr>
<td>EC-10:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area harvested</td>
<td>0.027</td>
<td>0.015</td>
<td>29.41</td>
</tr>
<tr>
<td>Food use</td>
<td>0.011</td>
<td>0.007</td>
<td>47.06</td>
</tr>
<tr>
<td>Feed use</td>
<td>0.076</td>
<td>0.048</td>
<td>29.41</td>
</tr>
<tr>
<td>Ending stocks</td>
<td>0.141</td>
<td>0.076</td>
<td>29.41</td>
</tr>
<tr>
<td>Net exports</td>
<td>1.502</td>
<td>0.087</td>
<td>35.29</td>
</tr>
<tr>
<td>Producer price</td>
<td>0.021</td>
<td>0.011</td>
<td>11.76</td>
</tr>
<tr>
<td>Argentina:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area planted</td>
<td>0.071</td>
<td>0.040</td>
<td>23.53</td>
</tr>
<tr>
<td>Domestic use</td>
<td>0.030</td>
<td>0.020</td>
<td>29.41</td>
</tr>
<tr>
<td>Ending stocks</td>
<td>0.294</td>
<td>0.128</td>
<td>29.41</td>
</tr>
<tr>
<td>Net exports</td>
<td>0.301</td>
<td>0.096</td>
<td>29.41</td>
</tr>
<tr>
<td>Real wholesale price</td>
<td>0.132</td>
<td>0.077</td>
<td>41.18</td>
</tr>
<tr>
<td>F.o.b. export price</td>
<td>0.121</td>
<td>0.066</td>
<td>35.29</td>
</tr>
<tr>
<td>Japan:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area harvested</td>
<td>0.210</td>
<td>0.100</td>
<td>11.76</td>
</tr>
<tr>
<td>Domestic use</td>
<td>0.011</td>
<td>0.006</td>
<td>29.41</td>
</tr>
<tr>
<td>Ending stocks</td>
<td>0.081</td>
<td>0.041</td>
<td>41.18</td>
</tr>
<tr>
<td>Net imports</td>
<td>0.027</td>
<td>0.017</td>
<td>41.18</td>
</tr>
<tr>
<td>Producer price</td>
<td>0.090</td>
<td>0.046</td>
<td>5.88</td>
</tr>
<tr>
<td>Resale price</td>
<td>0.044</td>
<td>0.021</td>
<td>23.53</td>
</tr>
</tbody>
</table>

1For wheat supply, use and prices.
2MARE: mean absolute relative error.
3PTPE: percent turning point error.
The MARE and Theil U statistics also suggest large errors for nonprogram area and feed use in the United States, the offboard and export price in Canada, feed use and ending stocks in Australia, ending stocks and net exports in the EC-10 and Argentina, and area planted and the producer price in Japan. The equations with a PTPE exceeding 40 percent are: U.S. food use; Canadian feed use, exports, and export price; Australian food use, feed use, GMP, and export price; EC-10 food use; Argentine real wholesale price; and Japanese ending stocks and net imports. In general, however, most equations have U statistics less than 0.1, although most have PTPE's exceeding 10 percent.

Figures 8 and 9 present the simulated and actual values for U.S. wheat net exports and the gulf ports price. An examination of figure 8 suggests U.S. wheat net exports track fairly well over the historical period. Major errors occur in 1972/73, 1982/83, and 1985/86. An examination of figure 9 also suggests the U.S. gulf ports price tracks actual values fairly well, but does reveal one significant problem. The model appears to be overshooting price changes, resulting in wide fluctuations in the simulated values for the gulf ports price. There are two possible explanations for this problem. One is that the approach employed of aggregating competitor excess supply and world import demand schedules to a June/May crop year does not accurately reflect the timing of actual export shipments. This would result in an improper shift in the import demand schedule facing the United States, resulting in a biased U.S. gulf ports price. Another possible explanation is that the U.S. excess supply schedule is too price inelastic, thus resulting in wide U.S. price swings. An examination of these possible sources of bias is in order for any future studies.

References


United States

Efforts to formulate supply-inducing prices for crop producers that utilized the effects of governmental program variables and market information to estimate national crop acreage response models were first attempted by Houck, Subotnik, and Ryan (29, 30). Two supply-inducing policy variables were specified. The first variable was an "effective support" rate, which was the announced support price weighted by planting restrictions. It was assumed that this weighted support price is positively correlated with the supply of crop acreage. The second variable was diversion payments weighted by eligible diversion acreage (later termed an "effective diversion" rate). The weighted diversion payment rate acted to shift the acreage supply function to the left.

The so-called Houck-Ryan (H-R) acreage response model was employed by the U.S. Department of Agriculture in a series of estimates of supply relationships for corn, sorghum, oats, and barley (47, 48, 49). Hoffman developed a regional wheat acreage-response model using the H-R specification (27). Houck and others revisited the H-R model and used the "effective support" and "effective voluntary diversion" rate variables to estimate a linked system of area-response equations for corn, grain sorghum, barley, oats, wheat, soybeans, and cotton (28). Gallagher and others estimated spring and winter wheat equations using the H-R policy variables and polynomial lags to quantify expectations of market prices (22).

The H-R policy specification was employed recently in a regional wheat acreage-response model (4). The supply-
inducing price was specified as a weighted average of the effective support price and the expected market price. The weights were determined by actual program participation. The effective voluntary diversion rate variable was included as a separate regressor. Duffy, Richardson, and Wohlgemant employed a similar specification of the supply-inducing price in a regional cotton acreage-response model (16). Non-linear weights were specified to allow increasingly more weight to be placed on the expected market price as this price increases with respect to the effective support price. The advantage of this formulation is that the effective support price always has at least some weight placed on it even when it is exceeded by the expected market price.

The H-R model has provided researchers an ability to quantify the effect of governmental programs on producer expectations of program/market returns and acreage planted. There are, however, two weaknesses with this approach. First, participation rates in government commodity programs are not explicitly endogenized in the H-R model. Such rates are implicitly imbedded in the estimated coefficients for the expected market price and the effective support and diversion rate variables. Hence, actual diversion rates are not endogenized. Minimum and maximum diversion rates are program parameters announced prior to planting. The average of the minimum to maximum rate has often been used in the H-R specification. Hence, the actual rate of diversion above the minimum rate for program participants is not explicitly accounted for.

Bancroft attempted to overcome these two shortcomings by developing a new approach to incorporating governmental commodity programs in acreage-response models (5). Bancroft first derived input demand functions for land for program and nonprogram participants from an expected profit function. The derived land demand function for program participants reflected both acres planted and acres diverted (the total demand for land for a program participant). Empirical models were then developed for corn, sorghum, barley, and wheat. Behavioral equations were estimated for (1) acres planted in the program, (2) acres diverted above the minimum level, and (3) acres planted outside the program. Economic incentives to participate were modeled as a function of expected net returns per acre for participation relative to nonparticipation. Program participation and diversion rates could then be computed via identities from the three estimated equations. Bancroft's model was then used in the crop component of the USDA's FAPSIM model (21).

U.S. producers face a great deal of information at planting time: market information (lagged farm prices, input costs, yields) and farm program information (loan rates, target prices, diversion rates, allotment/base levels). Producers must make two simultaneous decisions at planting time based on this information: (1) which commodities to plant and at what level, and (2) whether or not to join the farm program. The first decision is based on the relative prices of commodities and the announced base for each commodity. If, for example, the expected returns for sorghum production increase relative to that of wheat, one would expect total acres of wheat (program plus nonprogram) to fall relative to that of sorghum. Also, an increase in the wheat base is expected to increase the amount of land available to program participants. The second decision is based on expected net returns for program relative to nonprogram participants. If expected net returns for wheat program participants rise relative to that of market participants, one would expect an increase in program acres (planted plus diverted) relative to nonprogram acres and in the participation rate.18

The approach taken to estimate a U.S. wheat area-response model in this study is to estimate behavioral equations for program and nonprogram participants by effectively endogenizing the participation rate. There are a number of ways to implement this approach. One way would be to directly estimate participation rates. The participation rate times total acreage would determine program and nonprogram acreage. This approach would be easiest if historically the participation rate times the base equaled total program acreage since an estimate of total acreage would not be needed. However, an examination of the data (see 2, app. table 3) reveals that this is not the case. Hence, one would have to estimate the percentage of the base planted in the program, and either the nonparticipation rate or nonprogram acreage as a percentage of the base. If both program and nonprogram acreage is estimated as a percentage of the base, it is understood that the total can exceed 1, since total acreage (program plus nonprogram) has historically fluctuated between 99 and 142 percent of the base (see 2, app. table 3).

Another approach to estimating program and nonprogram acreage would be to behaviorally estimate the participation rate and total acres (program plus nonprogram). One would then multiply the participation rate times total acreage to determine program and then nonprogram acreage. One could estimate total acreage as a function of the base or as a percentage of the base. Either way, it is hypothesized that it would be a function of a weighted average of net returns per acre for program and nonprogram participants for wheat and any substitute crops. Hypothesizing a substitute crop for wheat in an aggregate supply response model is difficult because of the regional nature of U.S. wheat production and

18 The participation rate is defined as the ratio of program acres (planted plus diverted) to program plus nonprogram acres.
because of the complementary relationship between wheat and soybeans in the Southeast in recent years.

