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WORLD WHEAT POLICY SIMULATION MODEL: DESCRIPTION AND COMPUTER PROGRAM DOCUMENTATION

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Highlights

Wheat is a differentiated product. Substitution among wheat classes is imperfect and consumer preferences differ among countries, suggesting that wheat characteristics are an important determinant of trade flows.

The World Wheat Policy Simulation Model is a partial equilibrium model that distinguishes among 11 classes of wheat. It is used for evaluating the effects on the world wheat economy of farm and trade policies. This document describes the model structure and computer implementation.

Following are some of the major features of the model:

- *There are 5 exporting countries: Argentina, Australia, Canada, the United States, and the European Union.*

- *There are 13 importing countries and regions: Algeria, Brazil, China, Egypt, the Former Soviet Union, Japan, Mexico, Morocco, South Korea, Taiwan, Tunisia, Venezuela, and a Rest of the World region.*

- *There are 11 wheat classes: Argentine wheat, Australian wheat, Canadian western red spring wheat, Canadian western amber durum wheat, E.U. common wheat, E.U. durum wheat, U.S. hard red spring wheat, U.S. hard red winter wheat, U.S. soft red winter wheat, U.S. white wheat, and U.S. durum wheat.*

- *The model simulates production, consumption, stocks, exports, and trade flows for wheat over a 10-15 year period.*

- *It is a multi-commodity model, where all commodities are wheat classes.*

- *It is a dynamic partial equilibrium model. In every year, the model is solved for a set of equilibrium prices such that for each wheat class demand equals supply*

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INTRODUCTION

World wheat trade is dominated by a few exporting countries: the United States, Canada, the European Union, Australia, and Argentina. While competition for world market share is strong, the world wheat market is not perfectly competitive. Australia and Canada use wheat boards to market their grain, while the European Union and the United States rely on export subsidies for increased market share. In addition, all major wheat exporters use credit guarantees and long-term preferential trade agreements to promote their exports.

Simulation models, including the FAPRI model (Devadoss et al.) and SWOPSIM (Roningen et al.), assume wheat to be a homogenous commodity. This seems to be a strong assumption since wheat is a differentiated product (Larue). Wheat is consumed in a wide variety of bread, pastry, noodle, and pasta products, and these products require flour or semolina with specific characteristics. Since these characteristics depend on the properties of the wheat kernel, wheat classes are imperfect substitutes. For example, low protein soft wheat yields excellent flour for cake and cookie production, while high protein durum wheat semolina is the preferred raw material for pasta products.

Depending on soil type and climate, different regions of the world grow different kinds of wheat, and exporting countries use quality standards, grading systems, export promotions, and long-term preferential trade agreements to further differentiate their products. The United States grows five classes of wheat: hard red spring wheat, hard red winter wheat, soft red winter wheat, white wheat, and durum wheat. These classes are grown in different parts of the country, and they are used for different food products.

Generally, grain hardness and yield are inversely related, provided that moisture and growing season are not limiting; the softer the wheat, the higher the yield. As a rule of thump, protein content drops by 1 percent for every 10-15 percent increase in yield (Ulrich et al.). Therefore, the Canadian prairies with their low rainfall and short growing season produce mainly high-protein, low-yielding, hard wheat. On the other hand, France with a

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relatively high precipitation and a long growing season produces low-protein, high-yielding, soft wheat.

Wheat types differ in their inherent quality characteristics, and consumer preferences for wheat products differ among countries, suggesting that international trade flows are to a large extent determined by preferences for certain kinds of wheat. This explains why Pakistan imports mainly soft wheat from the United States and Australia, while Algeria imports primarily hard wheat and durum wheat from Canada, the European Union, and the United States. Since hard wheat, soft wheat, and durum wheat are imperfect substitutes in consumption, world wheat trade is fragmented into several submarkets.

World durum wheat exports are dominated by Canada, the European Union, and the United States, while the 'Mahgreb' nations (Algeria, Morocco, and Tunisia), Italy, the former Soviet Union, and Venezuela are major durum wheat importers. Any changes in durum wheat trade policies will have a significant impact on the durum wheat industries in these countries, but it will have a smaller effect on exporters and importers of soft and hard wheat. Similarly, changes in the soft wheat market may have a large impact on soft wheat trade, but they will be felt less in the hard and durum wheat markets.

Aggregation of wheat classes may bias the results of policy simulations. Moreover, it provides little information on how producers in different regions will be affected by changing market conditions. For instance, hard red spring wheat and durum wheat producers in the Northern Plains face different circumstances than soft red winter wheat producers in the Corn Belt. Northern farmers rely more on government support and, because of climate, can grow fewer crops than southern farmers. Therefore, farmers in the Northern Plains and in the Corn Belt will be affected differently if wheat policies change.

Aggregate models that treat wheat as a homogenous product cannot capture such differences. However, these differences are important. Perhaps they are even more important than overall changes in wheat markets. The 1994 Canada - United States wheat trade dispute illustrates this (Alston et al., Simone). At the center of this dispute are rising U.S. imports of Canadian wheat. In 1992/93, these wheat imports reached 51.4 million bushels. Compared to total U.S. wheat production of 2,467 million bushels and U.S. exports of 1,354 million bushels, Canadian wheat imports appear to be insignificant. Canadian wheat has a market share of 4.6 percent of domestic consumption.

However, these aggregate figures hide the impact of Canadian wheat imports on producers in the Northern Plains. Canadian imports compete primarily with hard red spring wheat and durum wheat produced in the Northern Plains. In 1992/93, the United States imported 14.8 million bushels of durum wheat from Canada. The U.S. durum wheat production and exports equaled 100 million bushels and 47 million bushels, respectively. Thus, Canada captured a significant share (17.4 percent of domestic consumption) of the U.S. durum wheat market. Canada's share of the U.S. hard red spring wheat market is smaller (13.9 percent of domestic consumption), but still significant.

The world wheat policy simulation model is a dynamic simulation model for evaluating the consequences of polices over a 10- to 15-year period. It differs from existing policy simulation models because it distinguishes among different classes of wheat. Therefore, it provides more detail on how regions within the United States will be affected by changes in wheat policies. In addition, it provides information on production, domestic consumption, stocks, imports, exports, and trade flows between exporting and importing countries.

Major exporting countries are the United States, Canada, Australia, Argentina, and the European Union. Importing countries or regions are Algeria, Brazil, China, Egypt, Japan, Mexico, Morocco, South Korea, Taiwan, Tunisia, Venezuela, and a "Rest of the World" region. Tables 1 and 2 show average world market shares for the period from 1990/91 to 1992/93, and Figure 1 shows trade flows between countries.

The European Union and United States are major exporters of wheat, but they also import considerable amounts of wheat. The United States imports wheat from Canada, while the European Union imports wheat from the United States, Canada, Australia, and Argentina. To model this behavior, the model includes import demand equations for the United States and the European Union. Thus, the model shows concurrent wheat exports and imports (though not of the same wheat class). This feature distinguishes it from models that aggregate over wheat classes and assume wheat to be a homogenous commodity.

WHEAT CLASSES

Most of the wheat varieties grown today belong to the broad category of common or bread wheat, which accounts for approximately 95 percent of world production. The remaining 5 percent of world production are durum wheats used for products such as pasta and couscous.

Wheat is a highly differentiated product with wheat varieties differing in their agronomic and end-use attributes. Based on criteria such as kernel hardness, color, growth habit, and protein content, wheat is divided into several classes. Within these classes, wheat is further differentiated using measures such as test weight, cleanliness, level of screenings, degree of soundness, and moisture content.

Color and hardness refer to physical properties of the wheat kernel. Based on the color of the outer layer of the kernel, common wheat varieties are described as white, amber, red, or dark, while the hardness of the kernel is used to characterize them as hard or soft.[1]

Hardness of the wheat kernel is a major determinant of protein content and flour characteristics. Hard wheat flour has a higher protein content and a coarser particle size than soft wheat flour, and these differences in flour composition and texture determine its use. High protein hard wheat flour is well-suited for baking bread, while low protein soft wheat flour is preferred for cookies, cakes, and snack foods.

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[1]In Australia, Canada, the United States, and Japan, the terms soft and hard refer to the texture of the wheat kernel. In the European Union, all bread wheats (hard and soft) are referred to as soft wheat, while the term hard wheat is reserved for durum wheats. In Eastern Europe, wheat is often classified into hard wheat and soft wheat according to suitability for bread baking. Wheat unfit for bread baking is labeled soft wheat. In most parts of the world, wheat production statistics do not distinguish between soft and hard wheat kernels.

Table 1: Wheat Exports, 1990/91 to 1992/93 Averages

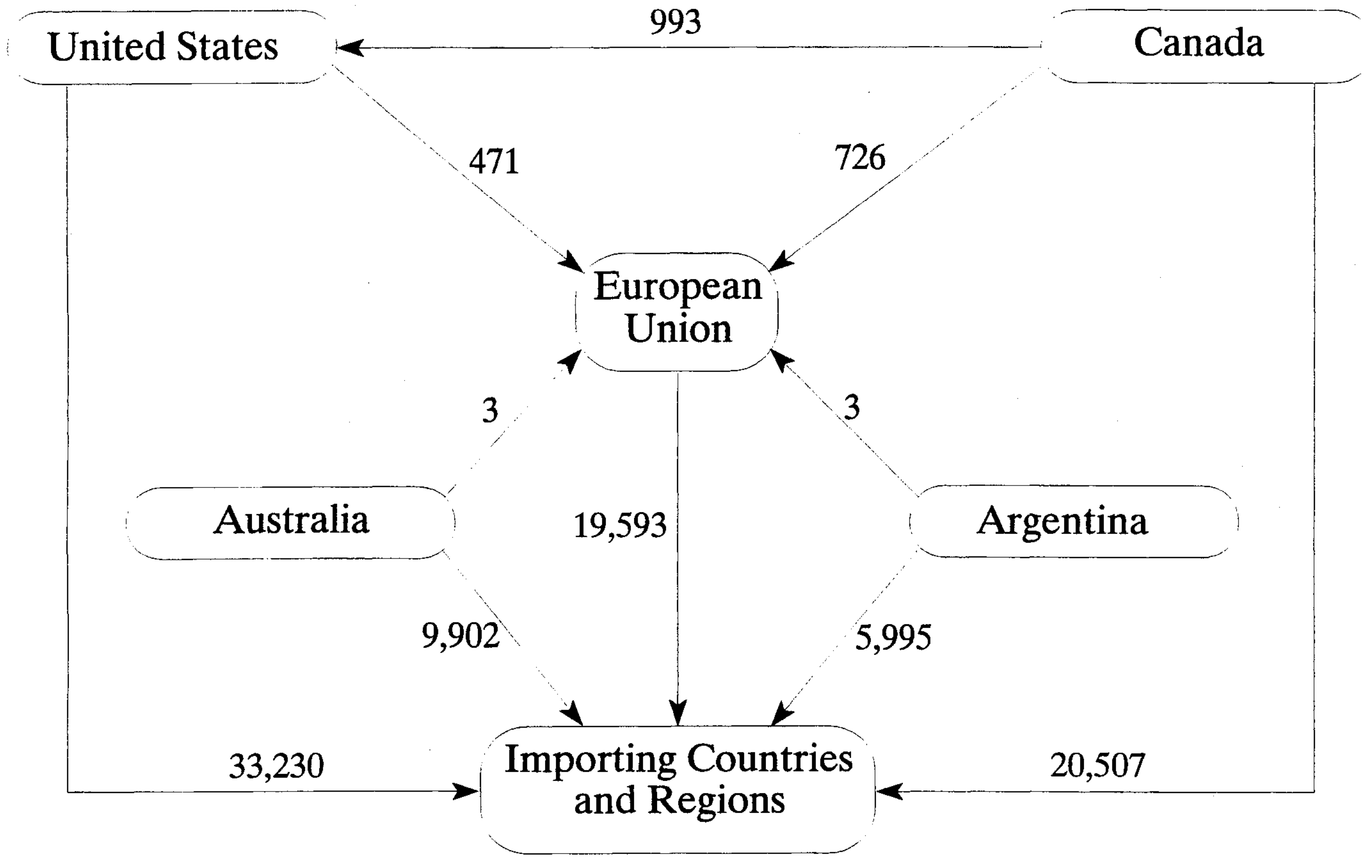
Country/Region	Wheat Class	Average Wheat Exports: Quantity (1000 m.tons)	Average Wheat Exports: Market Share (percent)
Argentina	All Wheat	5,999	6.00
Australia	All Wheat	9,911	9.89
Canada	All Wheat	22,227	22.18
	Common Wheat	19,497	19.46
	Durum Wheat	2,730	2.72
European Union	All Wheat	19,593	19.55
	Common Wheat	18,806	18.77
	Durum Wheat	787	0.79
United States	All Wheat	33,701	33.63
	Hard Red Spring Wheat	9,244	9.22
	Hard Red Winter Wheat	12,601	12.57
	Soft Red Winter Wheat	4,944	4.93
	White Wheat	5,480	5.47
	Durum Wheat	1,315	1.31
Other Exporters	All Wheat	8,785	8.77
Total World Exports	All Wheat	100,215	100.00
	Common Wheat	95,474	95.27
	Durum Wheat	4,741	4.73

Source: International Wheat Council, *World Grain Statistics 1993*, London, 1994.

Table 2: Wheat Imports, 1990/91 to 1992/93 Averages

Country/Region	Average Wheat Imports	
	Quantity (1000 metric tons)	Market Share (percent)
Algeria	2,749	2.74
Brazil	4,651	4.64
China	10,694	10.67
Egypt	5,927	5.91
European Union	1,361	1.36
Japan	5,740	5.73
Korea	4,169	4.16
Mexico	862	0.86
Morocco	2,132	2.13
Former Soviet Union	18,447	18.41
Taiwan	882	0.88
Tunisia	689	0.69
United States	1,002	1.00
Venezuela	1,161	1.16
Other Importers	39,746	39.66
Total World Imports	100,215	100.00

Source: International Wheat Council, *World Grain Statistics 1993*, London, 1994.



Source: International Wheat Council, *World Grain Statistics*, 1992 and 1993.

Figure 1: Wheat Export Flows, 1990/91 to 1992/93 Averages
(1000 metric tons)

Growth habit is an important agronomic feature of wheat varieties. Winter wheat is planted in late summer or fall and requires a period of cold winter temperatures for heading to occur. Using fall moisture for germination, the plants remain in a vegetative phase during the winter and resume growth in early spring, effectively using early spring sunshine, warmth, and rainfall. In contrast to winter wheat, spring wheat changes from vegetative growth to reproductive growth without exposure to cold temperatures. In temperate climates, spring wheat is, as the name implies, sown in spring. Since yields tend to be higher for winter wheat than for spring wheat, spring wheat is produced primarily in regions where winter wheat production is infeasible, either because freezing soil kills winter wheat plants or winters are too warm. Countries with mild winters, such as Argentina, Australia, and Brazil, produce spring wheat, but this spring wheat is planted in the fall rather than in the spring.

Different wheat classes have their preferred uses. Hard wheat flour has excellent bread baking properties; soft wheat flour is well-suited for cookies, cakes, and Asian noodles; and durum wheat semolina is used for pasta products and couscous. However, since different types of wheat can be blended to produce flours or semolina with certain characteristics, some substitution among wheat classes is possible in flour and semolina milling.

Due to changing growing conditions, protein content can vary considerably from year to year, and these differences affect wheat class purchases by millers. When the hard red winter crop is low in protein, millers of bread flour increase their hard red spring wheat purchases and blend these two classes. This drives up protein premiums, especially if supplies are tight. On the other hand, if the protein content of the hard red winter crop is high, protein premiums tend to be lower.

Blending is, however, only one of several options available to millers for producing flour with certain characteristics. Instead of blending different classes, millers can fortify low protein wheat flour by adding vital wheat gluten, or they can segregate flour particles using air classification. Both technologies increase the substitutability among wheat classes, and millers use them to tailor flour of exact protein content to customer specifications.

Wheat gluten contains 70-80 percent protein and is obtained by separating wheat flour into starch, gluten, and other byproducts. While gluten is used in a wide variety of products, adding it to wheat flour is of particular importance since it increases the protein content of the flour and changes its dough and baking properties. For example, using this process, the European Union has been able to improve the bread baking quality of flour milled from domestically produced soft wheat. Over time, the expanded use of fortified soft wheat flour has significantly reduced E.U. hard wheat imports.

With air classification, finely ground flour is directed to classifiers, where swirling air funnels segregate flour particles by size. Since smaller particles tend to be higher in protein content, this procedure yields low protein flour suitable for cakes and pastries and high protein flour for breads and buns. Air classification eliminates the expense of shipping wheat classes with specific characteristics from distant locations. For instance, when hard red winter wheat is low in protein, Kansas and Oklahoma mills with air classification facilities can use local wheat supplies rather than importing hard red spring wheat from the Dakotas.

Although wheat is used primarily for human consumption, it is also an excellent feed grain for poultry and livestock. Feed use of wheat tends to be highly variable and depends on the quality of the wheat crop and on the price relationship between wheat and other feed grains. Generally, only lower quality wheat is used for feed, and differences among wheat classes are unimportant. Wheat is a differentiated product only for human consumption.

In the model, wheat is viewed as a differentiated product and, based on origin and end-use properties, divided into 11 classes: U.S. hard red spring wheat, U.S. hard red winter wheat, U.S. durum wheat, U.S. soft red winter wheat, U.S. white wheat, Canadian western red spring wheat, Canadian western amber durum wheat, E.U. common wheat, E.U. durum wheat, Argentine wheat, and Australian wheat. Figure 2 shows the relationship between these classes.

CONCEPTUAL WHEAT MODEL

Wheat is considered to be a differentiated product with wheat classes being defined by producing region and end-use properties. Let there be m importing countries and n classes of wheat.

Export supply of wheat class j is a function of prices, income, consumption preferences, weather, and government policies:

$$X^j = X^j(p^1, ..., p^n, \alpha_X^j) \quad \text{for } j = 1,...,n \tag{1}$$

where superscript j refers to wheat classes, p^j is the price of wheat class j, and α_X^j is a shift parameter that embodies all other variables affecting export supply of class j.

In a differentiated product model, the n wheat classes are considered to be imperfect substitutes in consumption. Country i's import demand for class j is a function of prices, income, consumption preferences, weather, and government policies:

$$M^{ij} = M^{ij}(p^1, ..., p^n, \alpha_M^{ij}) \quad \text{for } i = 1, ..., m \text{ and } j = 1, ..., n \tag{2}$$

where superscript i denotes the importing country, and α_M^{ij} is a shift parameter that represents all other factors affecting import demand for class j in country i.

In equilibrium, export supply equals import demand for each class of wheat:

$$\sum_{i=1}^{m} M^{ij} = X^j \quad \text{for } j = 1, ..., n \tag{3}$$

The model is solved by substituting the export supply equations (1) and import demand equations (2) into the equilibrium conditions (3) and finding a set of equilibrium prices such that, for each class of wheat, export supply equals the sum of all import demands.

If, for each class of wheat, there is only one supplier, then the model identifies trade flows between exporting and importing countries. Of course, products can always be defined so this is the case. For instance, if Canadian durum wheat and U.S. durum wheat are two distinct classes, then there is only one exporter for each of these wheat classes, and M^{ij} indicates who supplies whom. On the other hand, if Canadian durum wheat and U.S. durum

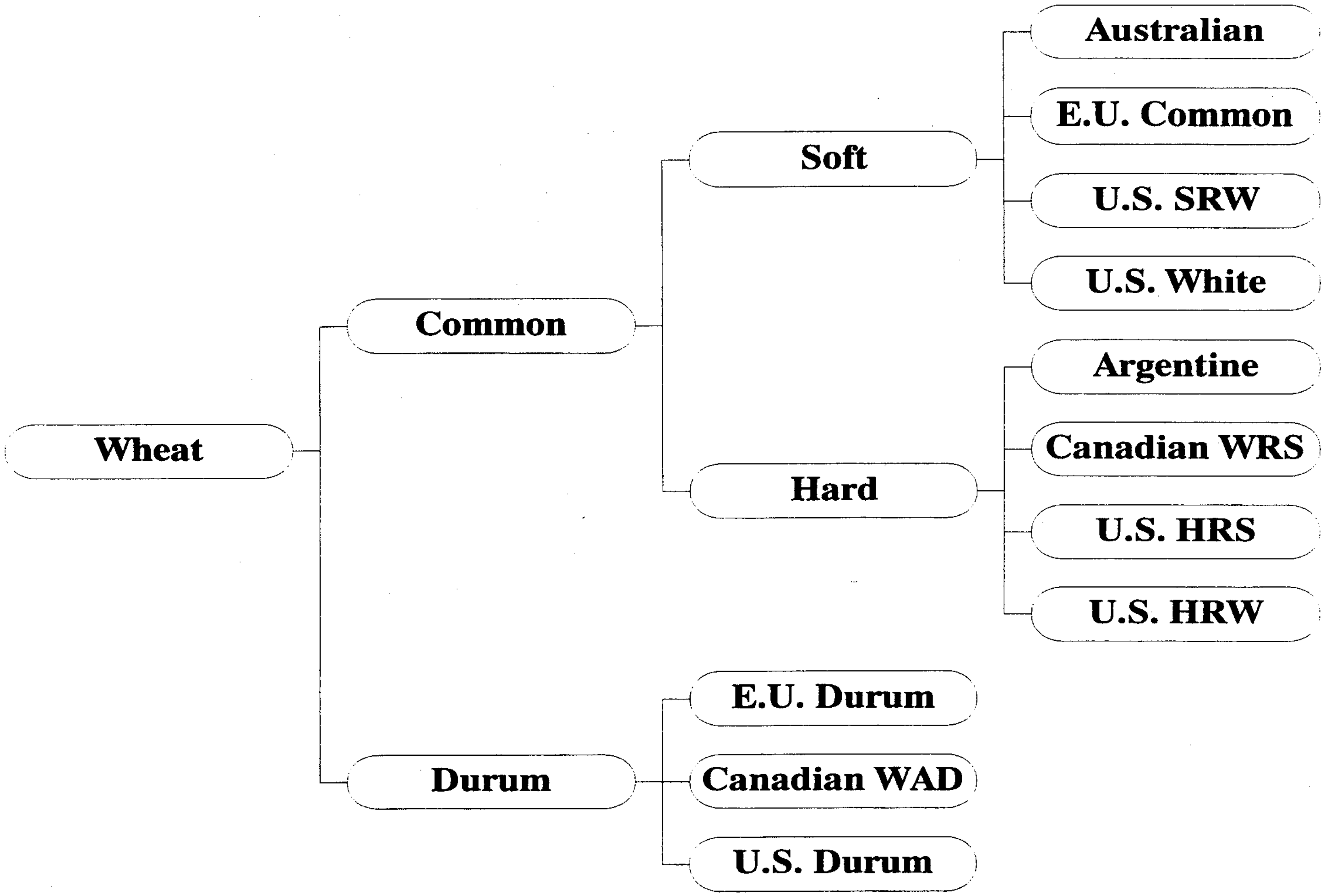


Figure 2: Wheat Classes

wheat are considered to be perfect substitutes and lumped together into one class, then M^{ij} does not provide any information on whether Canada or the U.S. supply durum wheat to country i. In sum, if products are properly defined, then a differentiated product model identifies trade flows, i.e., it is a trade flow model.[2]

Compare the trade flow model to the structure of a model that assumes wheat to be a homogenous commodity. In such a model, since all classes of wheat are perfect substitutes, there is only one wheat price:

$$p = p^1 = p^2 = \ldots = p^{n-1} = p^n \tag{4}$$

Therefore, country j's export supply is a function of only one wheat price:

$$X^j = X^j(p, \alpha_X^j) \quad for\ j = 1, \ldots, n \tag{5}$$

Moreover, since all classes are perfect substitutes, each importing country has only one import demand function:

$$M^i = \sum_{j=1}^{n} M^{ij} = M^i(p, \alpha_M^i) \quad \text{for } i = 1, \ldots, m \tag{6}$$

This homogenous-commodity model is solved by finding a price such that the sum of all imports equals the sum of all exports:

$$\sum_{i=1}^{m} M^i = \sum_{j=1}^{n} X^j \tag{7}$$

Equation (7) is the equilibrium condition requiring that markets clear. Compare this to the differentiated product model. Instead of n equilibrium conditions and n prices, one for each class, there is only one equilibrium condition and one price if wheat is assumed to be a homogenous commodity. Clearly, solving one equation for one variable is easier than solving a system of n equations for n variables.

Specifying behavioral equations for export supply and import demand is a valid approach, but it has its limitations since no information on supply and demand changes occurring in domestic markets is provided. To analyze such effects, it is necessary to explicitly model domestic supply and demand. Since export supply is the difference between domestic supply and domestic demand, the specification of an export supply function is straightforward once behavioral functions for domestic supply and domestic demand are known:

$$X^j = S^j(p^1, \ldots, p^n, \alpha_S^j) - D^j(p^1, \ldots, p^n, \alpha_D^j) \quad \text{for } j = 1, \ldots, n \tag{8}$$

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[2]Generally, the term *spatial model* refers to mathematical programming models that focus on transport costs.

where $S^j(\cdot)$ is the supply function for wheat class j, $D^j(\cdot)$ is the domestic demand function for wheat class j, and α_S^j and α_D^j are shift parameters affecting domestic supply and demand, respectively.

Similarly, explicitly modeling domestic demand and supply behavior in importing countries shows how domestic supply and demand in these countries adjust to price changes. Import demand is simply the difference between domestic demand and supply:

$$M^{ij} = D^{ij}(p^1, ..., p^n, \alpha_D^{ij}) - S^{ij}(p^1,..., p^n, \alpha_S^{ij}) \qquad \text{for } i = 1, ..., m \text{ and } j = 1, ..., n \tag{9}$$

where $S^{ij}(\cdot)$ is the supply function for wheat class j in country i, $D^{ij}(\cdot)$ is the domestic demand function for wheat class j in country i, and α_S^{ij} and α_D^{ij} are shift parameters affecting domestic supply and demand, respectively.

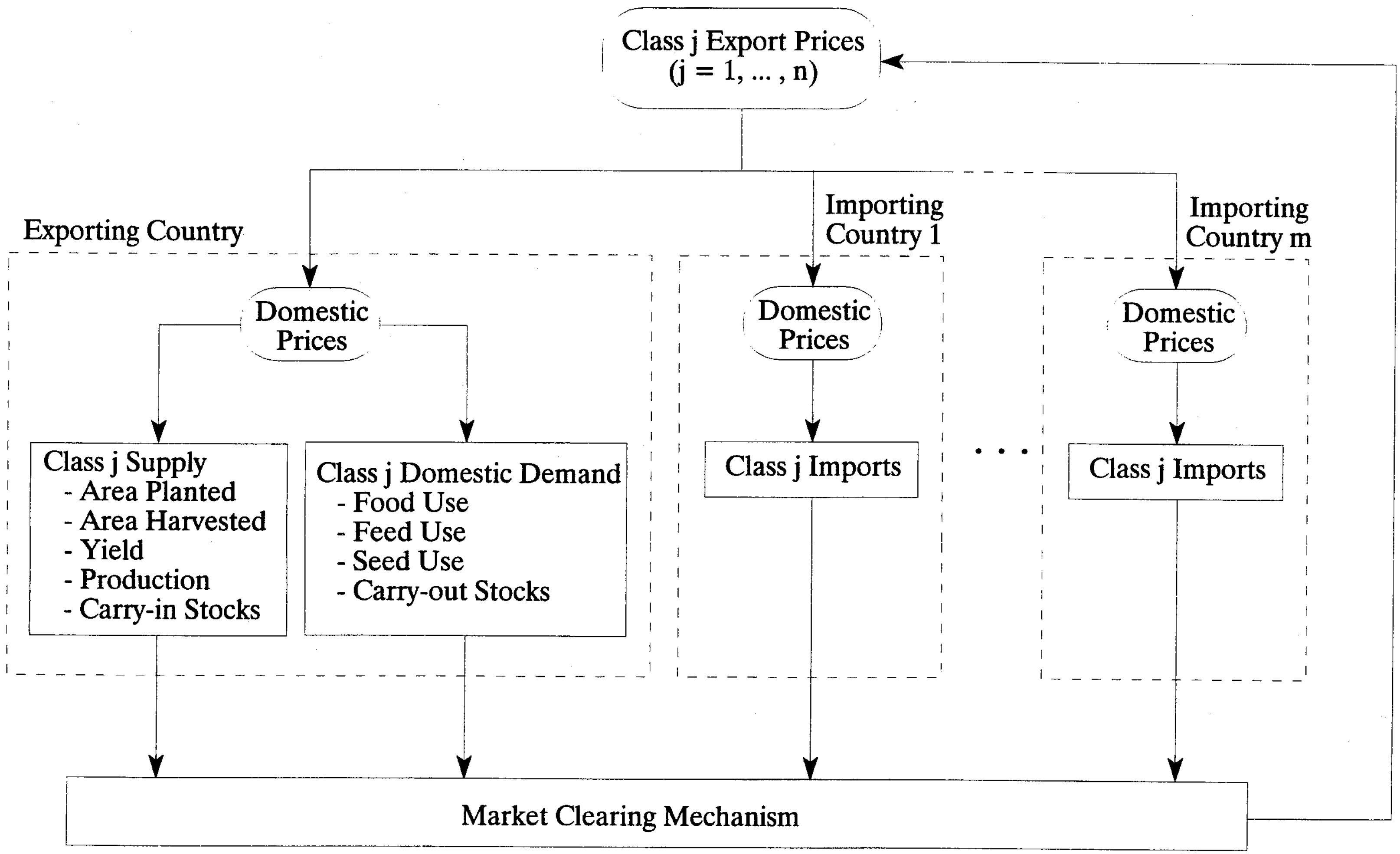
The World Wheat Policy Simulation Model is a combination of the two model specifications outlined above. Domestic supply and demand are explicitly modeled in exporting countries, while net-import demand equations are specified for importing countries. Thus, the model structure is as follows:

$$\begin{aligned} X^j &= S^j(p^1, ..., p^n, \alpha_S^j) - D^j(p^1, ..., p^n, \alpha_D^j) \quad \text{for } j = 1, ..., n \\ M^{ij} &= M^{ij}(p^1, ..., p^n, \alpha_M^{ij}) \quad \text{for } i = 1, ..., m \text{ and } j = 1, ..., n \\ \sum_{i=1}^{m} M^{ij} &= X^j \quad \text{for } j = 1,...,n \end{aligned} \tag{10}$$

The complete model consists of n export supply functions, mn import demand functions, and n equilibrium conditions. Export supplies are explicitly modeled as the difference between domestic supplies and demands in exporting countries, while import demands are only implicitly related to domestic supplies and demands in importing countries. For each class, equilibrium implies that markets clear. Prices adjust to satisfy this condition.

Substituting the behavioral equations for export supply and import demand into the equilibrium conditions yields a system of n equations. The solution of this system of equations is a vector of n prices such that, for all classes, supply equals demand.

Figure 3 displays the basic structure of the model and indicates some of the components of domestic supply and demand. If the word "commodity" is substituted for the word "class," the figure outlines the structure of a standard multi-commodity net-trade model. This is perhaps the simplest characterization of the World Wheat Policy Simulation Model. It is a multi-commodity model where the commodities are classes of wheat.



*There are m importing countries and n wheat classes. The figure shows only one representative class.

Figure 3: Conceptual Wheat Class Model*

MODEL STRUCTURE

The World Wheat Policy Simulation Model is a dynamic simulation model of the world wheat industry. It is a hybrid between an econometric model and a synthetic model. Some behavioral equations are estimated, while others are based on assumptions.

Exporting countries are modeled in great detail, and most parameters are estimated econometrically. The exporting country submodels include behavioral equations for acreage harvested, yield, production, domestic consumption, and carry-out stocks. If data are available, domestic consumption is further disaggregated into food use, feed use, and seed use.

Rather than explicitly modeling domestic supply and demand in importing countries, generic wheat import demand equations are specified for these countries. Estimating import demand equations turned out to be difficult because wheat prices tend to be highly correlated. Thus, multicollinearity is a problem. In addition, the Australian and Canadian wheat boards are secretive about their pricing strategies, and quoted export prices are often a poor indicator of prices actually paid for imports. Therefore, five-stage Armington demand models are specified for the European Union, the United States, and the importing countries.

ARMINGTON'S DEMAND SYSTEM

Importing countries view imports of the same good from different countries as imperfect substitutes. This product differentiation arises from intrinsic or perceived differences among products produced at different locations and from established historical, cultural, or political relationships. Armington proposed a theory of demand for products distinguished by place of origin, a theory that also applies to products differentiated by criteria other than place of origin.

With differentiated products, estimation of demand systems can be difficult. Almost by definition, these products are close substitutes, implying that prices move closely together. Therefore, price data may be available only for a few representative products or in the form of a price index. Even if price data for all products is available, multicollinearity is likely to be a problem.

Armington addresses these problems by developing a theory that reduces the number of parameters that have to be estimated. His approach assumes that utility is weakly separable so that the consumers' decision process may be viewed as occurring in two stages. First, the total quantity to be consumed is determined, and then this quantity is allocated among the competing suppliers. In addition, the total quantity consumed is assumed to be a constant elasticity of substitution (CES) function of the product quantities. Given these assumptions, Armington derives formulas for the calculation of own-price and cross-price demand elasticities from the overall price elasticity of demand, the (assumed to be constant) elasticity of substitution, and the budget shares.

If the differentiated product is wheat, Armington's formula for the own-price elasticity of wheat class k is

$$\epsilon^{k,k} = s^{k} \epsilon - (1 - s^{k}) \sigma$$

where $\epsilon^{k,k}$ is the elasticity of class k demand with respect to class k price, s^k is the budget share of class k in total wheat consumption, σ is the elasticity of substitution between wheat classes, and ϵ is the overall price elasticity of wheat demand ($\epsilon < 0$).

The cross-price elasticity of demand for class k with respect to the price of class j is

$$\epsilon^{k,j} = s^j (\epsilon + \sigma), \quad \text{for } j \neq k$$

Two wheat classes are substitutes in consumption if their cross-price elasticities have positive signs; they are complements otherwise. Thus, in Armington's demand system, wheat classes are substitutes if and only if $\sigma > |\epsilon|$. Also, for every wheat class, the sum of own-price and cross-price elasticities equals the overall price elasticity:

$$\epsilon^{k,k} + \sum_{j \neq k} \epsilon^{k,j} = \epsilon$$

Armington's formulas reduce the number of parameters that have to be estimated. Since budget shares are easily calculated, only the overall elasticity of demand and the elasticity of substitution have to be estimated. This is a significant reduction of work compared to the estimation of n^2 price elasticities if there are n classes of wheat and no constraints are imposed on the demand system.

However, this simplicity comes at a price. In Armington's model, elasticities of substitution between any pairs of wheat classes are identical. For instance, the elasticity of substitution between white wheat and durum wheat is identical to the elasticity of substitution between hard red spring wheat and hard red winter wheat. This is unrealistic. Hard red winter wheat and hard red spring wheat are more similar in their end-use characteristics than are white wheat and durum wheat. Therefore, substitution between hard red spring wheat and hard red winter wheat is easier than substitution between durum wheat and white wheat.

This problem is solved by specifying a five-stage Armington model. To implement this structure, wheat classes are grouped according to their end-use properties into soft wheats, hard wheats, and durum wheats. Within these groups, the elasticity of substitution between classes is assumed to be identical. In addition, it is assumed that some substitution is possible between soft wheat and hard wheat and between common wheat and durum wheat.

Figure 4 shows the hierarchical grouping of wheat classes and the corresponding elasticities of substitution. In addition to budget shares, the overall price elasticity of wheat demand and five elasticities of substitution are used to generate the matrix of price elasticities.

The wheat class demand elasticities with respect to wheat class prices are computed recursively. First, elasticities for common wheat and durum wheat are computed using the overall elasticity of wheat demand and the elasticity of substitution between common wheat and durum wheat. Next, soft and hard wheat elasticities are derived using the common wheat price elasticity computed in the previous stage and the elasticity of substitution between soft wheat and hard wheat. Finally, elasticities for wheat classes are generated using the soft wheat, hard wheat, and durum wheat price elasticities of demand and the corresponding elasticities of substitution. Cross-price elasticities are split up according to

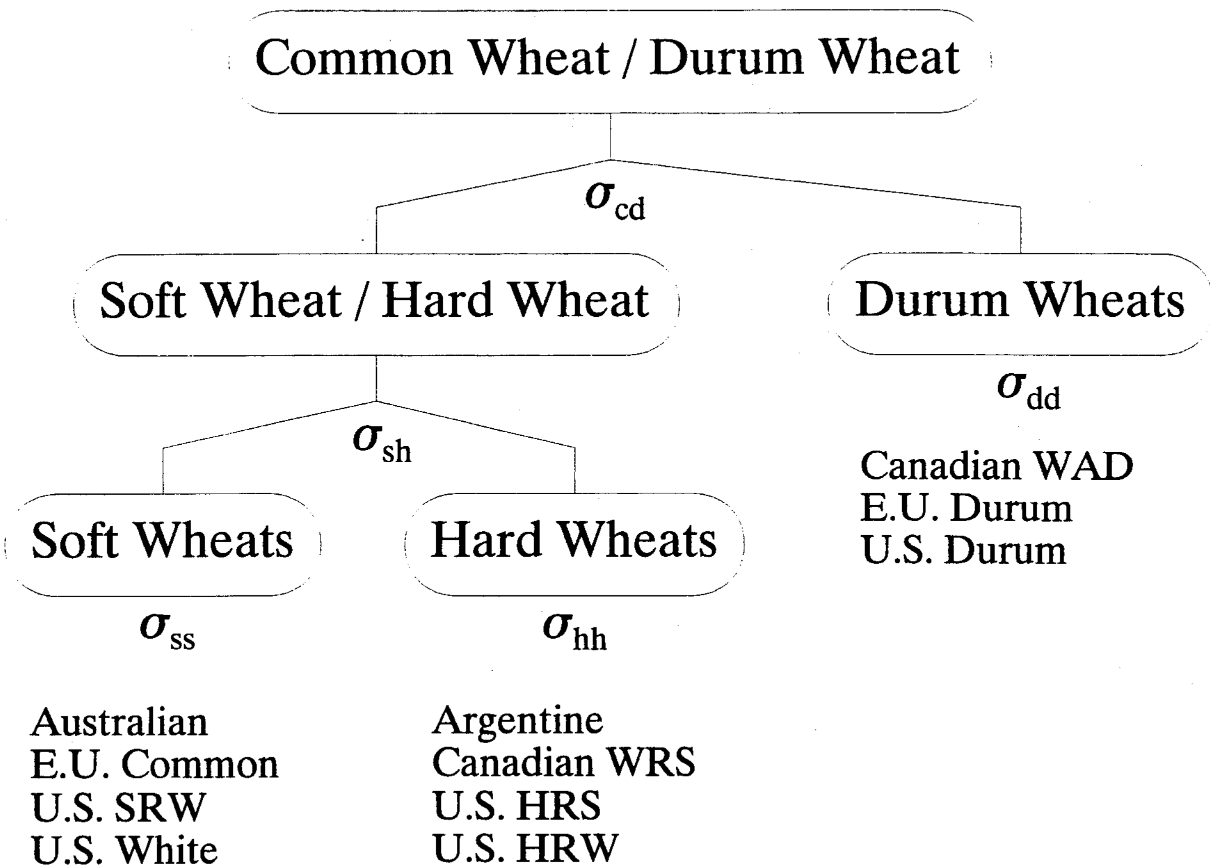


Figure 4: Elasticites of Substitution

budget shares. For instance, the elasticity of soft wheat demand with respect to durum wheat price is derived by multiplying the elasticity of common wheat demand with respect to durum wheat price by the share of soft wheat in common wheat consumption.

Table 3 shows a matrix of demand elasticities with respect to wheat class prices that was generated using the five-stage Armington procedure. In this example, the overall elasticity of wheat demand is assumed to be -0.4, and the elasticities of substitution are assumed to be 0.5 between common and durum wheats, 1.0 between soft and hard wheats, 10.0 between soft wheats, 10.0 between hard wheats, and 10.0 between durum wheats. Budget shares are computed using average prices and quantities for the 1990/91 to 1992/93 period. Table 4 shows the corresponding matrix of substitution effects.

All rows in Table 3 sum to -0.4, the overall elasticity of wheat demand. Note the cross-price elasticity pattern. While there are blocks of identical cross-price elasticities in every column, cross-price elasticities differ within columns. This is the major difference to the standard Armington model with only one elasticity of substitution. If the elasticity of substitution is identical for all classes of wheat, all cross-price elasticities are identical within columns.

MODEL CALIBRATION

All behavioral equations of the model are calibrated to a base period. This ensures that the model replicates base period wheat supply and demand conditions.

To calibrate the behavioral equations, the intercept terms are computed such that base period values are generated for the endogenous variables if the exogenous variables are set to base period values. The procedure is simple and is best demonstrated using an example. Consider the following estimated behavioral equation:

$$y = \hat{\beta}_0 + \hat{\beta}_1 x_1$$

where y is a dependent variable, x is an explanatory variable, and $\hat{\beta}_0$ and $\hat{\beta}_1$ are estimated parameters.

If this equation is estimated with ordinary least squares, the intercept is computed such that the regression line passes through the arithmetic means of x and y:

$$\hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \bar{x}$$

where $\bar{x}$ and $\bar{y}$ indicate the arithmetic means of x and y, respectively.

When calibrating this equation to the base period, the estimated intercept, $\hat{\beta}_0$, is discarded and a new intercept, $\tilde{\beta}_0$, is computed such that the regression line passes though the base period values of x and y:

$$\tilde{\beta}_0 = y^* - \hat{\beta}_1 x^*$$

where $\tilde{\beta}_0$ denotes the calibrated intercept, y^* and x^* refer to the base period values of x and y, respectively.

Table 3: Matrix of Price Elasticities, United States

	US Durum	Canada WAD	US HRS	US HRW	Canada WRS	US SRW	US White
US Durum	-2.6439	2.1508	0.0186	0.0466	0.0022	0.0193	0.0065
Canada WAD	7.3561	-7.8492	0.0186	0.0466	0.0022	0.0193	0.0065
US HRS	0.0053	0.0016	-7.4004	6.5195	0.3097	0.1226	0.0416
US HRW	0.0053	0.0016	2.5996	-3.4805	0.3097	0.1226	0.0416
Canada WRS	0.0053	0.0016	2.5996	6.5195	-9.6903	0.1226	0.0416
US SRW	0.0053	0.0016	0.1182	0.2965	0.0141	-3.1586	2.3228
US White	0.0053	0.0016	0.1182	0.2965	0.0141	6.8414	-7.6772

Table 4: Matrix of Substitution Effects, United States

	US Durum	Can. WAD	US HRS	US HRW	Can. WRS	US SRW	US White
US Durum	-0.1814	0.1214	0.0013	0.0034	0.0001	0.0015	0.0004
Canada WAD	0.1214	-0.1066	0.0003	0.0008	0.0000	0.0004	0.0001
US HRS	0.0013	0.0003	-1.8919	1.7004	0.0569	0.0342	0.0099
US HRW	0.0034	0.0008	1.7004	-2.3227	0.1455	0.0874	0.0254
Canada WRS	0.0001	0.0000	0.0569	0.1455	-0.1521	0.0029	0.0008
US SRW	0.0015	0.0004	0.0342	0.0874	0.0029	-0.9940	0.6249
US White	0.0004	0.0001	0.0099	0.0254	0.0008	0.6249	-0.5995

In the calibrated equation,

$$y = \tilde{\beta}_0 + \hat{\beta}_1 x$$

the dependent variable equals y^* whenever the exogenous variable equals x^*. Thus, this "one equation model" replicates the base period.