A final approach would be to estimate separate behavioral equations for program and nonprogram acres. An identity could then be used to estimate participation rates if this information were needed. The individual equations would each reflect substitution between crops and between program and nonprogram acres. Hence, one would specify program and nonprogram acres as a function of (1) net returns per acre for program and nonprogram participants, (2) net returns per acre for substitute crops, and (3) base acres. One would assume that program acres would increase as returns per acre for program participants increase relative to nonprogram participants. It is expected that both program and nonprogram acreage would fall as net returns for substitute crops increase relative to the net returns for wheat program and market participants. It is also assumed that both program and nonprogram acreage would increase as the wheat base increases, assuming all else remains the same. To illustrate this latter assumption, assume the national wheat base increases 20 percent from 100 million acres to 120 million acres, and that all other price relatives remain unchanged. Then, assuming a 50-50 distribution between program and nonprogram acreage before and after the base increase, one would expect both program and nonprogram acreage to increase from 50 million acres to 60 million acres. This was the modeling approach used in this report.

Canada

Canadian supply-response studies have typically focused on the expected area-inducing price and the marketing quota. Canada is unique in that producers face numerous prices and the area-inducing price is affected by a system of marketing quotas.

The price expectations function has been specified numerous ways in previous Canadian wheat area-response studies. Schmitz used the latest final payment received prior to planting in both a lagged price and distributed lag model (54). Capel used the March average CWB International Wheat Agreement price in a Nerlovian adaptive expectations model (9). Meilke used the initial and final payments both combined and separately as area-inducing variables, whereas Devadoss and others used the sum of the two payments only (39, 14). Jolly and Abel specified an expected CWB total realized price as the sum of the expected initial and final payment, which was then reduced to the CWB selling quotation price (33). Spriggs, who referenced the Jolly and Abel theoretical model, used the expected offboard price for wheat as the supply-inducing price whether quotas were binding or not (58). Spriggs assumed that producers formed price expectations on both the CWB and offboard markets and that both these prices affected planting decisions. Since most premium quality wheat, however, is marketed through the CWB and only feed quality wheat is marketed through the offboard markets, prices in the offboard markets cannot be expected to affect planting decisions. Producers can market their high-grade wheats through the offboard markets as feed wheat, but premiums for the higher quality grades encourage producers to grow the best quality wheat they can and market it through the CWB. Krakar and Paddock used an average initial payment less CWB deductions for transportation and handling as one area-inducing variable, and the final payment lagged two periods as a separate area-inducing variable (36). CWB deductions were included in the specification to express the area-inducing price as a farmgate price. A recent USDA study (1) also used two separate area-inducing variables, but used the current announced initial payment instead of the average initial payment used by Krakar and Paddock.

Another item of concern is how to measure the restrictiveness of the CWB's marketing quotas and reflect its effect on producers' decisions to plant. This variable typically has been represented as a separate variable in previous reports. Schmitz used beginning stocks, Capel used total wheat supply in February divided by a 5-year moving average of wheat production, and Meilke used marketings of wheat divided by farm wheat supply. Spriggs' measure of quota restrictiveness was equal to deliveries to the CWB divided by farm supply. Spriggs, however, used offboard market prices in his area-response model and used the quota restrictiveness variable in an offboard-CWB export quotation price link equation.

The USDA study used farm plus commercial stocks to reflect quota restrictiveness. It was assumed that if total ending stocks are expected to be higher than in the prior year, farmers will anticipate that (1) marketing quotas will be more restrictive over the coming marketing year, and (2) the final payment associated with the CWB marketing receipts from the coming crop year will be lower than from the prior year. Hence, farmers will take their most recent final payment, which is often received early in the calendar year, and discount it accordingly. Farmers will then respond by planting less wheat. In contrast, if total ending stocks are tight at planting, farmers will anticipate that the marketing quota will not be binding in the coming marketing year, and that final payments associated with the coming crop year will be much higher than previous final payments. Hence, farmers would respond by planting more area to wheat.

One problem with the USDA specification was that only the expectation of the final payment could be altered by a change in stock conditions. One would expect a priori that expectations of both the initial and final payment would be
altered by stock conditions. For example, if stocks were large and the final payment lagged two periods was zero, one would expect the area-inducing price to fall below the guaranteed initial payment. This problem was considered in another USDA study by combining the initial and final prices as a single variable and deflating it by Canadian wheat beginning stocks (3).

**Australia**

There have been a number of Australian wheat supply-response studies over the past two or three decades that have attempted to identify proper area-inducing prices for wheat and substitute commodities. This is particularly difficult for Australian wheat because of the price stabilization schemes, and because the AWB typically makes a number of payments for any one pool over more than one crop year. Spriggs observed from the literature three different methods to model price expectations (57): (1) the first advance, (2) total realization, and (3) an effective price series.

The first advance is an initial payment made by the AWB to producers on delivery of their crop to a local grain storage facility. This price is announced by the AWB prior to harvesting and represents anywhere between 80 and 95 percent of the final net realized price. One problem using the initial price as an area-inducing price, however, is that it ignores producer expectations of any later payments. Another problem is that it did not vary from 1960/61 to 1971/72, creating a statistical problem in an area-response specification.

The lagged total realized price for the wheat pool has also been used as a proxy for the expected price, even though the final payment for the previous year’s wheat pool is unknown at planting time. Fisher, Griffiths and Anderson, Sanderson and others, Meyers, and Fisher and Munro used such a variable under the assumption that farmers had sufficient information to accurately forecast the final payment (19, 25, 53, 41, 20).

An effective price series used data known at planting time and information from the wheat price stabilization scheme to construct an average producer’s expectation of the AWB total realized price. Such a variable was used by Duloy and Watson, Powell and Gruen, and Spriggs (17, 43, 57). Since the total realized pooled price is simply a weighted average of the home consumption price and the season average export price, it was hypothesized that farmers’ knowledge of the parameters of the stabilization scheme and of the international market was sufficient to accurately forecast the total realized price. However, according to Duloy and Watson:

> Because of the stabilization scheme, wheat prices do not vary greatly from year to year, so that this definition is not so bad as it would be if prices were extremely variable from year to year.

Australian wheat export prices have varied considerably since the Duloy and Watson study. This may explain why Devadoss and others had incorrect signs for their effective wheat price variable and were forced to drop it from their specification.

In this study, the guaranteed minimum price is hypothesized to be the proper area-inducing price since (1) it is a government-guaranteed producer price, (2) it represents a substantial portion of the net realized price, and (3) farmers have a great deal of information on what that price will be prior to planting. The guaranteed price was chosen over the initial price for two reasons. First, the initial price was usually set below the guaranteed price and did not represent the minimum producer guaranteed price. The exception was the seventh stabilization plan from 1979-83 which set the initial price equal to the guaranteed minimum price. Second, the initial price was fixed at A$40.42 from 1960-71 and would provide zero correlation with the dependent variable in an area-response specification.

One problem with using the guaranteed price as an area-inducing price, however, is that it ignores producer expectations of additional payments. In other words, it assumes that the producer expectation of the total realized price does not exceed the guaranteed price. This is a reasonable assumption, since the average net return to growers (total producer payments less AWB deductions) was greater than the guaranteed price only six times in the past 25 years.

**Argentina**

Lucio Reca analyzed land use in the Argentine pampas over two periods, 1924-44 and 1945-65 (45). He hypothesized that prices were more significant in allocating land use during the former period, since government intervention distorted price signals in the period 1945-65. Reca estimated area planted to wheat, corn, oats, and flaxseed as a function of (1) the relative prices of wheat, corn, flax, beef, and a wage rate, (2) rainfall, and (3) a lagged dependent variable. Regional estimates were made for the four provinces of Buenos Aires, San Fe, Cordoba, and Entre Rios. The price of sunflower was also included in the specification, but produced insignificant results. The statistical results were not very significant, and only those in the Entre Rios province supported his hypothesis. Maffucci employed the

---

19 Called the “guaranteed price” under the first five stabilization plans until 1973, called the “stabilization price” under the sixth stabilization plan from 1974-78, and called the “guaranteed minimum price,” or GMP, under the seventh stabilization plan starting in 1979.
same methodological approach for wheat and corn and produced similar results (38).

Wainio analyzed the effect of government intervention on grain supply-response by estimating area-response functions for wheat, corn, flaxseed, and sunflowerseed (65, 66). Dummy variables were used to test for changes in the response of Argentine farmers to price incentives during periods of heavy governmental intervention. Wainio estimated wheat area as a function of (1) the lagged prices of wheat, corn, flaxseed, sunflowerseed, and beef, and (2) a lagged dependent variable. The statistical results showed the price of wheat and sunflowerseed were statistically significant during periods of no government intervention.

More recently, Westhoff developed a methodological approach to measuring the response of Argentine field crops to changes in U.S. prices (67). Westhoff linked the U.S. gulf ports price of wheat to the Argentine wheat f.o.b. price, and then linked the f.o.b. price to the farm price (wholesale price) via an identity. The f.o.b.-wholesale price margin and the ad valorem tax rate formed a wedge between the border and internal price and were both endogenized. A systems approach was then employed to estimate area planted to wheat, corn, sorghum, and soybeans. Total area planted to all four crops was first estimated as a function of a weighted average farm price index of all four crops lagged one period, cattle numbers, a yield index for all four crops, and trend. Next, the percentage of each crop of the total area was then estimated as a function of the own-price relative to the weighted average price, both lagged one period, the lagged dependent variable, trend, and a yield index.
Appendix B—World Wheat Trade Model Equations

United States submodel equations

1. Wheat expected U.S. farm price

\[ EWHPFUS_t = \max( WHPFUS_{t-1}, WHLRUS_t ) - 0.53 \times DUM86_t \]

2. Wheat expected U.S. deficiency payment

\[
\begin{align*}
EWDPAY_t & = WHFUS_t - EWHPFUS_t & \text{if } (WHFUS_t - EWHPFUS_t) \geq 0 \\
& = 0 & \text{if } (WHFUS_t - EWHPFUS_t) < 0 
\end{align*}
\]

3. Wheat expected net return minimum program participant

\[
EWNPMP_t = (EWHPFUSt \times WTYLUS_t - WHVCUS_t) \times (1 - WPGMDR_t) + EWDPAY_t \times WPYLUS_t \times WLFAC_t \times (1 - WPGMDR_t)
\]

4. Wheat expected net return maximum program participant

\[
EWXNPMP_t = (EWHPFUS_t \times WTYLUS_t - WHVCUS_t) \times (1 - (WPGMDR_t + WPGADR_t)) + EWDPAY_t \times WPYLUS_t \times WLFAC_t \times (1 - (WPGMDR_t + WPGADR_t)) + WPGMDP_t \times WPYLUS_t \times WCLDIV_t + WPGADP_t \times WPYLUS_t \times WPGADR_t
\]

5. Wheat expected net return non-program participant

\[ EWNNP_t = EWHPFUS_t \times WTYLUS_t - WHVCUS_t \]

6. U.S. wheat total program acreage

\[
WTPAUS_t = 0.272 \times RWMAXPP_t - 0.338 \times REWRNPP_t - 0.061 \times RCENRPNP_t + 0.284 \times WBASE_t + 40.96 \times DUMWP_t
\]

Estimator: OLS

\[
\text{Adj. } R^2 = 0.906 \quad \text{D.W.} = 1.808
\]

Estimated rho = 0.096

Calculated variables:

\[
\begin{align*}
RWMAXPP_t & = \max(WMAXPP_t \times 100 / CPIUS_t, \max(EMMP_{t-1} \times 100 / CPIUS_t, EMXPP_t)) \\
REWRNPP_t & = \max(REWNPP_t \times 100 / CPIUS_t, \max(REWNPP_t, EMXPP_t)) \\
RCENRPNP_t & = \max(CTENRPNP_t \times 100 / CPIUS_t, \max(REWNPP_t, EMXPP_t)) \\
EMXNPMP_t & = \max(WHFPUS_{t-1}, WHLRUS_t) \times WTYUS_t - WHVCUS_t \\
CTENRPNP_t & = \max(CUPFUS_{t-1}, CTRLUS_t) \times \text{CITYUS}_{t-1} / 100 - \text{CTVCUS}_t \\
WTYUS_t & = -952.58 + 0.50 \times \text{TREND}_t \\
\text{CITYUS}_t & = -6,356.97 + 3.47 \times \text{TREND}_t
\end{align*}
\]

Continued--
7. U.S. wheat planted program acreage

\[ WP_{PAUS_t} = WTP_{PAUS_t} \times (1 - WP_{DRACT_t}) \]

8. U.S. wheat nonprogram acreage

\[ WN_{PAUS_t} = 60.40 + 0.584 \quad REM_{NPP}_t + 0.598 \quad RA_{MAXPP}_t + 0.315 \quad WBASE_t - 48.53 \quad DU_{MP}_t \]

\[ (4.31) \quad (4.10) \quad (-3.53) \quad (2.73) \quad (-9.63) \]

Estimator: OLS  \[ Adj. R^2 = 0.930 \]
Estimated rho = 0.336  \[ Est. period = 1962-1986 \]
No. of obs. = 25

Calculated variables: See equation 1.

9. U.S. wheat total planted acreage

\[ WAP_{TUUS_t} = WP_{PAUS_t} + WN_{PAUS_t} \]

10. U.S. wheat harvested acreage

\[ WH_{ARUS_t} = 0.886 \quad WAP_{TUS_t} - 6.34 \quad DU_{MP}_3 \]

\[ (164.21) \quad (-3.38) \]

Estimator: OLS  \[ Adj. R^2 = 0.970 \]
Estimated rho = 0.470  \[ Est. period = 1960-1986 \]
No. of obs. = 27

11. U.S. wheat yield per harvested acre

\[ WY_{LDUS_t} = -952.58 + 0.498 \quad TREND_t \]

\[ (-9.86) \quad (10.17) \]

12. U.S. wheat production

\[ WP_{RDUS_t} = WH_{ARUS_t} \times WY_{LDUS_t} \]

13. U.S. wheat supply

\[ WS_{UFUS_t} = WP_{RDUS_t} + WT_{BSUS_t} \]

14. U.S. wheat per-capita food use

\[ WP_{CFUS_t} = 3.05 - 0.0567 \times \frac{YP_{DCUS_t} \times 100}{D_{CEUS_t} \times TP_{OPUS_t}} + 0.192 \times D_{7586_t} + 0.224 \times DU_{MP65_t} + 0.392 \times DU_{MP66_t} \]

\[ (34.06) \quad (-4.80) \quad (5.94) \quad (4.42) \quad (7.57) \]

Estimator: OLS  \[ Adj. R^2 = 0.800 \]
Estimated rho = 0.243  \[ Est. period = 1960-1986 \]
No. of obs. = 27
United States submodel equations—continued

15. U.S. wheat total food use

\[ W_{FODUS}^t = W_{PCFUS}^t \cdot T\text{POPRUSt} \]

16. U.S. wheat feed use

\[ W_{FEDUS}^t = 6.68 \cdot S\text{AHKSFDF}_t - 37.01 \left( \frac{W_{HPFU}$^t \cdot 100}{CPIUS_t} \right) + 75.80 \left( \frac{L\text{IVIF77}_t \cdot 100}{CPIUS_t} \right) + 219.80 \cdot D8386 \]

\[ (-4.59) \quad (-4.44) \quad (2.01) \quad (9.35) \]

\[ <1.06> \quad <-0.97> \quad <0.73> \]

\[ -102.86 \cdot D6785 + 85.72 \cdot DUM71 \]

\[ (-3.94) \quad (2.37) \]

Estimator: OLS
Adj. \( R^2 = 0.908 \)
D.W. = 1.595
Estimated rho = 0.203
Est. period = 1960-1986
No. of obs. = 27

17. U.S. wheat seed use

\[ W_{SEDUS}^t = -16.77 - 3.71 \cdot DUM66^t + 3.75 \cdot D8386^t + 1.46 \cdot WAPTUS^t \]

\[ (-10.55) \quad (-2.61) \quad (4.21) \quad (70.45) \]

<1.21>

Estimator: OLS
Adj. \( R^2 = 0.994 \)
D.W. = 1.670
Estimated rho = 0.165
Est. period = 1960-1985
No. of obs. = 26

18. U.S. wheat commercial ending stocks

\[ W_{COMSTKS}^t = 679.85 + 0.102 \left( W_{PRDUS}^t + W_{COMSTKS}^t \right) - 73.94 \left( \frac{W_{HPFU}_t \cdot 100}{CPIUS_t} \right) - 0.346 \left( W_{CCCSTKS}^t + W_{FORSTKS}^t \right) \]

\[ (4.60) \quad (2.37) \quad (-3.83) \quad (-5.55) \]

<0.50>

<0.58>

<0.38>

\[ -196.21 \cdot DUM56^t + 448.25 \cdot DUM76^t + 329.23 \cdot DUM85^t \]

\[ (-1.73) \quad (3.85) \quad (2.85) \]

Estimator: OLS
Adj. \( R^2 = 0.773 \)
D.W. = 1.940
Estimated rho = 0.030
Est. period = 1962-1986
No. of obs. = 25

19. U.S. wheat CCC ending stocks

\[ W_{CCCSTKS}^t = -68.12 \left( \frac{W_{HPFU}_t}{WHLRUS_t} \right) + 0.068 \cdot W_{PRDUS}^t + 0.832 \cdot W_{CCCSTKS}^t - 256.57 \cdot DUM66^t \]

\[ (-2.20) \quad (2.81) \quad (15.52) \quad (2.30) \]

<0.25>

<0.37>

Estimator: OLS
Adj. \( R^2 = 0.888 \)
D.W. = 1.499
Estimated rho = 0.250
Est. period = 1961-1986
No. of obs. = 26

Mean Elasticities:

\[ W_{HPFU} = 0.25 \quad W_{HLRUS} = 0.25 \quad W_{PRDUS} = 0.37 \]

20. U.S. wheat total ending stocks

\[ W_{TESUS}^t = W_{COMSTKS}^t + W_{CCCSTKS}^t + W_{FORSTKS}^t \]
United States submodel equations—continued

21. U.S. wheat market-clearing identity

\[ WNEXUS_t = WPRDUS_t + WTESUS_{t-1} - WFEDUS_t - WSEDUS_t - WTESUS_t \]

Calculated variables:

\[ WNEXUS_t = WEXPUS_t - WIMPUS_t \]

22. U.S. wheat season average farm price

\[ WHRFUS_t = 0.022 WGLFt + 0.411 DUM4t \]

(99.75) (3.09)

<1.00>

Estimator: OLS

Adj. R² = 0.986

D.W. = 1.985

Estimated rho = 0.008

Est. period = 1964-1986

No. of obs. = 23

Canadian submodel equations

23. Canadian wheat area harvested

\[ WHARCA_t = 4,121.26 + 1,505.73 \left( \frac{WRCWB_t}{FIPFER_t} \right) - 2,364.11 \left( \frac{BRCWB_t}{FIPFER_t} \right) - 2,009.54 DUM69_t \]

(3.85) (2.91) (-4.12) (-3.41)

<0.33> <-0.35> <-0.33>

\[ - 5,893.11 DUM70_t + 1,573.29 DUM85_t + 0.679 WHARCA_{t-1} \]

(-10.08) (2.43) (10.11)

Estimator: OLS

Adj. R² = 0.942

Estimated rho = -0.180

Est. period = 1968-1986

No. of obs. = 19

Calculated variables:

\[ WRCWB_t = WIPYCA_t + WAPYCA_{t-1} + WINPCA_{t-1} + WFPYCA_{t-2} \]

\[ BRCWB_t = BIPYCA_t + BAPYCA_{t-1} + BFPYCA_{t-2} \]