International wheat supply and demand conditions can change significantly from year to year. Calibrating the model to a base year may cause problems since anomalies in this particular year have a large impact on the model solution. Therefore, the behavioral equations of the world wheat policy simulation model are calibrated using average values for all variables for the period from 1990/91 to 1992/93.

Ideally, supply equals demand in the base period. This will be the case if the data source is an official supply-demand balance table. In these tables, total supply always equals total demand because one variable takes care of any imbalances: either a variable "errors and omissions" accounts explicitly for statistical discrepancies or one of the variables implicitly includes these errors.

The data for the wheat policy simulation model come from several sources, and sometimes there is an imbalance of supply and demand. To correct this problem, one of the domestic demand variables (e.g., feed use) is computed such that total supply equals total demand in the base period. In addition, a "Rest of the World" region takes care of imports by countries not explicitly accounted for in the model. Imports of this region are the residual that balances exports and the sum of all imports in the base year.

MODEL SOLUTION

The model is solved by finding a set of equilibrium prices such that, for each wheat class, total demand equals total supply. Thus, the model has a total of 11 equilibrium conditions: five for the United States, two for Canada, two for the European Union, one for Argentina, and one for Australia. These 11 equilibrium conditions are solved simultaneously for 11 equilibrium wheat prices.

UNITED STATES

Wheat Classes

In the United States, wheat is divided into five classes: hard red winter wheat, hard red spring wheat, soft red winter wheat, white wheat, and durum wheat. These wheat classes are grown in different regions depending on rainfall, temperature, and soil type. Hard red spring wheat is produced mainly in the Northern Plains states of North Dakota and Montana. Hard red winter wheat is planted primarily in the Central Plains states of Kansas and Oklahoma. Soft red winter wheat is grown in the Corn Belt and southern states. White wheats are grown in the Pacific Northwest, Michigan, and New York. Durum wheat is produced in the Northern Plains and under irrigation in Arizona and California. Table 5 summarizes the characteristics and uses of the U.S. wheat classes.

The U.S. wheat model distinguishes among these five wheat classes. For each class, equations are specified to describe supply, domestic demand, foreign demand, price linkages, and market equilibrium. Since there are five U.S. wheat classes, there are five equilibrium conditions; and the model is solved for a set of prices such that supply equals demand for each class of wheat.

In addition to consuming and exporting domestically produced wheat classes, the United States imports western red spring wheat and western amber durum wheat from Canada. Thus, the United states is an exporter and importer of wheat, and the U.S. model includes import demand equations for Canadian wheat.

While the Canadian wheat classes are close substitutes for U.S. wheat classes, they are considered to be imperfect substitutes. Thus, wheat imports from Canada do not enter supply-demand balances for domestically produced U.S. wheat classes. Nevertheless, imports from Canada affect the U.S. wheat economy since Canadian prices affect U.S. demand for domestically produced wheat classes.

Wheat Supply

The supply model consists of equations for area planted, area harvested, yield, and production for each wheat class. Planting decisions depend on factors such as land quality, climate, expected prices at harvest, and government programs, while yields depend on soil quality, fertilizer use, wheat variety, and weather conditions.

Depending on climate and soil conditions, farmers may be able to grow a variety of crops on their land. Generally, they will grow the most profitable crop. Therefore, if government farm support payments or farm prices change, they may decide to change the acreage planted to a particular class of wheat. For instance, land in the North Central Plains is suitable for crops such as hard red spring wheat, durum wheat, barley, and sunflower. If the price of hard red spring wheat increases relative to the durum wheat price, farmers may decide to plant more hard red spring wheat and less durum wheat. Similarly, farmers in the Corn Belt are likely to substitute soft red winter wheat for corn if the price of this wheat class increases relative to the corn price.

Table 5: United States Wheat Classes*

Class	Subclass	Characteristics	Utilization
Hard Red Spring	Dark Northern Spring, Northern Spring, Red Spring	spring seeded, hard kernel, high-protein (11.5-18%)	blends with lower-protein wheats, whole wheat breads, hearth breads
Hard Red Winter		fall seeded, hard kernel, medium- to high-protein (9%-14.5%)	white baker's bread, baker's rolls
Soft Red Winter		fall seeded, soft kernel, low- to medium-protein (8%-11.5%)	waffles, muffins, quick yeast bread, all-purpose flour
White	Hard White, Soft White, White Club, Western White,	fall or spring seeded, soft or hard kernel, low-protein (8%-10.5%)	oriental noodles, kitchen cakes and crackers, pie crust, doughnuts, cookies, foam cakes
Durum	Hard Amber Durum, Amber Durum, Durum	spring seeded, very hard kernel, high-protein (10-16.5%)	semolina, pasta products
Mixed		a mixture of several wheat classes	

*Except for mixed wheat, wheat classes and subclasses are further divided into grades.

Source: W. G. Heid, Jr. *U.S. Wheat Industry*. U.S. Department of Agriculture, Agricultural Economic Report 432, Washington DC, August 1979.

In the U.S. supply model, area planted is a function of area planted and crop prices in the previous year, and idled wheat base acreage and wheat target price in the current year:[3]

$$ap_t^k = f(ap_{t-1}^k, pf_{t-1}^k, pf_{t-1}^j, ai_t, pt_t)$$

where ap^k denotes the area planted to wheat class k, pf^k is the farm price of class k, pf^j is the farm price of substitute crop j, ai is the idled wheat base acreage, and pt is the wheat target price.

Lagged wheat area is included as an explanatory variable since planting decisions are assumed to follow a partial adjustment process. Thus, due to some constraints, the actual change in acreage planted is only a fraction of the desired change in acreage planted. Such a behavior results in a model specification that includes the lagged dependent variable, i.e., acreage planted. The coefficient of this variable is expected to be between zero and one.

Lagged farm prices are included because harvest prices are unknown when crops are planted. Farmers are assumed to form price expectations based on prices that prevail when crops are planted, i.e., one period lagged prices. The acreage planted to class k is expected to increase if the lagged class k price increases, but it is expected to decrease if the price of a competing crop increases.

Idled wheat base acreage and target price are policy parameters. Idled wheat base acreage includes all land taken out of production under government programs such as the conservation reserve program (CRP) and the acreage reduction program (ARP). The idled acreage coefficient is expected to have a negative sign. The target price is expected to have a positive sign since farmers are likely to increase participation in government programs if deficiency payments increase.

The wheat area harvested is a function of the area planted:

$$ah_t^k = f(ap_t^k)$$

where ah^k is the wheat class k area harvested. The area harvested is always smaller than or equal to the area planted ($ah_t^k \leq ap_t^k$).

Yield is assumed to depend on previous year's yield and time:

$$y_t^k = f(y_{t-1}^k, t)$$

where y^k is the yield of wheat class k, and t is a time trend. In order to estimate these yield equations, an additional dummy variable is included to account for severe drought years.

Production is simply the product of area harvested and yield:

$$qp_t^k = ah_t^k * y_t^k$$

where qp^k is class k wheat production.

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[3]Subscripts indicate the crop year: *t* indicates the current crop year, while *t-1* refers to the previous crop year.

These equations summarize the supply block of the U.S. wheat model. By definition, wheat production is either consumed domestically, exported, or stored for future use. The next section summarizes the domestic demand block of the U.S. wheat model.

Wheat Demand

Domestic wheat consumption includes food, feed, industrial, and seed use. While the aggregate wheat supply-demand balance distinguishes among different uses of wheat, domestic consumption data for wheat classes do not. Thus, the U.S. model includes only equations for domestic consumption. There is no breakdown of consumption into different uses such as food and feed.

Estimation of demand functions for the various wheat classes turned out to be rather difficult. Since the estimated equations often had unreasonable coefficients, a demand system for domestically produced wheat classes and imported Canadian wheat classes was specified using Armington's methodology. Using an aggregate elasticity of wheat consumption, five elasticities of substitution, and average 1990/91 to 1992/93 consumption shares of the various wheat classes, Armington's formulas were used to create a 7x7 matrix of demand elasticities for U.S. and Canadian wheat classes.[4]

For each domestically consumed wheat class (produced domestically or imported from Canada), a demand function is specified. Prices in the demand equations are deflated using the GDP deflator. In addition to wheat class prices, per capita demand is assumed to depend on real per capita GDP and a time trend:

$$cqd_t^k = f(rpd_t^1, ..., rpd_t^n, crgdp_t, t)$$

where cqd^k is per capita demand for class k, rpd^j is the real prices of class j, and $crgdp$ is real per capita GDP. Domestic demand for class k depends on the prices of all domestically produced wheat classes and on the prices of all classes imported from Canada.

Total consumption of class k is the product of per capita consumption and population:

$$qd_t^k = cqd_t^k * pop_t$$

where pop denotes the population.

Not all wheat is consumed in the current marketing year. Some wheat is stored for future consumption. These carry-out stocks include farmer-owned reserve stocks, loan stocks, Commodity Credit Corporation owned stocks, and free market stocks. In the U.S. model, no distinction is made between different types of stocks such as privately owned stocks and government stocks.

For each wheat class, demand for carry-out stocks is a function of carry-in stocks, production, the domestic market price, and the loan rate:

$$qs_t^k = f(qs_{t-1}^k, qp_t^k, pd_t^k, lr_t^k)$$

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[4]See the section *Armington's Demand System* for more details.

where qs^k is the carry-out stocks of wheat class k, qs^k is the carry-in stocks of class k, and lr^k is the loan rate for class k.

Loan rates are policy parameters. If loan rates are high, farmers are more likely to default on their loans, implying that government stocks increase. Thus, the sign of the loan rate coefficient is expected to be positive.

Since grain production fluctuates from year to year, a certain proportion of supply is generally stored as a grain reserve. Thus, carry-out stocks are expected to increase if supply (carry-in stocks or production) increases. They are expected to decline if prices rise since high prices signal tight market supplies (calling for a release of grain reserves) and increase the opportunity cost of storage.

By definition, U.S. exports are the difference between domestic supply and domestic demand:

$$qx_t^k = qs_{t-1}^k + qp_t^k - qd_t^k - qs_t^k$$

Price Linkages

For U.S. wheat classes, the model distinguishes between export prices, domestic market prices, and farm prices. Domestic market prices are a function of export prices:

$$pd_t^k = f(px_t^k)$$

where pd^k and px^k are the domestic market price and export price of wheat class k, respectively.

Domestic farm prices, in turn, are a function of domestic market prices:

$$pf_t^k = f(pd_t^k)$$

where pf^k is the farm price of wheat class k.

Domestic prices of Canadian wheat are a function of Canadian export prices (in U.S. dollars) and U.S. tariffs on imports:

$$pd_t^j = px_t^j + tx_t^j$$

where pd^j is the U.S. price of Canadian wheat class j, px^j is the export price of Canadian wheat class j, and tx^j is the U.S. tariff on wheat class j imports from Canada.

The Canadian import price equations are not estimated. Trade issues, such as the recent trade dispute between Canada and the United States., can be analyzed by varying the tariff on Canadian imports or adding constraints on Canadian exports to the United States.

Market Equilibrium

In equilibrium, markets must clear, implying that, for each class of wheat, total supply equals total demand:

$$qs_{t-1}^{k} + qp_t^{k} = qd_t^{k} + qs_t^{k} + \sum_{i=1}^{m} qm_t^{i,k}$$

where $qm^{i,k}$ denotes country i's imports of wheat class k.

The left-hand side of this equation shows total supply consisting of carry-in stocks and production, while the right-hand side shows total demand comprising domestic consumption, carry-out stocks, and purchases of importing countries. In equilibrium, total demand equals total supply. The model is solved for a set of prices that satisfies this condition.

Data Sources

U.S. export prices are taken from the *International Grain Statistics* (International Wheat Council). U.S. wheat imports from Canada are reported in the *Canadian Grains Industry Statistical Handbook* (Canada Grains Council). U.S. Department of Agriculture program data computer files are the source of idled wheat base acreage by state, while the *International Financial Statistics CD-ROM* (International Monetary Fund) provided data for macroeconomic variables. Data for the remaining variables are listed in the *Wheat Situation and Outlook Report* (U.S. Department of Agriculture).

Model Equations

Hard Red Spring Wheat

United States - Hard Red Spring Wheat Area Planted

$$aphrs_t = \underset{(1.89)}{10.401} + \underset{(0.19)}{0.047}\, aphrs_{t-1} + \underset{(1.31)}{1.992}\, pfhrs_{t-1} - \underset{(-1.30)}{1.382}\, pfdur_{t-1}$$

$$- \underset{(-2.87)}{0.498}\, aihrs_t + \underset{(1.32)}{1.131}\, ptwt_t$$

$n = 18$, $R^2 = 0.512$, $\bar{R}^2 = 0.324$

United States - Hard Red Spring Wheat Area Harvested

$$ahhrs_t = \underset{(1.24)}{1.237} + \underset{(13.16)}{0.872}\, aphrs_t - \underset{(-4.33)}{2.470}\, dum_{88}$$

$n = 20$, $R^2 = 0.928$, $\bar{R}^2 = 0.919$

United States - Hard Red Spring Wheat Yield

$$yhrs_t = \underset{(-0.44)}{-5.072} + \underset{(1.11)}{0.190}\, yhrs_{t-1} + \underset{(2.28)}{0.358}\, t - \underset{(-4.18)}{14.806}\, dum_{88}$$

$n = 19$, $R^2 = 0.620$, $\bar{R}^2 = 0.549$

United States - Hard Red Spring Wheat Production

$$qphrs_t = ahhrs_t * yhrs_t$$

United States - Hard Red Spring Wheat Per Capita Domestic Demand

$$cqdhrs_t = f(rpdhrs_t, rpdhrw_t, rpdsrw_t, rpdwhi_t, rpddur_t,$$

$$rpdcawrs_t, rpdcawad_t, crgdp_t, t)$$

United States - Hard Red Spring Wheat Domestic Demand

$$qdhrs_t = cqdhrs_t * pop_t$$

United States - Hard Red Spring Wheat Carry-out Stocks

$$qshrs_t = \underset{(2.78)}{448.525} + \underset{(1.05)}{0.178}\ qshrs_{t-1} - \underset{(-0.56)}{0.088}\ qphrs_t - \underset{(-3.81)}{115.873}\ pdhrs_t + \underset{(3.85)}{107.475}\ lrhrs_t$$

$n = 19, \quad R^2 = 0.831, \quad \bar{R}^2 = 0.786$

Unite States - Hard Red Spring Wheat Exports

$$qxhrs_t = qshrs_{t-1} + qphrs_t - qdhrs_t - qshrs_t$$

United States - Hard Red Spring Wheat Market Price

$$pdhrs_t = \underset{(-0.60)}{-0.143} + \underset{(16.82)}{0.025}\ pxushrs_t$$

$n = 19, \quad R^2 = 0.940, \quad \bar{R}^2 = 0.937$

United States - Hard Red Spring Wheat Real Market Price

$$rpdhrs_t = \frac{pdhrs_t}{gdefl_t}$$

United States - Hard Red Spring Wheat Farm Price

$$pfhrs_t = \underset{(-0.98)}{-0.239} + \underset{(15.22)}{0.955}\ pdhrs_t$$

$n = 20, \quad R^2 = 0.924, \quad \bar{R}^2 = 0.920$

United States - Hard Red Spring Wheat Equilibrium Condition

$$qshrs_{t-1} + qphrs_t = qdhrs_t + qshrs_t + \sum_{i=1}^{m} qmhrs_t^i$$

Hard Red Winter Wheat

United States - Hard Red Winter Wheat Area Planted

$$aphrw_t = \underset{(1.38)}{5.685} + \underset{(6.81)}{0.658}\ aphrw_{t-1} + \underset{(4.95)}{2.849}\ pfhrw_{t-1} - \underset{(-1.61)}{0.163}\ aihrw_t - \underset{(-0.17)}{0.114}\ ptwt_t$$

$n = 20,\quad R^2 = 0.889,\quad \bar{R}^2 = 0.857$

United States - Hard Red Winter Wheat Area Harvested

$$ahhrw_t = \underset{(-0.92)}{-5.286} + \underset{(6.56)}{0.963}\ aphrw_t - \underset{(-2.35)}{4.717}\ dum_{89}$$

$n = 20,\quad R^2 = 0.745,\quad \bar{R}^2 = 0.717$

United States - Hard Red Winter Wheat Yield

$$yhrw_t = \underset{(0.73)}{6.943} + \underset{(1.03)}{0.209}\ yhrw_{t-1} + \underset{(1.75)}{0.230}\ t - \underset{(-2.38)}{7.079}\ dum_{89}$$

$n = 19,\quad R^2 = 0.433,\quad \bar{R}^2 = 0.326$

United States - Hard Red Winter Wheat Production

$$qphrw_t = ahhrw_t * yhrw_t$$

United States - Hard Red Winter Wheat Per Capita Domestic Demand

$$cqdhrw_t = f(rpdhrs_t, rpdhrw_t, rpdsrw_t, rpdwhi_t, rpddur_t, rpdcawrs_t, rpdcawad_t, crgdp_t, t)$$

United States - Hard Red Winter Wheat Domestic Demand

$$qdhrw_t = cqdhrw_t * pop_t$$

United States - Hard Red Winter Wheat Carry-out Stocks

$$qshrw_t = \underset{(-0.66)}{-250.564} + \underset{(3.15)}{0.559}\ qshrw_{t-1} + \underset{(2.39)}{0.684}\ qphrw_t - \underset{(-1.12)}{81.005}\ pdhrw_t + \underset{(0.28)}{23.649}\ lrhrw_t$$

$n = 19,\quad R^2 = .794,\quad \bar{R}^2 = 0.739$

United States - Hard Red Winter Wheat Exports

$$qxhrw_t = qshrw_{t-1} + qphrw_t - qdhrw_t - qshrw_t$$

United States - Hard Red Winter Wheat Market Price

$$pdhrw_t = \underset{(-0.82)}{-0.115} + \underset{(27.15)}{0.026}\, pxushrw_t$$

$n = 19, \quad R^2 = 0.976, \quad \bar{R}^2 = 0.975$

United States - Hard Red Winter Wheat Real Market Price

$$rpdhrw_t = \frac{pdhrw_t}{gdefl_t}$$

United States - Hard Red Winter Wheat Farm Price

$$pfhrw_t = \underset{(-1.23)}{-0.137} + \underset{(30.79)}{0.922}\, pdhrw_t$$

$n = 20, \quad R^2 = 0.980, \quad \bar{R}^2 = 0.979$

United States - Hard Red Winter Wheat Equilibrium Condition

$$qshrw_{t-1} + qphrs_t = qdhrs_t + qshrs_t + \sum_{i=1}^{m} qmhrw_t^i$$

Soft Red Winter Wheat

United States - Soft Red Winter Wheat Area Planted

$$apsrw_t = -6.740 + 0.644\, apsrw_{t-1} + 3.491\, pfsrw_{t-1} - 0.703\, pfcn_{t-1}$$
$$(-1.95) \quad (3.58) \quad (3.17) \quad (-0.44)$$

$$- 0.094\, aisrw_t + 0.365\, ptwt_t$$
$$(-0.09) \quad (0.42)$$

$n = 18$, $R^2 = 0.794$, $\bar{R}^2 = 0.714$

United States - Soft Red Winter Wheat Area Harvested

$$ahsrw_t = -0.516 + 0.920\, apsrw_t - 0.470\, dum_{91}$$
$$(-1.21) \quad (25.41) \quad (-1.01)$$

$n = 20$, $R^2 = 0.973$, $\bar{R}^2 = 0.970$

United States - Soft Red Winter Wheat Yield

$$ysrw_t = -8.943 - 0.217\, ysrw_{t-1} + 0.712\, t - 12.132\, dum_{91}$$
$$(-0.84) \quad (-1.17) \quad (4.60) \quad (-3.64)$$

$n = 19$, $R^2 = 0.655$, $\bar{R}^2 = 0.591$

United States - Soft Red Winter Wheat Production

$$qpsrw_t = ahsrw_t * ysrw_t$$

United States - Soft Red Winter Wheat Per Capita Domestic Demand

$$cqdsrw_t = f(rpdhrs_t,\ rpdhrw_t,\ rpdsrw_t,\ rpdwhi_t,\ rpddur_t,$$
$$rpdcawrs_t,\ rpdcawad_t,\ crgdp_t,\ t)$$