24. Canadian wheat yield

\[ WYLDCA_t = -48.15 + 0.025 TREND_t \]

(-4.21) (4.35)

Estimator: OLS

Adj. R² = 0.379

Estimation period = 1960-1986

25. Canadian wheat production

\[ WPRDCA_t = WHARCA_t \times WYLDCA_t \]

26. Canadian wheat supply

\[ WSUPCA_t = WPRDCA_t + WTESCA_{t-1} \]

Continued--
27. Canadian wheat food use

\[
WFODCA_t = 1,518.96 - 79.16 (\text{WMLCA}_t / \text{CPICA}_t) + 0.304 (\text{PDINCA}_t / \text{CPICA}_t) + 96.27 D7479_t - 90.79 DUM76_t
\]

(17.85) (-1.88) (16.23) (2.70) (-1.89)

\(<-0.08> \quad <0.24> \quad <0.24> \quad <0.24> \quad <0.24>

Estimator: OLS
Estimated rho = -0.325
Adj. R^2 = 0.924
D.W. = 2.651
Est. period = 1960-1985
No. of obs. = 26

28. Canadian wheat feed use

\[
WFEDCA_t = -1,638.89 (\text{WOFFCA}_t / \text{CPICA}_t) + 1,192.0 (\text{BOFFCA}_t / \text{CPICA}_t) + 20.66 (\text{PHOGCA}_t / \text{CPICA}_t) + 0.191 \text{HOGNCA}_t
\]

(-3.69) (2.38) (10.02) (15.95)

\(<-2.85> \quad <2.38> \quad <2.38> \quad <2.38> \quad <2.38>

Estimator: OLS
Estimated rho = 0.211
Adj. R^2 = 0.798
D.W. = 1.578
Est. period = 1963-1985
No. of obs. = 23

29. Canadian wheat seed use

\[
WSEDCA_t = 4,420.35 + 0.096 \text{WHARCA}_{t+1} - 2.26 \text{TREND}_t
\]

(4.05) (45.01) (-4.05)

\(<-1.04> \quad <0.61> \quad <0.61> \quad <0.61> \quad <0.61>

Estimator: OLS
Estimated rho = 0.410
Adj. R^2 = 0.989
D.W. = 1.180
Est. period = 1960-1985
No. of obs. = 26

30. Canadian wheat total ending stocks

\[
WTESCA_t = 12,066.7 - 22.98 \text{WQUOCA}_t + 0.491 \text{WSUPCA}_t - 1.07 \text{WHARCA}_{t+1}
\]

(3.91) (-4.33) (6.76) (-6.05)

\(<-0.25> \quad <1.20> \quad <1.20> \quad <-0.25>

\[+ 5,073.54 \text{DUM67}_t + 5,914.23 \text{DUM68}_t - 4,572.75 \text{DUM72}_t - 4,572.75 \text{DUM72}_t
\]

(3.19) (3.75) (-2.97)

Estimator: OLS
Estimated rho = -0.219
Adj. R^2 = 0.912
Durbin h = 2.437
Est. period = 1961-1985
No. of obs. = 25

Calculated variables:

\[
\text{WSUPCA}_t = \text{WFRDCA}_t + \text{WTESCA}_{t-1}
\]

31. Canadian wheat market-clearing identity

\[
\text{WEXPAC}_t = \text{WFRDCA}_t + \text{WTESCA}_{t-1} - \text{WFODCA}_t - \text{WFEDCA}_t - \text{WSEDCA}_t - \text{WTESCA}_t
\]
World wheat trade model equations—Continued

Canadian submodel equations—continued

32. Canadian wheat offboard price

$$WOFFCA_t = 79.03 + 0.299 \text{WIPYCA}^t + 0.41 (WGULFP}_t - \text{EXSBUS}_t^*36.744)\text{ERCAUS}_t - 0.002 \text{WSUPCA}_t$$

(3.09) (2.15) (3.75) (-2.94) (-0.82)

Estimated rho = 0.199

Estimator: OLS

Adj. $R^2 = 0.944$

D.W. = 1.603

Estimated period = 1963-1985

No. of obs. = 25

33. Canadian wheat initial payment

$$WIPYCA^t = 14.29 + 36.34 \text{WHLRUS}_t - 0.035 \text{WTBSUS}_t + 0.461 \text{WIPYCA}_{t-1}$$

(3.39) (5.95) (-6.13) (4.49)

Estimated rho = -0.003

Estimator: OLS

Adj. $R^2 = 0.980$

Durbin h = -0.020

Estimated period = 1961-1985

No. of obs. = 25

34. Canadian wheat total realized price

$$WTRPCA_t = 17.87 + 0.872 (WGULFP}_t - \text{EXSBUS}_t^*36.744)\text{ERCAUS}_t$$

(4.48) (29.00)

Estimated rho = 0.475

Estimator: OLS

Adj. $R^2 = 0.971$

D.W. = 1.049

Estimated period = 1960-1985

No. of obs. = 26

Calculated variables:

$$\text{WTRPCA}_t = \text{WIPYCA}_t + \text{WAPYCA}_t + \text{WINPCA}_t + \text{WPPYCA}_t$$

35. Canadian wheat final payment

$$\text{WPPYCA}_t = \text{WTRPCA}_t - \text{WIPYCA}_t - \text{WAPYCA}_t - \text{WINPCA}_t$$

36. Canadian wheat mill price

$$\text{WMIILCA}_t = \text{WQUOCA}_t \text{ if } \text{LB}_t \leq \text{WQUOCA}_t \leq \text{UB}_t$$

$$= \text{UB}_t \text{ if } \text{WQUOCA}_t > \text{UB}_t$$

$$= \text{LB}_t \text{ if } \text{WQUOCA}_t < \text{LB}_t$$

37. Canadian Wheat Board selling quotation for wheat

$$\text{WQUOCA}_t = 10.68 + 1.07 (WGULFP}_t - \text{EXSBUS}_t^*36.744)\text{ERCAUS}_t$$

(2.02) (26.83)

Estimated rho = 0.521

Estimator: OLS

Adj. $R^2 = 0.966$

D.W. = 0.957

Estimated period = 1960-1985

No. of obs. = 26

Continued--
38. Canadian barley offboard price

\[
BOFFCA_t = 0.206 BIPYCA_t + 28.73 CRPFUS_t * ERCAUS_t - 0.0006 BSUPCA_t
\]

\[
\begin{align*}
(1.01) \\
(4.41) \\
(-1.05)
\end{align*}
\]

\[
<0.20> \\
<0.91> \\
<-0.12>
\]

Estimator: OLS  \quad \text{Adj. } R^2 = 0.870  \quad \text{Est. period} = 1963-1985  \quad \text{D.W.} = 1.072  \quad \text{No. of obs.} = 23

39. Canadian barley initial payment

\[
BIPYCA_t = 7.24 + 10.34 CRLRUS_t - 0.01 CTBSUS_t + 0.822 BIPYCA_{t-1}
\]

\[
\begin{align*}
(2.86) \\
(2.45) \\
(-5.85) \\
(9.72)
\end{align*}
\]

\[
<0.23> \\
<0.16> \\
<-0.16> \\
<-0.78>
\]

\[
+ 20.98 DUM73_t + 43.98 DUM80_t
\]

\[
(4.96) \\
(9.83)
\]

Estimator: OLS  \quad \text{Adj. } R^2 = 0.982  \quad \text{Durbin } h = 0.655  \quad \text{No. of obs.} = 21

40. Canadian barley total realized price

\[
BTRPCA_t = 6.88 + 34.22 CRPFUS_t * ERCAUS_t + 25.27 DUM73_t + 22.72 DUM81_t
\]

\[
\begin{align*}
(1.69) \\
(20.16) \\
(3.22) \\
(2.86)
\end{align*}
\]

\[
<0.90> \\
<0.16> \\
<-0.16> \\
<-0.78>
\]

Estimator: OLS  \quad \text{Adj. } R^2 = 0.955  \quad \text{D.W.} = 1.397  \quad \text{No. of obs.} = 23

Calculated variables:

\[
BTRPCA_t = BIPYCA_t + BAPYCA_t + BFPYCA_t
\]

41. Canadian barley final payment

\[
BFPYCA_t = BTRPCA_t - BIPYCA_t - BAPYCA_t
\]

Australian submodel equations

42. Australian wheat area

\[
WAPAU_t = 1,224.63 (WGMPAU_t/SGWPAU_{t-1}) + 494.11 (WGMFAU_t/BWAPAU_{t-1}) + 0.879 WAPAU_{t-1}
\]

\[
\begin{align*}
(1.96) \\
(2.32) \\
(25.2)
\end{align*}
\]

\[
+ 1,531.22 DROUGHT_{t-1} - 3,125.1 DUM70_t
\]

\[
(4.87) \\
(-5.86)
\]

Estimator: OLS  \quad \text{Adj. } R^2 = 0.939  \quad \text{Durbin } h = -0.127  \quad \text{No. of obs.} = 26

Mean elasticities:

\[
WGMPAU = 0.127  \quad \text{SGWPAU} = -0.058  \quad \text{BWAPAU} = -0.059
\]
World wheat trade model equations—Continued

Australian submodel equations—continued

43. Australian wheat yield

\[ WYLDUAU = 0.779 + 0.007 \text{TREND} \]

\[ (1.7) \quad (1.08) \]

Estimator: OLS \quad Adj \( R^2 = 0.007 \quad \) Est. period = 1960-1986

44. Australian wheat production

\[ \text{WFRDAU} = \text{WAPTAU} \times \text{WYLDUAU} \]

45. Australian wheat supply

\[ \text{WSUPAU} = \text{WFRDAU}_{t} - \text{WOFBAU}_{t} - \text{WPFDAU}_{t} + \text{WTESAU}_{t-1} \]

46. Australian wheat per-capita food use

\[ \text{WPCFAU} = 0.142 - 0.003 \left( \frac{\text{WHCPAU}}{\text{CPIAU}} \right) - 0.682 \left( \frac{\text{HDINAU}}{(\text{POPAU} \times \text{CPIAU})} \right) - 0.019 \text{ DUM81} + 0.013 \text{ DUM82} \]

\[ (5.15) \quad (-0.23) \quad (-3.86) \quad (-4.05) \quad (2.87) \]

Estimator: OLS \quad Adj. \( R^2 = 0.836 \quad \) Est. period = 1960-1985 \quad No. of obs. = 26 \quad D.W. = 1.482 Estimated rho = 0.259

47. Australian wheat total food use

\[ \text{WFODAU} = \text{WPCFAU} \times \text{POPAU} \]

48. Australian wheat feed use

\[ \text{WFEDAU} = -1,116.88 \left( \frac{\text{WSFPAU}}{\text{BFDPAU}} \right) + 2.33 \text{ LSIAU} + 517.82 \left( \frac{\text{PSYPAU}}{\text{CPIAU}} \right) + 218.75 \text{ DROUGHT} \]

\[ (-4.33) \quad (5.03) \quad (4.23) \quad (1.48) \]

Estimator: OLS \quad Adj. \( R^2 = 0.605 \quad \) Est. period = 1965-1985 \quad No. of obs. = 21 \quad D.W. = 1.892

Calculated variables:

\[ \text{LSIAU} = 0.6667 \times \text{EFRDAU} + \text{FFRDAU} + \text{HFRDAU} \]

49. Australian wheat ending stocks

\[ \text{WTESAU} = -3,085.65 + 0.543 \left( \text{WTESAU}_{t-1} + \text{WFRDAU}_{t} \right) - 17.69 \text{ WXPAM} \]

\[ (-5.73) \quad (11.12) \quad (-3.35) \quad (-3.35) \]

Estimator: OLS \quad Adj. \( R^2 = 0.864 \quad \) Estimated rho = 0.208 \quad Est. period = 1960-1985 \quad No. of obs. = 26

Continued--
Australian submodel equations—continued

50. Australian wheat market-clearing identity

\[ WEXPAU_L = WPDAU_L - WOFBAU_L - WFEDAU_L - WTESAU_{L-1} - WFEDAU_L - WTESAU_L \]

51. Australian wheat guaranteed minimum price

\[
\begin{align*}
WMPAU_t &= 31.53 D6073_t + 47.73 D7478_t + 53.36 D7966_t + 8.83 WHLRIUS_t * D7966_t + 0.439 WMPAU_{L-1} \\
& (8.07) \quad (9.16) \quad (5.15) \quad (2.75) \quad (6.47) \quad <0.20> 1 \\
& <0.42>
\end{align*}
\]

Estimator: OLS
Adj. \( R^2 = 0.991 \)
Estimated rho = -0.154
Est. period = 1961-1986
No. of obs. = 26

52. Australian wheat human consumption price

\[
WHCPAU_t = 32.11 + (0.61 + 0.379 DUMWSA_t) * (WGULFP_t - EXSBUS_t) \cdot \cdot \cdot US \cdot \cdot \cdot US \cdot \cdot \cdot US \cdot \cdot \cdot US
\]

\[
\begin{align*}
(1.29) \quad (5.94) \quad (5.30)
\end{align*}
\]

Estimator: OLS
Adj. \( R^2 = 0.946 \)
D.W. = 1.301
Estimated rho = 0.350
Est. period = 1961-1985
No. of obs. = 25
Mean elasticities: \( \text{WGULFP} = 0.63 \)
\( \text{EVARUS} = 0.63 \)

53. Australian annual average wheat export price

\[
WXPAL_t = 14.32 + 0.893 (WGULFP_t - EXSBUS_t * 36.744) * ERAUUS_t
\]

\[
(3.14) \quad (2.41) \quad (0.86)
\]

Estimator: OLS
Adj. \( R^2 = 0.948 \)
D.W. = 1.46
Estimated rho = 0.271
Est. period = 1960-1985
No. of obs. = 26

54. Australian Barley Board barley feed price

\[
BFDPAU_t = 13.36 + 18.58 (BRPFUS_t * ERAUUS_t) + 0.391 BFDPAU_{L-1} + 45.18 DUM80_t + 59.15 DUM82_t
\]

\[
\begin{align*}
(4.29) \quad (4.78) \quad (4.74) \quad (6.55) \quad (8.63)
\end{align*}
\]

Estimator: OLS
Adj. \( R^2 = 0.965 \)
Durbin h = -0.246
Estimated rho = -0.045
Est. period = 1960-1985
No. of obs. = 25

EC-10 submodel equations

55. EC-10 aggregate wheat area harvested

\[
WHAREC_t = 7.175.90 + 12.44 EGRBEC_t - 17.02 EGRBEC_t + 0.495 WAPTEC_{L-1}
\]

\[
\begin{align*}
(2.70) \quad (2.76) \quad (-2.91) \quad (2.94)
\end{align*}
\]

Estimator: OLS
Adj. \( R^2 = 0.407 \)
Durbin h = -1.289
Estimated rho = -0.159
Est. period = 1963-85
No. of obs. = 23

See footnotes at end of table
World wheat trade model equations--Continued

EC-10 submodel equations--continued

Calculated variables:

\[ \text{EGRWEC}_t = \frac{\text{WW}_i \times (\text{WHPP}_i_{t-1} \times \text{WMD}_{i_{t-1}})}{(\text{ER}_{1980i} \times \text{FPIN}_i_{t-1})} \]

\[ \text{EGRBEC}_t = \frac{\text{BW}_i \times (\text{BRPP}_i_{t-1} \times \text{BMD}_{i_{t-1}})}{(\text{ER}_{1980i} \times \text{FPIN}_i_{t-1})} \]

\[ \text{WMD}_{i_{t}} = \frac{(\text{WYL}_{i_{t-1}} + \text{WYL}_{i_{t-2}} + \text{WYL}_{i_{t-3}})}{3} \]

\[ \text{BMD}_{i_{t}} = \frac{(\text{BYL}_{i_{t-1}} + \text{BYL}_{i_{t-2}} + \text{BYL}_{i_{t-3}})}{3} \]

56. EC-10 wheat yield

\[ \text{WYLDEC}_t = -207.33 + 0.107 \text{TRENDE}_t \]

\(-15.21\) \((15.47)\)

Estimator: OLS     Adj. \(R^2 = 0.905\)     Estimation period = 1963-1985

57. EC-10 wheat production

\[ \text{WPRDEC}_t = \text{WHEAREC}_t \times \text{WYLDEC}_t \]

58. EC-10 wheat supply

\[ \text{WSUPEC}_t = \text{WPRDEC}_t + \text{WTESEC}_{t-1} \]

59. EC-10 per-capita wheat food use

\[ \text{WPCFEC}_t = 135.06 - 3.01 (\text{RDPFEC}_t / \text{POPEC}_t) + 5.58 \text{DUM67}_t - 4.73 \text{DUM82}_t + 4.26 \text{DUM84}_t \]

\(71.63\) \((-9.87)\) \((3.04)\) \((-2.55)\) \((2.27)\)

Estimator: OLS     Adj. \(R^2 = 0.850\)     D.W. = 1.425

Estimated rho = 0.288     Est. period = 1960-1985     No. of obs. = 26

60. EC-10 total wheat food use

\[ \text{WFODEC}_t = \text{WPCFEC}_t \times \text{POPEC}_t \]

61. EC-10 wheat feed use

\[ \text{WFEDEC}_t = -20,627.4 - 1,058.41 \text{RWHPPFC}_t + 1,179.20 \text{RBRPPFC}_t + 127.31 \text{PFSWHEC}_t + 0.202 \text{LNUMEC}_t + 0.299 \text{WPRDEC}_t \]

\(-1.08\) \((-2.33)\) \((2.97)\) \((4.07)\) \((1.39)\) \((5.67)\)

Estimator: OLS     Adj. \(R^2 = 0.912\)     D.W. = 2.23

Estimated rho = -0.117     Est. period = 1960-1984     No. of obs. = 25

Calculated variables:

\[ \text{LNUMEC}_t = \text{BVMEC}_t + \text{FKNMEC}_t + \text{SGNMEC}_t \]

See footnotes at end of table

Continued--
World wheat trade model equations—Continued

EC-10 submodel equations—continued

62. EC-10 wheat total ending stocks

\[ WTESEC_t = -1,912.99 - 54,816.50 \left( \frac{WHPFEC_t}{WHINTP_t} \right) - 330.10 \left( \frac{WCIFEC_t}{WHINTP_t} \right) + 0.280 WSUPEC_t \]

(1.09)     (1.75)     (0.21)     (5.56)

Estimator: OLS
Estimated rho = -0.143
Mean elasticities:

\[
\begin{align*}
WHPFEC &= -0.61 \\
WHINTP &= 0.64 \\
WCIFEC &= -0.03 \\
WSUPEC &= 1.85
\end{align*}
\]

63. EC-10 all wheat market-clearing identity

\[ WNEXEC_t = WFRDEC_t + WTESEC_{t-1} - WFODEC_t - WFEDEC_t - WTESEC_t \]

64. Aggregate EC-10 producer prices

\[
\begin{align*}
WHPFEC_t &= WHPFi_t * Wi / ER1980i \\
RWHPPEC_t &= WHPFi_t * Wi / (ER1980i * CPIi_t) \\
RBRPFEC_t &= BRPFi_t * Wi / (ER1980i * CPIi_t)
\end{align*}
\]

65. Wheat c.i.f. price, Rotterdam

\[ WCIFEC_t = 22.06 + 0.815 (WGULFP_t - 36.744 * EXSBUS_t) / ERUSEC + 43.52 DUM73 \]