United States - Soft Red Winter Wheat Domestic Demand

$$qdsrw_t = cqdsrw_t * pop_t$$

United States - Soft Red Winter Wheat Carry-out Stocks

$$qssrw_t = 135.674 - 0.121\, qssrw_{t-1} + 0.017\, qpsrw_t - 29.386\, pdsrw_t$$
$$(5.13) \quad (-0.68) \quad (0.61) \quad (-5.01)$$

$$+ 8.849\, lrsrw_t$$
$$(1.61)$$

$n = 19$, $R^2 = 0.697$, $\bar{R}^2 = 0.616$

United States - Soft Red Winter Wheat Exports

$$qxsrw_t = qssrw_{t-1} + qpsrw_t - qdsrw_t - qssrw_t$$

United States - Soft Red Winter Wheat Market Price

$$\underset{(-2.06)}{pdsrw_t = -0.390} + \underset{(20.98)}{0.028}\, pxussrw_t$$

$n = 19, \quad R^2 = 0.961, \quad \bar{R}^2 = 0.959$

United States - Soft Red Winter Wheat Real Market Price

$$rpdsrw_t = \frac{pdsrw_t}{gdefl_t}$$

United States - Soft Red Winter Wheat Farm Price

$$pfsrw_t = \underset{(0.25)}{0.027} + \underset{(30.94)}{0.925}\, pdsrw_t$$

$n = 20, \quad R^2 = 0.981, \quad \bar{R}^2 = 0.980$

United States - Soft Red Winter Wheat Equilibrium Condition

$$qssrw_{t-1} + qpsrw_t = qdsrw_t + qssrw_t + \sum_{i=1}^{m} qmsrw_t^i$$

White Wheat

United States - White Wheat Area Planted

$$apwhi_t = \underset{(2.24)}{3.820} + \underset{(1.47)}{0.326}\, apwhi_{t-1} + \underset{(1.57)}{0.368}\, pfwhi_{t-1} - \underset{(-1.02)}{0.307}\, aiwhi_t - \underset{(-1.02)}{0.258}\, ptwt_t$$

$n = 18, \quad R^2 = 0.745, \quad \bar{R}^2 = 0.672$

United States - White Wheat Area Harvested

$$ahwhi_t = \underset{(0.61)}{0.218} + \underset{(13.92)}{0.882}\, apwhi_t - \underset{(-5.42)}{1.220}\, dum_{91}$$

$n = 20, \quad R^2 = 0.922, \quad \bar{R}^2 = 0.914$

United States - White Wheat Yield

$$ywhi_t = \underset{(-1.26)}{-21.090} + \underset{(0.55)}{0.129}\, ywhi_{t-1} + \underset{(3.00)}{0.817}\, t - \underset{(-1.74)}{8.965}\, dum_{91}$$

$n = 19, \quad R^2 = 0.594, \quad \bar{R}^2 = 0.518$

United States - White Wheat Production

$$qpwhi_t = ahwhi_t * ywhi_t$$

United States - White Wheat Per Capita Domestic Demand

$$cqdwhi_t = f(rpdhrs_t, rpdhrw_t, rpdsrw_t, rpdwhi_t, rpddur_t, rpdcawrs_t, rpdcawad_t, crgdp_t, t)$$

United States - White Wheat Domestic Demand

$$qdwhi_t = cqdwhi_t * pop_t$$

United States - White Wheat Carry-out Stocks

$$qswhi_t = \underset{(-0.62)}{-38.090} + \underset{(4.22)}{0.730}\, qswhi_{t-1} + \underset{(1.34)}{0.203}\, qpwhi_t - \underset{(-0.61)}{6.957}\, pdwhi_t + \underset{(1.22)}{14.967}\, lrwhi_t$$

$n = 19, \quad R^2 = 0.856, \quad \bar{R}^2 = 0.818$

United States - White Wheat Exports

$$qxwhi_t = qswhi_{t-1} + qpwhi_t - qdwhi_t - qswhi_t$$

United States - White Wheat Market Price

$$pdwhi_t = 0.162 + 0.026\ pxuswhi_t$$
$$(1.17)\quad (27.17)$$

$n = 19,\quad R^2 = 0.976,\quad \bar{R}^2 = 0.975$

United States - White Wheat Real Market Price

$$rpdwhi_t = \frac{pdwhi_t}{gdefl_t}$$

United States - White Wheat Farm Price

$$pfwhi_t = -0.292 + 0.977\ pdwhi_t$$
$$(-3.24)\quad (42.37)$$

$n = 20,\quad R^2 = 0.990,\quad \bar{R}^2 = 0.989$

United States - White Wheat Equilibrium Condition

$$qswhi_{t-1} + qpwhi_t = qdwhi_t + qswhi_t + \sum_{i=1}^{m} qmwhi_t^i$$

Durum Wheat

United States - Durum Wheat Area Planted

$$apdur_t = \underset{(0.97)}{1.148} + \underset{(2.81)}{0.431}\, apdur_{t-1} + \underset{(4.25)}{1.239}\, pfdur_{t-1} - \underset{(-2.78)}{1.377}\, pfhrs_{t-1} - \underset{(-0.49)}{0.291}\, pfbl_{t-1} - \underset{(-3.01)}{0.156}\, aidur_t + \underset{(2.42)}{0.644}\, ptwt_t$$

$n = 19, \quad R^2 = 0.831, \quad \bar{R}^2 = 0.753$

United States - Durum Wheat Area Harvested

$$ahdur_t = \underset{(1.31)}{0.136} + \underset{(34.07)}{0.929}\, apdur_t - \underset{(-3.22)}{0.386}\, dum_{88}$$

$n = 21, \quad R^2 = 0.984, \quad \bar{R}^2 = 0.983$

United States - Durum Wheat Yield

$$ydur_t = \underset{(-0.14)}{-1.820} + \underset{(1.13)}{0.183}\, ydur_{t-1} + \underset{(2.00)}{0.327}\, t - \underset{(-4.10)}{16.422}\, dum_{88}$$

$n = 19, \quad R^2 = 0.598, \quad \bar{R}^2 = 0.523$

United States - Durum Wheat Production

$$qpdur_t = ahdur_t * ydur_t$$

United States - Durum Wheat Per Capita Domestic Demand

$$cqddur_t = f(rpdhrs_t, rpdhrw_t, rpdsrw_t, rpdwhi_t, rpddur_t, rpdcawrs_t, rpdcawad_t, crgdp_t, t)$$

United States - Durum Wheat Domestic Demand

$$qddur_t = cqddur_t * pop_t$$

United States - Durum Wheat Carry-out Stocks

$$qsdur_t = \underset{(-1.60)}{-44.116} + \underset{(3.60)}{0.720}\, qsdur_{t-1} + \underset{(4.55)}{0.596}\, qpdur_t - \underset{(-0.41)}{1.574}\, pddur_t + \underset{(0.47)}{3.666}\, lrdur_t$$

$n = 19, \quad R^2 = 0.870, \quad \bar{R}^2 = 0.835$

United States - Durum Wheat Exports

$$qxdur_t = qsdur_{t-1} + qpdur_t - qddur_t - qsdur_t$$

United States - Durum Wheat Market Price

$$pddur_t = \underset{(0.94)}{0.203} + \underset{(20.82)}{0.027}\ pxusdur_t$$

$n = 19, \quad R^2 = 0.960, \quad \bar{R}^2 = 0.958$

United States - Durum Wheat Real Domestic Market Price

$$rpddur_t = \frac{pddur_t}{gdefl_t}$$

United States - Durum Wheat Farm Price

$$pfdur_t = \underset{(-1.23)}{-0.408} + \underset{(12.94)}{0.910}\ pddur_t$$

$n = 20, \quad R^2 = 0.898, \quad \bar{R}^2 = 0.893$

United States - Durum Wheat Equilibrium Condition

$$qsdur_{t-1} + qpdur_t = qddur_t + qsdur_t + \sum_{i=1}^{m} qmdur_t^i$$

Wheat Class k Imports

United States - Wheat Class k Per Capita Imports

$$cqd_t^k = f(rpdhrs_t, rpdhrw_t, rpdsrw_t, rpdwhi_t, rpddur_t, rpdcawrs_t, rpdcawad_t, crgdp_t, t)$$

United States - Wheat Class k Total Imports

$$qm_t^k = cqm_t^k * pop_t$$

United States - Wheat Class k Domestic Price

$$pd_t^k = px_t^k + tm_t^k$$

Table 6: United States - Variable Definitions and Units of Measurement

Variable	Definition	Unit
	Endogenous Variables	
ahdur	durum wheat area harvested	million acres
ahhrs	hard red spring wheat area harvested	million acres
ahhrw	hard red winter wheat area harvested	million acres
ahsrw	soft red winter wheat area harvested	million acres
ahwhi	white wheat area harvested	million acres
apdur	durum wheat area planted	million acres
aphrs	hard red spring wheat area planted	million acres
aphrw	hard red winter wheat area planted	million acres
apsrw	soft red winter wheat area planted	million acres
apwhi	white wheat area planted	million acres
cqddur	durum wheat per capita domestic consumption	bushels
cqdhrs	hard red spring wheat per capita domestic consumption	bushels
cqdhrw	hard red winter wheat per capita domestic consumption	bushels
cqdsrw	soft red winter wheat per capita domestic consumption	bushels
cqdwhi	white wheat per capita domestic consumption	bushels
cqdcawad	Canadian western amber durum per capita imports	bushels
cqdcawrs	Canadian western red spring per capita imports	bushels
pfdur	durum wheat farm price	dollars/bushel
pfhrs	hard red spring wheat farm price	dollars/bushel
pfhrw	hard red winter wheat farm price	dollars/bushel
pfsrw	soft red winter wheat farm price	dollars/bushel
pfwhi	white wheat farm price	dollars/bushel
pddur	durum wheat market price	dollars/bushel

Table 6: continued

Variable	Definition	Unit
pdhrs	hard red spring wheat market price	dollars/bushel
pdhrw	hard red winter wheat market price	dollars/bushel
pdsrw	soft red winter wheat market price	dollars/bushel
pdwhi	white wheat market price	dollars/bushel
pxusdur	durum wheat export price	dollars/metric ton
pxushrs	hard red spring wheat export price	dollars/metric ton
pxushrw	hard red winter wheat export price	dollars/metric ton
pxussrw	soft red winter wheat export price	dollars/metric ton
pxuswhi	white wheat export price	dollars/metric ton
qddur	durum wheat domestic consumption	million bushels
qdhrs	hard red spring wheat domestic consumption	million bushels
qdhrw	hard red winter wheat domestic consumption	million bushels
qdsrw	soft red winter wheat domestic consumption	million bushels
qdwhi	white wheat domestic consumption	million bushels
qdcawad	Canadian western amber durum imports	million bushels
qdcawrs	Canadian western red spring imports	million bushels
$qmdur^{i}$	country i's U.S. durum wheat imports	million bushels
$qmhrs^{i}$	country i's U.S. hard red spring wheat imports	million bushels
$qmhrw^{i}$	country i's U.S. hard red winter wheat imports	million bushels
$qmsrw^{i}$	country i's U.S. soft red winter wheat imports	million bushels
$qmwhi^{i}$	country i's U.S. white wheat imports	million bushels
qpdur	durum wheat production	million bushels
qphrs	hard red spring wheat production	million bushels
qphrw	hard red winter wheat production	million bushels
qpsrw	soft red winter wheat production	million bushels

Table 6: continued

Variable	Definition	Unit
qpwhi	white wheat production	million bushels
qsdur	durum wheat carry-out stocks	million bushels
qshrs	hard red spring wheat carry-out stocks	million bushels
qshrw	hard red winter wheat carry-out stocks	million bushels
qssrw	soft red winter wheat carry-out stocks	million bushels
qswhi	white wheat carry-out stocks	million bushels
qxdur	durum wheat exports	million bushels
qxhrs	hard red spring wheat exports	million bushels
qxhrw	hard red winter wheat exports	million bushels
qxsrw	soft red winter wheat exports	million bushels
qxwhi	white wheat exports	million bushels
rpdcawad	Canadian western amber durum wheat real domestic price	1990 dollars/bushel
rpdcawrs	Canadian western red spring wheat real domestic price	1990 dollars/bushel
rpddur	durum wheat real domestic market price	1990 dollars/bushel
rpdhrs	hard red spring wheat real domestic market price	1990 dollars/bushel
rpdhrw	hard red winter wheat real domestic market price	1990 dollars/bushel
rpdsrw	soft red winter wheat real domestic market price	1990 dollars/bushel
rpdwhi	white wheat real domestic market price	1990 dollars/bushel
ydur	durum wheat yield	bushels/acre
yhrs	hard red spring wheat yield	bushels/acre
yhrw	hard red winter wheat yield	bushels/acre

Table 6: continued

Variable	Definition	Unit
ysrw	soft red winter wheat yield	bushels/acre
ywhi	white wheat yield	bushels/acre
	Exogenous Variables	
aidur	durum wheat idled base acreage	million acres
aihrs	hard red spring wheat idled base acreage	million acres
aihrw	hard red spring wheat idled base acreage	million acres
aisrw	soft red winter wheat idled base acreage	million acres
aiwhi	white wheat idled base acreage	million acres
crgdp	real per capita GDP	billion 1990 dollars
dum_{88}	drought dummy	
dum_{89}	drought dummy	
dum_{91}	drought dummy	
gdefl	GDP deflator	1990 = 1
lrdur	durum wheat loan rate	dollars/bushel
lrhrs	hard red spring wheat loan rate	dollars/bushel
lrhrw	hard red winter wheat loan rate	dollars/bushel
lrsrw	soft red winter wheat loan rate	dollars/bushel
lrwhi	white wheat loan rate	dollars/bushel
pfcn	corn farm price	dollars/bushel
pop	population	millions
ptwt	wheat target price	dollars/bushel
t	time trend	
tmcawad	Canadian western amber durum specific tariff	U.S. dollars/metric ton
tmcawrs	Canadian western red spring specific tariff	U.S. dollars/metric ton

CANADA

The Canadian Wheat Board (CWB) handles most sales of wheat grown in the western prairie provinces. It has a monopoly on sales of wheat for export and for food use within Canada. Feed wheat can be sold domestically either through the board or through private companies. In practice most feed wheat sales are handled by private grain companies. The Wheat Board does not handle the small quantities of wheat grown in the eastern provinces.

The objective of the Canadian Wheat Board is maximizing the returns to farmers. Farmers receive initial payments (basis Thunder Bay or Vancouver) when they deliver their grain to country elevators. For farmers, this initial payment is a guaranteed minimum price. After all grain of a particular crop is sold by the Canadian Wheat Board, the profits are distributed equitably among farmers. Thus, every farmer receives the same price (basis Thunder Bay or Vancouver) for the grain and grade delivered. This is known as price pooling; every producer receives a price that is based on all sales during the marketing year.

Since producers pay all charges for country elevation, handling, and rail freight, prices received by producers differ by location. Producers close to Vancouver or Thunder Bay pay less for freight, and thus they receive a higher net initial payment than producers less favorably located. Pooling does not eliminate spatial price differentials.

Wheat Classes

Western Canada produces seven classes of wheat: Western Red Spring, Western Red Winter, Western Soft White Spring, Prairie Spring, Western Extra Strong Spring, Western Amber Durum, and Western Feed (CWB, Grains from Western Canada). Table 7 lists some properties and uses of these wheat classes.

The most important wheat type grown in Canada is hard spring wheat. Western Red Spring wheat has a high protein content and has excellent bread baking properties. It is used either alone or in blends with lower-protein wheats for the production of a wide range of products. Canada Prairie Spring wheat comes in two types: red and white. The red varieties are particularly well suited for the production of French-style hearth breads, while the white varieties are used for flat breads and many types of noodles. Canada Western Extra Strong Red Spring, formerly known as Canada Western Utility, has a somewhat harder wheat kernel than the Canada Western Red Spring class. It can be used to produce a variety of breads, buns, and frozen bread-type doughs.

Canada is a major producer and exporter of durum wheat. Canada Western Amber Durum is high quality durum wheat that produces pasta of bright yellow color and good cooking characteristics.

In addition to hard spring wheats, western Canada grows also smaller amounts of winter wheat and soft wheat. Canada Western Red Winter is a medium-protein wheat with hard kernel characteristics that is ideally suited for the production of french-style hearth breads and certain types of noodles. Canada Western Soft White Spring is grown under irrigation in the southern regions of the western prairies and used primarily for the production of cookies, biscuits, and crackers. Wheat unsuitable for milling is classified as Canada Western Feed.

Table 7: Western Canadian Wheat Classes

Wheat Class	Grade	Characteristics	Utilization
Canada Western Red Spring	3 grades, further differentiated by protein content	hard kernel, high-protein, high gluten strength	high-volume pan breads, blends with weaker lower-protein wheats
Canada Western Red Winter	3 grades	hard kernel, medium-protein, high gluten strength	French-style hearth breads, certain types of noodles, flat breads, steam breads
Canada Western Soft White Spring	3 grades	soft kernel, low-protein (9%-10%), weak gluten strength	cookies, pastries, biscuits, crackers, various types of flat breads, noodles, steam bread, and dumplings
Canada Prairie Spring Red	2 grades	semi-hard, medium-protein (on average 11%), medium gluten strength	French-style hearth breads, various types of flat breads, noodles, steam breads, pan breads, crackers
Canada Prairie Spring Red	2 grades	semi-hard, medium-protein, medium gluten strength	various types of noodles, flat breads, chapatis, household flours
Canada Western Extra Strong Red Spring (formerly Canada Western Utility)	2 grades	hard kernel, high-protein, high gluten strength	pan breads, hearth breads, buns, frozen bread-type doughs, whole wheat breads, specialty breads
Canada Western Amber Durum	4 grades	hard kernel, high-protein, high gluten strength, yellow pigment	semolina for pasta products
Canada Western Feed		unsuitable for milling	animal feed

Source: Canadian Wheat Board, *Grains from Western Canada, 1993-94.*

Wheat Supply

Canada produces two wheat classes: western red spring wheat and western amber durum wheat. For each class, production is determined by area harvested and yield.

Canadian wheat area harvested is a function of area harvested, crop prices, and carry-out stocks in the previous year:[5]

$$ah_t^k = f(ah_{t-1}^k, pi_{t-1}^k, pi_{t-1}^j, qs_{t-1}^k)$$

where ah^k is the class k wheat area harvested, pi^k is the initial payment for class k, pi^j is either the initial payment or the off-board price of competing crop j, and qs^k are the carry-in stocks of class k.

Yield is assumed to be depend on previous year's yield and time:

$$y_t^k = f(y_{t-1}^k, t)$$

where y^k is the yield of wheat class k, and t is a time trend. For estimation, a dummy variable is included to account for severe drought years.

Production is simply the product of area harvested and yield:

$$qp_t^k = ah_t^k * y_t^k$$

where qp^k is class k wheat production.

Wheat Demand

Domestic per capita food demand for wheat class k is a function of domestic prices, per capita GDP, and a time trend:

$$cqd_t^k = f(rpd_t^k, rpd_t^j, crgdp_t, t)$$

where cqd^k is per capita demand for class k, rpd^k is the real domestic price of class k, rpd^j is the real domestic price of substitute j, *crgdp* is real per capita GDP, and t is a time trend.

Total consumption of class k is the product of per capita consumption and population:

$$qd_t^k = cqd_t^k * pop_t$$

where *pop* denotes the population.

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[5]Subscripts indicate the crop year: *t* indicates the current crop year, while *t-1* refers to the previous crop year.

Feed demand for class k is a function of the off-board wheat price, the off-board barley price, the hog price, and a time trend:

$$qf_t^k = f(pf_t^{wt}, pf_t^{bl}, pd_t^{hg}, t)$$

where qf^k is the feed demand for class k, pf^{wt} is the off-board wheat price, pf^{bl} is the off-board barley price, pd^{hg} is the hog price, and t is a time trend.

Seed use is a function of next year's harvested area and a time trend:

$$qe_t^k = f(ah_{t+1}^k, t)$$

where qe^k is wheat class k seed demand.

Carry-out stocks are a function of carry-in stocks, wheat production, and export price:

$$qs_t^k = f(qs_{t-1}^k, qp_t^k, px_t^k * er_t)$$

where qs^k are the carry-out stocks of wheat class k, px^k is the export price of class k (in U.S. dollars), and er is the exchange rate.

By definition, Canadian exports are the difference between domestic supply and domestic demand:

$$qx_t^k = qs_{t-1}^k + qp_t^k - qd_t^k - qf_t^k - qe_t^k - qs_t^k$$

Price Linkages

Initial payments are a function of initial payments and export prices in the previous year:

$$pi_t^k = f(pi_{t-1}^k, px_{t-1}^k * er_{t-1})$$

where pi^k is the initial payment for class k.

Domestic prices are a function of domestic prices in the previous year and export prices in the current year:

$$pd_t^k = f(pd_{t-1}^k, px_t^k * er_t)$$

The off-board wheat price is a function of the western red spring wheat and western amber durum wheat export prices:

$$pf_t^{wt} = (px_t^{cawrs} * er_t, px_t^{cawad} * er_t)$$

Market Equilibrium

In equilibrium, total supply equals total demand:

$$qs_{t-1}^{k} + qp_t^{k} = qd_t^{k} + qf_t^{k} + qe_t^{k} + qs_t^{k} + \sum_{i=1}^{m} qm_t^{i,k}$$

where $qm^{i,k}$ is country i's imports of wheat class k.

The left-hand side of this equation shows total supply consisting of carry-in stocks and production, while the right-hand side shows total demand comprising domestic food use, feed use, seed use, carry-out stocks, and purchases of importing countries. In equilibrium, total demand equals total supply. The model is solved for a set of prices that satisfies this condition.

Data Sources

Export prices are provided by the *International Grain Statistics* (International Wheat Council), while domestic milling wheat prices are supplied by *Grain Trade of Canada* (Statistics Canada). The *International Financial Statistics CD-ROM* (International Monetary Fund) is the source for macroeconomic data. The remaining variables are taken from the *Canadian Grains Industry Statistical Handbook* (Canada Grains Council).