(3.35)     (15.28)
<0.79>

Estimator: OLS
Estimated rho = 0.105

\[
\begin{align*}
\text{Adj. } R^2 &= 0.937 \\
\text{D.W.} &= 1.791 \\
\text{Est. period} &= 1967-1985 \\
\text{No. of obs.} &= 19
\end{align*}
\]

Argentine submodel equations

66. Argentine wheat area planted

\[
\begin{align*}
WAPTAR_t &= 5,126.10 + 61.98 RWHWPAR_{t-1} - 50.74 RSFWPAR_{t-1} - 1,833.20 DUM70_t + 0.313 WAPTAR_{t-1} \\
& \quad (5.02) \quad (3.46) \quad (-6.72) \quad (-3.93) \quad (3.15)
\end{align*}
\]

Estimator: OLS
Estimated rho = -0.279

\[
\begin{align*}
\text{Adj. } R^2 &= 0.751 \\
\text{Est. period} &= 1961-85 \\
\text{No. of obs.} &= 25
\end{align*}
\]

Calculated variables:

\[
\begin{align*}
RWHWPAR_t &= WHWPAR_{t} * 100 / WPINAAR_t \\
RSFWPAR_t &= SFWPAR_{t} * 100 / WPINAAR_t
\end{align*}
\]

See footnotes at end of table

Continued--
World wheat trade model equations—Continued

Argentine submodel equations—continued

67. Argentine wheat area harvested

\[ WHARAR_t = -48,704.8 + 0.992 \cdot WAPTAR_t + 24.40 \cdot TREND_t - 737.89 \cdot DUM80_t \]

Estimator: OLS                Adj. \( R^2 = 0.932 \)                D.W. = 1.921
Estimated rho = 0.039            Est. period = 1960-85    No. of obs. = 26

Estimator: OLS                Adj. \( R^2 = 0.328 \)                Est. Period = 1960-85

68. Argentine wheat yield

\[ WYLDAR_t = -42.41 + 0.022 \cdot TREND_t \]

Estimator: OLS                Adj. \( R^2 = 0.328 \)                Est. Period = 1960-85

69. Argentine wheat production

\[ WPRDAR_t = WHARAR_t \cdot WYLDAR_t \]

70. Argentine wheat supply

\[ WSUPAR_t = WPRDAR_t + WTESAR_{t-1} \]

71. Argentine wheat per-capita domestic use

\[ WPCDAR_t = 214.06 - 43.59 \cdot \left( \frac{RGDPAR_t}{POPAR_t} \right) + 29.44 \cdot DUM69_t + 44.92 \cdot DUM72_t + 34.80 \cdot DUM75 - 21.52 \cdot D7686_t \]

Estimator: OLS                Adj. \( R^2 = 0.836 \)                D.W. = 1.853
Estimated rho = 0.073            Est. period = 1960-86    No. of obs. = 27

72. Argentine wheat total domestic use

\[ WDOMAR_t = WPCDAR_t \cdot POPAR_t \]

73. Argentine wheat total ending stocks

\[ WTESAR_t = 0.087 \cdot WPRDAR_t + 680.18 \cdot D7677_t + 559.77 \cdot D8486_t \]

Estimator: OLS                Adj. \( R^2 = 0.514 \)                D.W. = 1.854
Estimated rho = 0.073            Est. period = 1965-86    No. of obs. = 22

74. Argentine wheat market-clearing identity

\[ WNEXAR_t = WPRDAR_t + WTESAR_{t-1} - WDOMAR_t - WTESAR_t \]

See footnotes at end of table

Continued--
World wheat trade model equations—Continued

Argentine submodel equations—continued

75. Real Argentine wheat wholesale price

$$\text{RWHWPAR}_t = 6.26 - 36.92 \text{WHXTAR}_t + 0.749 \left( \frac{\text{WFOBAR}_t \cdot \text{ERARUS}_t}{100 \cdot \text{WPINAAR}_t} \right)$$

$(3.35) \ (-12.81) \ (15.27)$

$<-0.21> \ <1.01>$

$$+ 4.52 \text{DUMMAR}_t - 11.36 \text{DUM74}_t - 23.11 \text{DUM75}_t$$

$(5.62) \ (-5.79)$

$(10.74)$

Estimator: OLS
Estimated rho = -0.419
Adj. $R^2 = 0.933$
D. W. = 2.88
Est. period = 1961-86
No. of obs. = 26

Calculated variables:

$$\text{RWHWPAR}_t = \frac{\text{WHWFAR}_t}{100 \cdot \text{WPINAAR}_t}$$

76. Argentine wheat export price

$$\text{WFOBAR}_t = 10.90 + 0.510 \left( \frac{\text{WGULFP}_t \cdot \text{EXSBUS}_t}{36.744} \right) + 0.368 \left( \frac{\text{WGULFP}_t - \text{EXSBUS}_t}{36.744} \right) + 39.67 \text{DUM80}_t$$

$(2.44) \ (5.67) \ (4.11)$

$(3.92)$

$<0.51> \ <0.38> \ <0.51>$

$$+ 23.24 \text{DUM81}_t - 30.55 \text{D8586}_t$$

$(2.28) \ (-4.12)$

Estimator: OLS
Estimated rho = 0.299
Adj. $R^2 = 0.964$
D. W. = 1.402
Est. period = 1961-86
No. of obs. = 26

Japanese submodel equations

77. Japanese wheat area harvested

$$\text{WHARJP}_t = -102.57 + 259.81 \left( \frac{\text{WPDPJP}_t \cdot \text{RPDPJP}_t}{100 \cdot \text{RPDPJP}_t} \right) + 0.854 \text{WHARJP}_{t-1}$$

$(-4.61) \ (5.82) \ (39.73)$

$<0.52>$

Estimator: OLS
Estimated rho = 0.474
Adj. $R^2 = 0.986$
Durbin h = 2.335
Est. period = 1963-86
No. of obs. = 24

78. Japanese wheat yield

$$\text{WYLDJP}_t = -80.93 + 0.042 \text{TREND}_t$$

$(-4.29) \ (4.44)$

Estimator: OLS
Adj. $R^2 = 0.419$
Est. period = 1960-86

79. Japanese wheat production

$$\text{WFRDJP}_t = \text{WHARJP}_t \cdot \text{WYLDJP}_t$$

See footnotes at end of table.
Japanese submodel equations—continued

80. Japanese wheat supply

\[ WSUP_{JP_t} = WPRD_{JP_t} + WTES_{JP_{t-1}} \]

81. Japanese wheat per-capita domestic use

\[ WPCD_{JP_t} = 53.25 - 0.142 \left( \frac{WRSP_{JP_t}}{CPI_{JP_t}} \right) + 0.026 \left( \frac{RRSP_{JP_t}}{CPI_{JP_t}} \right) \]

\[ (32.04) \quad (-17.01) \quad (3.06) \quad <-0.18> \quad <-0.12> \]

Estimator: OLS
Adj. R^2 = 0.932
D.W. = 2.144
Estimated rho = -0.072
Est. period = 1960-85
No. of obs. = 26

82. Japanese wheat total domestic use

\[ WDOM_{JP_t} = WPCD_{JP_t} + POP_{JP_t} \]

83. Japanese wheat ending stocks

\[ WTES_{JP_t} = -2,253.77 + 0.246 \left( WPRD_{JP_t} + WTES_{JP_{t-1}} \right) + 0.557 WDOM_{JP_t} - 221.24 DUM_{84} - 231.85 DUM_{85} \]

\[ (-6.86) \quad (3.63) \quad (9.63) \quad (-1.59) \quad (-1.69) \]

\[ <-0.36> \quad <-2.32> \]

Estimator: OLS
Adj. R^2 = 0.853
D.W. = 1.488
Estimated rho = 0.256
Est. period = 1964-86
No. of obs. = 23

84. Japanese wheat market-clearing identity

\[ WNTM_{JP_t} = WDOM_{JP_t} + WTES_{JP_t} - WPRD_{JP_t} - WTES_{JP_{t-1}} \]

85. Japanese wheat producer price

\[ WPDP_{JP_t} = 0.810 CWPRD_{JP_t} + 0.823 WPDP_{JP_{t-1}} + 39,884.5 DUM_{77} \]

\[ (1.66) \quad (6.61) \quad (5.26) \]

\[ <-0.20> \quad <-0.78> \]

Estimator: OLS
Adj. R^2 = 0.987
Durbin h = 2.848
Estimated rho = 0.570
Est. period = 1968-85
No. of obs. = 18

86. Japanese wheat resale price

\[ WRSP_{JP_t} = 6,599.25 + 13.70 CPI_{JP_{t-1}} + 30.57 WCIF_{JP_{t-1}} + 0.575 WRSP_{JP_{t-1}} \]

\[ (2.61) \quad (2.56) \quad (1.72) \quad (4.58) \]

\[ <-0.24> \quad <-0.08> \quad <-0.56> \]

Estimator: OLS
Adj. R^2 = 0.980
Durbin h = -2.229
Estimated rho = -0.347
Est. period = 1961-85
No. of obs. = 25
Japanese submodel equations—continued

87. Japanese rice producer price

\[ \text{RPDPJP}_t = 64,518.6 \, D6073 + 133,425.0 \, D7486 + 25,459.3 \, DUM73 + 0.602 \, \text{RPDPJP}_t-1 \]
\[ (14.84) \quad (16.05) \quad (5.70) \quad (22.32) \]

Estimator: OLS  \quad Adj. \, R^2 = 0.997  \quad \text{Durbin} \, h = 2.215  \quad \text{Est. period} = 1968-86 \quad \text{No. of obs.} = 19