Model Equations

Western Red Spring Wheat

Canada - Western Red Spring Wheat Area Harvested

$$ahwrs_t = \underset{(3.13)}{4181.753} + \underset{(8.04)}{0.681}\, ahwrs_{t-1} + \underset{(2.73)}{46.225}\, piwrs_t - \underset{(-2.29)}{33.811}\, piwad_t - \underset{(-1.41)}{11.176}\, pofbl_{t-1} - \underset{(-2.16)}{0.151}\, qswrs_{t-1}$$

$n = 21, \quad R^2 = 0.897, \quad \bar{R}^2 = 0.865$

Canada - Western Red Spring Wheat Yield

$$ywrs_t = \underset{(0.23)}{0.109} + \underset{(1.29)}{0.211}\, ywrs_{t-1} + \underset{(2.89)}{0.018}\, t - \underset{(-4.12)}{0.753}\, dum_{88}$$

$n = 22, \quad R^2 = 0.591, \quad \bar{R}^2 = 0.526$

Canada - Western Red Spring Wheat Production

$$qpwrs_t = ahwrs_t * ywrs_t$$

Canada - Western Red Spring Wheat Per Capita Food Consumption

$$cqdwrs_t = \underset{(7.17)}{111.104} - \underset{(-0.77)}{0.014}\, rpdwrs_t + \underset{(1.03)}{0.016}\, rpdwad_t + \underset{(3.38)}{1.776}\, crgdp_t - \underset{(-3.40)}{0.892}\, t$$

$n = 17, \quad R^2 = 0.701, \quad \bar{R}^2 = 0.601$

Canada - Western Red Spring Wheat Total Food Consumption

$$qdwrs_t = cqdwrs_t * pop_t$$

Canada - Western Red Spring Feed Use

$$qfwrs_t = \underset{(-1.88)}{-3592.013} - \underset{(-1.92)}{21.230}\, pofwt_t + \underset{(1.44)}{22.961}\, pofbl_t + \underset{(0.98)}{15.368}\, pdhg_t + \underset{(2.99)}{60.283}\, t$$

$n = 16, \quad R^2 = 0.640, \quad \bar{R}^2 = 0.519$

Canada - Western Red Spring Wheat Seed Use

$$qewrs_t = -466.743 + 0.083\ ahwrs_{t+1} + 6.902\ t$$
$$(-8.24) \quad (19.14) \qquad\qquad (7.28)$$

$n = 16$, $R^2 = 0.989$, $\bar{R}^2 = 0.988$

Canada - Western Red Spring Wheat Carry-out Stocks

$$qswrs_t = 5599.572 + 0.385\ qswrs_{t-1} + 0.179\ qpwrs_t - 20.026\ (pxcawrs_t * er_t)$$
$$(1.57) \quad (2.41) \qquad\qquad (2.25) \qquad\qquad (-2.25)$$

$n = 21$, $R^2 = 0.566$, $\bar{R}^2 = 0.494$

Canada - Western Red Spring Wheat Exports

$$qxwrs_t = qswrs_{t-1} + qpwrs_t - qdwrs_t - qfwrs_t - qewrs_t - qswrs_t$$

Canada - Western Red Spring Wheat Initial Payment

$$piwrs_t = 9.447 + 0.582\ piwrs_{t-1} + 0.224\ (pxcawrs_{t-1} * er_{t-1})$$
$$(0.70) \quad (3.96) \qquad\qquad (2.08)$$

$n = 22$, $R^2 = 0.806$, $\bar{R}^2 = 0.787$

Canada - Western Red Spring Wheat Domestic Market Price

$$pdwrs_t = -9.933 + 0.500\ pdcawrs_{t-1} + 0.524\ (pxcawrs_t * er_t)$$
$$(-0.29) \quad (3.35) \qquad\qquad (2.73)$$

$n = 17$, $R^2 = 0.754$, $\bar{R}^2 = 0.718$

Canada - Western Red Spring Wheat Real Domestic Market Price

$$rpdwrs_t = \frac{pdwrs_t}{gdefl_t}$$

Canada - Off-board Wheat Price

$$pofwt_t = 7.620 + 0.361\ (pxcawrs_t * er_t) + 0.132\ (pxcawad_t * er_t)$$
$$(0.35) \quad (1.75) \qquad\qquad (0.82)$$

$n = 20$, $R^2 = 0.561$, $\bar{R}^2 = 0.512$

Canada - Western Red Spring Wheat Equilibrium Condition

$$qswrs_{t-1} + qpwrs_t = qdwrs_t + qfwrs_t + qewrs_t + qswrs_t + \sum_{i=1}^{m} qmwrs_t^i$$

Western Amber Durum Wheat

Canada - Western Amber Durum Wheat Area Harvested

$$ahwad_t = \underset{(3.02)}{1329.104} + \underset{(4.83)}{0.715}\ ahwad_{t-1} + \underset{(1.20)}{9.404}\ piwad_t - \underset{(-1.10)}{10.020}\ piwrs_t - \underset{(-0.44)}{1.570}\ pofbl_{t-1} - \underset{(-3.15)}{0.458}\ qswad_{t-1}$$

$n = 21, \quad R^2 = 0.697, \quad \bar{R}^2 = 0.603$

Canada - Western Amber Durum Wheat Yield

$$ywad_t = \underset{(-0.59)}{-0.442} + \underset{(1.83)}{0.317}\ ywad_{t-1} + \underset{(2.26)}{0.020}\ t - \underset{(-3.72)}{1.084}\ dum_{88}$$

$n = 22, \quad R^2 = 0.517, \quad \bar{R}^2 = 0.441$

Canada - Western Amber Durum Wheat Production

$$qpwad_t = ahwad_t * ywad_t$$

Canada - Western Amber Durum Wheat Per Capita Food Demand

$$cqdwad_t = \underset{(-1.76)}{-7.527} - \underset{(-2.45)}{0.006}\ rpdwad_t + \underset{(2.40)}{0.351}\ crgdp_t + \underset{(1.00)}{0.072}\ t$$

$n = 17, \quad R^2 = 0.897, \quad \bar{R}^2 = 0.873$

Canada - Western Amber Durum Wheat Food Demand

$$qdwad_t = cqdwad_t * pop_t$$

Canada - Western Amber Durum Wheat Feed Use

$$qfwad_t = \underset{(-2.30)}{-1717.576} - \underset{(-0.76)}{3.290}\ pofwt_t + \underset{(0.25)}{1.584}\ pofbl_t + \underset{(0.82)}{5.060}\ pdhg_t + \underset{(2.94)}{23.161}\ t$$

$n = 16, \quad R^2 = 0.587, \quad \bar{R}^2 = 0.450$

Canada - Western Amber Durum Wheat Seed Use

$$qewad_t = \underset{(-4.78)}{-93.231} + \underset{(32.97)}{0.094}\ ahwad_{t+1} + \underset{(4.15)}{1.075}\ t$$

$n = 16, \quad R^2 = 0.993, \quad \bar{R}^2 = 0.992$

Canada - Western Amber Durum Wheat Carry-out Stocks

$$qswad_t = 480.435 + 0.471\, qswad_{t-1} + 0.294\, qpwad_t - 2.440\, (pxcawad_t * er_t)$$
$$(0.86) \quad (2.80) \quad (3.33) \quad (-1.73)$$

$n = 21$, $R^2 = 0.551$, $\bar{R}^2 = 0.476$

Canada - Western Amber Durum Wheat Exports

$$qxwad_t = qswad_{t-1} + qpwad_t - qdwad_t - qfwad_t - qewad_t - qswad_t$$

Canada - Western Amber Durum Wheat Initial Payment

$$piwad_t = 33.677 + 0.605\, piwad_{t-1} + 0.087\, (pxcawad_{t-1} * er_{t-1})$$
$$(1.35) \quad (3.81) \quad (0.76)$$

$n = 20$, $R^2 = 0.546$, $\bar{R}^2 = 0.495$

Canada - Western Amber Durum Wheat Domestic Market Price

$$pdwad_t = -6.548 + 0.143\, pdcawad_{t-1} + 0.849\, (pxcawad_t * er_t)$$
$$(-0.22) \quad (0.99) \quad (5.62)$$

$n = 17$, $R^2 = 0.805$, $\bar{R}^2 = 0.778$

Canada - Western Amber Durum Wheat Real Domestic Market Price

$$rpdwad_t = \frac{pdwad_t}{gdefl_t}$$

Canada - Western Amber Durum Wheat Equilibrium Condition

$$qswad_{t-1} + qpwad_t = qdwad_t + qfwad_t + qewad_t + qswad_t + \sum_{i=1}^{m} qmwad_t^i$$

Table 8: Canada - Variable Definitions and Units of Measurement

Variable	Definition	Unit
	Endogenous Variables	
ahwad	western amber durum wheat area harvested	1000 hectares
ahwrs	western red spring wheat area harvested	1000 hectares
cqdwad	western amber durum wheat per capita food demand	kilograms
cqdwrs	western red spring wheat per capita food demand	kilograms
pdwad	western amber durum wheat domestic price	Canadian dollars/metric ton
pdwrs	western red spring wheat domestic price	Canadian dollars/metric ton
piwad	western amber durum wheat initial payment	Canadian dollars/metric ton
piwrs	western red spring wheat initial payment	Canadian dollars/metric ton
pofwt	off-board wheat price	Canadian dollars/metric ton
pxcawad	western amber durum wheat export price	U.S. dollars/metric ton
pxcawrs	western red spring wheat export price	U.S. dollars/metric ton
qdwad	western amber durum wheat food demand	1000 metric tons
qdwrs	western red spring wheat food demand	1000 metric tons
qewad	western amber durum wheat seed use	1000 metric tons
qewrs	western red spring wheat seed use	1000 metric tons
qfwad	western amber durum wheat feed use	1000 metric tons
qfwrs	western red spring wheat feed use	1000 metric tons
$qmwrs^{i}$	country i's Canadian western red spring wheat imports	1000 metric tons
$qmwad^{i}$	country i's Canadian western amber durum wheat imports	1000 metric tons

Table 8: continued

Variable	Definition	Unit
qpwad	western amber durum wheat production	1000 metric tons
qpwrs	western red spring wheat production	1000 metric tons
qswad	western amber durum wheat carry-out stocks	1000 metric tons
qswrs	western red spring wheat carry-out stocks	1000 metric tons
qxwad	western amber durum wheat exports	1000 metric tons
qxwrs	western red spring wheat exports	1000 metric tons
rpdwad	real western amber durum wheat domestic price	Canadian dollars/metric ton, 1990 prices
rpdwrs	real western red spring wheat domestic price	Canadian dollars/metric ton, 1990 prices
ywad	western amber durum wheat yield	metric tons/hectare
ywrs	western red spring wheat yield	metric tons/hectare
	Exogenous Variables	
crgdp	real per capita gdp	million Canadian dollars, 1990 prices
dum_{88}	drought dummy variable	
er	exchange rate	Canadian dollars/U.S. dollar
gdefl	GDP deflator	1990 = 1
pdhg	hog price	Canadian dollars/100 pounds
pofbl	off-board barley price	Canadian dollars/metric ton
pop	population	millions
t	time trend	

EUROPEAN UNION

In 1957, the Treaty of Rome created the European Economic Community. The initial six member countries were Belgium, France, Germany, Italy, Luxembourg, and the Netherlands. In 1973, Denmark, Ireland, and the United Kingdom joined the European Community, followed by Greece in 1980, Portugal and Spain in 1986, and Austria, Finland, and Sweden in 1995.

The creation of a customs union and a common market significantly reduced trade barriers within the community. However, internal border controls remained in place, and different rules and regulations in member countries inhibited the free flow of goods. For instance, agricultural products were subject to border taxes and subsidies (monetary compensatory amounts), implying that agricultural prices differed among member countries not only because of transport costs.

In the mid eighties, the European Community embarked on a drive toward full economic integration and the elimination of all internal border controls by the end of 1992. This program included the establishment of community-wide standards for the production and trade of food and agricultural products and the harmonization of transportation, financial services, value-added taxes, and excise taxes. Further steps toward tighter integration were taken in 1989, when the Maastricht Treaty changed the name of the organization to European Union and laid out a blueprint for monetary union at some future date.

Wheat Policies

Since July 1, 1967, wheat production in the European Union is governed by the E.U. Grain Market Regulation (Toepfer International). When the grain market regulation was designed, the European Union was a net-importer of grains, and world market prices were considered too low and volatile for E.U. farmers. Thus, a policy was pursued to increase and stabilize domestic farm prices. The hallmark of this policy is the *target price*, the desired market price.

Originally, the central elements of the grain market regulation were government purchases of domestically produced grain and variable levies (i.e., tariffs) on grain imports. Whenever market prices fall below the *intervention price*, government agencies are required to purchase grain in domestic markets. Therefore, intervention prices set domestic price floors for grains. On the other hand, variable levies increase the price of imports. The variable levy is the difference between the administratively set *threshold price* and the most favorable world market price (c.i.f.) in Rotterdam, and it is computed daily. Since the variable levy adjusts to compensate for changing world market prices, the price of imports remains almost constant even if world market prices fluctuate.

The E.U. regulations differentiate between common wheat and durum wheat. Until 1992/93, target, intervention, and threshold prices for durum wheat were higher than for common wheat. In addition, producers in traditional durum wheat production regions in France, Greece, Italy, and Spain receive a per hectare durum wheat subsidy.

Policy prices are quoted in ECU (Units of Account before April 9, 1979) and are converted to national currencies using an exchange rate. Therefore, prices quoted in national currency change whenever exchange rates change. To avoid this currency-related price instability, the European Union uses more stable "green exchange rates" for the conversion of support prices into national currencies. As a result, prices differ among countries at official rates of exchange and, without barriers to trade, spatial arbitrage will cause commodity flows from low-price to high-price countries. These trade flows are prevented through Monetary Compensatory Amounts (MCAs), internal border taxes and subsidies.

Green exchange rates and monetary compensatory amounts add another dimension to the common agricultural policy. Since the level of price support depends on policy prices quoted in ECU and on the green exchange rates, farm prices can be raised by increasing common agricultural prices or by appreciating the "green ECU." Over time, Monetary Compensatory amounts are gradually reduced, implying that prices in national currency rise less in countries having positive MCAs (i.e., import tariffs, export subsidies), and they rise more in countries having negative MCAs (i.e., import subsidies, export levies).

In 1984/85, positive MCAs were eliminated by raising the value of the ECU against all other currencies in the European Monetary System. Since then, MCAs are either zero or negative and a new quantity, the currency factor or switch-over coefficient, indicates the appreciation of the ECU in relation to the U.S. dollar. This coefficient is important for the determination of variable levies since it reduces the c.i.f. prices used in the levy calculation.

Agricultural policy parameters (i.e., target prices, threshold prices, intervention prices, per hectare subsidies, and green exchange rates) are determined annually by the Council of Agricultural Ministers. There are no well-defined rules for setting these policy parameters, and decisions depend heavily on political considerations.

The European Union was a net-importer of grain when the grain market regulation was conceived. With large amounts of grain imports, variable levies generated revenues that could be used to finance domestic price support operations. Thus, the main burden of the common agricultural policy was borne by consumers rather than taxpayers. However, this changed quickly as the European Union changed from a net-importer to a net-exporter of grain.

Revenues from grain import tariffs decreased as imports fell, and E.U. farmers, responding to higher domestic prices, significantly increased grain production. Moreover, imports of feed grain substitutes, such as corn gluten feed, citrus pulp, molasses, and tapioca, increased. As a result, government expenditures were rising, grain surpluses were accumulating, and the European Union became eventually a net-exporter of grain.

Since E.U. prices are higher than world market prices, exports are unprofitable unless export subsidies are paid. These export subsidies, referred to as *export refunds* or *export restitutions*, make up the difference between domestic and world market prices. Subsidies to certain regions, such as Africa, Switzerland, or Scandinavia, are fixed by the Commission and are published in the E.C. Journal. However, fixed export subsidies apply only to a small proportion of total E.U. exports. Most grain is exported by weekly tenders. The Commission publishes the quantities to be exported, and grain trading firms are invited to submit bids. Those bids requiring the lowest subsidies are accepted. Expenditures for export restitutions have increased over time, and E.U. exports have displaced exports from countries without export subsidy policies.

During the eighties, some attempts were made to constrain growing agricultural surpluses and government spending on agriculture. Quality standards for grain offered to the intervention agencies were increased, thus reducing the amount of grain that qualifies for intervention purchases. In 1986/87, a basic co-responsibility levy (tax) on all sales of grain was introduced. Initially, this tax was set at 3 percent of the bread wheat intervention price. It was increased to 5 percent in 1991/92. Beginning in 1987/88, the prices at which the intervention agencies purchase grain (buying-in prices) were reduced to 94 percent of the intervention price. In 1988/89, limits on annual expenditure increases, stabilizers, and land set-aside were introduced. The stabilizer mechanism triggered automatic reductions in intervention prices if grain production exceeded the Maximum Guaranteed Quantity. Moreover, an additional co-responsibility levy had to be paid whenever grain production exceeded this limit. The land set-aside scheme offered payments to farmers for voluntarily taking land out of production. However, this program had a larger effect on coarse grain production than on wheat production. Since wheat production is more profitable than barley production, farmers were reducing barley acreage rather than wheat acreage.

Eventually, escalating expenditures and international pressure resulted in a major overhaul of the common agricultural policy in 1992/93. The major elements of this reform were a significant reduction of policy prices, compensatory per hectare payments, and the set-aside of cropland. Over the next three years, the main policy prices (target, threshold, and intervention price) were set for significant reductions. To compensate producers for their income losses, per hectare payments based on historical regional grain yields were introduced. However, producers are eligible for compensatory payments only if they take a certain proportion of their land out of production. Initially, the set-aside requirement was set at 15 percent of all cropland, and small producers, i.e., those producing less than 92 tons of grain, were exempted.

In addition to a major reform of the Common Agricultural Policy, the basic and additional co-responsibility levies on sales of grain were repealed in 1992/93. The difference between intervention prices and buying-in prices was abolished in 1993/94, and the switchover mechanism was eliminated on February 1, 1995.

Wheat Classes

The European Union produces common wheat and durum wheat. However, these wheat types are labeled differently. Common wheat is referred to as soft wheat, while durum wheat is called hard wheat. Soft wheat is not further differentiated into soft and hard kernel types as in Australia, Canada, and the United States, although millers do recognize these differences. Thus, "soft" wheat is used to produce soft and hard wheat flours.

The characteristics of European wheat crops depend on prevailing weather conditions. Hot and dry summers produce hard wheats of high protein content. Cooler summers result in grain that is softer and lower in protein. Thus, the share of bread quality wheat varies from crop year to crop year. Since official statistics do not distinguish between soft and hard kernel wheat, assessing the precise share of soft and hard kernel wheats in total common wheat production is difficult. However, the consensus seems to be that most wheat produced in Europe has a soft kernel texture (Yamazaki and Greenwood) and low to medium protein content. High yielding winter varieties dominate, but spring wheats are favored in the northern regions.

The European Union has no official grading system for wheat. There are only minimum quality standards for intervention purchases. All wheat that satisfies these quality requirements is accepted for intervention at the guaranteed intervention price. Since July 1993, only one (bread) wheat quality qualifies for intervention. Before this date, the European Union distinguished between three types of wheat with different quality specifications and intervention prices: feed, bread, and quality wheat.

Wheat Supply

The European Union differs from other exporting countries because it is a major exporter and importer of wheat and because the common agricultural policy decouples domestic prices from world market prices. The E.U. wheat prices are above world market prices and above market clearing levels. Imports are taxed using variable levies, and excess supplies are disposed in world markets with the help of export subsidies. These features of the Common Agricultural Policy are important aspects of the European Union submodel.

The European Union produces two wheat classes: common wheat and durum wheat. For each class, production is determined by area harvested and yield; supply is the sum of carry-in stocks and production.

Wheat area harvested in the European Union is a function of area harvested, crop prices, and per hectare subsidies in the previous year:[6]

$$ah_t^k = f(ah_{t-1}^k, pf_{t-1}^k, pf_{t-1}^j, ss_{t-1}^k)$$

where ah^k is the class k wheat area harvested, pf^k is the class k farm price, pf^j is the farm price of competing crop j, and ss^k is the per hectare subsidy for class k. The per hectare subsidy applies only to durum wheat.

The changing composition over time of the European Union creates difficulties for the specification and estimation of the European Union submodel. Quantity data increase abruptly when membership expands, and these discontinuities have to be considered when behavioral equations are estimated. Wheat acreage and production of the community increase each time membership increases. We included dummy variables in the acreage equations to account for changes in the composition of the European Union.

Yield is assumed to depend on previous year's yield and a time trend:

$$y_t^k = f(y_{t-1}^k, t)$$

where y^k is the yield of wheat class k, and t is a time trend. Production is simply the product of area harvested and yield:

$$qp_t^k = ah_t^k * y_t^k$$

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[6]Subscripts indicate the crop year: t denotes the current crop year, while $t\text{-}1$ refers to the previous crop year.

where qp^k is class k wheat production. Supply in crop year t consists of production and carry-in stocks.