88. Japanese rice resale price

\[ \text{RRSFJP}_t = 5,782.90 + 48.49 \, \text{CPIJP}_t-1 + 0.232 \, \text{RPDPJP}_t + 0.522 \, \text{RRSFJP}_t-1 \]
\[ (1.79) \quad (1.99) \quad (6.58) \quad (4.63) \]

Estimator: OLS  \quad Adj. \, R^2 = 0.997  \quad \text{Durbin} \, h = 2.251  \quad \text{Est. period} = 1961-86 \quad \text{No. of obs.} = 26

89. Japanese wheat import price

\[ \text{WCIFJP}_t = 10.05 + 1.18 \, (\text{WGULFP}_t - \text{EXSBUS}_t*36.744) - 44.89 \, \text{DUM72}_t - 91.80 \, \text{DUM73}_t \]
\[ (1.64) \quad (21.80) \quad (-3.21) \quad (-6.35) \]

Estimator: OLS  \quad Adj. \, R^2 = 0.952  \quad \text{D.W.} = 1.366  \quad \text{Est. period} = 1960-85 \quad \text{No. of obs.} = 26

World market-clearing conditions

90. Rest-of-world import demand for U.S. wheat

\[ \text{WNNEXUS}_t = (36.744/1000)* (\text{WNIMPC}_t + \text{WNIMSU}_t + \text{WNIMJP}_t + \text{WNIMEE}_t + \text{WSMNFL}_t + \text{WSMNOAS}_t + \text{WSMNWE}_t + \text{WSMNWR}_t + \text{WNIRW}_t - \text{WEXPCA}_t - \text{WNEXEC} - (D6080_t + D81_t) + D8286_t) + \text{WEXPAU}_t - \text{WNEXAR}_t \]

91. World wheat market-clearing condition

\[ \text{NET}_t = \text{WNNEXUS}_t - \text{MMEXUS}_t \]

92. World wheat price

\[ \text{WGULFP}_t = \text{WGULFP}_t^* (1 - 0.01* (\text{NET} / (\text{ABS} (\text{NET}_t) + 100))) \]

1\text{Computed over the period 1979/80-1986/87.}
2\text{Elasticity computed with respect to the wheat gulf ports price less any historical export subsidies.}
3\text{Evaluated at the mean of the period 1960/61-1972/73.}
### Appendix C—Variable Definitions

#### World wheat trade model variable definitions

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<thead>
<tr>
<th>Variables</th>
<th>Definition</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>BFDPAU</td>
<td>Australian barley, ABB feed price</td>
<td>A$/mt</td>
</tr>
<tr>
<td>BFFYCA</td>
<td>CWB barley final payment, No. 1 feed</td>
<td>C$/mt</td>
</tr>
<tr>
<td>BIPYCA</td>
<td>CWB barley initial payment, No. 1 feed</td>
<td>C$/mt</td>
</tr>
<tr>
<td>BOFFCA</td>
<td>Western Canadian feed barley, offboard price</td>
<td>C$/mt</td>
</tr>
<tr>
<td>BTRPCA</td>
<td>CWB barley total realized price, No. 1 feed</td>
<td>C$/mt</td>
</tr>
<tr>
<td>BWi</td>
<td>EC-10 mean barley production share for 1960-85, country i</td>
<td>mt/ha</td>
</tr>
<tr>
<td>BYLDi</td>
<td>EC-10 barley yield, country i</td>
<td></td>
</tr>
<tr>
<td>CTENRNP</td>
<td>Cotton expected market net returns</td>
<td>US$/bt</td>
</tr>
<tr>
<td>CTYUS</td>
<td>U.S. cotton trend yield</td>
<td>lb/acre</td>
</tr>
<tr>
<td>EMDPAY</td>
<td>U.S. wheat expected deficiency payment</td>
<td>US$/bu</td>
</tr>
<tr>
<td>EMWFP</td>
<td>U.S. wheat expected farm price, June-May</td>
<td>US$/bu</td>
</tr>
<tr>
<td>EWRNP</td>
<td>Wheat expected net returns, minimum diversion program participant, June-May</td>
<td>US$/ac</td>
</tr>
<tr>
<td>EWRXP</td>
<td>Wheat expected net returns, maximum diversion program participant, June-May</td>
<td>US$/ac</td>
</tr>
<tr>
<td>MNXUS</td>
<td>World import demand for U.S. wheat</td>
<td></td>
</tr>
<tr>
<td>NEX</td>
<td>U.S. wheat excess supply less rest-of-the-world import demand facing the U.S.</td>
<td></td>
</tr>
<tr>
<td>RDPJP</td>
<td>Japanese rice producer price</td>
<td>Yen/mt</td>
</tr>
<tr>
<td>RSPJP</td>
<td>Japanese rice resale price</td>
<td>Yen/mt</td>
</tr>
<tr>
<td>TREND</td>
<td>Year: 1960, ..., 1986</td>
<td></td>
</tr>
<tr>
<td>WAPTAU</td>
<td>Argentine wheat, area planted</td>
<td>1,000 ha</td>
</tr>
<tr>
<td>WAU</td>
<td>Australian wheat, area planted</td>
<td>1,000 ha</td>
</tr>
<tr>
<td>WAPUS</td>
<td>U.S. wheat, total planted acreage</td>
<td>mil acres</td>
</tr>
<tr>
<td>WCCSTKS</td>
<td>U.S. wheat, CCC ending stocks, June-May</td>
<td>mil bu</td>
</tr>
<tr>
<td>WCFPEC</td>
<td>Wheat c.i.f. import price, Rotterdam, Aug-July</td>
<td>ECU/bt</td>
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<td>WCPPJ</td>
<td>Japanese wheat cif import price</td>
<td>US$/bt</td>
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<td>WCOMSTKS</td>
<td>U.S. wheat, commercial ending stocks, June-May</td>
<td>mil bu</td>
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<td>WXOMAR</td>
<td>Argentine wheat, domestic use, Dec-Nov</td>
<td>1,000 mt</td>
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<td>WXOPJ</td>
<td>Japanese wheat, domestic use</td>
<td>1,000 mt</td>
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<td>WEXAU</td>
<td>Australian wheat, exports</td>
<td>1,000 mt</td>
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<td>WEXCA</td>
<td>Canadian wheat, exports, Aug-July</td>
<td>1,000 mt</td>
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<td>WEPUS</td>
<td>U.S. wheat, export, June-May</td>
<td>mil bu</td>
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<td>WEDAU</td>
<td>Australian wheat, livestock feed</td>
<td>1,000 mt</td>
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<td>WEFCRA</td>
<td>Canadian wheat, feed use and loss in handling, Aug-July</td>
<td>1,000 mt</td>
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<tr>
<td>WEFDCA</td>
<td>EC-10 wheat feed use, Aug-July</td>
<td>1,000 mt</td>
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<tr>
<td>WEDUS</td>
<td>U.S. wheat, feed use, June-May</td>
<td>mil bu</td>
</tr>
<tr>
<td>WFOBAR</td>
<td>Argentine wheat f.o.b. export price, Buenos Aires, Jan-Dec</td>
<td>US$/mt</td>
</tr>
<tr>
<td>WFOAR</td>
<td>Australian wheat for flour, breakfast food, and industrial use</td>
<td>1,000 mt</td>
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<td>WFOBCA</td>
<td>Canadian wheat, human food and and industrial use, Aug-July</td>
<td>1,000 mt</td>
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<tr>
<td>WFOCA</td>
<td>EC-10 all wheat nonfeed use, Aug-July</td>
<td>1,000 mt</td>
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<tr>
<td>WFOCUR</td>
<td>U.S. wheat, food use, June-May</td>
<td>mil bu</td>
</tr>
<tr>
<td>WFOPOA</td>
<td>CWB wheat final payment, No. 1 CHRS</td>
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<tr>
<td>WMABAU</td>
<td>U.S. wheat guaranteed minimum price, ASW</td>
<td>A$/mt</td>
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<tr>
<td>WFDU</td>
<td>U.S. wheat, gulf ports price, June-May</td>
<td>US$/mt</td>
</tr>
<tr>
<td>WHAAR</td>
<td>Argentine wheat, area harvested</td>
<td>1,000 ha</td>
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<tr>
<td>WHAHC</td>
<td>Canadian wheat, total area harvested, Aug-July</td>
<td>1,000 ha</td>
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<td>WHAREC</td>
<td>EC-10 all wheat area harvested</td>
<td>1,000 ha</td>
</tr>
<tr>
<td>WHARJP</td>
<td>Japanese wheat, area harvested</td>
<td>1,000 ha</td>
</tr>
<tr>
<td>WHARUS</td>
<td>U.S. wheat, harvested acreage</td>
<td>mil acres</td>
</tr>
<tr>
<td>WHCPAU</td>
<td>AWB human consumption price</td>
<td>A$/mt</td>
</tr>
<tr>
<td>WHEFUS</td>
<td>U.S. wheat season average farm price, June-May</td>
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<tr>
<td>WHITUS</td>
<td>U.S. wheat trend yield,</td>
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<td>MBP1</td>
<td>Wheat wholesale price, Buenos Aires, Jan-Dec</td>
<td>peso/100kg</td>
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<td>WIMPUS</td>
<td>U.S. wheat, imports, June-May</td>
<td>mil/acre</td>
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<td>CWB wheat initial payment, No. 1 CHRS</td>
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<td>WMLCA</td>
<td>Canadian wheat, domestic milling price, Aug-July</td>
<td>C$/mt</td>
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<td>WNEKAR</td>
<td>Argentine wheat, net exports, Dec-Nov</td>
<td>1,000 mt</td>
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<td>WNEC8</td>
<td>EC-10 all wheat net exports, Aug-July</td>
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<td>WNECUS</td>
<td>U.S. wheat, net exports, June-May</td>
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<td>WNINMP</td>
<td>Japanese wheat, net imports</td>
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<td>WNINM</td>
<td>Rest-of-world wheat, net imports</td>
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<tr>
<td>WNFPAUS</td>
<td>U.S. wheat, nonprogram acreage</td>
<td>mil acres</td>
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<td>WFPCCA</td>
<td>Western Canadian feed wheat, offboard price</td>
<td>C$/mt</td>
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<tr>
<td>WFCPAL</td>
<td>Argentine wheat, per-capita domestic use</td>
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<tr>
<td>WFCOAD</td>
<td>Japanese wheat, per-capita domestic use</td>
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</table>