Wheat Demand

Estimation of food demand functions for the various wheat classes turned out to be rather difficult. Since the estimated equations often had unreasonable coefficients, a demand system for domestically produced wheat classes and imported Canadian wheat classes was specified using Armington's methodology. Using an aggregate elasticity of wheat consumption, five elasticities of substitution, and average 1990/91 to 1992/93 consumption shares of the various wheat classes, Armington's formulas were used to create an 11x11 matrix of demand elasticities for all wheat classes.[7]

For each domestically consumed wheat class (produced domestically or imported from the United States, Canada, Australia, or Argentina), a food demand function is specified. Prices in the demand equations are deflated using the GDP deflator. In addition to wheat class prices, per capita demand is assumed to depend on per capita GDP and a time trend:

$$cqd_t^k = f(rpd_t^1, \ldots, rpd_t^n, crgdp_t, t)$$

where cqd^k is per capita food consumption of wheat class k, rpd^j is the real prices of wheat class j, *crgdp* is real per capita GDP, and t is a time trend. Domestic demand for class k depends on the prices of all domestically produced wheat classes and on the prices of all imported classes.

Total consumption of class k is the product of per capita consumption and population:

$$qd_t^k = cqd_t^k * pop_t$$

where *pop* denotes the population.

We assume that all durum wheat is used for human consumption. A feed demand function is specified only for common wheat. Feed use of common wheat is a function of the common wheat producer price, the barley producer price, and a time trend:

$$qf_t^{cw} = f(pf_t^{cw}, pf_t^{bl}, t)$$

where qf^{cw} is the common wheat feed use, pf^{cw} is the common wheat producer price, pf^{bl} is the barley producer price, and t is a time trend. Feed wheat demand is expected to decrease if wheat prices increase, and it is expected to increase if barley prices increase.

In other wheat-exporting countries, domestic prices are linked to world market prices; and wheat exports are the difference between domestic supply and domestic demand. In contrast, in the European Union, the link between world market prices and domestic prices is

[7]See the section "Armington's Demand System" for more details.

severed, and an explicit export supply function is specified. Wheat exports are a function of U.S. export prices, exchange rates, and carry-in stocks:

$$qx_t^k = f(px_t^j * er_t, qs_{t-1}^k)$$

where qx^k is E.U. exports of wheat class k, px^j is the U.S. wheat class j export price, er is the ECU/U.S. dollar exchange rate, and qs^k is class k carry-in stocks.

In the European Union, exports are an instrument for the administrative disposal of surplus commodities, and export restitutions are set such that this objective is achieved. Therefore, wheat exports are expected to increase if carry-in stocks are high. Government expenditures for export restitutions depend on the quantity exported and on world market prices. Since export restitutions are inversely related to world market prices, the cost of subsidizing exports rises if world market prices fall. Therefore, wheat exports are expected to increase whenever U.S. prices increase.

Carry-out stocks are the residual that adjusts to clear domestic markets:

$$qs_t^k = qs_{t-1}^k + qp_t^k - qd_t^k - qf_t^k - qx_t^k$$

where qs_t^k is carry-out stocks of wheat class k. If carry-out stocks are smaller than zero, carry-out stocks are set to zero, and exports are the residual that balances domestic supply and demand:

$$qx_t^k = qs_{t-1}^k + qp_t^k - qd_t^k - qf_t^k$$

Price Linkages

Due to the Common Agricultural Policy, E.U. farm prices are not linked to world market prices. They are determined by domestic policy prices. In particular, the intervention price is important since it is set above market clearing levels, implying that it determines market prices. In addition to the intervention price, grain quality standards determine the amount of grain purchased by government intervention agencies. If quality standards are tightened, less grain qualifies for intervention, and market prices fall. It appears that the European Union raises quality standards if intervention stocks increase, suggesting that stock levels affect market prices.

The E.U. farm price is a function of the intervention price and carry-in stocks:

$$pf_t^k = f(pi_t^k, qs_{t-1}^k)$$

where pi^k is the intervention price for wheat class k.

Domestic prices of imported wheat classes are a function of export prices, exchange rates, and variable levies:

$$pd_t^k = px_t^k * er_t + vl_t^k$$

where pd^k is the wheat class k domestic price, px^k is the wheat class k export price, *er* is the exchange rate, and vl^k is the variable levy for wheat class k.

Variable levies are a function of the threshold price, the U.S. wheat export price, the switch-over coefficient, and the exchange rate:

$$vl_t^k = f(pt_t^k, px_t^j \,/\, soc_t * er_t)$$

where pt^k is the threshold price for class k, px^j is the U.S. wheat class j export price, *soc* is the switch-over coefficient, and *er* is the exchange rate.

Market Equilibrium

In equilibrium, markets must clear, implying that, for each class of wheat, exports must equal imports:

$$qx_t^k = \sum_{i=1}^{m} qm_t^{i,k}$$

where $qm^{i,k}$ is country i's import of wheat class k.

The model is solved for a set of prices that satisfies this condition. In the domestic market, supply equals demand since carry-out stocks are computed such that this condition holds:

$$qs_{t-1}^k + qp_t^k = qd_t^k + qf_t^k + qs_t^k + qx_t^k$$

The left-hand side of this equation shows total supply consisting of carry-in stocks and production, while the right-hand side shows total demand comprising domestic food use, feed use, carry-out stocks, and exports. Substituting the definition of carry-out stocks into this equation shows that domestic markets always clear.

Data Sources

Export prices, E.U. exports by destination, and durum wheat stocks are provided by the *International Grain Statistics* (International Wheat Council) The *International Financial Statistics CD-ROM* (International Monetary Fund) is the source for macroeconomic data. ECU exchange rates are listed in the *Agriculture: Statistical Yearbook* (Eurostat). Durum wheat per hectare subsidies, switch-over coefficients, and green exchange rates are taken from *Europe: International Agriculture and Trade Reports* (U.S. Department of Agriculture). Feed wheat use is supplied by *PS&D View* (U.S. Department of Agriculture). Intervention prices, threshold prices, and variable levies are reported in *Agricultural Markets* (Commission of the European Communities). Producer prices are supplied by *Agricultural Prices* (Eurostat) and *Agricultural Statistics of the European Community, 1960-85* (Herlihy et al.).

Model Equations

Common Wheat

European Union - Common Wheat Area Harvested

$$ahcw_t = \underset{(2.92)}{5187.084} + \underset{(1.61)}{0.312}\ ahcw_{t-1} + \underset{(0.95)}{25.759}\ pfcw_{t-1} - \underset{(-0.92)}{24.816}\ pfbl_{t-1}$$

$$+ \underset{(1.20)}{621.095}\ dum_{eu9} + \underset{(1.96)}{1313.148}\ dum_{eu10} + \underset{(3.36)}{1957.796}\ dum_{eu12}$$

$n = 25,\quad R^2 = 0.946,\quad \bar{R}^2 = 0.929$

European Union - Common Wheat Yield

$$ycw_t = \underset{(-1.24)}{-1.198} + \underset{(1.91)}{0.400}\ ycw_{t-1} + \underset{(2.32)}{0.051}\ t$$

$n = 25,\quad R^2 = 0.804,\quad \bar{R}^2 = 0.787$

European Union - Common Wheat Production

$$qpcw_t = ahcw_t * ycw_t$$

European Union - Common Wheat Per Capita Food Demand

$$cqdcw_t = f(rpdushrs_t,\ rpdushrw_t,\ rpdussrw_t,\ rpduswhi_t,\ rpdusdur_t,$$
$$rpdcawrs_t,\ rpdcawad_t,\ rpdauwt_t,\ rpdarwt_t,$$
$$rpfcw_t,\ rpfdw_t,\ crgdp_t,\ t)$$

European Union - Common Wheat Food Demand

$$qdcw_t = cqdcw_t * pop_t$$

European Union - Common Wheat Feed Use

$$qfcw_t = \underset{(-2.62)}{-32534.000} - \underset{(-2.08)}{155.231}\ pfcw_t + \underset{(1.46)}{120.300}\ pfbl_t + \underset{(3.25)}{650.306}\ t$$

$$+ \underset{(0.43)}{698.197}\ dum_{eu9} + \underset{(2.35)}{4176.233}\ dum_{eu10} - \underset{(-0.37)}{801.862}\ dum_{eu12}$$

$n = 25,\quad R^2 = 0.951,\quad \bar{R}^2 = 0.935$

European Union - Common Wheat Exports

$$qxcw_t = -3056.117 + 51.839\ (pxussrw_t * er_t) + 0.950\ qscw_{t-1}$$
$$(-1.35) \quad (2.59) \quad (4.93)$$

$n = 23$, $R^2 = 0.703$, $\bar{R}^2 = 0.675$

European Union - Common Wheat Carry-out Stocks

$$qscw_t = qscw_{t-1} + qpcw_t - qdcw_t - qfcw_t - qxcw_t$$

European Union - Common Wheat Variable Levy

$$vlcw_t = -23.578 + 1.202\ ptcw_t - 1.036\ (pxushrw_t\ /\ soc_t * er_t)$$
$$(-2.34) \quad (18.37) \quad (-12.00)$$

$n = 24$, $R^2 = 0.939$, $\bar{R}^2 = 0.933$

European Union - Common Wheat Farm Price

$$pfcw_t = 21.427 - 0.000591\ qscw_{t-1} + 0.847\ picw_t$$
$$(3.65) \quad (-1.24) \quad (18.72)$$

$n = 24$, $R^2 = 0.959$, $\bar{R}^2 = 0.955$

European Union - Common Wheat Equilibrium Condition

$$qxcw_t = \sum_{i=1}^{m} qmcw_t^i$$

Durum Wheat

European Union - Durum Wheat Area Harvested

$$ahdw_t = \underset{(4.29)}{1547.274} - \underset{(-1.14)}{0.194}\ ahdw_{t-1} + \underset{(2.13)}{2.677}\ pfdw_{t-1} - \underset{(-1.13)}{2.226}\ pfbl_{t-1}$$

$$+ \underset{(5.38)}{7.713}\ ssdw_{t-1} - \underset{(-0.08)}{9.042}\ dum_{eu10} + \underset{(4.15)}{442.476}\ dum_{eu12}$$

$n = 20, \quad R^2 = 0.970, \quad \bar{R}^2 = 0.957$

European Union - Durum Wheat Yield

$$ydw_t = \underset{(-3.07)}{-2.323} + \underset{(0.23)}{0.048}\ ydw_{t-1} + \underset{(4.02)}{0.054}\ t$$

$n = 24, \quad R^2 = 0.725, \quad \bar{R}^2 = 0.700$

European Union - Durum Wheat Production

$$qpdw_t = ahdw_t * ydw_t$$

European Union - Durum Wheat Per Capita Food Demand

$$cqddw_t = f(rpdushrs_t^i,\ rpdushrw_t,\ rpdussrw_t,\ rpduswhi_t,\ rpdusdur_t,\ rpdcawrs_t,\ rpdcawad_t,\ rpdauwt_t,\ rpdarwt_t,\ rpfcw_t,\ rpfdw_t,\ crgdp_t,\ t)$$

European Union - Durum Wheat Food Demand

$$qddw_t = cqddw_t * pop_t$$

European Union - Durum Wheat Exports

$$qxdw_t = \underset{(-2.54)}{-290.948} + \underset{(0.55)}{0.420}\ (pxusdur_t * er_t) + \underset{(10.06)}{0.498}\ qsdw_{t-1}$$

$n = 23, \quad R^2 = 0.830, \quad \bar{R}^2 = 0.813$

European Union - Durum Wheat Carry-out Stocks

$$qsdw_t = qsdw_{t-1} + qpdw_t - qddw_t - qxdw_t$$

European Union - Durum Wheat Variable Levy

$$vldw_t = -17.207 + 0.989\ ptdw_t - 0.965\ (pxusdur_t\ /\ soc_t * er_t)$$
$$(-1.29)\quad (17.25)\qquad\qquad (-10.33)$$

$n = 24, \quad R^2 = 0.931, \quad \bar{R}^2 = 0.925$

European Union - Durum Wheat Farm Price

$$pfdw_t = 84.285 - 0.00695\ qsdw_{t-1} + 0.701\ pidw_t$$
$$(7.63)\quad (-2.04)\qquad\qquad (14.01)$$

$n = 23, \quad R^2 = 0.908, \quad \bar{R}^2 = 0.899$

European Union - Durum Wheat Equilibrium Condition

$$qxdw_t = \sum_{i=1}^{m} qmdw_t^i$$

Wheat Class k Imports

European Union - Wheat Class k Per Capita Imports

$$cqm_t^k = f(rpdushrs_t, rpdushrw_t, rpdussrw_t, rpduswhi_t, rpdusdur_t, rpdcawrs_t, rpdcawad_t, rpdauwt_t, rpdarwt_t, rpfcw_t, rpfdw_t, crgdp_t, t)$$

European Union - Wheat Class k Total Imports

$$qm_t^k = cqm_t^k * pop_t$$

European Union - Wheat Class k Domestic Price

$$pd_t^k = px_t^k * er_t + vl_t^k$$

Table 9: European Union - Variable Definitions and Units of Measurement

Variable	Definition	Unit
	Endogenous Variables	
ahcw	common wheat area harvested	1000 hectares
ahdw	durum wheat area harvested	1000 hectares
cqdcw	common wheat per capita domestic demand	kilograms
cqddw	durum wheat per capita domestic demand	kilograms
cqm^{k}	wheat class k per capita imports	kilograms
pfcw	common wheat farm price	ECU/metric ton
pfdw	durum wheat farm price	ECU/metric ton
pxarwt	Argentine wheat export price	U.S. dollars/metric ton
pxauwt	Australian wheat export price	U.S. dollars/metric ton
pxcawad	Canadian western amber durum wheat export price	U.S. dollars/metric ton
pxcawrs	Canadian western red spring wheat export price	U.S. dollars/metric ton
pxusdur	U.S. durum wheat export price	U.S. dollars/metric ton
pxushrs	U.S. hard red spring wheat export price	U.S. dollars/metric ton
pxushrw	U.S. hard red winter wheat export price	U.S. dollars/metric ton
pxussrw	U.S. soft red winter wheat export Price	U.S. dollars/metric ton
pxuswhi	U.S. white wheat export Price	U.S. dollars/metric ton
qdcw	common wheat domestic food use	1000 metric tons
qdcw	durum wheat domestic food use	1000 metric tons
qfcw	common wheat feed use	1000 metric tons
$qmcw^{i}$	country i's imports of E.U. common wheat.	1000 metric tons
$qmdw^{i}$	country i's imports of E.U. durum wheat	1000 metric tons
qm^{k}	wheat class k imports	1000 metric tons
qpcw	common wheat production	1000 metric tons
qpdw	durum wheat production	1000 metric tons

Table 9: continued

Variable	Definition	Unit
qscw	common wheat carry-out stocks	1000 metric tons
qsdw	durum wheat carry-out stocks	1000 metric tons
qxeucw	common wheat exports	1000 metric tons
qxeudw	durum wheat exports	1000 metric tons
rpdarwt	Argentine wheat real domestic price	ECU/metric ton
rpdauwt	Australian wheat real domestic price	ECU/metric ton
rpdcawad	Canadian western amber durum wheat real domestic price	ECU/metric ton
rpdcawrs	Canadian western red spring wheat real domestic price	ECU/metric ton
rpdusdur	U.S. durum wheat real domestic price	ECU/metric ton
rpdushrs	U.S. hard red spring wheat real domestic price	ECU/metric ton
rpdushrw	U.S. hard red winter wheat real domestic price	ECU/metric ton
rpdussrw	U.S. soft red winter wheat real domestic price	ECU/metric ton
rpduswhi	U.S. white wheat real domestic price	ECU/metric ton
rpfcw	common wheat real farm price	ECU/metric ton
rpfdw	durum wheat real farm price	ECU/metric ton
vlcw	common wheat variable levy	ECU/metric ton
vldw	durum wheat variable levy	ECU/metric ton
ycw	common wheat yield	metric tons/hectare
ydw	durum wheat yield	metric tons/hectare
	Exogenous Variables	
crgdp	real per capita GDP	million ECU
dum_{eu9}	EC-9 dummy variable	
dum_{eu10}	EC-10 dummy variable	
dum_{eu12}	EC-12 dummy variable	

Table 9: continued

Variable	Definition	Unit
er	exchange rate	ECU/U.S. dollar
gdefl	GDP deflator	1990 = 1
pfbl	barley farm price	ECU/metric ton
pop	population	millions
picw	common wheat intervention price	ECU/metric ton
pidw	durum wheat intervention price	ECU/metric ton
ptcw	common wheat threshold price	ECU/metric ton
ptdw	durum wheat threshold price	ECU/metric ton
soc	switch-over coefficient	
ssdw	durum wheat per hectare subsidy	ECU/hectare
t	time trend	

AUSTRALIA

Australia's principal wheat producing areas are located in the "wheat-sheep zone" in South Australia, New South Wales, Queensland, and Western Australia. Due to periodic droughts and undependable rainfalls, wheat production is a risky business that is usually complemented with sheep and/or beef production. In addition to unstable yields, the reliance on export markets and the fluctuations of world market prices pose a second major risk for Australian wheat producers. Most wheat is produced near ports, and generally more than 80 percent of production is exported.

Australia grows only spring wheat varieties. Unlike spring wheat in North America and Europe, it is planted in the fall and harvested in the summer. High-protein hard wheats are produced in Queensland and the northern part of New South Wales, while soft wheats are produced in the southern regions. Most Australian wheat (about 70 percent) is classified as Australian Standard White. Australian wheat is unique because it is very clean and insect free.

In 1939, the Australian Wheat Board (AWB) was founded. Until 1989, the Australian Wheat Board had a monopoly on wheat purchases and sales of wheat. Producers had to deliver their grain to state-owned elevators, and it was transported by state-owned railways. Private grain companies had little role in the grain handling system.

The high cost of marketing Australian grain eventually led to a deregulation of the grain storage, handling, and transport system in 1989. The Wheat Board's monopoly on domestic sales was revoked, and it is now required to use the most cost-effective means of storing, handling, and moving grain. While the Wheat Board's monopoly on domestic sales was revoked, it still is the sole exporter of Australian wheat.

Before 1989, a two-price scheme kept domestic prices in most years above export prices, and producers received government-guaranteed minimum prices. In addition, the Australian Wheat board pooled costs and revenues of a particular wheat crop. Within broad grades, all growers received the same price regardless of the cost of handling their grain. Thus, pooling redistributes income among producers; growers at locations with a high cost of marketing grain are subsidized, while those more favorably located are taxed.

The 1989 Wheat Marketing Act introduced important changes to the Australian wheat marketing system. The Australian Wheat board lost its monopoly power in the domestic market. In addition, it can now trade grains other than wheat, it has more flexibility in operating pools and making payments to growers, and it is exempted from restrictive state regulations that increase the cost of grain marketing. The law also replaced the government-guaranteed minimum price with a government guarantee on the Board's borrowing to finance the harvest (advance) payment to producers.

Wheat Classes

Australia distinguishes eight classes of wheat: Prime Hard, Hard, Standard White, Noodle, Soft, Durum, General Purpose, and Feed. Hard, Standard White, General Purpose, and Feed are produced in all states; Prime Hard is produced in Queensland and New South Wales; Noodle is produced in all states except Queensland; Soft is produced in Western

Australia; and Durum is produced in northern New South Wales (AWB, *Crop Report 1993-94*). Table 10 summarizes properties and uses of these wheat classes.

Australian Prime Hard is a high quality, high-protein, hard-grained class of wheat with excellent milling characteristics and dough properties. It is used mainly for blending with lower-protein wheats and for producing high-protein breads and Chinese-style noodles. Likewise, Australian Hard is a high-protein wheat of good bread-baking quality that is used in a range of breads and in blends for Chinese-style noodles.

Australia's leading wheat class is Australian Standard White, a multi-purpose wheat with intermediate grain hardness and protein content that is suitable for a variety of breads and most type of noodle products. The 1993/94 annual report of the Australian Wheat Board shows that, for the 10-year period from 1984/85 to 1993/94, 73.5 percent of receivals were classified as Standard White (this figure also includes minor quantities of Australian Soft and Durum). Prime Hard and Hard wheat had shares of 4.9 percent and 12.0 percent, respectively. The remaining 9.6 percent of receivals were General Purpose and Feed wheat.

While most Australian wheat is classified as either Standard White, Hard, or Prime Hard, Australia also produces minor quantities of soft and durum wheat. Australian Noodle is a class of soft wheats of intermediate protein content, ideally suited for the production of white, salted noodles (e.g., Japanese Udon and Korean dry noodles). Australian Soft has excellent flour characteristics for the production of sweet biscuits, cakes, and pastry products. Australian Durum is used primarily to produce semolina for pasta products.

Wheat that fails to meet the milling wheat receival standards of the Australian Wheat Board is classified either as Australian General Purpose or as Australian Feed. General Purpose is still suitable for milling if blended with higher quality wheats, while Feed is considered unsuitable for flour milling.

Wheat Supply

The Australia submodel assumes that Australia produces only one wheat class. This assumption is necessary since data on wheat exports by class and destination are unavailable for Australian wheat.

Australian wheat area harvested is a function of area harvested in the previous year, wheat and wool prices that prevailed in the previous two years, and carry-in stocks:[8]

$$ah_t^k = f(ah_{t-1}^k, pi_{t-1}^k, pi_{t-2}^k, pd_{t-1}^j, pd_{t-2}^j, qs_{t-1}^k)$$

where ah^k is the Australian wheat area harvested, pi^k is the initial payment for Australian wheat, pd^j is the wool price, and qs^k are Australian wheat carry-in stocks.

Yield is assumed to depend on previous year's yield and time:

$$y_t^k = f(y_{t-1}^k, t)$$

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[8]Subscripts indicate the crop year: *t* indicates the current crop year, while *t-1* refers to the previous crop year.

Table 10: Australian Wheat Classes*

Wheat Class	Grade	Characteristics	Utilization
Australian Prime Hard	15%, 14%, or 13% minimum protein	hard kernel, high-protein	blends with lower-protein wheats, high-protein breads, Chinese-style noodles
Australian Hard	No. 1 (14%, 13%, 12%, or 11.5% minimum protein), No. 2 (11%-13% protein)	hard kernel, high-protein	volume breads, Middle Eastern-style flat breads, blends for Chinese-style noodles
Australian Standard White		semi-hard kernel, medium-protein (9%-11.5%)	European-style loaf breads, Middle Eastern, Iranian, and Indian-style flat breads, steamed bread, most types of noodle products
Australian Noodle		soft kernel, medium-protein	salted, white noodles (Japanese udon noodles, Korean dry noodles)
Australian Soft		soft kernel, low-protein	sweet biscuits, snack food, sponge cake, pastry products
Australian Durum	No. 1 (13% minimum protein), No. 2 (11.5% minimum protein)	hard kernel, high-protein	pasta products
Australian General Purpose	2 grades**	wheat that failed to meet AWB milling wheat receival standards	blends with higher quality milling wheats
Australian Feed		unsuitable for flour milling***	animal feed

*In some seasons, Australia also produces special grades to meet market requirements at the time.
**No. 1, high screenings, low test weight (68-74 kg/hl), or excessive weeds; No. 2, in addition minor weather damage.
***Less than 68 kg/hl test weight.

Source: Australian Wheat Board, *Crop Report: 1993-94 Season.*

where y^k is the Australian wheat yield, and t is a time trend.

Production is simply the product of area harvested and yield:

$$qp_t^k = ah_t^k * y_t^k$$

where qp^k is the Australian wheat production. Wheat supply in any given year comprises carry-in stocks and production.

Wheat Demand

Domestic per capita food consumption of Australian wheat is a function of the domestic prices, per capita GDP, and a time trend:

$$cqd_t^k = f(rpd_t^k, crgdp_t, t)$$

where cqd^k is per capita demand for Australian wheat, rpd^k is the real domestic wheat price, $crgdp$ is real per capita GDP, and t is a time trend.

Total consumption of Australian wheat is the product of per capita consumption and population:

$$qd_t^k = cqd_t^k * pop_t$$

where pop denotes the population.

Feed demand for Australian wheat is a function of the domestic wheat price, the barley price, and a time trend:

$$qf_t^k = f(pd_t^k, pd_t^{bl}, t)$$

where qf^k is Australian feed wheat demand, pd^k is the domestic wheat price, pd^{bl} is the domestic barley price, and t is a time trend.

Carry-out stocks are a function of carry-in stocks, wheat production, and export price:

$$qs_t^k = f(qs_{t-1}^k, qp_t^k, px_t^k * er_t)$$

where px^k is the Australian wheat export price (in U.S. dollars), and er is the exchange rate.

By definition, Australian exports are the difference between domestic supply and domestic demand:

$$qx_t^k = qs_{t-1}^k + qp_t^k - qd_t^k - qf_t^k - qs_t^k$$

Price Linkages

Initial payments are a function Australian wheat export prices:

$$pi_t^k = f(px_t^k * er_t)$$

where pi^k is the initial payment.

Domestic wheat prices are a function of domestic prices in the previous year and export prices in the current year:

$$pd_t^k = f(pd_{t-1}^k, px_t^k * er_t)$$

Market Equilibrium

In equilibrium, total supply equals total demand:

$$qs_{t-1}^k + qp_t^k = qd_t^k + qf_t^k + qs_t^k + \sum_{i=1}^{m} qm_t^{i,k}$$

where $qm_t^{i,k}$ is country i's imports of Australian wheat.

The left-hand side of this equation shows total supply consisting of carry-in stocks and production, while the right-hand side shows total demand comprising domestic food use, feed use, carry-out stocks, and purchases of importing countries. In equilibrium, total demand equals total supply. The model is solved for a set of prices that satisfies this condition.

Data Sources

Export prices are provided by the *International Grain Statistics* (International Wheat Council). The *International Financial Statistics CD-ROM* (International Monetary Fund) is the source for macroeconomic data. The remaining variables are taken from the *Commodity Statistical Bulletin* (Australian Bureau of Agricultural and Resource Economics).

Model Equations

Australia - Wheat Area Harvested

$$ahwt_t = \underset{(1.13)}{1080.200} + \underset{(6.57)}{0.894}\, ahwt_{t-1} + \underset{(2.89)}{22.921}\, piwt_{t-1} - \underset{(-0.92)}{3.590}\, piwt_{t-2}$$

$$- \underset{(-0.36)}{1.028}\, pdwl_{t-1} - \underset{(-1.24)}{3.475}\, pdwl_{t-2} - \underset{(-2.88)}{0.293}\, qswt_{t-1}$$

$n = 31$, $R^2 = 0.806$, $\bar{R}^2 = 0.759$

Australia - Wheat Yield

$$ywt_t = \underset{(0.96)}{0.323} - \underset{(-1.50)}{0.263}\, ywt_{t-1} + \underset{(3.74)}{0.018}\, t$$

$n = 32$, $R^2 = 0.318$, $\bar{R}^2 = 0.273$

Australia - Wheat Production

$$qpwt_t = ahwt_t * ywt_t$$

Australia - Wheat Per Capita Food Demand

$$cqdwt_t = \underset{(3.76)}{463.494} - \underset{(-2.62)}{0.281}\, rpdwt_t - \underset{(-1.08)}{9.033}\, crgdp_t - \underset{(-0.41)}{1.199}\, t$$

$n = 33$, $R^2 = 0.515$, $\bar{R}^2 = 0.467$

Australia - Wheat Food Consumption

$$qdwt_t = cqdwt_t * pop_t$$

Australia - Wheat Feed Use

$$qfwt_t = \underset{(1.15)}{1533.975} - \underset{(-0.58)}{1.349}\, pdwt_t + \underset{(2.23)}{10.995}\, pdbl_t - \underset{(-0.64)}{13.161}\, t$$

$n = 23$, $R^2 = 0.363$, $\bar{R}^2 = 0.268$

Australia - Wheat Carry-out Stocks

$$qswt_t = \underset{(-4.61)}{-2763.340} + \underset{(5.35)}{0.452}\, qswt_{t-1} + \underset{(8.57)}{0.508}\, qpwt_t - \underset{(-3.86)}{15.019}\, pxauwt_t * er_t$$

$n = 32$, $R^2 = 0.809$, $\bar{R}^2 = 0.789$

Australia - Wheat Exports

$$qxwt_t = qswt_{t-1} + qpwt_t - qfwt_t - qdwt_t - qswt_t$$

Australia - Wheat Initial Payment

$$\underset{}{piwt_t} = \underset{(3.65)}{27.292} + \underset{(11.19)}{0.633}\ (pxauwt_t * er_t)$$

$n = 32, \quad R^2 = 0.802, \quad \bar{R}^2 = 0.795$

Australia - Wheat Domestic Price

$$pdwt_t = \underset{(0.93)}{6.685} + \underset{(7.68)}{0.802}\ pdwt_{t-1} + \underset{(1.52)}{0.157}\ (pxauwt_t * er_t)$$

$n = 32, \quad R^2 = 0.917, \quad \bar{R}^2 = 0.911$

Australia - Equilibrium Condition

$$qswt_{t-1} + qpwt_t = qdwt_t + qfwt_t + qswt_t + \sum_{i=1}^{m} qmwt_t^i$$

Table 11: Australia - Variable Definitions and Units of Measurement

Variable	Definition	Unit
	Endogenous Variables	
ahwt	wheat area harvested	1000 hectares
cqdwt	wheat per capita food consumption	1000 metric tons
pdwt	wheat domestic price	Australian dollars/metric ton
piwt	wheat initial payment	Australian dollars/metric ton
pxauwt	Australian wheat export price	U.S. dollars/metric ton
qdwt	wheat total food consumption	1000 metric tons
qfwt	wheat feed use	1000 metric tons
$qmwt^{i}$	country i's imports of Australian wheat	1000 metric tons
qpwt	wheat production	1000 metric tons
qswt	wheat carry-out stocks	1000 metric tons
qxwt	wheat exports	1000 metric tons
rpdwt	wheat real domestic price	Australian dollars/metric ton, 1990 prices
ywt	wheat yield	metric tons/hectare
	Exogenous Variables	
crgdp	real per capita GDP	million Australian dollars, 1990 prices
er	exchange rate	Australian dollars/U.S. dollar
pdbl	barley domestic price	Australian dollars/metric ton
pop	population	millions
pdwl	wool auction price	Australian cents/kilogram
t	time trend	

ARGENTINA

Argentina is a major producer of grains, wool, and beef. Agriculture has a relatively high share in GDP and employment, and it is a major source of export revenue. In 1989, agriculture contributed 13 percent of GDP, employed 13 percent of the work force, and provided 70 percent of total export earnings (World Bank, 1989). In addition, agriculture is a major source of tax revenue. Over the last decades, agricultural sector taxes were used to subsidize industrialization and the expansion of the public sector.

Wheat is Argentina's most important crop. About 40 percent of the total grain and oilseed area is planted with wheat. It is grown primarily in the Pampas, an area of temperate climate that covers most of the provinces of Buenos Aires, Cordoba, La Pampa, Santa Fe, and Entre Rios. Most of this region has deep fertile soils. Because winters are mild, Argentine farmers plant spring wheat varieties in the fall.

Argentine use of fertilizer and other farm chemicals is low, and most yield increases over the past decades were due to improved varieties. Of particular importance was the introduction of early maturing semi-dwarf varieties in the mid seventies. These early maturing varieties permit farmers to double-crop wheat and soybeans.

Argentina has a natural comparative advantage for grain production and exports. However, government policies and an inefficient grain marketing system offset some of these natural advantages. Export taxes and quotas, an overvalued currency, tariffs on agricultural inputs, domestic transport monopolies, and direct government intervention in the grain trade have been used to extract rents from grain producers. In addition to these disincentives, Argentine producers have to cope with an inadequate transportation and grain handling system. The highways and railways are poorly maintained, and there have been few public sector investments in the transportation infrastructure over the last decades. In addition, many port facilities are outdated, and port costs tend to be high.

Wheat Supply

Argentina produces only one wheat class, and wheat production is determined by area harvested and yield.

Argentine wheat area planted is a function of area planted and wheat and corn export prices in the previous year:[9]

$$ap_t^k = f(ap_{t-1}^k, px_{t-1}^k, px_{t-1}^j)$$

where ap^k is the Argentine wheat area planted, px^k is the Argentine wheat export price, and px^j is the U.S. corn export price.

Area harvested is a function of area planted:

$$ah_t^k = f(ap_t^k)$$

[9]Subscripts indicate the crop year: *t* indicates the current crop year, while *t-1* refers to the previous crop year.

where ah^k is the wheat area planted.

Yield is assumed to depend on previous year's yield and a time trend:

$$y_t^k = f(y_{t-1}^k, t)$$

where y^k is the Argentine wheat yield, and t is a time trend.

Production is simply the product of area harvested and yield:

$$qp_t^k = ah_t^k * y_t^k$$

where qp^k is the Argentine wheat production. Wheat supply in any given year comprises carry-in stocks and production.

Wheat Demand

Domestic per capita food demand for Argentine wheat is a function of the domestic wheat price, per capita GDP, and a time trend:

$$cqd_t^k = f(rpd_t^k, crgdp_t, t)$$

where cqd^k is per capita demand for Argentine wheat, rpd^k is the wheat real domestic price, $crgdp$ is real per capita GDP, and t is a time trend.

Total consumption of Argentine wheat is the product of per capita consumption and population:

$$qd_t^k = cqd_t^k * pop_t$$

where pop denotes the population.

Carry-out stocks are a function of carry-in stocks, wheat production, and export price:

$$qs_t^k = f(qs_{t-1}^k, qp_t^k, px_t^k)$$

where qs^k is Argentine carry-out stocks, and px^k is the Argentine wheat export price.

By definition, Argentine exports are the difference between domestic supply and domestic demand:

$$qx_t^k = qs_{t-1}^k + qp_t^k - qd_t^k - qs_t^k$$

Price Linkages

Argentine domestic prices are a function of export prices and exchange rates:

$$pd_t^k = f(px_t^k * er_t)$$

where *er* is the exchange rate.

Market Equilibrium

In equilibrium, total supply equals total demand:

$$qs_{t-1}^k + qp_t^k = qd_t^k + qs_t^k + \sum_{i=1}^{m} qm_t^{i,k}$$

where $qm^{i,k}$ is country i's imports of Argentine wheat.

The left-hand side of this equation shows total supply consisting of carry-in stocks and production, while the right-hand side shows total demand comprising domestic food use, feed use, carry-out stocks, and purchases of importing countries. In equilibrium, total demand equals total supply. The model is solved for a set of prices that satisfies this condition.

Data Sources

The *International Financial Statistics CD-ROM* (International Monetary Fund) is the source for macroeconomic data. Data for the remaining variables are taken from the *International Grain Statistics* (International Wheat Council).

Model Equations

Argentina - Wheat Area Planted

$$apwt_t = 3113.266 + 0.501\ apwt_{t-1} + 27.591\ pxarwt_{t-1} - 38.050\ pxuscn_{t-1}$$
$$(3.31)\quad (3.26)\qquad (4.08)\qquad (-3.54)$$

$n = 29,\quad R^2 = 0.491,\quad \bar{R}^2 = 0.430$

Argentina - Area Harvested

$$ahwt_t = -309.770 + 0.958\ apwt_t$$
$$(-0.82)\quad (14.38)$$

$n = 34,\quad R^2 = 0.0.866,\quad \bar{R}^2 = 0.862$

Argentina - Wheat Yield

$$ywt_t = -0.258 + 0.174\ ywt_{t-1} + 0.021\ t$$
$$(-0.83)\quad (0.95)\qquad (3.62)$$

$n = 33,\quad R^2 = 0.567,\quad \bar{R}^2 = 0.538$

Argentina - Wheat Production

$$qpwt_t = ahwt_t * ywt_t$$

Argentina - Wheat Per Capita Consumption

$$cqdwt_t = 354.556 + 0.032\ rpdwt_t - 10.162\ crgdp_t - 2.135\ t$$
$$(4.18)\quad (0.15)\qquad (-0.50)\qquad (-3.38)$$

$n = 21,\quad R^2 = 0.547,\quad \bar{R}^2 = 0.467$

Argentina - Wheat Total Consumption

$$qdwt_t = cqdwt_t * pop_t$$

Argentina - Wheat Carry-out Stocks

$$qswt_t = 98.810 + 0.252\ qswt_{t-1} + 0.107\ qpwt_t - 4.047\ pxarwt_t$$
$$(0.22)\quad (1.44)\qquad (2.23)\qquad (-1.48)$$

$n = 30,\quad R^2 = 0.233,\quad \bar{R}^2 = 0.144$

Argentina - Wheat Exports

$$qxwt_t = qswt_{t-1} + qpwt_t - qdwt_t - qswt_t$$

Argentina - Wheat Domestic Price

$$pdwt_t = \underset{(1.26)}{0.002} + \underset{(550.54)}{0.663}\,(pxarwt_t * er_t)$$

$n = 20, \quad R^2 = 0.999, \quad \bar{R}^2 = 0.999$

Argentina - Equilibrium Condition

$$qswt_{t-1} + qpwt_t = qdwt_t + qswt_t + \sum_{i=1}^{m} qmwt_t^i$$

Table 12: Argentina - Variable Definitions and Units of Measurement

Variable	Definition	Unit
	Endogenous Variables	
ahwt	wheat area harvested	1000 hectares
apwt	wheat area planted	1000 hectares
cqdwt	wheat per capita food demand	1000 metric tons
pdwt	wheat domestic price	pesos/metric ton
pxarwt	Argentine wheat export price	U.S. dollars/metric ton
qdwt	wheat domestic consumption	1000 metric tons
$qmwt^{i}$	country i's imports of Argentine wheat	1000 metric tons
qpwt	wheat production	1000 metric tons
qswt	wheat carry-out stocks	1000 metric tons
qxwt	wheat exports	1000 metric tons
rpdwt	wheat real domestic price	pesos/metric ton, 1990 prices
ywt	wheat yield	metric tons/hectare
	Exogenous Variables	
crgdp	real per capita GDP	million pesos, 1990 prices
er	exchange rate	pesos/U.S. dollar
pop	population	millions
pxuscn	U.S. corn export price	U.S. dollars/metric ton
t	time trend	

IMPORTING COUNTRIES AND REGIONS

The Wheat Policy Simulation Model distinguishes 13 importing regions and countries: Algeria, Brazil, China, Egypt, Japan, Korea, Morocco, Mexico, the former Soviet Union, Tunisia, Taiwan, Venezuela, and the "Rest of the World" region that includes all other importers of wheat. Table 13 shows average 1990/91 to 1992/93 trade flows between wheat exporting countries and importing countries.[10]

Import Demand

Import demand of the importing countries and regions is described by import demand equations. For each importing country, import demand is assumed to be a function of wheat class prices, GDP, domestic production, and a trend:

$$cqm_t^{i,k} = f(rpd_t^{i,1}, ..., rpd_t^{i,n}, crgdp_t^i, cqpwt_t^i, t)$$

where $cqm^{i,k}$ is per capita import demand for wheat class k in country i, $rpd^{i,j}$ is the real domestic price of wheat class j in country i, $crgdp^i$ is real per capita GDP in country i, $cqpwt^i$ is per capita wheat production in country i, and t is a time trend.

Since every import demand function comprises 11 highly correlated wheat prices, Armington's modeling approach is used. For each importing country, an aggregate elasticity of import demand and 5 elasticities of substitution are specified, and these elasticities are used to derive the matrix of price elasticities of import demand.[11] This matrix and the base year quantities and prices are used to obtain the matrix of substitution effects.

All price elasticities, elasticities of substitution, income elasticities, production coefficients, and trend coefficients for the importing countries are either based on values reported in previous studies or are ad hoc estimates. These values are adjusted until the model performs reasonably well. Tables 14, 15, and 16 show the elasticity and coefficient estimates.

Total import demand is the product of per capita imports and population:

$$qm_t^{i,k} = cqm_t^{i,k} * pop_t$$

where *pop* is the population.

Wheat class prices in importing countries are a function of export prices, exchange rates, and tariffs:

$$pd_t^{i,k} = px_t^k * er_t^i * (1 + tm_t^{i,k})$$

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[10]See Appendix Tables A1 and A2 for a listing of country/region codes and commodity codes, respectively.

[11]See the section *Armington's Demand System* for more details.

Table 13: Wheat Trade Flow Matrix, 1990/91 to 1992/93 Averages (1000 metric tons)

	Imports[a]										
Country	us hrs	us hrw	us srw	us whi	us dur	ca wrs	ca wad	eu cw	eu dw	au wt	ar wt
al	187	380	142	43	729	-	592	1081	76	-	-
br	188	170	2	-	-	1114	2	22	-	-	3247
ch	314	2066	1539	-	-	4525	-	1277	-	761	173
eg	809	672	430	1169	-	43	-	824	-	1495	-
jp	1168	1155	-	930	7	1301	146	1	-	1050	-
ko	355	476	-	760	-	1339	-	312	-	780	-
mo	271	264	296	-	45	49	14	855	45	-	-
mx	118	236	6	27	-	375	-	24	-	-	12
su	1014	2804	1298	13	-	3845	830	5548	-	388	89
tu	102	164	34	-	42	-	9	216	20	-	-
tw	345	323	-	126	3	99	-	-	-	16	-
ve	352	2	67	-	135	342	174	44	-	-	27
rw	3685	3913	1104	2419	263	5583	471	8602	646	5327	2446
us	-9244	-12628	-4944	-5479	-1315	510	398	-	-	-	-
ca	-	-	-	-	-	-19730	-2864	-	-	-	-
eu	406	4	25	2	91	607	228	-18806	-787	3	3
au	-	-	-	-	-	-	-	-	-	-9819	-
ar	-	-	-	-	-	-	-	-	-	-	-5999

[a]Only imports exceeding 500 metric tons are reported. Negative figures indicate exports.
Sources: International Wheat Council, *World Grain Statistics*; U.S. Department of Agriculture. *Wheat Situation and Outlook Report*; Canada Grains Council. *Canadian Grains Industry Statistical Handbook*.

where $pd^{i,k}$ is the domestic price of wheat class k in importing country i, px^k is the wheat class k export price, er^i is the exchange rate of country i (national currency units per U.S. dollar), and $tm^{i,k}$ is importing country i's tariff on wheat class k.

These price linkage equations are not estimated. They are included to analyze trade policies such as export subsidies or import tariffs. For instance, the effects of Export Enhancement Program (EEP) subsidies are analyzed by setting the import tariffs of importing countries to (negative) values that reflect the EEP subsidy amounts.

Data Sources

Data on wheat imports from the United States are supplied by the *Wheat Situation and Outlook Report* (U.S. Department of Agriculture). Imports from Canada are reported in the *Canadian Grains Industry Statistical Handbook* (Canada Grains Council). Wheat production and imports from Argentina, Australia and the European Union are taken from the *International Grain Statistics* (International Wheat Council). EEP bonuses and quantities by wheat class are listed in the *Quarterly Wheat Outlook* (Tierney). The *International Financial Statistics CD-ROM* (International Monetary Fund) provided data for macroeconomic variables.