Continued—
### World wheat trade model variable definitions—Continued

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definition</th>
<th>Units</th>
</tr>
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<tbody>
<tr>
<td>WPCFUS</td>
<td>U.S. wheat, per-capita food use</td>
<td>bu/person</td>
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<tr>
<td>WPCFAU</td>
<td>Australian wheat, per-capita wheat for human use</td>
<td>mt/person</td>
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<td>WPCEF</td>
<td>EC-10 all wheat per-capita food use</td>
<td>mt/1,000 persons</td>
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<tr>
<td>WPDWP</td>
<td>Japanese wheat producer price</td>
<td>Yen/mt</td>
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<td>WDRCA</td>
<td>Actual wheat diverted acres divided by total program acres</td>
<td>ratio</td>
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<td>WPFP</td>
<td>U.S. wheat, planted program acreage</td>
<td>mil. acres</td>
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<td>WFPAR</td>
<td>Argentine wheat, production</td>
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<td>WFDAC</td>
<td>Canadian wheat, production, Aug-July</td>
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<tr>
<td>WFDDEC</td>
<td>EC-10 all wheat production</td>
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<td>WFDUS</td>
<td>U.S. wheat, production</td>
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<td>WQOUCA</td>
<td>CWB wheat selling quotations, basis in storage Thunder Bay or St. Lawrence</td>
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<td>WSJPF</td>
<td>Japanese wheat resale price</td>
<td>Yen/mt</td>
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<td>WSEDCA</td>
<td>Canadian wheat, seed use, Aug-July</td>
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<td>WSEDUS</td>
<td>U.S. wheat, seed use, June-May</td>
<td>mil bu</td>
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<td>WSUPAR</td>
<td>Argentine wheat, supply</td>
<td>1,000 mt</td>
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<tr>
<td>WSUPAU</td>
<td>Australian wheat, available supplies</td>
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<tr>
<td>WSUPCA</td>
<td>Canadian wheat, total supply, Aug-July</td>
<td>1,000 mt</td>
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<td>WSUPEC</td>
<td>EC-10 all wheat total supply, Aug-July</td>
<td>1,000 mt</td>
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<tr>
<td>WSUPF</td>
<td>Japanese wheat, supply</td>
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<td>WSUPUS</td>
<td>U.S. wheat, supply, June-May</td>
<td>mil bu</td>
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<tr>
<td>WTESAR</td>
<td>Argentine wheat, total ending stocks</td>
<td>1,000 mt</td>
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<td>WTESAU</td>
<td>Australian wheat, total ending stocks</td>
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<td>Canadian wheat, total ending stocks, Aug-July</td>
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<td>EC-10 all wheat total ending stocks, Aug-July</td>
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<td>Japanese wheat, total ending stocks</td>
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<tr>
<td>WTPAUS</td>
<td>U.S. wheat, total program acreage</td>
<td>mil. acres</td>
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<td>WTPRCA</td>
<td>CWB wheat total realized price, No. 1 CWRS</td>
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<td>WTYLUS</td>
<td>U.S. wheat trend yield</td>
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<tr>
<td>WYLDAR</td>
<td>Argentine wheat, yield per harvested hectare</td>
<td>mt/ha</td>
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<td>WYLDCA</td>
<td>Canadian wheat yield</td>
<td>mt/ha</td>
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<td>WYLDJP</td>
<td>Japanese wheat, yield per hectare</td>
<td>mt/ha</td>
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<td>U.S. wheat, yield per harvested acre</td>
<td>bu per acre</td>
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<tr>
<td>WYPAU</td>
<td>Australian annual average export price for Australian Standard White wheat, F.O.B.</td>
<td>A$/mt</td>
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### Exogenous

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<td>BAPYCA</td>
<td>CWB barley adjustment payment, No. 1 feed</td>
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<td>BRFP1</td>
<td>EC-10 member barley producer price, country i, Aug-July</td>
<td>currency/100kg</td>
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<td>U.S. barley, season average farm price, June-May</td>
<td>US$/bu</td>
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<td>BSUPCA</td>
<td>Canadian barley, production plus beginning stocks, Aug-July</td>
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<td>BWAFAU</td>
<td>Australian beef, weighted average price</td>
<td>AU cents/kg</td>
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<td>CPIAU</td>
<td>Australian consumer price index</td>
<td>index:1980=100</td>
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<td>Canadian consumer price index</td>
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<td>Japanese consumer price index</td>
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<td>CRLRUS</td>
<td>U.S. corn loan rate, Oct-Sept</td>
<td>US$/bu</td>
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<td>CRPS</td>
<td>U.S. corn, season average farm price, Oct-Sept</td>
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<td>U.S. corn total beginning stocks, Oct-Sept</td>
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<td>Cotton loan rate</td>
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<td>CVTUCS</td>
<td>U.S. cotton cost</td>
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<td>CUPRUS</td>
<td>U.S. upland cotton season average farm price</td>
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<td>CWPRDJF</td>
<td>Primary cost of wheat production</td>
<td>Yen/10 ares</td>
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<td>D7478</td>
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<td>D7479</td>
<td>Dummy variable, equals 1 in 1974 and 1979, 0 elsewhere</td>
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Continued--
## World wheat trade model variable definitions—Continued

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<td>Dummy variable, equals 1 in 1967, 1972, 1982, 0 elsewhere</td>
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<td>Dummy variable, equals one in year 19(ij), zero elsewhere</td>
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<td>EC-10 national currency/ECU exchange rate for 1980</td>
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<td>Argentine-US exchange rate, period average</td>
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<td>Australian-U.S. exchange rate, Australian dollar per U.S. dollar</td>
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<td>ERCAUS</td>
<td>Canadian-U.S. exchange rate, Canadian dollar per U.S. dollar</td>
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<td>U.S.-EC exchange rate, Aug-July</td>
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<td>EXSBUS</td>
<td>U.S. wheat export subsidy</td>
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<td>Farm price index for fertilizer, Canada, Aug-July</td>
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<td>FPINI</td>
<td>EC-10 fertilizer price index, country i</td>
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<td>HDINAU</td>
<td>Australian household disposable income</td>
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<td>HGONCA</td>
<td>Canadian hog numbers, on farm, July 1</td>
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<td>HRODAU</td>
<td>Australian total poultry production, dressed weight</td>
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<td>Lower bound to the Canadian wheat domestic milling price</td>
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<td>PDINCA</td>
<td>Canadian personal disposable income</td>
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<td>PFSAUCE</td>
<td>EC-10 denaturing premium for wheat, Aug-July</td>
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<td>Canadian price index 100 hogs, dress basis, Winnipeg</td>
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<td>Argentine population, mid-year</td>
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<td>Australian population, at January 1</td>
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<td>RBFPEC</td>
<td>EC-10 real barley producer price, Aug-July</td>
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<td>RDGPAR</td>
<td>Argentine real GDP, 1980 prices</td>
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<td>RDGPEC</td>
<td>EC-10 real gross domestic product, 1980 prices</td>
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<td>RWFPEC</td>
<td>EC-10 real common wheat producer price, Aug-July</td>
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<td>SARKSF</td>
<td>U.S. steer and heifer fed slaughter plus slaughter</td>
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<td>SFPAR</td>
<td>Sunflower wholesale price, Buenos Aires, Jan-Dec</td>
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<td>Australian greasy wool price, July-June</td>
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<td>TPOFRUS</td>
<td>Total U.S. residence population, includes armed forces</td>
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<td>UB</td>
<td>Upper bound to the Canadian wheat domestic milling price</td>
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<td>CBW wheat adjustment payment, No. 1 CWRS</td>
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<td>WBASE</td>
<td>National wheat allotment/base</td>
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<td>WCLDIV</td>
<td>U.S. wheat program, percent of base eligible for cash land diversion payments</td>
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<td>U.S. wheat, farmer-owned reserve ending stocks, June-May</td>
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<td>WHINTP</td>
<td>ECU/mt</td>
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<td>Argentine wheat ad valorem export tax</td>
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<td>WINPCA</td>
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<td>WOTEU</td>
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<td>Peoples Republic of China, wheat net imports</td>
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<td>WNMU</td>
<td>USSR, wheat net imports, July-June</td>
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<td>Australian wheat, on farm balance</td>
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<td>U.S. wheat program, additional diversion payment</td>
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<td>Variables</td>
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<td>WPGMDP</td>
<td>U.S. wheat program, minimum diversion payment</td>
<td>US$/bu</td>
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<td>U.S. wheat program, minimum diversion rate</td>
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<td>Argentine wholesale price index, nonagr. total</td>
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<td>WPYLUS</td>
<td>U.S. wheat program yield</td>
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<td>WSFPAU</td>
<td>Australian wheat, AWB stockfeed price, FOR</td>
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<td>Africa and Middle East, wheat net imports</td>
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<td>Other Asia less India, wheat net imports</td>
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<td>Other Western Europe, wheat net imports</td>
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<td>U.S. wheat, total beginning stocks, June-May</td>
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<td>YPDCUS</td>
<td>U.S. personal disposable income</td>
<td>billion US$</td>
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