Table 14: Wheat Demand Price Elasticities, Importing Countries

Country / Region	Elasticity
Algeria	-0.20
Brazil	-0.30
China	-0.45
Egypt	-0.50
European Union	-0.25
Former Soviet Union	-0.20
Japan	-0.35
Korea	-0.40
Mexico	-0.40
Morocco	-0.20
Rest of the World	-0.70
Taiwan	-0.40
Tunisia	-0.20
United States	-0.20
Venezuela	-0.30

Table 15: Wheat Demand Elasticities of Substitution, Importing Countries*

Country/Region	σ_{cd}	σ_{hs}	σ_{ss}	σ_{hh}	σ_{dd}
Algeria	2.0	5.0	10.0	10.0	10.0
Brazil	2.0	5.0	10.0	10.0	10.0
China	2.0	5.0	10.0	10.0	10.0
Egypt	2.0	5.0	10.0	10.0	10.0
European Union	2.0	5.0	10.0	10.0	10.0
Former Soviet Union	2.0	5.0	10.0	10.0	10.0
Japan	2.0	5.0	10.0	10.0	10.0
Korea	2.0	5.0	10.0	10.0	10.0
Mexico	2.0	5.0	10.0	10.0	10.0
Morocco	2.0	5.0	10.0	10.0	10.0
Rest of the World	2.0	5.0	10.0	10.0	10.0
Taiwan	2.0	5.0	10.0	10.0	10.0
Tunisia	2.0	5.0	10.0	10.0	10.0
United States	2.0	5.0	10.0	10.0	10.0
Venezuela	2.0	5.0	10.0	10.0	10.0

*σ denotes elasticities of substitution between wheat types: cd = common/durum, hs = hard/soft, ss = soft/soft, hh = hard/hard, dd = durum/durum.

Table 16: Wheat Demand Income Elasticities, Importing Countries

	Wheat Class										
Country	us hrs	us hrw	us srw	us whi	us dur	ca wrs	ca wad	eu cw	eu dw	au wt	ar wt
al	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
br	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
ch	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
eg	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
jp	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
ko	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
mo	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
mx	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
su	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
tu	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
tw	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
ve	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
rw	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
us	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
eu	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Model Equations

Importing Country - Wheat Class k Per Capita Imports

$$cqm_t^{i,k} = f(rpdushrs_t^{i}, rpdushrw_t^{i}, rpdussrw_t^{i}, rpduswhi_t^{i}, rpdusdur_t^{i}, rpdcawrs_t^{i}, rpdcawad_t^{i}, rpdeucw_t^{i}, rpdeudw_t^{i}, rpdauwt_t^{i}, rpdarwt_t^{i}, crgdp_t^{i}, cqpwt_t^{i}, t)$$

Importing Country - Wheat Class k Imports

$$qm_t^{i,k} = cqm_t^{i,k} * pop_t^{i}$$

Importing Country - Wheat Class k Domestic Price

$$pd_t^{i,k} = px_t^{k} * er_t^{i} * (1 + tm_t^{i,k})$$

Table 17: Importing Countries - Variable Definitions and Units of Measurement

Variable	Definition	Unit
	Endogenous Variables	
$cqm^{i,k}$	country i's per capita imports of wheat class k	1000 metric tons
$qm^{i,k}$	country i's imports of wheat class k	1000 metric tons
$rpd^{i,k}$	country i's wheat class k real domestic price	national currency units/metric ton, 1990 prices
	Exogenous Variables	
$cqpwt^{i}$	country i's wheat per capita production	kilograms
$crgdp^{i}$	country i's real per capita GDP	million national currency units, 1990 prices
er^{i}	country i's exchange rate	national currency units/U.S. dollar
$gdefl^{i}$	country i's GDP deflator	1990 = 1
pop	population	millions
t	time trend	
$tm^{i,k}$	country i's tariff on wheat class k imports	percent

COMPUTER IMPLEMENTATION

The simulation model is written in Turbo Pascal, version 7.0, and runs on IBM compatible PC's with at least 640k bytes of memory. The main components of the simulation model are an executable file "wheat.exe" and several Lotus-123 files containing the input for the simulation program.

Figure 5 illustrates the steps involved in running a simulation. To set up a simulation, the user edits the Lotus files. First, the file "aa-wheat.wk1", which contains tables with general simulation information (output file names, output file format, base period, simulation period, etc.), is edited. After all values in this file are entered, an input file must be generated using the "alt-p" macro, and the Lotus file should be saved. Next, the country files are edited. There is one wk1 file for every country and region in the model. For every one of these files, once the input is entered, an input file must be generated using the "alt-p" macro, and the Lotus file should be saved. The Lotus files can be saved under a different name. However, the name of the input file generated by the "alt-p" should not be changed.

After entering the input for the simulation into the wk1 files and generating the input files for the simulation, the simulation is run by typing "wheat" at the DOS prompt. The simulation program reads the input files, performs the simulation, and writes output files in a format that can be edited with a word processor or read into Lotus-123 for further analysis.

Lotus Files

Lotus-123 is used as an interface between the user and the simulation program, and Lotus wk1 files contain all input for the simulation. The files contain tables with simulation parameters, base period values, and exogenous variables. By editing these tables, simulation scenarios are changed.

Table 18 lists the Lotus-123 input files. There is one "xx-wheat.wk1" file for every country or region, where the xx in the file name refers to the country code. For instance, the file "br-wheat.wk1" contains all input for the Brazil submodel. In addition to the country files, there is the main input file "aa-wheat.wk1" that contains global simulation parameters, such as the title of the simulation, the base period, and the simulation period. This file should be edited first, before any of the country files are edited. Some of the cells in the country files are linked to the file "aa-wheat.wk1" and are automatically updated.

In addition to data tables, each file contains a macro (alt-p) that automatically generates an input file for the simulation program. The files generated with these macros are named "xx-wheat.prn", where the xx stands for the country code. To execute the macro, hold down the "alt-key", and enter "p". Then save the wk1 file.

Output Files

The simulation program generates two output files. The file "1-log.xxx" contains tables summarizing all input for the simulation. (The xxx indicates a file extension that depends on the chosen output file format.) Thus, this file provides a record of all model

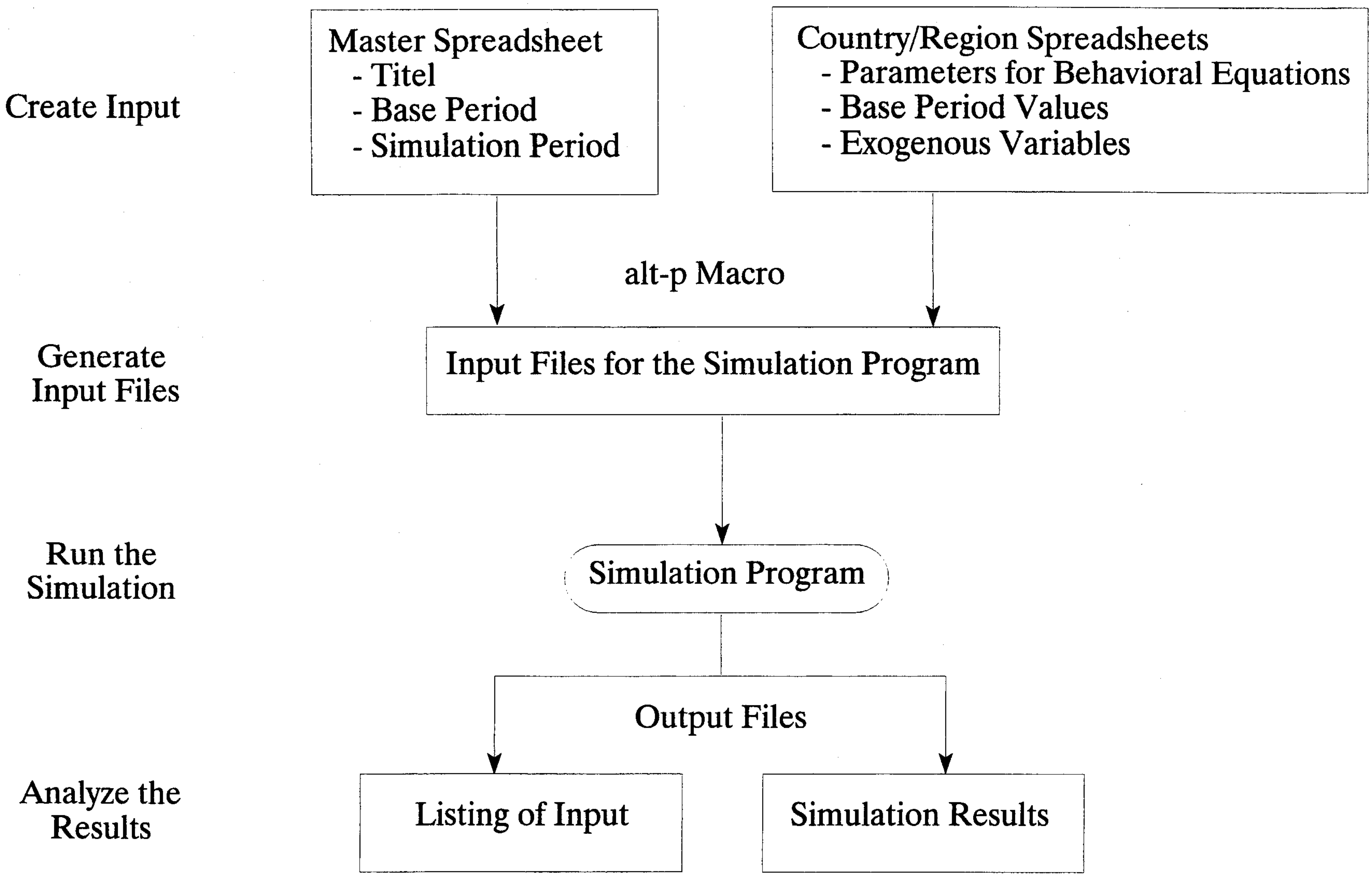

Figure 5: Wheat Policy Simulation

Table 18: World Wheat Policy Simulation Model Input Files

Lotus-123 File	Input File for the Simulation	Content
aa-wheat.wk1	aa-wheat.prn	Simulation Parameters
al-wheat.wk1	al-wheat.prn	Algeria
ar-wheat.wk1	ar-wheat.prn	Argentina
au-wheat.wk1	au-wheat.prn	Australia
br-wheat.wk1	br-wheat.prn	Brazil
ca-wheat.wk1	ca-wheat.prn	Canada
ch-wheat.wk1	ch-wheat.prn	China
eg-wheat.wk1	eg-wheat.prn	Egypt
eu-wheat.wk1	eu-wheat.prn	European Union
jp-wheat.wk1	jp-wheat.prn	Japan
ko-wheat.wk1	ko-wheat.prn	South Korea
mo-wheat.wk1	mo-wheat.prn	Morocco
mx-wheat.wk1	mx-wheat.prn	Mexico
rw-wheat.wk1	rw-wheat.prn	Rest of the World
su-wheat.wk1	su-wheat.prn	Former Soviet Union
tu-wheat.wk1	tu-wheat.prn	Tunisia
tw-wheat.wk1	tw-wheat.prn	Taiwan
us-wheat.wk1	us-wheat.prn	United States
ve-wheat.wk1	ve-wheat.prn	Venezuela

parameters and exogenous variables for later reference. The file "1-result.xxx" contains tables showing the results of the simulation.

Output files can be generated in either of three formats: an ASCII text file (txt), a Lotus-123 spreadsheet file (wk1), and a Lotus-123 import file (prn). ASCII text files (file extension: txt) can be loaded into any editor or word processor, or they can be printed with the DOS print or copy commands. However, tables in these files have more than 80 columns, implying that a small font is required to fit tables on regular-sized paper. Lotus-123 spreadsheet files (file extension: wk1) can be read by a several programs (including Lotus-123). This format is suitable for further analysis of the simulation results, using spreadsheet programs such as Lotus-123. Lotus-123 import files (file extension: prn) are text files in a format that can be imported into spreadsheets. This file format can be imported into a Lotus spreadsheet using the command sequence "/fin" since labels are enclosed in double quotes.

Pascal Files

The Pascal source code for the simulation program is contained in files with "pas" file extension. Generally, users of the simulation program do not need to bother with these files. All model input can be changed by modifying the Lotus-123 tables. The Pascal files are of interest only if the structure of the simulation model has to be changed. For instance, editing the Pascal files and recompiling the program are necessary if equations are added to the model.

For every country or region, there is one "u-xx.pas" Pascal file that contains the country model, where xx stands for the country code. for example, the file "u-us.pas" contains the Pascal source code for the United States submodel. In addition to the country files, there are several files with auxiliary procedures. For example, the "u-solv1.pas" file contains the equation solver. Table 19 lists the various Pascal files and their function. The main program file is called "wheat.pas".

Compiling and linking the source code files produces a set of files with the "tpu" file extension and an executable file "wheat.exe" that runs the simulation. The "tpu" files are compiled Pascal units and are only needed to generate the executable file. These files can be deleted; only the file "wheat.exe" is required for running the simulation. After entering "wheat" at the prompt, the simulation program reads the input files, runs the simulation, and generates output files with simulation results.

Table 19: Pascal Source Code Files

File Name	Content
wheat.pas	main program file
Country and Region Files	
u_al.pas	Algeria
u_ar.pas	Argentina
u_au.pas	Australia
u_br.pas	Brazil
u_ca.pas	Canada
u_ch.pas	China
u_eg.pas	Egypt
u_eu.pas	European Union
u_jp.pas	Japan
u_ko.pas	Korea
u_mo.pas	Morocco
u_mx.pas	Mexico
u_rw.pas	Rest of the World
u_su.pas	Former Soviet Union
u_tu.pas	Tunisia
u_tw.pas	Taiwan
u_us.pas	United States
u_ve.pas	Venezuela

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APPENDIX A

Country and Commodity Codes

Table A1: Country/Region Codes

Code	Country/Region
ar	Argentina
au	Australia
ca	Canada
eu	European Union
us	United States
al	Algeria
br	Brazil
ch	China
eg	Egypt
jp	Japan
ko	Korea
mo	Morocco
mx	Mexico
rw	Rest of the World
su	Former Soviet Union
tu	Tunisia
tw	Taiwan
ve	Venezuela

Table A2: Commodity Codes

Code	Commodity
dur	durum wheat
hrs	hard red spring wheat
hrw	hard red winter wheat
srw	soft red winter wheat
whi	white wheat
wrs	western red spring wheat
wad	western amber durum wheat
cw	common wheat
dw	durum wheat
wt	all wheat
bl	barley
cn	corn
hg	hogs
wl	wool

Appendix B

European Union Data Aggregation

EUROPEAN UNION DATA AGGREGATION

The existence of internal border taxes and subsidies poses difficulties since such measures imply that prices and price changes differ among regions in the European Union. Hence, aggregating data across regions and treating the European Union as one entity may introduce some bias. However, modeling every member country separately has problems, too. Some countries have been members for only a short time, and supply and demand behavior is likely to change once a country implements the common agricultural policy. Thus, for countries that joined the European Union recently, the estimation of behavioral equations will be difficult.

In any case, the specification of country models may yield only minor improvements. Bailey (p. 23) finds that a country-level approach for E.U. wheat area response is only marginally better than the aggregate approach, but involves a more complex model. Since we are not interested in how various regions of the European Union are affected by policy changes and in view of the model complexity and data requirements, we use the aggregate approach.

Data for individual member countries are aggregated. Quantities are computed by adding up the member countries' quantities, while prices are weighted average prices, where the weights are chosen to reflect the importance of member countries. For instance, E.U. wheat production is the sum of wheat production in member countries, and producer prices are determined using member countries' producer prices and their shares in total production as weights. The following formulas provide the details.*

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*Superscripts i represent member countries, and subscripts t indicate the year. Note that m, the number of member countries, depends on t; membership increased over time.

European Union Macroeconomic Variables

GDP at Current Prices:

$$gdp_t^{eu} = \sum_{i=1}^{m} \frac{gdp_t^i}{er_t^i}$$

GDP at Constant (1990) Prices:

$$rgdp_t^{eu} = \sum_{i=1}^{m} \frac{rgdp_t^i}{er_{1990}^i}$$

GDP Deflator (1990 = 1):

$$gdefl_t^{eu} = \frac{gdp_t^{eu}}{rgdp_t^{eu}}$$

Population:

$$pop_t^{eu} = \sum_{i=1}^{m} pop_t^i$$

European Union Crop Area Harvested

All Wheat (Common and Durum) Area Harvested:

$$ah_t^{eu,wt} = \sum_{i=1}^{m} ah_t^{i,wt}$$

Durum Wheat Area Harvested:

$$ah_t^{eu,dw} = \sum_{i=1}^{m} ah_t^{i,dw}$$

Common Wheat Area Harvested:

$$ah_t^{cw} = ah_t^{wt} - ah_t^{dw}$$

European Union Crop Production

All Wheat (Common and Durum) Production:

$$qp_t^{eu,wt} = \sum_{i=1}^{m} qp_t^{i,wt}$$

Durum Wheat Production:

$$qp_t^{eu,dw} = \sum_{i=1}^{m} qp_t^{i,dw}$$

Common Wheat Production:

$$qp_t^{cw} = qp_t^{wt} - qp_t^{dw}$$

Barley Production:

$$qp_t^{eu,bl} = \sum_{i=1}^{m} qp_t^{i,bl}$$

European Union Imports

Wheat Class k Imports:

$$qm_t^{eu,k} = \sum_{i=1}^{m} qm_t^{i,k}$$

European Union Feed Use

All Wheat (Common and Durum) Feed Use:

$$qf_t^{eu} = \sum_{i=1}^{m} qf_t^{i}$$

European Union Carry-out Stocks

All Wheat (Common and Durum) Carry-out Stocks:

$$qs_t^{eu,wt} = \sum_{i=1}^{m} qs_t^{i,wt}$$

Common Wheat Carry-out Stocks:

$$qs_t^{eu,cw} = qs_t^{eu,wt} - qs_t^{eu,dw}$$

European Union Producer Prices
Common Wheat Producer Price:

$$pf_t^{eu,cw} = \sum_{i=1}^{m} \frac{pf_t^{i,cw}}{er_t^{i}} * s_t^{i} \quad \text{where} \quad s_t^{i} = \frac{qp_t^{i,cw}}{qp_t^{eu,cw}}$$

Durum Wheat Producer Price:

$$pf_t^{eu,dw} = \sum_{i=1}^{m} \frac{pf_t^{i,dw}}{er_t^{i}} * s_t^{i} \quad \text{where} \quad s_t^{i} = \frac{qp_t^{i,dw}}{qp_t^{eu,dw}}$$

Barley Producer Price:

$$pf_t^{eu,bl} = \sum_{i=1}^{m} \frac{pf_t^{i,bl}}{er_t^{i}} * s_t^{i} \quad \text{where} \quad s_t^{i} = \frac{qp_t^{i,bl}}{qp_t^{eu,bl}}$$

European Union Policy Parameters
Common Wheat Intervention Price:

$$pi_t^{eu,cw} = \sum_{i=1}^{m} \frac{pi_t^{cw} * gr_t^{i,cw}}{er_t^{i}} * s_t^{i} \quad where \quad s_t^{i} = \frac{qp_t^{i,cw}}{qp_t^{eu,cw}}$$

Durum Wheat Intervention Price:

$$pi_t^{eu,dw} = \sum_{i=1}^{m} \frac{pi_t^{dw} * gr_t^{i,dw}}{er_t^{i}} * s_t^{i} \quad where \quad s_t^{i} = \frac{qp_t^{i,dw}}{qp_t^{eu,dw}}$$

Durum Wheat Per Hectare Subsidy:

$$ss_t^{eu,dw} = \sum_{i=1}^{m} \frac{ss_t^{dw} * gr_t^{i,dw}}{er_t^{i}} * s_t^{i} \quad where \quad s_t^{i} = \frac{qp_t^{i,dw}}{qp_t^{eu,dw}}$$

Table B1: E.U. Data Aggregation - Variable Definitions and Units of Measurement

Variable	Definition	Unit
ah^{cw}	country i's common wheat area harvested	1000 hectares
ah^{dw}	country i's durum wheat area harvested	1000 hectares
ah^{wt}	country i's total (common plus durum) wheat area harvested	1000 hectares
er^{i}	country i's exchange rate	national currency units/ECU
$gdefl^{i}$	country i's GDP deflator	1990 = 1
gdp^{i}	country i's GDP	national currency units
$gr^{i,cw}$	country i's common wheat green exchange rate	national currency units/ECU
$gr^{i,dw}$	country i's durum wheat green exchange rate	national currency units/ECU
qf^{i}	country i's feed wheat use	1000 metric tons
$qm^{i,k}$	country i's wheat class k imports	1000 metric tons
$qp^{i,bl}$	country i's barley production	1000 metric tons
$qp^{i,cw}$	country i's common wheat production	1000 metric tons
$qp^{i,dw}$	country i's durum wheat production	1000 metric tons
$qp^{i,wt}$	country i's total (common plus durum) wheat production	1000 metric tons
$qs^{i,wt}$	country i's total (common plus durum) wheat carry out stocks	1000 metric tons
$pf^{i,bl}$	country i's barley producer price	national currency/metric ton
$pf^{i,cw}$	country i's common wheat producer price	national currency/metric ton
$pf^{i,dw}$	country i's durum wheat producer price	national currency/metric ton
pi^{cw}	E.U. common wheat intervention price	ECU/metric ton
pi^{dw}	E.U. durum wheat intervention price	ECU/metric ton

Table B1: continued

Variable	Definition	Unit
pop^{i}	country i's population	millions
$rgdp^{i}$	country i's real GDP	billion national currency units (1990 prices)
ss^{dw}	E.U. durum wheat per hectare subsidy	ECU/hectare